Forces

Contact Forces *and* Pressure

Ideas you have met before

Forces

Forces can act in any direction, causing stretching, compression and changes in motion.

Some types of forces require contact whereas others are non-contact forces, such as gravity.

Friction and resistance

Friction is a force that acts between moving surfaces, causing them to slow down or stop.

Air resistance is friction between air and an object moving through it.

A boat moving through water experiences water resistance.

Floating and sinking

When an object is placed in water, weight will pull it down and an upthrust will act upwards.

If the weight is greater than the upthrust, the object will sink.

If the upthrust is equal to the weight, it will float.

Resultant forces

There may be several forces acting on an object. To understand how they affect the motion of the object we need to consider all of them.

If forces are acting in the same direction, we get the resultant by adding them but if they are acting in opposing directions, we subtract one from the other.

If the resultant is zero the object will have a steady speed, which might be zero. If the resultant is not zero the object will speed up, slow down or change direction.

In this chapter you will find out

Effects of forces

- Elastic materials behave in a special way when forces such as tension or compression change their shape.
- Materials can become permanently deformed when they are stretched or compressed by large forces.
- Stresses on a solid can explain effects such as the scratching of a surface, sinking or breakage.

Friction and drag

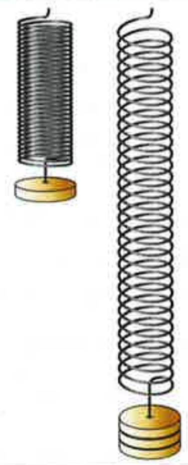
- Friction is caused by one surface moving over another.
- If one of the surfaces is a fluid, it is called 'drag'.

Pressure, floating and sinking

- Pressure is the force acting on a certain area.
- Pressure can act in solids, liquids and gases.
- An upthrust force affects all objects that are submerged in a liquid.
- Pressure in a fluid increases with depth.
- The volume of an object affects the amount of upthrust it experiences in a liquid.

Forces in equilibrium

- A force on a moving object may cause its speed to increase or decrease.
- If opposing forces act on an object and are balanced the object is in equilibrium.



Analysing equilibrium

We are learning how to:

- Analyse situations to identify the various forces that are acting.
- Explore situations in which objects are held in equilibrium and the nature of the forces involved.

Forces are all around you, but you cannot see, touch or smell them. When forces cause movement you can see what they do, but when something is not moving there are still forces at work.

Types of force

A force can be a **pushing force**, a **pulling force** or a **turning force.** There is a pulling force from the Earth on this bungee jumper. Once he steps off the platform, the pulling force makes him fall. The arrow shows the pulling force making him move downwards. Without the pulling force of the Earth, he would not fall. The pulling force of the Earth on objects is called gravity. Gravity is a **non-contact force**. However the force applied through the bungee line is a **contact force**.

FIGURE 2.1.1a: A bungee jumper is pulled downwards by gravity.

1. How would you describe the type of force that the Earth produces on the bungee jumper?
2. What is the name given to this force?

Balancing forces

We can look at an object and identify the forces acting on it. In Figure 2.1.1b, gravity is pulling downwards on the mass on the left and the spring is pulling upwards with the same force, but in the opposite direction. The forces are **balanced** or in **equilibrium.**

If you increase the mass, the force of gravity will increase and the mass will move downwards. However, the forces reach equilibrium again as the greater weight becomes balanced by a greater upwards force from the spring.

3. Look at the right-hand part of Figure 2.1.1b. Describe the forces that are acting on the mass and spring.
4. Draw force diagrams to show the forces acting on:
   a) a small mass hanging from a spring
   b) a larger mass hanging from a spring.
5. Explain why neither mass in Figure 2.1.1b is moving.

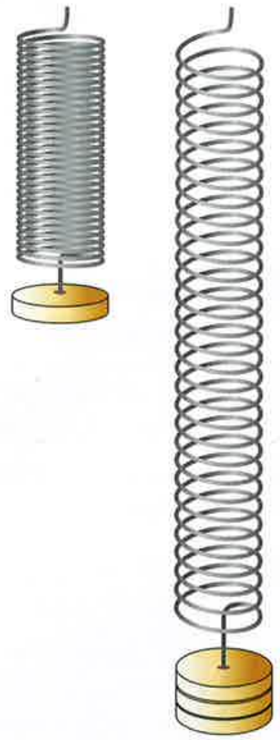


FIGURE 2.1.1b: Forces in equilibrium.

Two forces act on a sycamore seed when it falls from a tree – the force of weight acts downwards and the force of air resistance acts in the opposite direction. Once a sycamore seed starts to fall and spin, the force of air resistance is the same size as the force of weight. The two forces cancel each other out and the seed descends at a constant speed. The forces are in equilibrium.

Of course, forces aren't always in equilibrium. When the sycamore seed first drops, air resistance is less than gravity. We can work out the **resultant force** by combining the various forces acting, taking account of their direction and size. The resultant force is a single force which can replace all the forces acting and have the same effect. When the seed first drops the resultant force is downwards, so it accelerates. A few seconds later, when the air resistance balances gravity, the resultant force is zero, so it falls at a steady speed.

FIGURE 2.1.1c: The forces are in equilibrium as the seed falls steadily.

6. What does the word 'constant' mean?
7. Describe the forces acting on a sycamore seed as it falls and spins downwards.
8. Why does a sycamore seed not keep accelerating downwards?

Multiple forces in equilibrium

It is possible to have equilibrium between different forces at once. In this picture, the cyclist is travelling along a level road at a steady speed. The force applied by her legs is pushing her forwards and friction and air resistance are both pushing backwards. The two backwards forces added together are equal to the forwards force so they balance.

FIGURE 2.1.1d: If the forces on this cyclist are balanced, what does this say about her motion?

9. Based on Figure 2.1.1d, draw a force diagram to show all the horizontal forces acting on the cyclist.
10. Explain what would happen to the motion of the cyclist if the force she applied to the pedals was greater than air resistance and friction combined.

Did you know...?

Forces are measured in **newtons**, named after the famous scientist Sir Isaac Newton. It is said that he devised an explanation of gravity after an apple fell on his head. No-one knows if the story is true, but a typical apple has a weight of 1 newton.

Know this vocabulary

contact force
non-contact force
balanced forces
equilibrium
resultant force
newton

What a drag!

We are learning how to:

- Describe the effects of drag and other forces on objects as they move.
- Describe factors which affect the size of frictional and drag forces.
- Evaluate how well sports or vehicle technology reduces frictional or drag forces.

As soon as we try to move, we experience resistance. Air resistance builds up, the faster we travel, and if we're in water, the water tries to stop us. We need to understand how this works and how to minimise it, although sometimes it's actually quite useful.

Streamlining in nature and technology

If you wade through deep water you can feel the resistance of the water. It's harder to move your legs forward compared with being on dry land, and walking through air. We call any material that will flow a **fluid**; liquids and gases are fluids. We call the resistance to movement **drag**.

Some objects are very good at moving through a fluid without causing a lot of drag. Animals that move very quickly, such as birds that dive to catch food, can make themselves into a shape that causes little drag. They are **streamlined**.

Engineers have copied these ideas to build vehicles that are streamlined. This reduces the amount of fuel they use. A lot of time and effort goes into reducing the amount of drag.

1. Why is it an advantage for birds to have a streamlined shape?
2. Think about cars that have a streamlined shape. How have the designers reduced the amount of drag?
3. How does this idea apply to the design of a speedboat?

FIGURE 2.1.2a: A Pelican diving for fish.

FIGURE 2.1.2b: An F-22 Raptor, stealth fighter aircraft.

Aircraft wings

Sometimes drag is a nuisance; we want objects to slip through a fluid as easily as possible. On other occasions drag is actually very helpful. Again, nature has taken a lead here – if you watch large birds coming in to land they alter the shape of their wings to slow them down.

Did you know...?

Designers need to make sure the body shape of a car causes as little resistance as possible. This will reduce wind noise and fuel consumption. They put the shape in a wind tunnel and look for places where the airflow is disturbed.

An airliner in flight needs drag to be minimal, but when landing it needs to reduce speed very quickly and does so by changing the shape of the wings. Flaps on the top of the wing are raised and the rear edges lowered. Air now can't flow as easily, drag is increased and the aircraft slows down.

Cars, of course, have brakes, in which one solid material presses on another. The **friction** caused slows the vehicle down. In extreme cases this isn't enough, however, and cars that travel at very high speeds, such as those attempting to break speed records, use parachutes. A parachute has a lot of drag as air gets caught inside it.

FIGURE 2.1.2c: The wing and flaps of a plane after landing.

4. Explain how wing flaps are altered to either increase or reduce drag.
5. Suggest the effect that fitting a roof rack to a car has on drag.
6. Explain why we sometimes use the term 'friction' and sometimes 'drag'.

Championship cycling

In championship cycling events speed is essential, but it's also important to reduce drag. To maintain a high speed a cyclist needs to slip through the air using as little **energy** as possible.

Look at this picture of a cyclist in action. Although it's clear that many of the features are similar to those on road bicycles, the bike has been modified for racing. The cyclist too is equipped and positioned in a particular way.

Air can flow very easily over both bicycle and rider; anything that can possibly be done to reduce drag has been. As a result, it is easier to maintain a high speed over a long distance.

FIGURE 2.1.2d: Everything is set up to reduce as much drag as possible for this championship cyclist.

7. Comment on the position of the rider and how it reduces drag.
8. How do the clothing and helmet help with this?
9. Suggest why the bike has
   a) a higher seat **b)** a single gear.

Know this vocabulary

fluid
drag
streamlined
friction
energy

Understanding stretch and compression

We are learning how to:

- Explain the relationship between and applied force and the change of shape of an object.
- Investigate the forces involved in stretching and compressing materials.
- Identify applications for compressible and stretchable materials.

Imagine a mattress made of solid wood; clothes with no stretch; balls that don't bounce. The world would be a very different place if materials and objects could not change shape when a force is applied to them.

Comparing materials

All materials can be squashed (for example, by a **compression** force) or stretched (for example, by a **tension** force) to some extent. Some materials change shape by tiny, unnoticeable amounts – even with extremely large forces. Some materials may change shape with a small force but then break. When materials return to their original shape after the force is removed, it is called elastic behaviour.

1. Name some materials or objects that can be noticeably compressed or stretched *and* show elastic behaviour.
2. Name materials that show non-elastic behaviour when they are compressed or stretched.

FIGURE 2.1.3a: The angler benefits from elastic materials.

Size of force and amount of deformation

If you compress or stretch a material too far, it may not be able to return to its original shape – it remains **deformed** or it may break. In these situations the compressing or stretching force is beyond the elastic limit of the material.

Materials that break with a relatively small force (only slightly beyond their elastic limit) are said to be brittle.

3. Name some brittle materials.
4. Look at the data in Table 2.1.3. This data can be displayed using a graph. List the features the graph should include.
5. Plot a line graph to display the data in Table 2.1.3. Describe what your graph shows about how the force applied affects the spring.

TABLE 2.1.3: Data showing effect of force on a spring.

Force applied (N)	Length the spring has been compressed by (cm)
0	0
10	3.1
20	6.2
30	9.3
40	12.4
50	15.5
60	16.1

6. a) From your graph, what do you notice about the compression when a force of 60 N is applied, compared to smaller forces?
   b) What could explain the difference in part a)? Suggest why the final data point does not fit the pattern of the others.

Applications of elastic materials

The elastic behaviour of springs make them ideal components in devices for measuring weight or force.

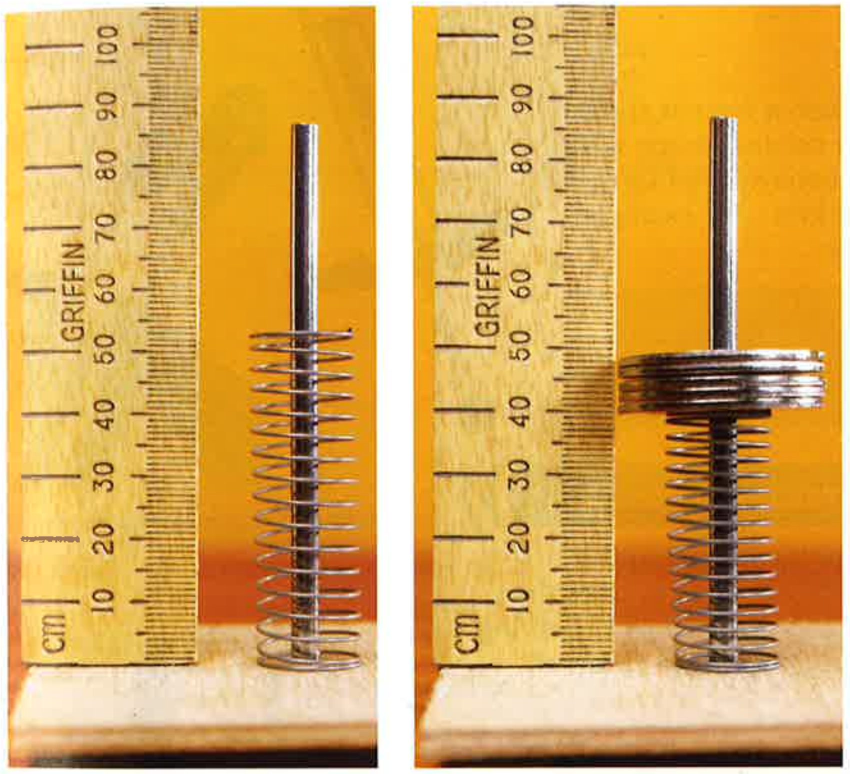


FIGURE 2.1.3b: The behaviour of a spring under an applied force allows us to measure weight.

Cushions on soft furniture, climbing ropes, clothing and the soles of sports shoes are all examples of uses of materials chosen for their elastic behaviour.

7. Why might a cushion not work well if the foam was:
   a) too soft?
   b) too hard?
8. Explain why springs are particularly suitable for use in weighing devices and forcemeters.
9. Suggest why a climbing rope would be less effective if it had no elasticity at all.

Did you know...?

The suspension in racing cars uses springs, which compress in a complex way depending on the force on them. This helps give the car good balance and grip at all speeds. The suspension also has dampers to help control the compression and bounce of the springs. Different springs and dampers are used at each race to suit the circuit and the track conditions.

Know this vocabulary

compression
tension
deformation

Investigating Hooke's Law

We are learning how to:

- Investigate the effects of applied forces on springs.
- Generate data to produce a graph and analyse outcomes.

Part of the skill of a scientist is collecting data and using it to find patterns that will improve our understanding of the world.

FIGURE 2.1.4a: Springs in action.

Springs are elastic

Elastic materials change shape when a force is applied to them, and then return to their original shape when the force is removed. The elastic behaviour of springs makes them useful in many situations – for example, a spring is used in a newtonmeter.

1. Give three uses of springs.
2. Suggest some properties of materials that would make good springs.

Investigating how a force stretches a spring

Figure 2.1.4b shows the set up for investigating the stretching of a spring. As the force increases so does the spring's extension. 'Extension' means how much the spring has stretched, compared to its original length when no force was applied.

Within a certain range of forces, a spring will extend by regular amounts for equal increases in the force applied. That is, there will be a **linear relationship** between the extension of the spring and the force applied. So if a spring stretches by 1 cm when you apply a force of 1 N, then it will stretch by 2 cm if you apply a 2 N force. This behaviour of a spring is known as Hooke's Law.

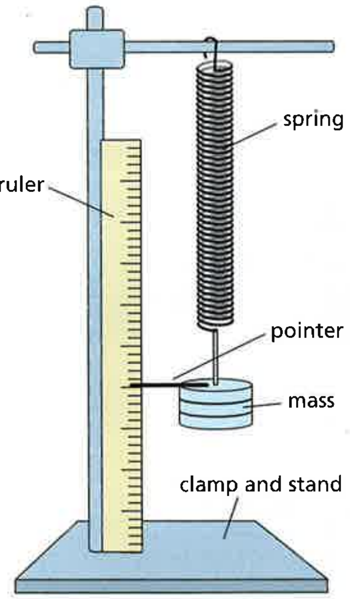


FIGURE 2.1.4b: Investigating Hooke's Law.

3. A spring is being tested. It stretches by 3 cm when a force of 10 N is applied to it. If it behaves according to Hooke's Law, how far would you expect it to extend when these forces are put on it?

   a) 20 N **b)** 70 N **c)** 2 N

4. State Hooke's Law in your own words.

Designing forcemeters

A newtonmeter can only work accurately within a certain range of forces. This is because a spring stretches in even amounts, according to Hooke's Law, only up to a certain extension. Also, if even more force is added, the spring may not return to its original length when the force is removed. The spring has been stretched beyond its **elastic limit** and the device will be damaged and cannot be used again. Newtonmeters have an end-stop so that the spring cannot be stretched too far.

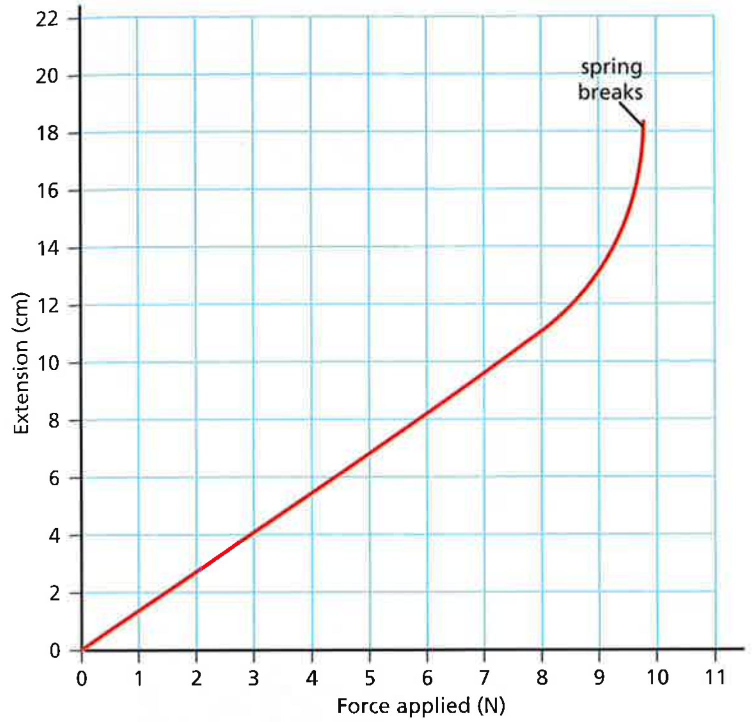


FIGURE 2.1.4d: The effect of a stretching force on a spring.

5. Look at Figure 2.1.4d. Describe what happens as the force on the spring is increased.
6. From the graph:
   a) how much force is needed to extend the spring by 7 cm?
   b) how much does the spring extend by if a force of 3.5 N is applied to it?
7. **a)** Suggest approximately what size of force is needed to exceed the elastic limit of the spring.
   b) Why is it not possible to be sure what the exact limit is from the graph?

FIGURE 2.1.4c: This spring has been stretched beyond its elastic limit.

Did you know...?

There are special phrases for describing relationships between variables in science and maths. When a graph, such as the one for Hooke's Law, has a straight line going through zero on both axes, we say that the two variables are *directly proportional*.

Know this vocabulary

linear relationship

Exploring pressure on a solid surface

We are learning how to:

- Explain how pressure can be applied on a solid surface.
- Describe some effects of varying pressure.

Many people would think that lying on a bed of nails would be very painful and dangerous. The whole force of a person's weight would be acting through the sharp ends of the nails. Understanding the idea of pressure helps us to explain how such a feat is possible.

FIGURE 2.1.5a: The force is spread over many nails to make this possible.

Spreading the force

When a person lies down they can feel comfortable even on a hard surface. The force of weight is spread over a large surface. This reduces the **pressure** on the body.

If the force of weight is acting over a small **area**, the pressure is greater. Trying to lie on the point of a single nail would mean that several hundred newtons would be acting over an area of less than 1 mm^2 on the nail's point – the pressure would be massive. The skin cannot withstand such pressure and would be pierced by the nail.

Look carefully at the bed of nails in Figure 2.1.5a. There are hundreds of nails, so the force of weight is shared. The pressure on any one nail is small and the person does not suffer pain or injury.

1. What unit is used to measure the downwards force of weight?
2. Complete this sentence: 'The greater the area that a force acts over, the ...'
3. Explain why sitting on a drawing pin can be painful.

Reduced pressure; increased pressure

Looking at Figure 2.1.5b you can see how the large area of a camel's feet helps to stop it sinking into the sand. Similarly, a tractor's tyres spread the weight of the tractor over a larger area than narrow tyres would.

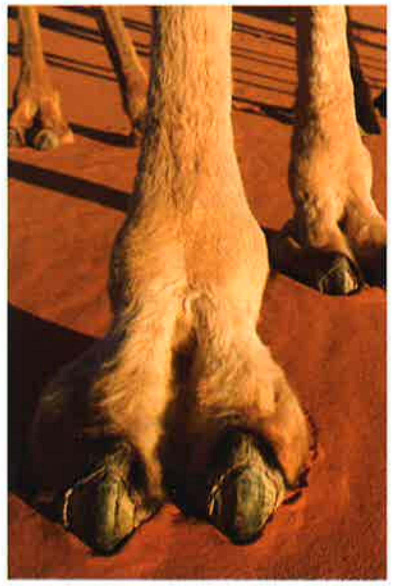


FIGURE 2.1.5b: Is it an increase in pressure or a reduction in pressure that helps in this situation?

A knife concentrates a force over the very small area of the blade's edge. The small area of the blade of an ice skate has two benefits. Firstly, the high pressure causes the ice to melt slightly underneath the blade. The thin layer of water formed acts as a lubricant. Secondly, when the skate is leaned over, there is so much pressure on one edge of the blade that it cuts into the ice, allowing the skater to turn.

4. Explain how a camel's feet allow it to walk on soft sand.
5. Explain why cutting with a sharp knife is easier than with a blunt one.
6. Suggest why roller skates would be ineffective on ice compared to ice skates.

Solving engineering problems

Engineers use the idea of pressure to improve designs for different purposes.

In skiing, a downhill racer uses a different ski design to someone skiing over deep powder snow. A hand-operated tin opener uses levers to multiply the force applied. This force then acts through the narrow cutting blade. The pressure is high enough to cut through the tin.

Did you know...?

Many car seats contain pressure sensors that allow them to detect if the seat is occupied. The seat belt warning sign will operate if the belt is not fastened.

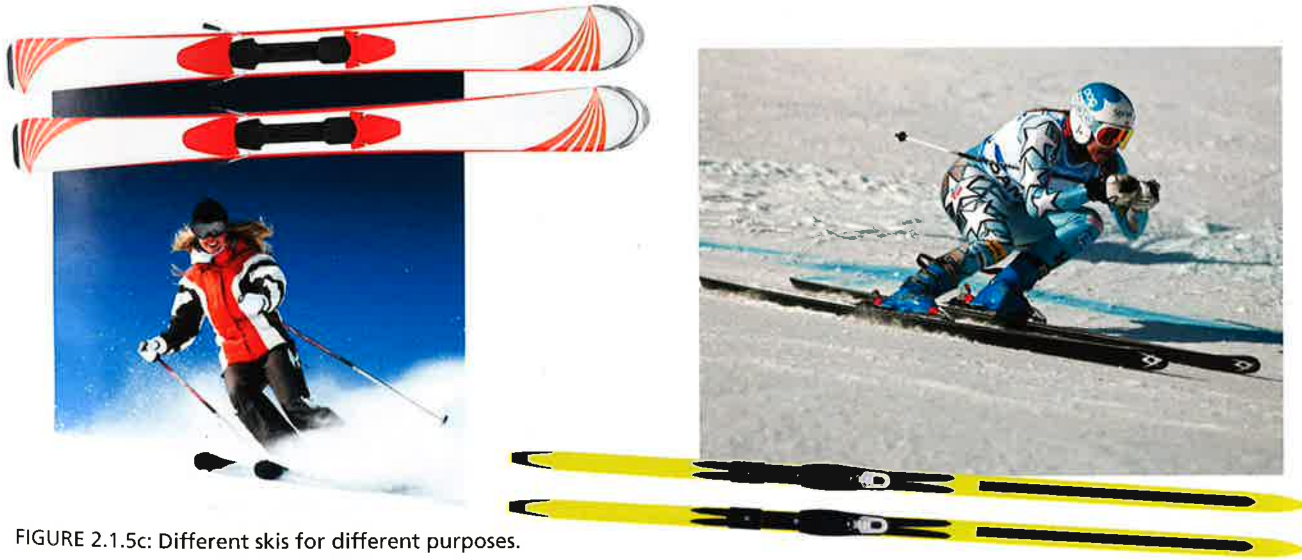


FIGURE 2.1.5c: Different skis for different purposes.

7. Explain the problems that a downhill ski racer and powder skier would encounter if they swapped skis.
8. Suggest how the design of a hand-operated tin opener could be improved. Use scientific ideas to explain how your improvement would work.
9. Sketch a design for a rucksack showing how its features make it comfortable to carry.

Know this vocabulary

pressure
area

Exploring pressure in a fluid

We are learning how to:

- Describe how pressure in a liquid increases with depth.
- Describe how pressure in a gas varies with height above Earth.
- Explain pressure changes in relation to particles and gravity.

Sea creatures and divers experience the effects of pressure as they swim in deep water. Whales have ribs that are joined by very flexible cartilage. This allows the rib cage to compress when they make a deep dive. Without this flexibility, the high pressure could break the rib cage.

FIGURE 2.1.6a: A whale in the deep sea.

How pressure varies

When we are on the land, the pressure inside our bodies is the same as the pressure of the air around us. However, when people go diving there is extra pressure from the water above – the greater the **depth**, the higher the pressure.

When you are deep in the water, the pressure results from the weight of water pressing down on you from above. The water is actually pressing all around you, so the pressure is the same all over your body.

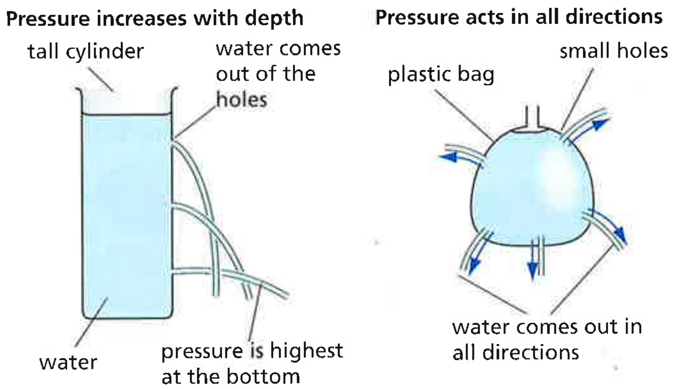


FIGURE 2.1.6b: Pressure in liquids.

1. Why would you experience more pressure at the bottom of a swimming pool than at the surface?
2. a) What dangers would face divers if they descended quickly to a great depth?
   b) How can a whale descend quickly and yet face no problems?

Explaining pressure in liquids

To help explain how pressure acts in a liquid, imagine the water particles to be represented by a large container of marbles. If you press your fist down into the marbles they push against each other and some of them are forced upwards, even though you are pressing downwards.

Did you know...?

There have been several manned and unmanned trips to the bottom of the deepest part of the ocean – the Mariana Trench in the Pacific Ocean. Even though the pressure is around 100 million pascals, there is a thriving ecosystem.

Imagine lying at the bottom of a deep swimming pool full of marbles. You would feel the weight of the marbles pressing down on you. The more marbles above you, the larger the force on your body.

3. Explain why the pressure in Figure 2.1.6c is greater at position B compared to position A.
4. How can the marbles model help us to understand pressure in liquids?
5. What drawbacks does the marbles model have in explaining pressure in liquids?

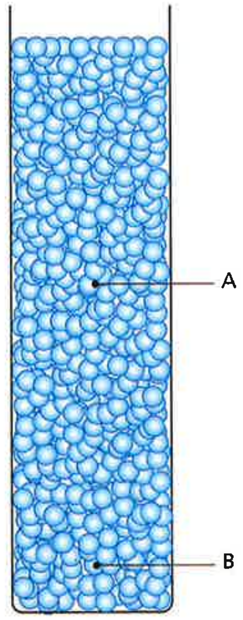


FIGURE 2.1.6c: Particles in a liquid causing pressure.

Explaining pressure in the atmosphere

The atmosphere contains **molecules** of oxygen, nitrogen and carbon dioxide as well as particles of other gases. The force of gravity pulls all these particles towards the Earth. This causes the atmosphere to press down on the Earth and everything on it. The pressing down is called **atmospheric pressure**.

The particles in the air are constantly moving and they do not lie in a compact layer on the Earth's surface. The higher you go from the Earth's surface, the more space there is between the particles.

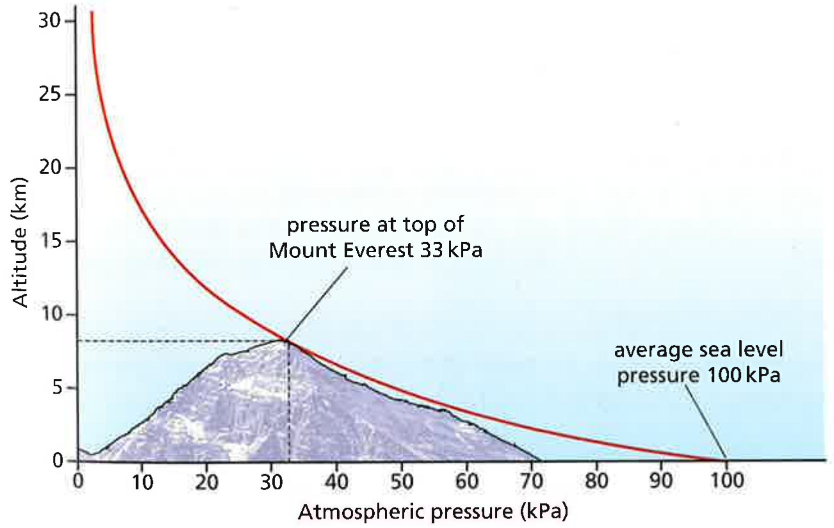


FIGURE 2.1.6e: Variation of atmospheric pressure with **height**.

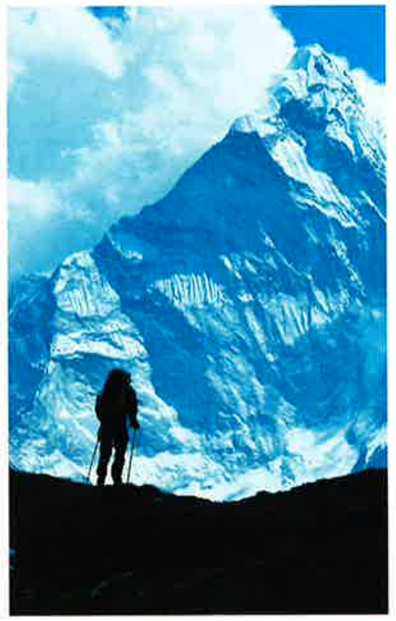


FIGURE 2.1.6d: What challenges does mountaineering present?

6. What causes the atmosphere to have pressure?
7. Suggest why there is no atmosphere in outer space.
8. Draw a pair of diagrams suggesting how the arrangement of gas particles in a balloon at an altitude of 25 km is different from that at 1 km.

Know this vocabulary

depth
molecules
atmospheric pressure
height

Calculating pressure

We are learning how to:

- Identify the factors that determine the size of pressure on a solid.
- Calulate the size of pressure exerted.

Calculating pressure is important to engineers. For example, the foundations of a building have to carry the full downwards force of its weight. There have been cases of buildings collapsing when the pressure on the foundations was too large. Engineers calculate the area needed for the foundations to support the structure.

Calculating pressure

Pressure tells us how much force is applied over an area. The **formula** used to calculate pressure is:

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

or in shorthand:

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

Force is measured in newtons (N) and area is measured in square metres, so the pressure is measured in newtons per square metre (N/m^2). The unit for pressure is the **pascal** (**Pa**). 1 Pa is exactly the same as 1 N/m^2.

FIGURE 2.1.7a: Because snow shoes have a larger surface area than your foot, they distribute the amount of pressure that your body puts on the snow over a larger area, so that your foot does not sink completely into the snow.

1. What is the unit for pressure?
2. What is the formula for calculating pressure?
3. If we calculated pressure using force in newtons and area in square centimetres, what unit would the answer be in?

Example calculations

To calculate the pressure exerted by a box with a base of 2 m^2 pressing onto the ground with a force of 40 N:

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

$$P = \frac{40}{2}$$

$P = 20\,N/m^2$ or $P = 20$ Pa

Did you know...?

Engineers build in a safety margin when designing structures. This reduces the chance of a structure failing if an unexpected force is applied or if materials gradually become weaker as they get older.

4. Calculate the pressure exerted on the ground by a piece of wood with a base area of 2 m^2 and weighing 20 N.
5. A concrete base for a barbeque has a mass of 500 N and an area of 4 m^2. Calculate the pressure it exerts on the ground.
6. Which exerts the largest pressure – a crate weighing 500 N acting on a surface of 25 m^2 or one weighing 400 N acting on a surface of 10 m^2?

Solving pressure problems

If you know what the values of two of the quantities in the pressure formula are, you can calculate the third quantity by rearranging the formula.

$A = \frac{F}{P}$ or $F = P \times A$

An engineer can work out the strength and size of designs needed to withstand certain pressures. For example, a bridge needs to take loads up to 45 000 N. It is built on ground that can withstand 5000 Pa. To calculate the area needed for the bridge supports:

$$A = \frac{F}{P} = \frac{45\,000}{5000} = 9\,m^2$$

Care must be taken to use the correct units for all quantities. The area is in square metres because the force was in newtons and the pressure was in pascals.

FIGURE 2.1.7b: How could you work out the pressure that this piano exerts on the floor?

7. An engineer wants the floor of a car to be able to take a total force of 12 000 N from all the seats. The floor can take a pressure of 24 000 Pa. What area must the seat supports be?
8. When someone is on a trampoline they may be sitting down or on their feet.
   a) Explain whether the pressure on the trampoline is higher when sitting or standing.
   b) How could you calculate the difference in the pressures exerted when sitting or standing?
   c) Explain why the pressure exerted on a trampoline is greater when a person bounces rather than stands still.

Know this vocabulary

pascal (Pa)

Explaining sinking and floating

We are learning how to:

- Explain why some objects float and others sink.
- Relate floating and sinking to density, displacement and upthrust.
- Explain the implications of these ideas.

The Greek physicist, mathematician and inventor Archimedes had ideas that help us to understand floating, sinking and buoyancy. Even though he lived more than 2000 years ago his principles are still used today.

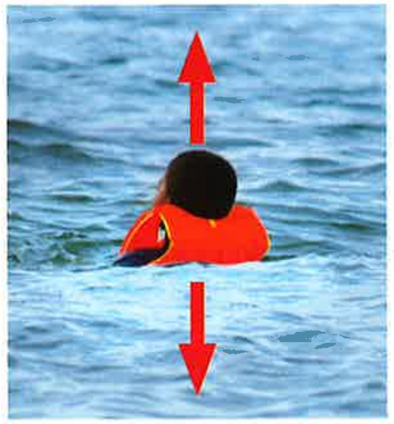


FIGURE 2.1.8a: Weight is supported by upthrust.

Density

The **density** of a material compared to water allows you to decide if it will float or sink in water. Density is the amount of mass in a particular volume of a material. If a material is denser than water it will sink, and if it less dense than water it will float.

When an object is in water, the water provides a **buoyancy** force called **upthrust**. If the force of weight is bigger than the upthrust, the object will sink. Even when it sinks it is partially supported by upthrust. When an object floats, its entire weight is supported by upthrust.

1. Name three materials that are denser than water and three that are less dense.
2. Explain why people feel heavy when they get out of water after a long swim.
3. Suggest why some materials are denser than others.

Measuring upthrust

The weight of an object in air can be compared with its apparent weight in water. The difference between the two is the difference in upthrust provided by each.

Water is **displaced** when an object is lowered into it. The weight of the displaced water is the same as the size of the upthrust force. The size of the upthrust force depends entirely on the volume of water displaced.

Neutral buoyancy happens when an object neither sinks to the bottom nor bobs to the surface. It appears to hover in the water.

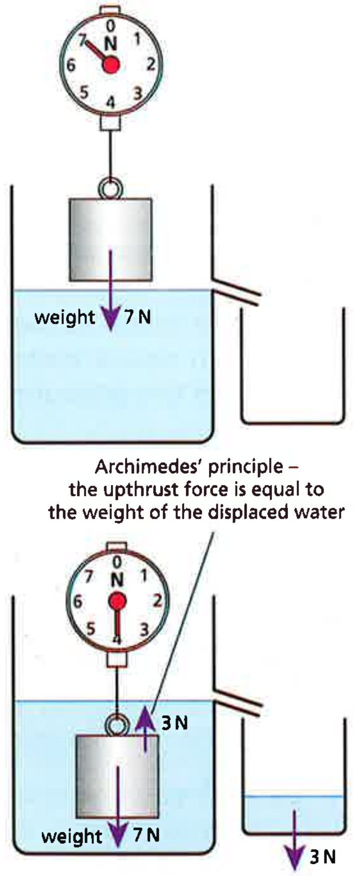


FIGURE 2.1.8b: Water provides upthrust when it is displaced.

4. Explain what the difference between the readings on the forcemeter in the two scales in Figure 2.1.8b tells you.
5. Explain the events in each of the situations (a) to (d) using at least one of these words in each explanation: dense, buoyant, upthrust, displace.
   - **a)** A lump of wood is lowered into water – the wood floats.
   - **b)** The reading on a forcemeter goes down when a suspended piece of steel is lowered into water.
   - **c)** A beaker full of water overflows when an object is lowered into the water.
   - **d)** A boat made of steel floats.

Did you know...?

The cruise liner in Figure 2.1.8c can carry up to 3600 people, their luggage and all the facilities needed. The hull underneath the water is very large so that it can displace enough water to provide the necessary upthrust.

Applying ideas about upthrust

Modern ships are made of steel. The reason that the shape allows them to float is that it displaces a large volume of water.

The air inside the boat weighs very little compared to the water displaced.

Any object floating in water displaces its own weight in water. The upthrust is equal to the force of weight, so the object does not rise or fall.

FIGURE 2.1.8c: How does this huge cruise liner float?

6. Draw force diagrams to show the forces acting on:
   - **a)** a lightly loaded ship floating in water.
   - **b)** the same heavily loaded ship floating on water.
   - **c)** a football that is being held under water.
   - **d)** a football the moment it was released after being held under water.
7. Explain what would happen to a boat that was gradually filled with water.

Know this vocabulary

density
buoyancy
upthrust
displaced

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

Represent forces using force diagrams.	Describe the size and direction of forces using force diagrams.	Explain how the size and direction of forces determines their effects.
Describe how materials behave when subjected to forces of tension or compression.	Explain the relationship between the amount of change in shape and the size of the force.	Explain that, in some materials, the change is proportional to the force applied.
Explain that friction is a contact force opposing the direction of movement.	Identify factors which affect the size of frictional and drag forces.	Evaluate how well a design reduces frictional or drag forces.
Recall that if the forces on an object cancel out that it is in equilibrium.	Explain that if a resultant force is zero, the object will remain at rest or continue to travel in a straight line at a steady speed.	Apply ideas about resultant forces and equilibrium to unfamiliar contexts.
Describe the causes and effects of varying pressure on and by solids.	Explain how force and area can be varied to alter the pressure applied.	Calculate the pressure applied by a solid from the force applied and the contact surface area.

Describe the variation of pressure in liquids with depth and the effects of this.	Explain the variation of pressure with depth in liquids.	Identify the causes and implications of variation of pressure with depth.
Explain why some objects float and others sink.	Use the concepts of density, displacement and upthrust in explaining floating and sinking.	Apply ideas about density and upthrust to predict the outcomes of various situations.
Describe how atmospheric pressure varies with height; state some implications of variations in pressure.	Explain why atmospheric pressure varies with height; describe how the effects of pressure are used and dealt with.	Identify some implications of pressure variation in situations such as weather patterns and high altitude activities.
Recognise that pressure acts in a fluid in all directions.	Explain how liquids are used in hydraulic systems to transmit forces.	Carry out calculations relating to hydraulic systems in which the applied forces are increased.

Questions

KNOW. Questions 1–5

See how well you have understood the ideas in this chapter.

1. Which of these statements about forces and movement is true? [1]

a) If an object is moving there must be a force acting.
b) When a parachutist opens his parachute he moves upwards.
c) Balanced forces cause movement.
d) A moving object continues at the same speed unless an unbalanced force acts.

2. Which of these statements about forces and movement is *always* true? [1]

a) A moving object will stop unless a force acts on it.
b) A stationary object with forces acting on it will start to move.
c) When all the forces acting on an object are in equilibrium, its position will not change.
d) When all the forces acting on an object are in equilibrium, its speed and direction of movement will not change.

3. Which is the correct explanation of pressure? [1]

a) Pressure is higher when the force applied is smaller.
b) Pressure reduces when the area that a force is applied to is decreased.
c) When you push a drawing pin into a board, the pressure is the same on both ends.
d) Pressure depends on the size of a force and the area over which it is acting.

4. Which of the units is correct for pressure? [1]

a) Pa **b)** Nm^2 **c)** N **d)** m^2

5. What pressure is produced by a 20 N force pressing on an area of $2\,m^2$? [1]

a) 100 Pa **b)** 40 Pa **c)** 10 Pa **d)** 0.1 Pa

APPLY. Questions 6–8

See how well you can apply the ideas in this chapter to new situations.

6. A child on a scooter is pushing herself along with a force of 100 N. Another child is helping to push the scooter along with a force of 70 N. Air resistance is 20 N and friction on the scooter's wheels is 140 N. What is the overall force on the scooter? What will happen to its motion? [2]

7. Why does a wooden block float but a steel one sink? [2]

8. Explain how the pressure that a chair exerts on the floor would be affected if wooden table mats were put under all the legs. [2]

EXTEND. Questions 9–11

See how well you can understand and explain new ideas and evidence.

9. A boat carrying steel bars is unloaded. It is then loaded with aluminium bars of the same size. Explain why the boat doesn't sit as low in the water now. [2]

10. Petrol engines need oxygen to react with fuel in the process of combustion. Suggest why such engines are less powerful at high altitudes. [2]

11. The air at high altitude is less dense. A person used to training at sea level travels to a mountain camp at an altitude of 4000 m. Comment on what the graph shows and suggest why. [4]

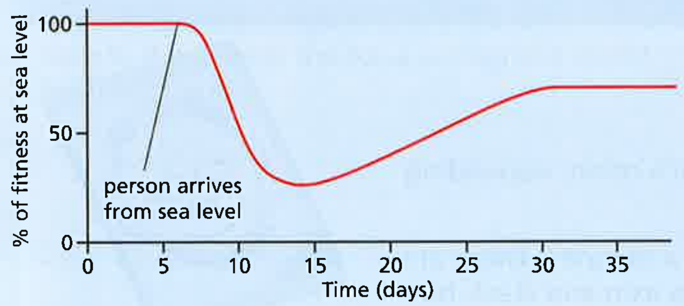


FIGURE 2.1.10a: Graph of a mountaineer's fitness against time when time is spent at 4000 m altitude.