PHYSICS

Exploring Contact and Non-Contact Forces

Ideas you have met before

Forces and what they do

Forces can be pushes, pulls or turning forces. They can be 'contact' forces – when objects are touching – or 'non-contact' forces – when the forces act at a distance.

Force arrows drawn to scale show the size and direction of forces.

A newtonmeter allows us to measure the size of a force.

When forces on an object are not balanced they can cause a stationary object to move or a moving object to change speed or direction.

Large objects, like planets, exert strong gravitational forces on other objects. These objects are attracted towards the planet.

Electricity and magnetism

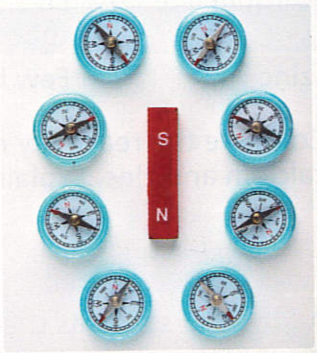
Electricity can flow through materials that are conductors.

Some materials are attracted to a magnet.

A magnet has a north pole and a south pole.

Like poles, such as two north poles, repel each other.

Unlike poles attract each other.



States of matter: solids, liquids and gases

Materials are made of particles.

Materials can be classified into three groups, or states – solids, liquids and gases.

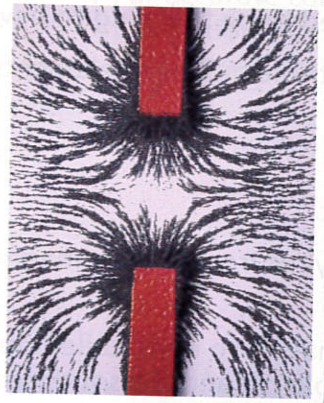
In this chapter you will find out

Gravity and space travel

- Gravity is a non-contact force that acts between all masses.
- A planet, like the Earth, has a gravitational field.
- The gravitational fields of the Earth and other objects in the Solar System affect space travel.

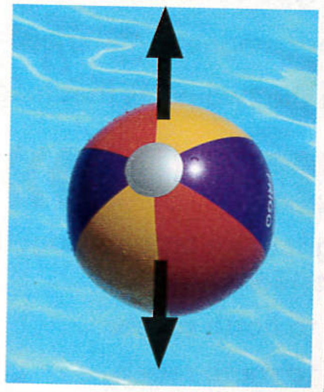
Electrostatic and magnetic forces

- Electrostatic charges have many effects. We can make use of these, but there are also dangers.
- A force field exists around a magnet, which affects certain materials.
- Magnetic fields can be drawn as lines of force.
- There are similarities and differences between magnetic fields and other types of field.



Pressure, floating and sinking

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



Exploring magnets

We are learning how to:

- Explain magnetic attraction and repulsion.
- Apply the concept of poles and the laws of attraction and repulsion.
- Predict the effects of arrangements of magnetic poles.

Magnets have many effects, sometimes surprisingly strong. They have many uses including computer hard drives, loudspeakers, credit card strips, magnetic fasteners and compasses for navigation. Even though satellite navigation is very effective, ships and aircraft still carry navigation compasses.

FIGURE 2.5.2a: Uses of magnets

Magnetic forces

Magnetism is an example of a **non-contact force**. Magnets exert a force on the region around them. A magnet will **attract** any magnetic materials that are close enough. They do not need to be touching to have an effect.

There are three magnetic elements:

- iron
- nickel
- cobalt.

Many alloys of iron are also magnetic, including most types of steel.

Magnets have two ends, called **poles**. These are the north-seeking pole (N) and the south-seeking pole (S).

1. What type of force is magnetism?
2. List four magnetic materials.
3. Name the two poles that magnets have.

Attracting and repelling

If two magnets are brought together, the effect will depend on their positions:

- north to north **repels**
- south to south repels
- north to south attracts.

5.2

A useful way to find out whether materials are magnetised or un-magnetised is by how they behave when another magnet is brought close. The unmagnetised material will be attracted by either pole of the magnet; the magnetised material will be either attracted or repelled, depending on the orientation of the poles. There will be no force from a magnet on non-magnetic materials.

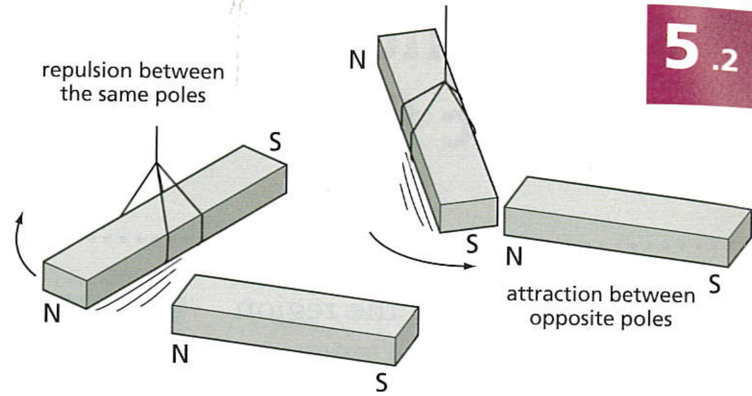


FIGURE 2.5.2b: Like poles repel, unlike poles attract.

4. Describe the rules about magnets attracting and repelling each other.
5. Describe what will happen in each of these situations:
   a) The N pole of a magnet is brought towards the S pole of another magnet.
   b) The S pole of a magnet is brought towards a piece of magnetised iron.
   c) The N pole of a magnet is brought towards a piece of copper.
6. Explain why a magnet hanging on a thread will respond to magnetic forces more easily than a magnet laying on a bench.

Did you know...?

The Earth's North Pole behaves as a magnetic south pole S, because it attracts the N end of a compass. Changes in the Earth's core mean that its magnetic poles move. For accurate compass navigation this has to be accounted for.

Effects of magnets

Magnets exert a force in the region around them and the effect can be detected with a magnetic compass. Normally, a compass needle orientates itself in line with the Earth's magnetism, but close to a magnet the force exerted is greater than the Earth's magnetism. As a magnet is brought towards a compass from a distance there comes a point when the needle is no longer in line with the Earth's magnetism. The stronger the magnet, the larger the region around it that will be affected.

7. Explain, using examples including magnetism, the differences between contact and non-contact forces.
8. Someone states that 'magnets stick together'. What would be a better explanation of the behaviour of magnets?
9. Explain the similarities and differences between the Earth's gravitational and magnetic forces.

Key vocabulary

non-contact force
attract
pole
repel

Understanding magnetic fields

We are learning how to:

- Describe magnetic fields.
- Explore the field around a magnet.
- Explain the shape, size and direction of magnetic fields.

Magnetic materials in the region around a magnet experience a magnetic force. The Earth behaves as a gigantic magnet that attracts particles from outer space towards the North and South Poles. As these particles enter the Earth's atmosphere they cause an amazing natural light display.

FIGURE 2.5.3a: The Aurora Borealis over Iceland

Magnetic fields

A **magnetic field** is the space around a magnet where its magnetic field works. Within the field, magnetic materials such as iron are attracted. Other magnets can be attracted if unlike poles are close enough or repelled if like poles are close enough.

Sprinkling iron filings around a magnet shows the magnetic field. Each of the filings becomes a tiny magnet that lines up with the field, because of magnetic forces acting on it. The arrangement of the filings shows the magnetic **field lines**. The closer the lines of magnetic force are to each other, the higher the **strength** of the magnetic field. The direction of the field lines is the direction in which a magnetic north pole would move if placed in the field – from north (N) towards south (S). This is the way a compass would point.

1. What does the pattern of iron filings around a magnet show? What does it not show?
2. Why are the lines of force closer together near the magnet poles?
3. Tiny fragments of substances other than iron could be used to show the force lines in a magnetic field. Choose which ones would work from this list: scraps of paper, steel, pepper, plastic, sawdust, nickel, house dust, copper, carbon.

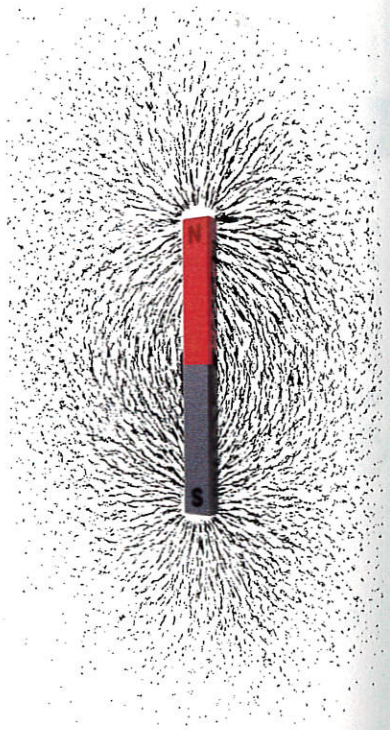


FIGURE 2.5.3b: The iron filings show the shape and strength of the magnetic field.

The Earth's magnetic field

The Earth's **core** contains materials that are rich in iron. Around a solid inner core is a molten outer core. Scientists believe that currents within the molten core create a magnetic field as they flow around.

Two well known effects of the Earth's magnetic field are:

- Magnets line up in a N to S direction, if they are free to turn. This is how a compass works.
- The Aurora Borealis (Northern Lights). Charged particles entering Earth's atmosphere are attracted to the magnetic poles. As they collide with the gas particles in the atmosphere an amazing natural light display is created.

The Earth also has a gravitational field, which is the region around the Earth where the force of gravity acts. The gravitational field attracts all masses, whereas only particular materials are affected by the magnetic field. You will learn more about the Earth's magnetic field in Chapter 6.

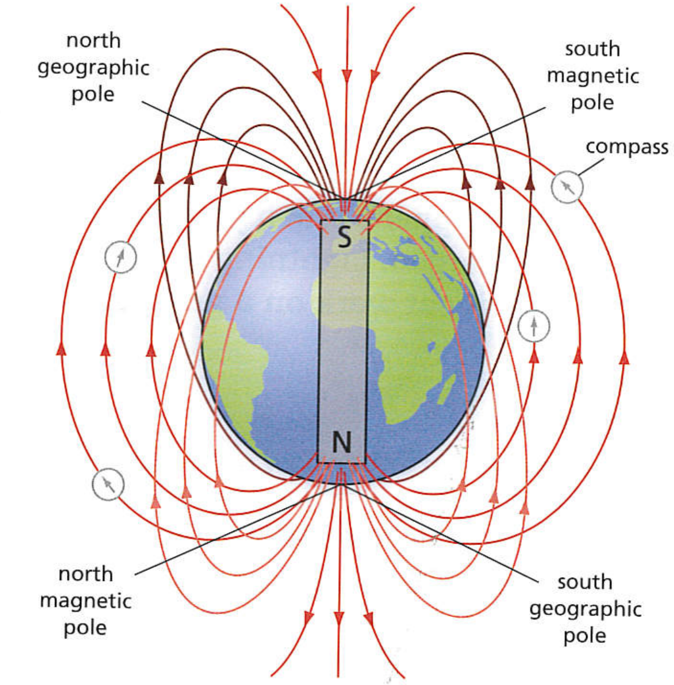


FIGURE 2.5.3c: The Earth's magnetic field. The geographic and magnetic poles do not exactly coincide.

4. Why does the Earth have a magnetic field around it?
5. Describe similarities and differences between magnetism and gravity.
6. How can evidence be collected to find out whether other planets have magnetic fields?

Did you know...?

You can magnetise a piece of steel by stroking it many times in the same direction with a magnet. When a magnet is heated or hammered its magnetism becomes weaker.

The magnetic field model

Scientists often use models to try to represent things that are hard to see or understand. A model can be a simplified version, a description or a picture. Figure 2.5.3c shows a model that represents the Earth's magnetic field. It is useful because it helps us to understand something we cannot see. Many models do not represent reality exactly and scientists need to be aware of the weaknesses of the models they use.

7. Explain, using examples, why scientists use models.
8. Evaluate the Figure 2.5.3c as a model of Earth's magnetism. What are its strengths and weaknesses?

Key vocabulary

magnetic field

strength

field lines

core

Investigating static charge

We are learning how to:

- Recognise the effects of static charge.
- Explain how static charge can be generated.
- Use evidence to develop ideas about static charge.

Static electricity is a common and sometimes spectacular phenomenon. You may have noticed that after walking across a carpet, you sometimes get a small electric shock when you touch a door handle. This happens when your body has become electrically charged. Lightning is a demonstration of static electricity at work on a grand scale.

FIGURE 2.5.4a: When a person's hair becomes charged the individual strands repel each other.

Static charge

Electrical charge can either flow or be gathered in one place. **Charge** that is flowing is called a current and when it is not flowing it is called **static electricity**.

Electricity flows through conductors, such as a copper wire. However, when a charged material is not connected to a conductor, the electricity cannot flow away and so the charge stays in place.

When a charged object comes close to a conductor the electricity jumps across as a spark. If your body has become charged by walking on a carpet, you feel the charge flowing away through your fingers when you reach for the door handle.

1. Name some materials that are good conductors of electricity.
2. What does the word 'static' mean?
3. How could a material that conducts electricity become charged?

FIGURE 2.5.4b: Static electricity can cause attraction.

Attraction and repulsion

When an object becomes charged with static electricity a **field** of electrostatic force exists around the object. This is a non-contact force. This force can **attract** other materials and may be strong enough to lift them. A charged balloon brought close to someone's head can attract strands of hair and lift them up without the balloon coming into contact with the hair. Scraps of paper can be made to jump off a table and stick to a charged plastic comb held a few centimetres above it.

When two objects of the same material become charged they **repel** each other.

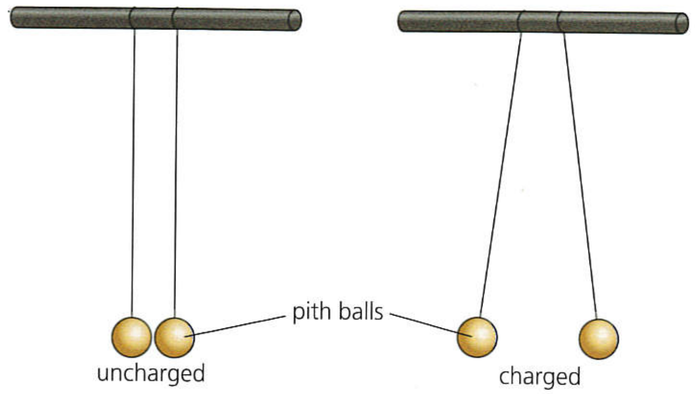


FIGURE 2.5.4.c: Repulsion between two identical charged objects

4. What could small pieces of dust and paper experience when a charged object is brought close?
5. What evidence supports the idea that static electricity exerts a non-contact force?
6. How could you find out if two charged combs repel each other?

Comparing static electricity and magnetism

Fields around charged objects and magnets result in forces of attraction and repulsion. Magnetism is restricted to iron-based materials plus nickel and cobalt. Static electricity can affect a much wider range of materials provided that there is no opportunity for the electrical charge to flow away. Magnetic effects are capable of producing much larger forces. Magnets vary in strength but can exert large forces on magnetic materials. Charged objects can attract objects around them, but in most circumstances the force is small.

When an object becomes very highly charged with static electricity the charge usually escapes through contact with other objects or into the air. Lightning occurs when a large charge escapes quickly from clouds that have become charged during a storm.

7. Thinking about forces, in what ways are magnetism and static electricity similar?
8. Devise a method for finding out which can give the greater force of attraction – magnetism or static electricity.
9. Suggest why TV screens often attract more dust than walls that are close by.

Did you know...?

Some items of clothing become charged so easily that when you take them off, the cloth crackles and sparks as the charge escapes. This occurs in dry weather and a dark room is needed to see the effect.

Key vocabulary

charge
static electricity
field
attract
repel

Explaining static charge

We are learning how to:

- Explain static charge in terms of electron transfer.
- Apply this explanation to various examples.

In ancient Greece, people started to put forward ideas about atoms. They thought that atoms were the most basic particles and that they could not be split further. It was not until the 1800s that ideas really developed beyond this. Scientists have developed a much better understanding of what atoms are like inside. These more modern ideas form the basis of our understanding in many areas of chemistry and physics, including static electricity.

Atoms and electrons

The simplest modern model of an atom is a nucleus being orbited by **electrons**. The nucleus has a **positive charge** because it contains positively charged **protons** – along with neutrons, which have no charge. Electrons have a **negative charge**. Overall an atom is **neutral** because the positively charged protons are balanced by an equal number of negatively charged electrons.

If some electrons get transferred from one object to another the charges no longer balance. This is what happens when an object becomes statically charged.

1. What are atoms made up of?
2. Why do atoms have no charge overall?
3. How can an object become negatively charged?
4. How can an object become positively charged?

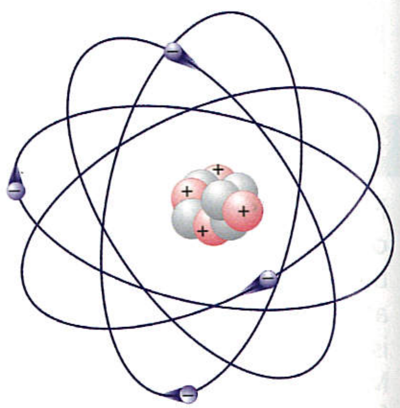


FIGURE 2.5.5a: Atoms contain a balance of positively charged protons and negatively charged electrons.

Positive and negative charge

When a nylon rod is rubbed with a cloth, electrons are transferred from the rod to the cloth. Because electrons are negatively charged this makes the cloth negatively charged. The rod has lost electrons so the positive charge of the protons is no longer balanced – its overall charge is now positive.

Other materials behave differently. A polythene rod, for example, gains electrons when rubbed with a cloth. It becomes negatively charged and the cloth, which has lost electrons, becomes positively charged.

5. Describe what happens to a cloth when it is rubbed on a nylon rod.
6. Explain how different materials behave differently when rubbed with a cloth.

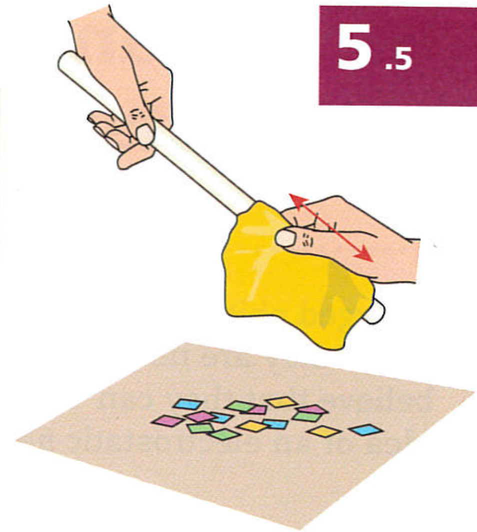


FIGURE 2.5.5b: Rubbing transfers electrons.

Loss of charge

Static charge depends on electrons being unable to flow into or out of an object. If a charged polythene rod is connected to a conductor, such as a wire, electrons will flow away from the rod. The rod loses its charge and becomes neutral.

Air is not a good conductor, but it can transfer some electrons, so charged objects gradually lose their charge. In wet weather, the water vapour in the air can transfer more electrons so charge is lost more quickly.

When a van de Graaff generator is turned on, the globe becomes positively charged. It can be neutralised by touching it with the earthing sphere. The earthing sphere is connected to a conductor so that electrons can flow freely to and from it.

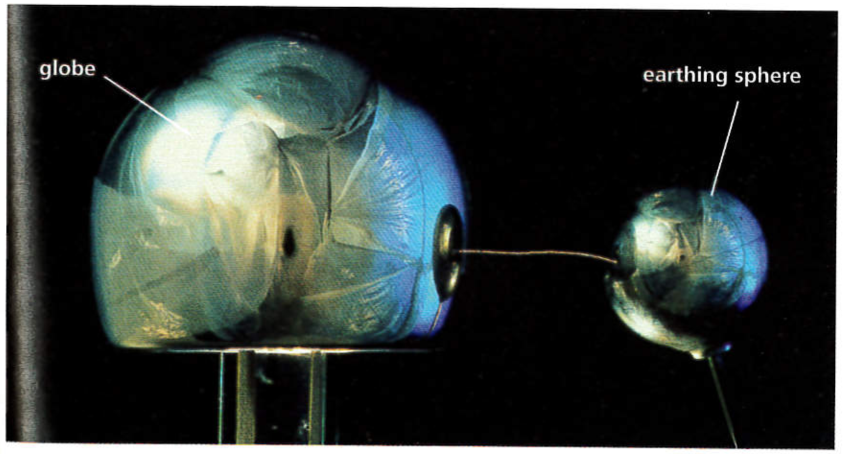


FIGURE 2.5.5.c: A van de Graaff generator and earthing sphere

7. Explain why experiments with static electricity give better effects in dry weather.
8. a) When a van de Graaff generator is turned on, explain what effect it has on the electrons in a person's body when they touch the globe.
   b) Using your answer from question 8a suggest why the person's hair stands on end.
   c) Explain the process of discharging the globe of a van de Graaff generator.

Did you know...?

A desk-top van de Graaff generator, like the ones used in schools, can produce 100 000 volts. Bigger van de Graaff generators can exceed two million volts.

Key vocabulary

electron
positive charge
proton
negative charge
neutral

Understanding electrostatic fields

We are learning how to:

- Explain static electricity in terms of fields.
- Explain how charged objects affect other objects.

Charged objects can affect their surroundings even when they are not in contact. Sometimes people believe that they can 'feel' electricity in the air. The idea of an electrostatic field helps to explain this.

Rules of attraction and repulsion

An **electrostatic field** exists around a charged object that can exert a non-contact force. Just as with magnetic poles, like charges repel and unlike charges attract. There is another similarity with magnetism – a magnet can attract an unmagnetised piece of iron and a charged object can attract an uncharged one.

Water has no overall electrical charge – it has a balance of negatively and positively charged particles. Despite this, water is affected by an electrostatic field.

1. What is the area around a charged object called?
2. Looking at Figure 2.5.6a, what evidence suggests that a non-contact force is working?
3. All substances contain charged particles. In many cases they have no charge – explain why.

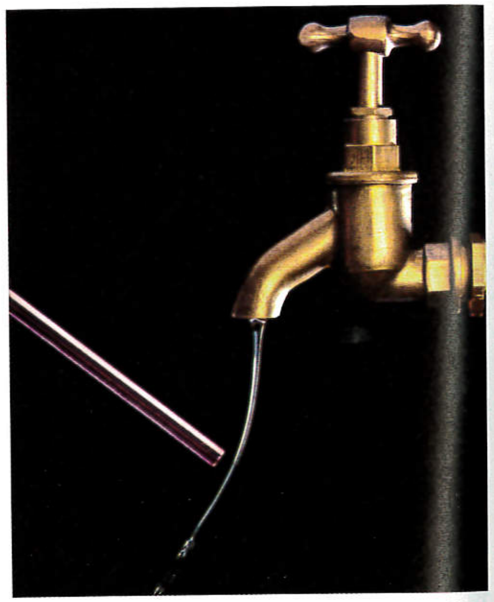


FIGURE 2.5.6a: The water is attracted towards a charged rod.

Charged particles moving

Within many substances, charged particles are free to move. When there is no electrostatic field present, the charged particles are spread evenly.

In Figure 2.5.6b the negatively charged balloon has electrons spread over its surface. When it is brought towards the wall, the negatively charged particles in the wall atoms are repelled. This leaves the surface of the wall with a positive charge. We say that a charge has been **induced** on the wall surface by the electrostatic field of the balloon. The opposite charges of the balloon and the wall's surface attract one another.

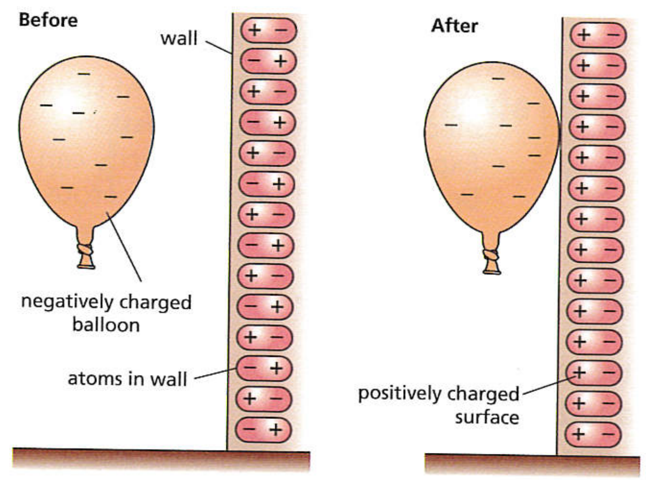


FIGURE 2.5.6b: The charged balloon has an electrostatic field around it.

4. Describe how charged particles move when an object is put in an electrostatic field.
5. Draw labelled diagrams to show how a positively charged rod can attract a trickle of water.
6. Suggest why a metal rod is unlikely to be able to attract a trickle of water.

Induced charge

A gold leaf electroscope allows us to explore static charge. The gold leaf is connected by a copper strip to a metal cap. This is all insulated from the rest of the electroscope and from the surroundings. Normally the gold leaf hangs downwards against the copper strip, but when it becomes charged it is repelled from the copper strip and lifts up.

7. Explain why it is important for the copper strip to be insulated from the body of the electroscope.
8. In an experiment a negatively charged rod is gradually brought closer to the cap of the electroscope. At first the gold leaf hangs down against the copper strip, but the closer the rod comes to the cap, the further the gold leaf is deflected.
   a) Explain why the gold leaf hangs down against the copper strip when the rod is far away from the electroscope.
   b) Explain why the gold leaf is deflected when the rod is close to the cap of the electroscope.
   c) Explain what you would expect to happen if the rod was taken away again.

FIGURE 2.5.6c: A gold leaf electroscope can detect electrostatic charge.

Did you know...?

Lines of force exist in an electrostatic field around a charged object, in a similar way to lines of magnetic force that exist around a magnet.

Key vocabulary

electrostatic field

induced

Applying what we know about electrostatics

We are learning how to:

- Apply an understanding of static electricity to various situations.
- Explain how static electricity can be useful and can be dangerous.

Static charge leads to more than just interesting scientific effects. Our understanding has led to useful applications and also plays a big role in keeping us safe in certain situations.

Using electrostatics

In paint spraying, a mist of tiny droplets of paint are forced from a nozzle onto the surface being painted. Spraying a flat surface is easy, but when spraying a complicated shape it is hard to reach into all the corners. Furthermore, a lot of paint can end up missing its target when small objects are sprayed.

Paint spraying can be improved by using spray guns that give a positive charge to the paint. The object being painted is negatively charged. The **electrostatic attraction** pulls the mist of paint onto the object.

1. State two advantages of using electrostatics in paint spraying.
2. When paint spraying uses electrostatics, how is the paint attracted to the object being painted?

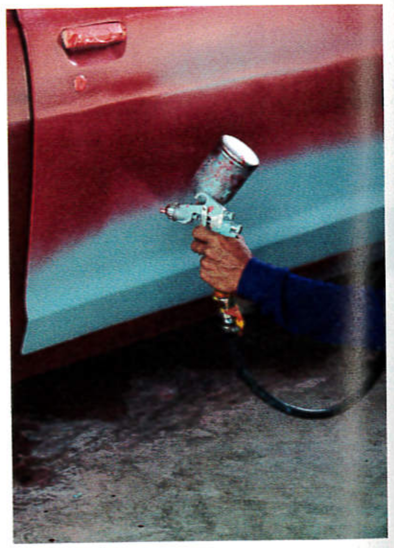


FIGURE 2.5.7a: Static charge attracts paint spray onto the car door.

Printers and photocopiers

Photocopiers work by using an electrostatic effect. Figure 2.5.7b shows how this works. Inside a photocopier a bright light is used to project the image to be copied onto a positively charged plate. The light areas lose their charge but the dark areas keep their positive charge. In the next stage the black toner ink is attracted to the positively charged areas on the plate. When paper is fed onto the plate, the toner sticks to the paper to create the image. In the final stage, the paper is heated to 'bake' the toner onto the page.

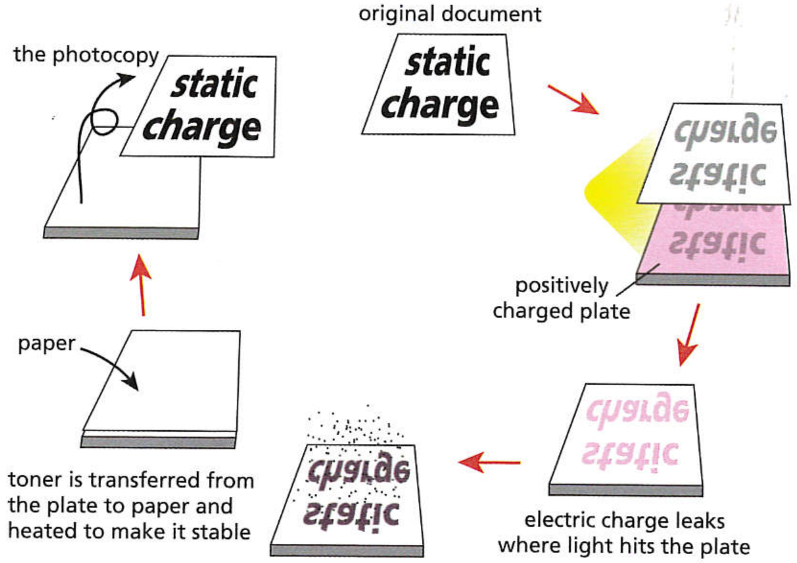


FIGURE 2.5.7b: Static charge attracts the ink to create an image in a photocopier.

3. From the information in Figure 2.5.7b, deduce what the charge on the toner in a photocopier is.
4. Suggest how a photocopier can be made to print shades of grey as well as black. Use the idea of static charge in your answer.
5. Even though printers and photocopiers use static charge, explain why it is unusual to get a shock from them.
6. Explain how an image can be copied accurately by a photocopier.

Lightning

Storm clouds create very strong updrafts and downdrafts. Temperatures inside the clouds can drop below −50 °C and tiny crystals of ice form. As these ice crystals fall inside the cloud, they collide with water being carried up and this causes electrons to be removed from the water. Negative charge accumulates at the base of the cloud and positive charge at the top. Eventually the difference in charge between the base of the cloud and the ground is so big that there is a massive discharge via a lightning bolt. A bolt of lightning can carry a current of 30 000 amps. Most domestic appliances, need a current of less than 10 amps.

7. What effect would you expect the electrical field from a storm cloud to have on the ground underneath?
8. Suggest why lightning strikes often happen from cloud to cloud.

Did you know...?

Lightning happens around the world many times every second. A bolt can reach temperatures over 20 000 °C. Electricity usually takes the path of least resistance, so tall buildings are fitted with lightning conductors. This protects the building and the surroundings from the damaging effects of a lightning strike.

FIGURE 2.5.7c: Lightning happens when massive charge differences exist.

Key vocabulary

electrostatic attraction

lightning

Exploring gravity on Earth

We are learning how to:

- Explain the effects of gravity.
- Compare gravity to other non-contact forces.
- Use the concept of a gravitational field.

Gravity is a pulling force that exists between *all* objects. For small objects the force is tiny and unnoticeable, but when one of the objects is a planet, gravity is certainly a force to be reckoned with. The gravitational field of Earth reaches well out into space.

Gravity and weight

The stronger **gravity** is, the greater the **weight** of an object. The strength of the Earth's gravity gets weaker the further from Earth you go. When scientists talk about the strength of gravity they often define the location, for example on the surface of a planet.

In space stations in orbit around the Earth, astronauts look as if they have no weight. However, the Earth's gravity is attracting them and also the space station. They fall at the same rate so inside the station it looks as if the astronauts are just floating.

1. Compared to standing on Earth, what would your weight be on a high-flying plane?

   a) stronger **b)** the same **c)** weaker **d)** zero

2. Explain your answer to question 1.
3. Explain what would happen if an extremely heavy object was released inside the space station shown in Figure 2.5.8a.

FIGURE 2.5.8a: These astronauts in the space station are falling at the same rate as the space station.

Did you know...?

You can pay for a flight in a plane that will give the experience of feeling weightless. A plane flown in a curved path in the shape of a parabola creates a sensation similar to, but more extreme than, going over the top on a big-dipper ride.

The Earth's gravitational field

The region around the Earth affected by its gravity is its **gravitational field**. The field can be represented by lines of force. Where the lines are close together, the field is stronger. The further apart the lines, the weaker the field. Gravity does not stop at the Earth's surface. If you descend into a deep mine you are still pulled towards the middle of the Earth.

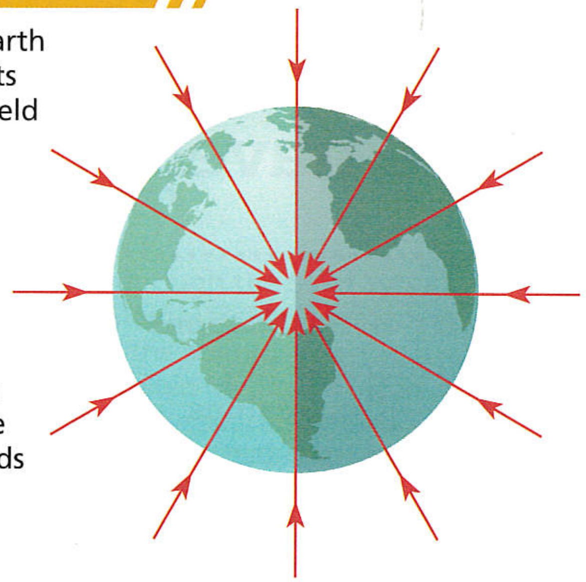


FIGURE 2.5.8b: The Earth's gravitational field

4. In what direction does Earth's gravitational force act?
5. Describe what the spacing between the field lines suggests about the gravitational field away from the Earth compared to that on the surface.
6. Describe how the Earth's gravitational field differs from its magnetic field.

Acceleration caused by gravity

Acceleration is a change in the speed or direction of an object's movement. Within the Earth's gravitational field, unsupported objects **accelerate** towards the Earth unless prevented by other forces.

Think about someone dropping an object (Figure 2.5.8c) – it starts to fall and gets faster. By the end of the first second it is falling at 10 m/s. During the next second the object continues to accelerate and by the end of that second it is falling at 20 m/s. For every one second of free fall the speed increases by 10 m/s. We say that the acceleration due to gravity (at the Earth's surface) is 10 metres per second, per second (10 m/s/s or 10 m/s^2).

7. Explain why the gaps between the object's positions in Figure 2.5.8c get bigger each time.
8. Imagine a situation where gravity on Earth could be magically turned off. Explain what would happen to the movement of an object if it was allowed to drop for one second and then gravity was turned off.

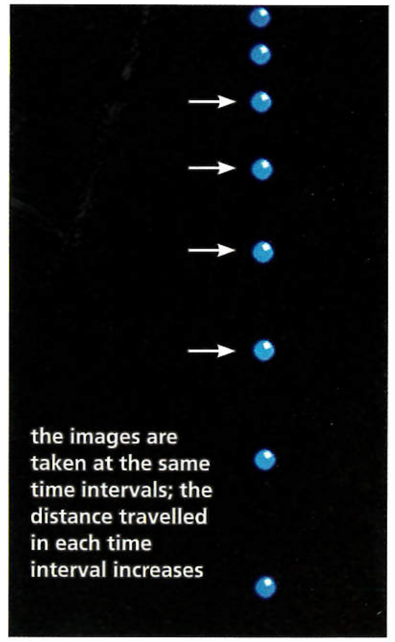


FIGURE 2.5.8c: The positions of a falling object at equal time intervals

Key vocabulary

gravity

weight

gravitational field

accelerate

Applying our understanding of gravity to space travel

We are learning how to:

- Apply ideas about gravity on Earth to other places.
- Explore how gravitational fields vary.
- Consider the effects of these changes.

Spaceships have travelled to far-off destinations in the Solar System, but the distance is tiny compared to outer space. Manned spaceships have travelled a fraction of the distance travelled by unmanned missions. Gravity is just one of the many obstacles that make space travel so challenging.

Voyager spacecraft

Two spacecraft, Voyager 1 and 2, were launched in 1977 and have been travelling ever since. In 2012, Voyager 1 left the Solar System and is now travelling through interstellar space (the region between the stars). Throughout their flights both spacecraft have been transmitting information and pictures back to Earth.

The Voyager spacecraft were launched aboard a Titan-Centaur rocket. This carried the fuel and the rocket engines needed to escape the Earth's gravity. It also protected the delicate Voyager craft from **air resistance**.

1. Describe the forces involved during the launch and flight of a space rocket.
2. State two benefits of carrying Voyager inside a rocket.
3. Explain why Voyager did not need to be streamlined.

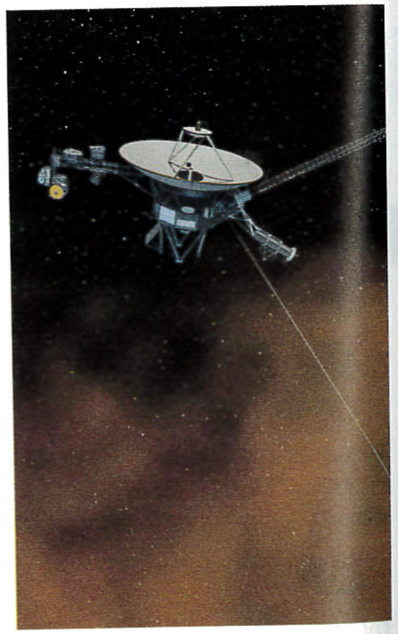


FIGURE 2.5.9a: Voyager 1

Escaping the Earth's gravity

To lift the mass of a rocket from the surface of the Earth takes a large and sustained force. It has to overcome the pulling force of gravity and the friction caused by air resistance in the atmosphere.

As the rocket climbs away from Earth, the pulling force from Earth's gravity gets weaker and eventually drops to zero. Similarly, air resistance also decreases until the rocket has left the Earth's atmosphere, then there is none.

4. Explain why the forces of gravity and friction reduce as a rocket climbs away from Earth.
5. What would happen to the motion of a space rocket after it had left the region affected by gravity from Earth or other bodies in space?

Keeping Voyager on track

As the Voyager spacecraft travel through the Solar System, they still experience weak gravitational fields from other planets and the Sun. Signals from the scientists on Earth allow Voyager 1 and 2 to be controlled by tiny thrusters that provide enough force to keep the spacecraft heading in the right direction. The thrusters are tiny jet engines that burn fuel, and the waste gases ejected from them provide the pushing force. They use very small amounts of fuel, but because there is no chance of refuelling, Voyager spacecraft will eventually drift uncontrolled through space.

6. Explain why Voyager spacecraft only need very weak thrusters to keep on track.
7. Suggest what might happen to the Voyager spacecraft if they had no thrusters.
8. Suggest why the Voyager spacecraft have jet engines rather than propellers.

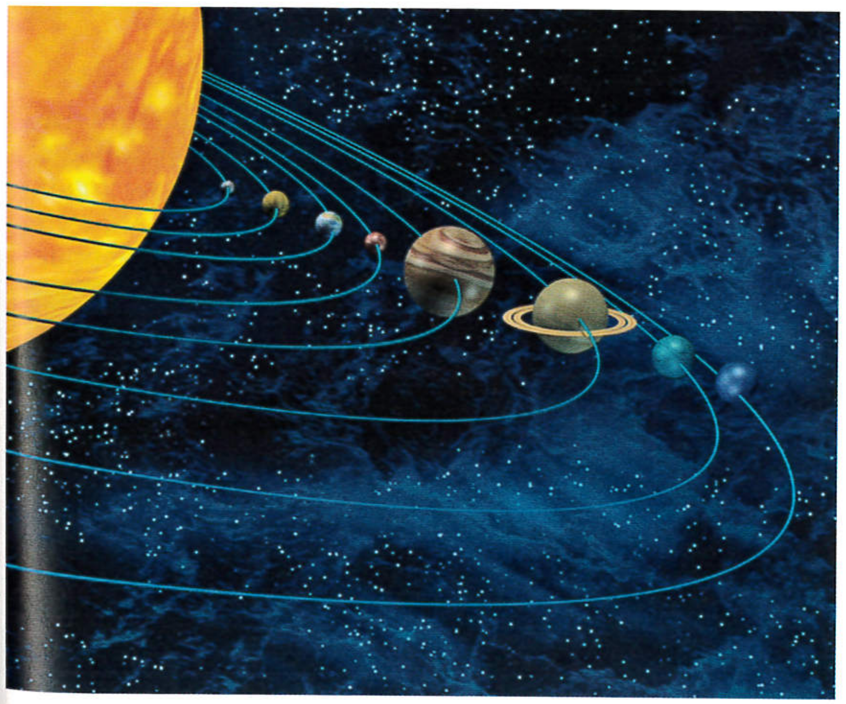


FIGURE 2.5.9c (not to scale): The regular orbital motion of the planets is evidence for the existence of gravitational fields throughout the Solar System.

FIGURE 2.5.9b: Rockets are used to deliver delicate spacecraft into space.

Did you know...?

The Voyager 1 and 2 missions are due to end, after 43 years, in 2020. By this time they will no longer be able to generate enough electrical energy to run the scientific instruments on board. The electrical needs are provided by plutonium (a nuclear fuel), which is continually decaying.

Key vocabulary

air resistance

Applying key ideas

You have now met a number of important ideas in this chapter. This activity gives an opportunity for you to apply them, just as scientists do. Read the text first, then have a go at the tasks. The first few are fairly easy – then they become a bit more challenging.

Exploring Earth's atmosphere and beyond

The Earth's atmosphere can be thought of as a protective layer around the Earth that helps sustain life. It is highly complex and constantly changing. Scientists study the atmosphere for many reasons: it helps us understand and predict the weather; we find out more about long-term changes to Earth and its climate; it is possible to learn about particles and radiation from space, which can pose a threat.

One way that scientists use to collect data is to send up balloons carrying instruments. Balloons like the one in Figure 5.2.10a are designed to go close to the edge of space – a height of 34 km above the Earth's surface. The instruments on board transmit the data they collect back to scientists on Earth.


FIGURE 2.5.10a: A high-altitude research balloon

High-altitude balloons are filled with helium, which is less dense than air. This makes it buoyant enough to overcome its weight and that of the instruments. The balloon has no propulsion or steering, so it just drifts along with the air currents.

From balloons launched in the polar regions, it has been discovered that fast-moving charged particles (protons and electrons) are held in the Earth's magnetic field. The particles spiral down the magnetic field lines towards the North and South Poles and give off harmful X-rays.

Balloons have also been very useful in the study of thunderstorms. These are one of the most dangerous weather events, not just because of the extreme wind and rain they cause but also because of massive electrical activity.


FIGURE 5.2.10b: Cloud to cloud lightning

Balloons and normal aeroplanes are not suitable for exploring space, beyond Earth's atmosphere. Specially designed spacecraft need to be used.

Task 1: Magnetic fields

Draw a labelled diagram to show the Earth and its magnetic field. Show or describe where the magnetic field is strongest. How and why would you expect different quantities of particles to strike the Earth's poles compared to the equator?

Task 2: Forces acting on a balloon

Thinking of the fields in the atmosphere, describe the forces that could be acting on a balloon – use force diagrams in your description. Suggest how these change as the balloon rises from the Earth's surface and climbs up through the atmosphere.

Task 3: Electrostatic charge

What causes electrostatic charge? A balloon climbing through a cloud may become electrostatically charged. How might this happen? How could you find out if it had become positively or negatively charged?

Task 4: Preventing lightning

Many tall structures are fitted with lightning conductors. Explain how lightning conductors help to prevent damage.

Task 5: Protecting the instruments

Scientists were worried that the expensive instruments suspended from a balloon could be damaged. They suggested three ways of protecting them: wrapped in foam; surrounded by a metal cage; surrounded by a plastic insulator. Evaluate the benefits and drawbacks of these suggestions.

Task 6: Exploring beyond the atmosphere

What are the challenges of sending instruments into space to collect data for scientific research? Consider the different methods of carrying the instruments. How can these challenges be overcome?

Task 7: Electrostatic charge in clouds

It was suggested that spraying copper dust into storm clouds could help prevent lightning. Evaluate this suggestion and try to suggest alternatives.

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.

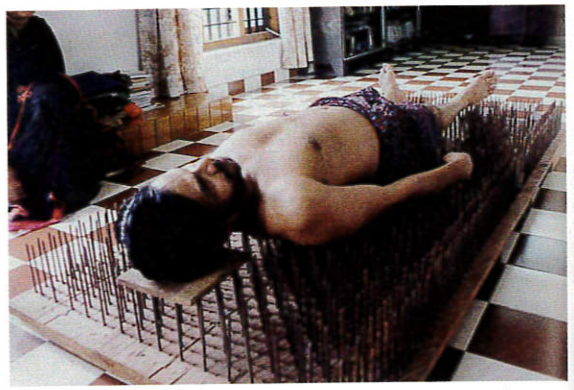


FIGURE 2.5.11a: The force is spread over many nails to make this possible.

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 2.5.11a. 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 2.5.11b 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.

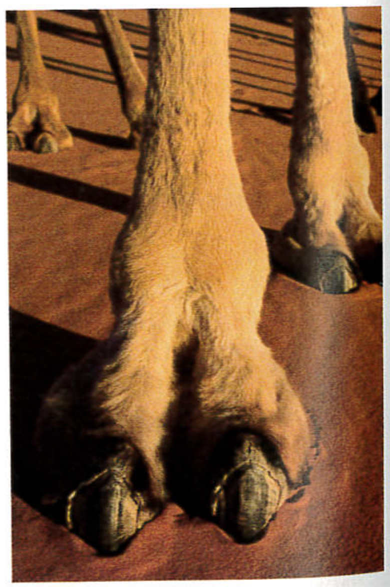


FIGURE 2.5.11b: Is it an increase in pressure or a reduction in pressure that helps in this situation?

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.

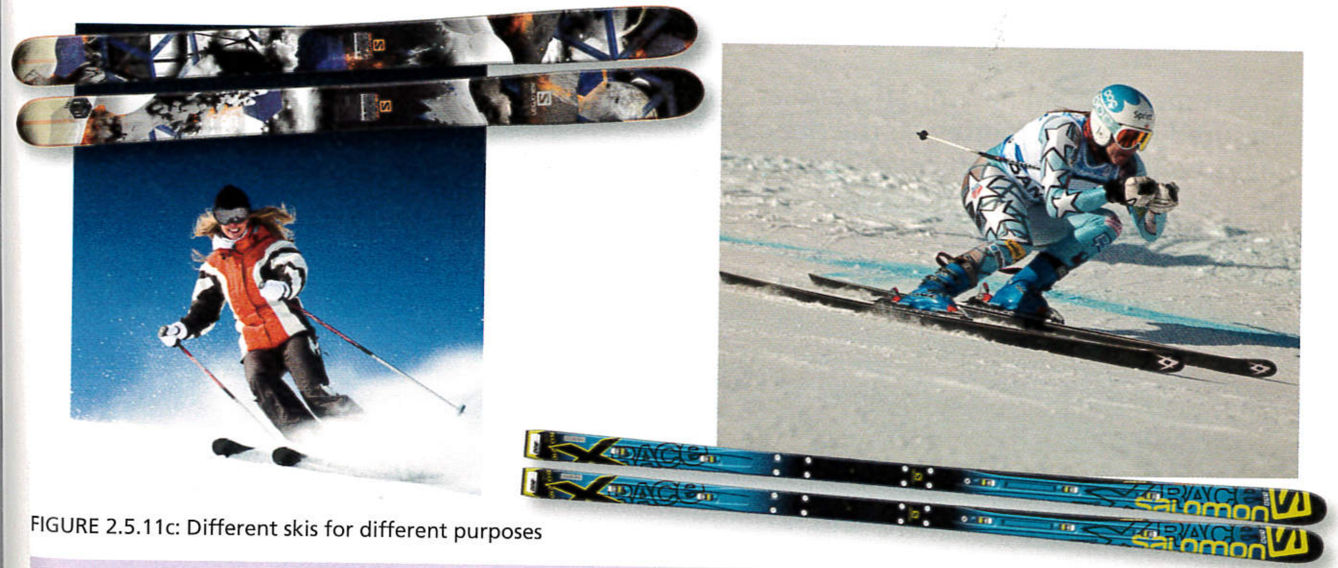


FIGURE 2.5.11c: Different skis for different purposes

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.

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.

Key vocabulary

pressure

area

Calculating pressure

We are learning how to:

- Identify the factors that determine the size of pressure on a solid.
- Calculate 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 2.5.12a: The bike rack exerts pressure where it is attached to the car.

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:

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

FIGURE 2.5.12b: How could you work out the pressure that this piano exerts on the floor?

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.

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.

Key vocabulary

formula

pascal (Pa)

Exploring pressure in a liquid

We are learning how to:

- Describe how pressure in a liquid alters with depth.
- Explain pressure increases 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 2.5.13a: 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.

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?

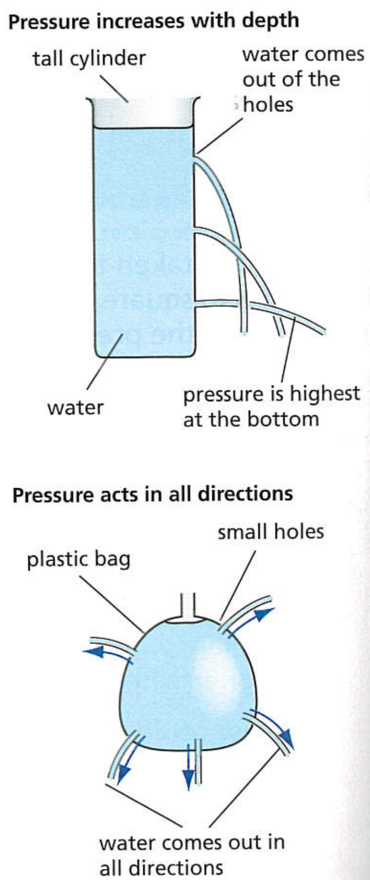


FIGURE 2.5.13b: Pressure in liquids

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.

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 2.5.13c 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?

Working at pressure

Humans are able to explore to great depths in the oceans using diving capsules like the one in Figure 2.5.13d. Inside the capsule the pressure is similar to surface pressure, so the people inside can work normally. On the outside the pressure is many times higher so the capsule has to be built to withstand it.

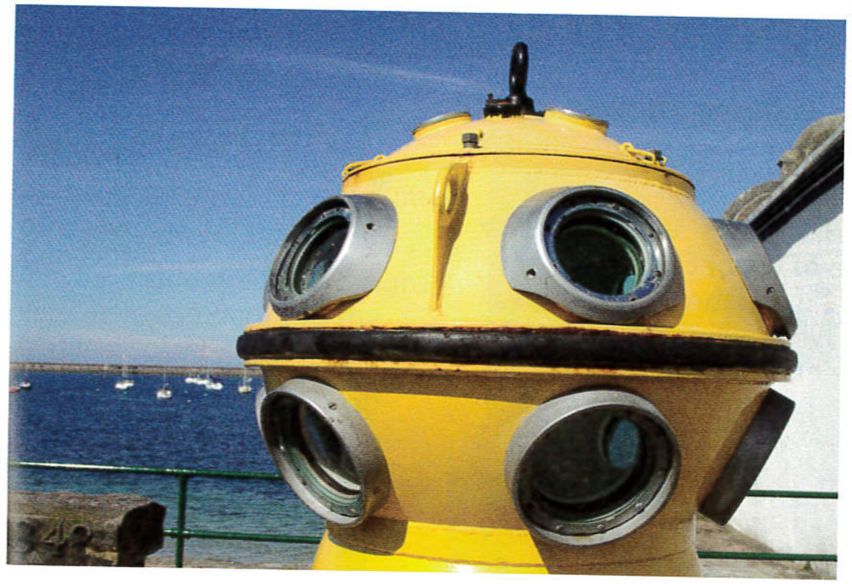


FIGURE 2.5.13d: A deep-sea diving capsule with special crystal glass windows

For work at shallower depths you can wear a diving suit, but if you come to the surface quickly you can suffer from **decompression** sickness. This is caused by gases inside the body bubbling in the way that they do when a fizzy drink is opened. You must be put into a decompression chamber so that the pressure can be reduced gradually to surface pressure.

6. Suggest what features of a diving capsule enable it to withstand the very high pressure in deep oceans.
7. Suggest differences between deep-sea creatures and humans that allows the creatures to live normally at high pressures.
8. Find out about what causes decompression sickness.

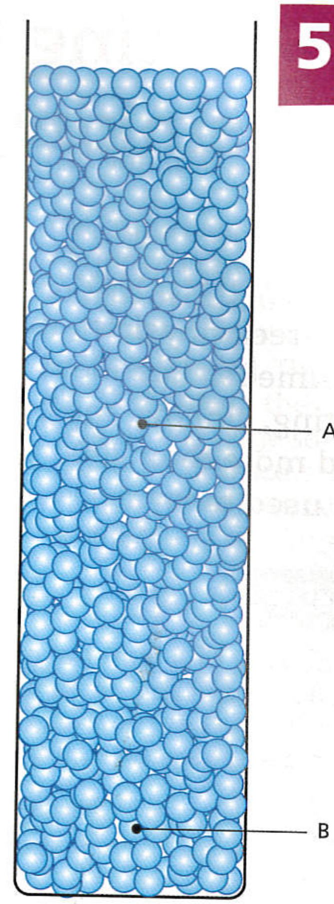


FIGURE 2.5.13c: Particles in a liquid causing pressure

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.

Key vocabulary

pressure
depth
decompression

Explaining floating and sinking

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.

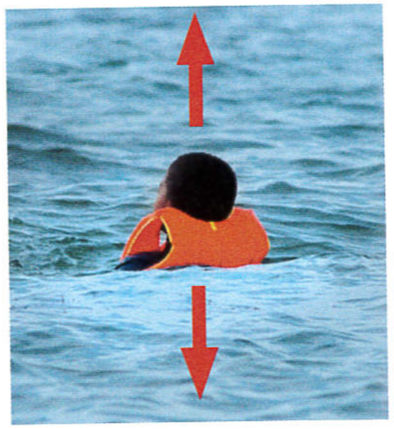


FIGURE 2.5.14a: Weight is supported by upthrust.

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 vice versa.

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 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.

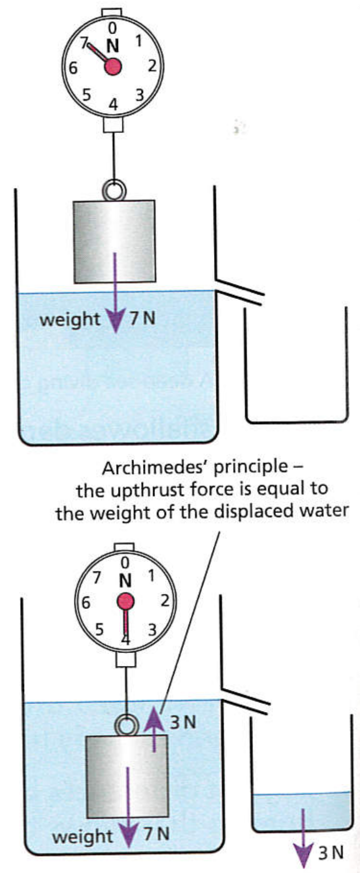


FIGURE 2.5.14b: Water provides upthrust when it is displaced.

4. Explain what the difference between the readings on the forcemeter in the two scales in Figure 2.5.14b 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 force meter 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 2.5.14c 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 2.5.14c: 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.

Key vocabulary

density
buoyancy
upthrust
displaced

Exploring gas pressure

We are learning how to:

- Explore how the pressure in a gas varies with height above the Earth.
- Explaining the implications of this changing pressure.

The pressure of the atmosphere is not the same in all places – it varies with height. High up a mountain the atmospheric pressure is much lower than at sea level. In space there is no atmosphere and so there is no pressure.

Explaining pressure in the atmosphere

The atmosphere contains molecules of oxygen, nitrogen and carbon dioxide as well as 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.

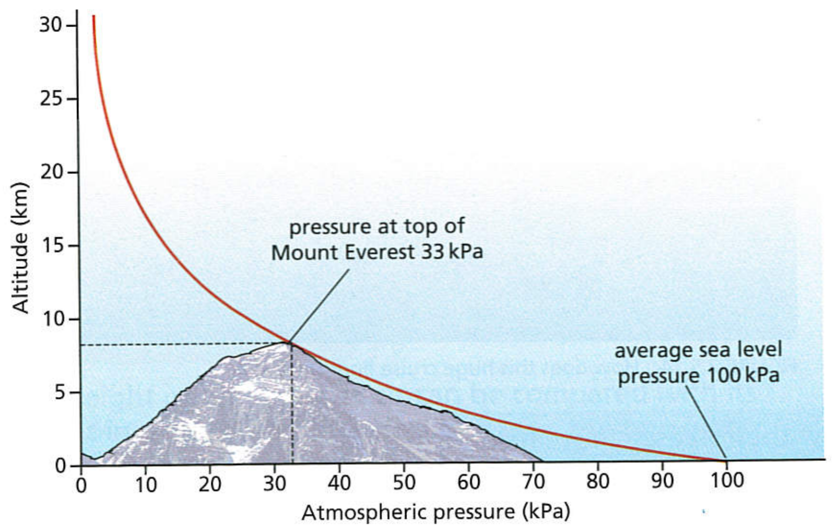


FIGURE 2.5.15a: Variation of atmospheric pressure with height

1. What causes the atmosphere to have pressure?
2. Suggest why there is no atmosphere in outer space.
3. What might limit the height that a hot-air balloon can go to?

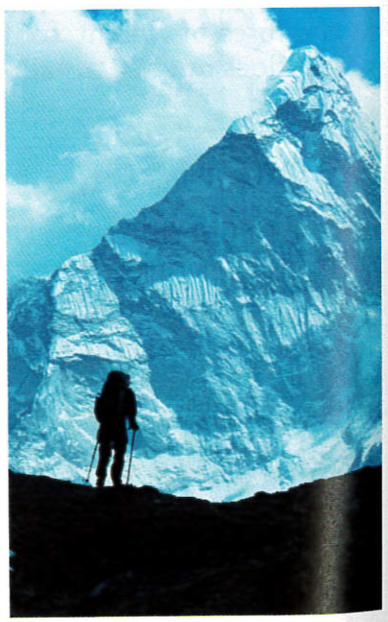


FIGURE 2.5.15b: What challenges does mountaineering present?

Pressure and weather

As well as varying with height, the atmospheric pressure is continually changing across the world. Figure 2.5.15c shows a surface-pressure chart. Where there is high pressure, the weather tends to be dry and sunny because the higher downwards force of the atmosphere reduces cloud growth. Where there is low pressure, cloud can develop more easily and it is more likely to rain. The lines are called 'isobars' and link areas of equal pressure. Where there are big pressure differences across a region, the isobars are closely packed and the winds will be strong.

Weather fronts are where warm- and cold-air masses collide. Lots of cloud usually forms at weather fronts. They are marked on the chart as lines with triangular or semicircular shapes along their length.

4. What would the atmosphere be like in an area of low pressure compared to that in an area of high pressure?
5. Look at Figure 2.5.15c and suggest what the weather over Britain might be.
6. Name some areas on the map where you would expect there to be a lot of cloud.

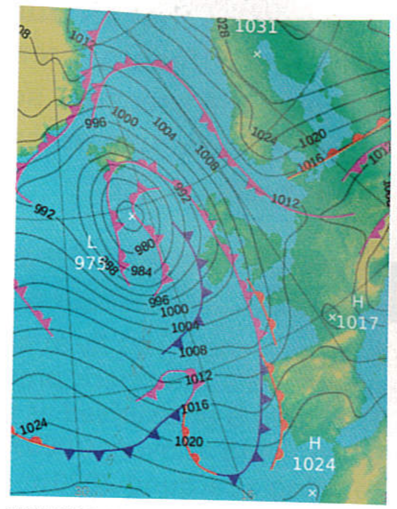


FIGURE 2.5.15c: Pressure charts help meteorologists to predict the weather.

Climbing mountains

Nearly all organisms depend on a readily available supply of oxygen so that they can release energy during respiration. This energy is essential for all life processes. At high **altitude** the body struggles to take in enough oxygen to function properly and even gentle movement can be exhausting.

The part of Mount Everest above 8000 m has become known as the 'death zone'. At this height, there is about one-third of the oxygen available at sea level. In addition to this, extreme terrain, cold and wind add to the dangers. Mountaineers spend weeks acclimatising at high altitude before attempting to go to the summit. They aim to spend as little time as possible in the 'death zone' and they often carry cylinders of oxygen to breathe from.

7. Draw particle diagrams to compare the air at the top of Everest with that at sea level.
8. Suggest some problems a mountaineer using bottled oxygen may meet.
9. Suggest how a climber's body could acclimatise to breathing at high altitude.

Did you know...?

Predicting the weather is a complex process that involves modelling the atmosphere using computers.

Data about air pressure, temperature, water vapour and winds throughout the world's atmosphere are used.

Key vocabulary

atmospheric pressure

weather front

altitude

Working with pressure

We are learning how to:

- Give examples of how pressure affects our lives.
- Explain how pressure is used and managed.

A life-support machine gently increases air pressure so that air fills the lungs of a patient who is having difficulty breathing. The machine then reduces the pressure so that air leaves the lungs. Many devices use pressure differences to make them work.

Dealing with low air pressure

Most passenger jets fly at around 10 000 m above sea level, where the atmospheric pressure is low and oxygen is scarce. The cabin is **pressurised** as the aircraft climbs so that even when flying at over 10 000 m the cabin pressure is equivalent to being at around 2000 m. In case of problems with the aircraft's systems, all commercial airliners are fitted with oxygen masks that supply oxygen from a backup system.

1. Why are airline cabins pressurised?
2. Explain why some people feel a pressure change on aeroplanes even though cabins are pressurised.
3. Why are parents advised to fit their own oxygen mask before helping their children in the event of a problem with cabin pressure on an aeroplane?

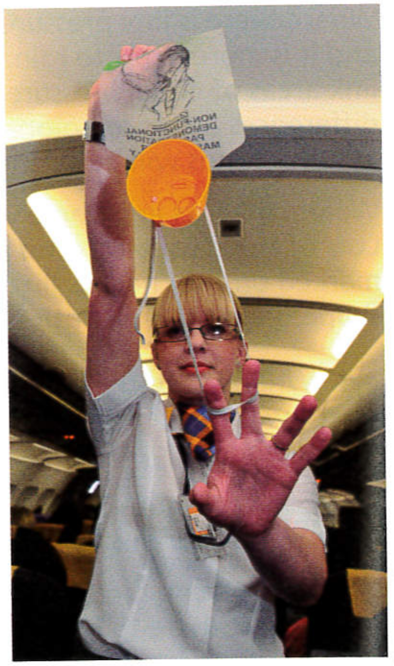


FIGURE 2.5.16a: Safety talks tell airline passengers about oxygen masks.

Measuring pressure

The historical method for measuring pressure uses a **barometer**. This instrument contains a sealed, flexible container of air that expands as the atmospheric pressure decreases and contracts when atmospheric pressure increases. The flexible container is linked to a pointer that moves over a scale.

Modern pressure sensors and digital displays have taken over and are small enough to be built into a wrist watch.

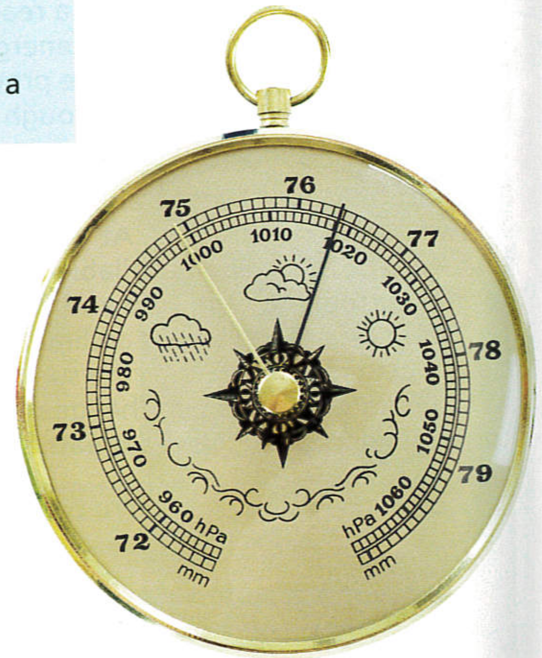


FIGURE 2.5.16b: An old-style barometer

FIGURE 2.5.16c: A modern digital altimeter on a hang glider

One complication for **altimeters** is that atmospheric pressure varies from day to day and place to place. To give an accurate reading of height a pilot needs to set the altimeter to the altitude of the airport. Even with this, the pressure changes during the flight cause errors in the height reading. Aeroplanes also have GPS (global positioning system), which uses satellites to indicate position and altitude.

4. Explain how a barometer could be affected by:
   a) a leak in the flexible container
   b) a rigid container of air instead of a flexible one.
5. Explain why even a top-quality altimeter will not always be accurate.

Pressure and movement

The pressure of the air in a bicycle tyre is a lot higher than that of the air in the atmosphere. This is achieved by using a pump that compresses air inside it. The pump is attached to the tyre via a **valve**, which lets air move from the pump into the tyre, but not the other way. When the pressure is higher in the pump than in the tyre, the air moves through the valve and into the tyre.

6. When a tyre is being inflated with a pump, explain where and when you would expect the air pressure to be at its greatest.
7. Explain the role played by a valve in a tyre.
8. Draw a sequence of particle diagrams to illustrate the pressure changes when blowing up a tyre.

Did you know...?

A racing bike's tyres are inflated to around 6000 kPa (kilopascal), which is six times normal atmospheric pressure and over double the pressure in a car tyre. The high pressure is needed because the tyres need to be extremely narrow and rigid to reduce the friction from the road surface.

Key vocabulary

pressurised
barometer
altimeter
valve

Checking your progress

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

☐ Describe the attraction of unlike poles and repulsion of like poles; show how a magnetic field can be represented.	☐ Identify magnetic attraction and repulsion as non-contact forces; explain how field lines indicate the direction and strength of forces.	☐ Apply and evaluate the concept of magnetic fields in various contexts.
☐ Describe how friction between objects may cause electrostatic charge through the transfer of electrons.	☐ Explain various examples of electrostatic charge; use ideas of electron transfer to explain different effects.	☐ Explain why some electrostatic charge mechanisms are more effective than others.
☐ Describe the field around a charged object; describe some applications of static electricity.	☐ Use the idea of fields to explain various examples and applications of static electricity.	☐ Compare and contrast useful and dangerous instances of static charge; compare electrostatic and magnetic fields.
☐ Describe the variation and effects of gravity on Earth and in space.	☐ Apply the concept of gravitational fields to explain the variation and effects of gravity on Earth and in space.	☐ Apply the concept of gravitational fields in explaining gravitational effects on Earth and in space, including acceleration.

☐ Describe the causes and effects of varying pressure on and by solids.	☐ Explain the effects of varying pressure on and by solids; calculate the pressure applied by a solid from the force applied and the contact surface area.	☐ Explain how force and area can be varied to alter the pressure applied.
☐ 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.
☐ Suggest 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.

Questions

Questions 1–7

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

1. Thinking about electrostatic charge, which of these statements is true? [1]
   - **a)** positive (+) charge repels negative (–) charge
   - **b)** positive (+) charge attracts positive (+) charge
   - **c)** negative (–) charge attracts positive (+) charge
   - **d)** negative (–) charge attracts negative (–) charge.

2. 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.

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

   a) Pa **b)** $N\,m^2$ **c)** N **d)** force

4. Which of these statements is *not* true? [1]
   - **a)** The gravitational field of a planet is stronger on its surface than 100 km away.
   - **b)** Gravity exists throughout the Solar System.
   - **c)** Small objects have very weak gravitational fields.
   - **d)** The acceleration caused by gravity is larger for heavy masses.

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

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

7. Explain, with the help of diagrams, how to indicate the strength of the field around a magnet. [4]

Questions 8–14

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

8. Four identically sized boats (a–d) were floated in some water. One was left empty and the other three were loaded with equal masses of different materials:

   a) boat loaded with wood **b)** boat loaded with aluminium

   c) boat carrying nothing **d)** boat loaded with steel

   Put the boats in order from the one that sits lowest in the water to the one that sits highest. [1]

9. 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

10. In which of these examples is pressure the smallest? [1]

    a) a person standing on one foot **b)** a doctor giving an injection

    c) a person lying on the floor **d)** a knife cutting an apple

11. Which of these statements about the atmosphere is *not* true? [1]
    - **a)** Atmospheric pressure is one of the factors that affect the weather.
    - **b)** Somebody with asthma is likely to have more difficulty breathing at the seaside than on a high mountain.
    - **c)** Car engines usually run better close to sea level than in high mountains.
    - **d)** There are more carbon dioxide molecules at low altitude compared to high altitude.

12. Suggest how you could find out if one charged rod has more charge than another of the same material. [2]

13. Describe how a magnet could be used to find pieces of buried metal. [2]

14. Figure 2.5.18a shows the path of a piece of debris travelling through space in the region of three planets. Explain why it takes the path it does at each part of the journey. [4]

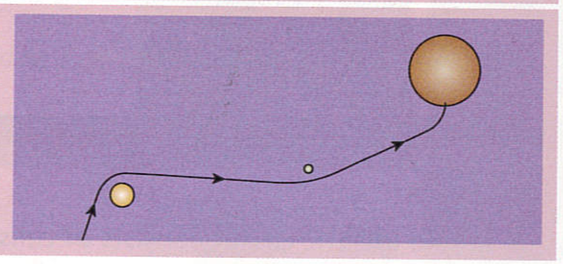


FIGURE 2.5.18a: Path of a piece of debris in space (sizes of planets to scale but distances reduced)

Questions 15–16

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

15. 'Powder' coating is an alternative to painting. Charged powder is sprayed onto an object of opposite charge. It is then heated to bake on the powder. What advantages does powder coating have over conventional painting? [2]

16. Using your knowledge and the data in Figure 2.5.18b to explain the challenges that face a high-altitude mountaineer. [4]

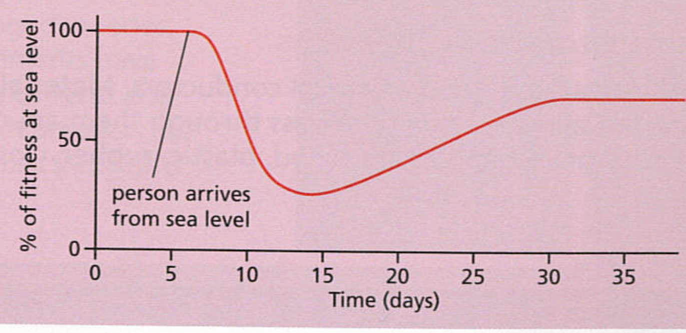


FIGURE 2.5.18b: Graph of a mountaineer's fitness against time when time is spent at 4000 m altitude.