PHYSICS

Forces and their Effects

Ideas you have met before

Gravity

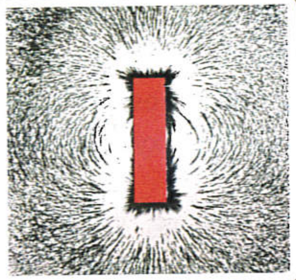
Unless we support things, the force (pull) of gravity makes them fall to Earth.

Scientists such as Isaac Newton and Galileo Galilei helped us to understand gravity.

Contact and non-contact forces

Some forces need a contact between two objects, for example a hand pushing a door. Some forces, like gravity, do not need contact – they can act over a distance.

The pulling force from a magnet can attract certain materials from some way away.



Friction

Friction is a force that acts between moving surfaces. When an object is moving, friction can cause it to slow down or even stop.

Air resistance is friction between air and an object moving through it. A parachute causes high air resistance and makes someone fall much more slowly.

A boat moving through water experiences water resistance. Boats are usually shaped so that they cut smoothly through the water.

Levers

Levers allow a small force to have a greater effect. For example, you could use a long metal tool like a screwdriver to lever a lid off a paint can. You probably could not produce a big enough force to do it with your bare hands.

Pulleys and gears also allow us to transfer forces in much more effective ways.

In this chapter you will find out

Types of force

Forces can stretch and compress things, or change the way something moves.

Forces can be turning forces as well as pushes or pulls.

We can draw force diagrams to help us understand the size and direction of forces and what effect they have.

We can use a newtonmeter to measure the size of a force.

Things that forces do

Elastic materials behave in a special way when a force changes their shape.

Materials can become permanently deformed when they are stretched or compressed by large forces.

A force on a moving object may cause its speed to increase or decrease.

The speed of an object depends on how far it travels in a certain time.

Useful and unwanted friction

Friction has many benefits and uses.

There are times when we want less friction.

Streamlining reduces frictional resistance.

Levers and turning forces

A lever works through a fulcrum to multiply a force.

By working out the size of turning forces we can make sure that structures balance.

Discovering forces

We are learning how to:

- Recognise different examples of forces.
- List the main types of force.
- Represent forces using arrows.

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.

FIGURE 1.5.2a: Gravity is a pulling force.

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?

Multiple forces

A number of forces can be acting on something at the same time. The aeroplane in Figure 1.5.2b has four main forces acting on it:

- the downward pull of gravity
- the forward push from the engines
- the upward pull provided by the lift from the wings
- the pushing force of the air which resists the plane as it moves.

The direction of a force can be shown by an arrow. We can show how strong one force is compared to another by using different-sized arrows.

3. Which forces are helping the plane in Figure 1.5.2b to fly?
4. Which forces are working against the plane when it flies?
5. Which of the forces in the picture is the largest?

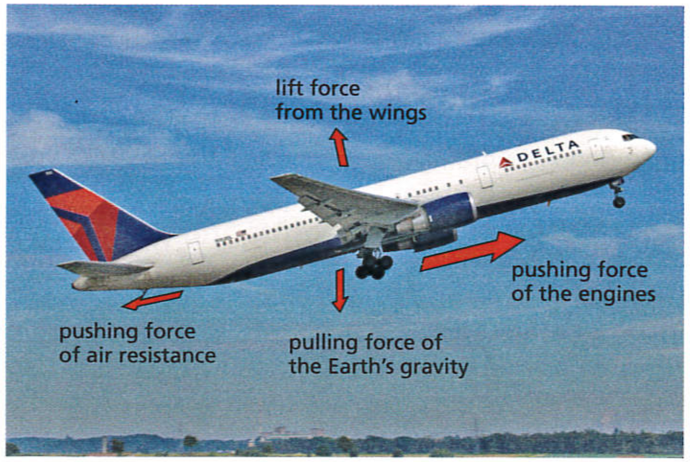


FIGURE 1.5.2b: These forces act on an aeroplane as it takes off.

Did you know…?

A moving object will keep going at the same speed for ever unless a force acts to slow it down.

Forces in balance

The two tug-of-war teams in Figure 1.5.2c are pulling equally and no one is moving. All the forces are in balance, which means each force is perfectly balanced by an equal force in the opposite direction. By accurately drawing the sizes and directions of the arrows on the diagram we can show that the forces are balanced. If the size of any one of the forces changes, the forces will no longer be in balance and there will be movement in the direction of the larger force.

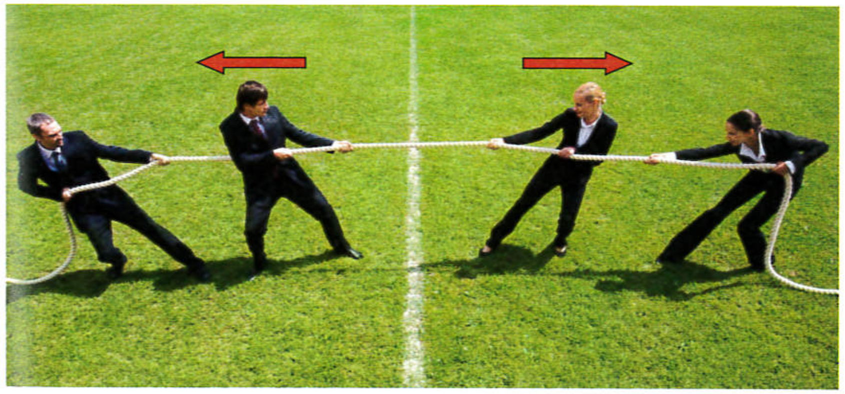


FIGURE 1.5.2c: Forces are present, but there is no movement.

6. Explain what would happen to each of the forces if an extra person was added to one of the teams in Figure 1.5.2c.
7. Sketch a car that is starting to move away from a set of traffic lights. Draw arrows to show the forces at work.
8. Draw and explain the forces at work in these situations:
   a) a boat sailing across the sea
   b) a sledge being pulled over snowy ground.

Key vocabulary

pushing force
pulling force
turning force

Measuring forces

We are learning how to:

- Measure forces using newtonmeters.
- Use the correct unit for force.
- Explain the difference between mass and weight.

Forces are involved in some way in almost everything you do. Forces are acting on your body all the time. Some forces are huge, while others are tiny. What examples of really big forces can you think of?

Newtons and newtonmeters

Sir Isaac Newton is famous as an English scientist who lived in the 17th century. His ideas helped people's understanding of forces and are still very important today. In recognition of his work, the unit of measurement of force is called the **newton** (N). Instruments called **newtonmeters** are used to measure force.

FIGURE 1.5.3a: Sir Isaac Newton (1643–1727)

1. What is the unit of measurement for force?
2. What is the correct abbreviation for the unit of force?
3. What instrument is used to measure force?

Measuring with precision

Newtonmeters come in different models for measuring different-sized forces. In Figure 1.5.3b, one of the newtonmeters can measure force to a greater degree of **precision** than the other one, but it cannot measure such large forces. Selecting the appropriate measuring instrument is important for scientists. Smaller divisions on the scale allow more precise measurements, but instruments with small divisions can usually not measure large values.

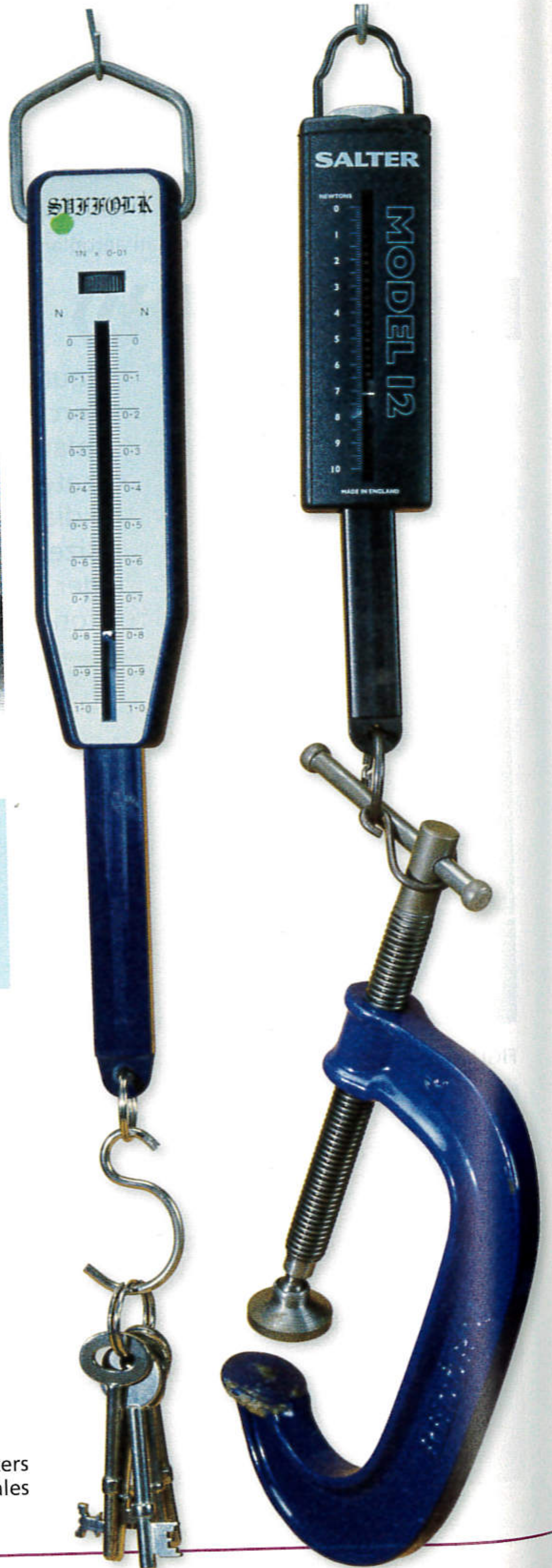


FIGURE 1.5.3b: Two newtonmeters with different scales

4. What is the maximum value that each of the newtonmeters in Figure 1.5.3b can measure?
5. Which of the newtonmeters in Figure 1.5.3b allows the most precise reading? Explain your answer.

Weight, gravity and mass

The **weight** of an object is the force of **gravity** pulling down on the object. If there were no gravity then everything would be weightless. Because weight is a force, it should be measured in newtons. Weight can be measured using instruments such as newtonmeters and bathroom scales. Both give a reading of weight because the object being weighed is pulled down by gravity.

Mass is a measure of the amount of material in an object – the number of particles and type of particles it is composed of. Mass does not depend on the force of gravity, so it does not change if you take it somewhere where gravity is not as strong, such as the Moon. Mass is measured in kilograms. The mass of an object can be measured using a balance that compares the object with a known mass.

Sometimes people mix up 'mass' and 'weight', so scientists need to be careful to choose which term to use.

FIGURE 1.5.3c: Using a balance to find the mass of an object

6. Why do you think that some people confuse weight and mass?
7. If you measured the mass and the weight of an object on two planets of different sizes, what differences would you notice? Explain your answer.
8. Imagine a car crash on the Moon and the same crash on Earth. There would probably be no difference in the damage between the two crashes. Explain why this is the case.

Did you know…?

If you were in free fall you would feel as if you had no weight. In fact, if an object hanging on a newtonmeter were in free fall together, the weight reading would be zero. But mass does not change (except when you grow!).

Key vocabulary

newton
newtonmeter
precision
weight
gravity
mass

Understanding weight on other planets

We are learning how to:

- Explain the meaning of 'weightless'.
- Investigate weight on the Moon and on different planets.
- Identify the link between weight and gravitational attraction.

On planets with a smaller mass than Earth you would feel lighter and you could jump higher. On planets with a very large mass you would be so heavy that you wouldn't even be able to stand up. If you were in deep space and far from any planets or stars, you would have no weight at all.

FIGURE 1.5.4a: The Earth and the Moon. The bigger the mass of a planet or moon, the stronger its force of gravity.

Gravity in space

The force of **gravity** on you (your weight) depends on your distance from a planet. The further away you are from the Earth, the weaker the force pulling you back. In outer space, the distance to the nearest planets and stars could be so big that there would be no noticeable force of gravity and so you would be **weightless**.

1. In much of outer space there is little or no gravity. Why is this?
2. Think of a spacecraft setting off from Earth and travelling directly to the Moon. Describe the changes in gravity you expect the spacecraft to experience during the journey.
3. Suggest some differences you would experience when eating and drinking in weightless conditions, compared to on Earth.

Understanding gravity

Gravity is a force that pulls objects together. For example, your body is pulled towards the Earth, and the Earth and other planets are held in orbit around the Sun.

Gravity actually exists between *all* objects, but the force is only large enough to be noticeable when a massive object, such as a planet or a star, is involved.

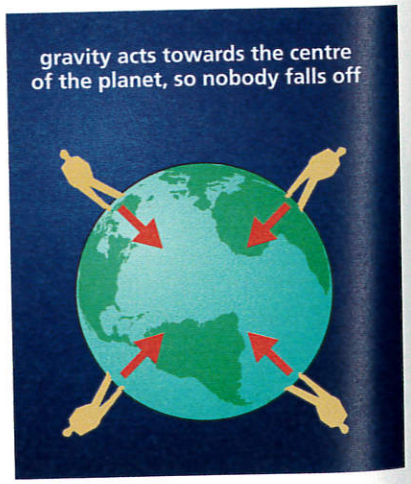


FIGURE 1.5.4b: Gravity acts all over the Earth towards its centre.

TABLE 1.5.4: The effect of different values of gravity on the Moon and on other planets in the Solar System

	Earth	Moon	Mercury	Venus	Mars
Surface gravity (compared with the Earth's)	1.00	0.17	0.38	0.90	0.38
Your mass (compared with your mass on Earth)	1	1	1	1	1
How much you can lift (kg)	10	60	30	10	30
How high you can jump (cm)	20	120	53	22	53
How long it takes to fall back to the ground (s)	0.4	2.4	1.1	0.4	1.1

4. Look at Table 1.5.4. Where is gravity highest?
5. Using information from the table, write the planets and the Moon in order of increasing gravitational attraction if you were standing on the surface.
6. Explain why the mass of an object is the same on all planets and on the Moon.

A gravity puzzle

Gravity is an attractive (pulling) force between masses. What gravity would you experience if you tunnelled towards the centre of the Earth? Under the surface there would be a force of gravity from the mass of the Earth above you as well as from that below you. Because these forces are in opposite directions, the overall force of gravity would be lower than on the Earth's surface.

7. Imagine it was possible to build a tower on Earth to the height of an orbiting space station.
   a) What force(s) would you experience if you stepped off the tower?
   b) What movement would you expect?
8. Explain what would happen if you tried to weigh yourself in these situations:
   a) outer space
   b) in a tunnel, halfway to the Earth's centre
   c) on top of a tower at space station level

Did you know ...?

When you see films of astronauts inside a space station orbiting the Earth, the astronauts appear to be weightless. But they, and the space station and everything in it, are actually still being attracted by the Earth's gravity. If there were no pulling force of gravity from the Earth, the space station would fly off into space.

Key vocabulary

gravity

weightless

Exploring the effects of forces

We are learning how to:

- Identify and describe the effects of forces of different sizes and directions.
- Predict and explain the changes caused by forces.
- Explain the concept of force pairs (action and reaction).

A spacecraft is hurtling through outer space. It is tempting to say that huge forces are involved, but in fact there are none.

A book is lying still on a table. People might think that there are no forces acting on the book, but there are.

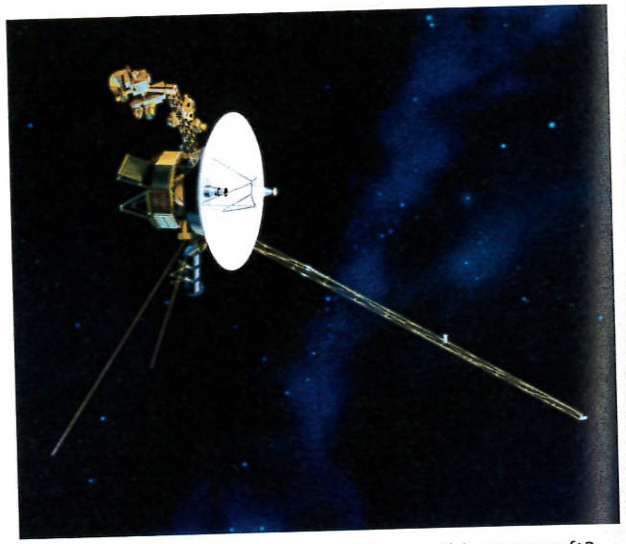


FIGURE 1.5.5a: What forces are acting on this spacecraft?

Forces causing movement

In Figure 1.5.5b, the trolley is still at first but will start to move as the mass is pulled downwards. When the mass reaches the floor, the string will go slack but the trolley will keep moving.

1. What force is acting on the hanging mass?
2. What forces are acting on the trolley:
   - **a)** before it is moving?
   - **b)** while the mass is dropping?
   - **c)** once the mass has reached the floor?

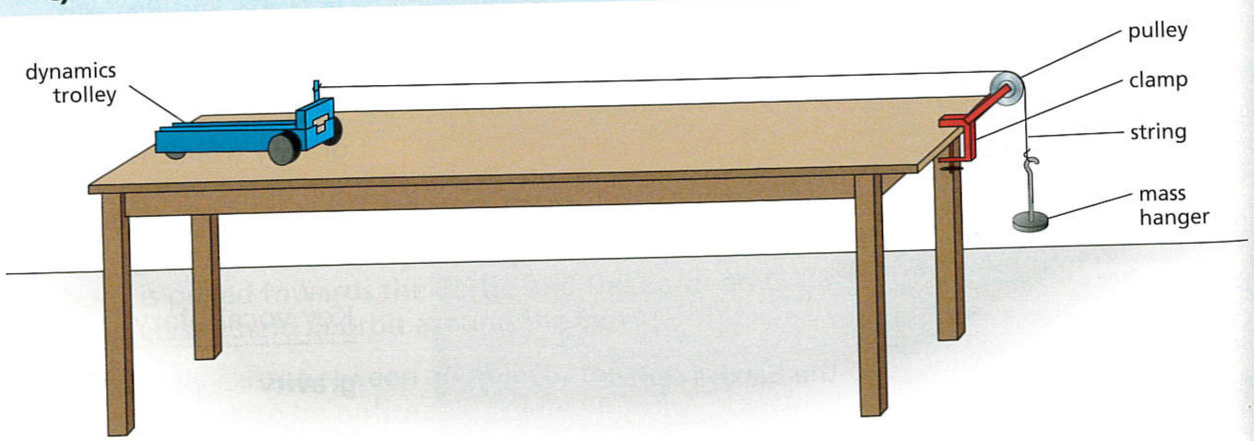


FIGURE 1.5.5b: Investigating the effect of force on motion

The effect of different sizes of force

If the trolley experiment in Figure 1.5.5b were repeated with a heavier hanging mass, a larger force would act on the trolley. The larger force would cause the trolley to move faster. In the same way, the harder a tennis player hits the ball, the larger the force on the ball and the faster the ball will leave the racket.

3. **a)** Write a **prediction** about the movement of the trolley in Figure 1.5.5b, using this sentence stem: 'The heavier the mass hanging on the pulley, ...'
   b) Use the idea of force to explain your prediction.
4. What do you think would happen to the speed of the trolley if, instead of increasing the mass hanging on the pulley, the mass of the trolley was increased?

Forces in pairs

When an object exerts a force on something else, it is called an **action force**. There is always an equal and opposite force called the **reaction force**.

Gravity is a pulling force between objects. A ball in the air is pulled towards the Earth, but the Earth is also pulled towards the ball!

When a person on a skateboard pushes against a wall, there is an action force against the wall, and the wall pushes back on the skateboarder with a reaction force. The two forces are equal in size and in the opposite direction to each other. When a cannonball is fired, the reaction force pushes the cannon backwards.

5. In each of these situations, identify the action force and the reaction forces:
   - **a)** a cricketer hitting a ball
   - **b)** a person catching a ball
   - **c)** someone opening a fridge door.
6. Draw simple diagrams to show the forces when:
   - **a)** a tennis player hits a ball
   - **b)** a cyclist pushes down on a pedal
   - **c)** a dog pulls on a lead.

FIGURE 1.5.5c: The reaction force from the wall pushes the skateboarder away.

Did you know...?

If an astronaut on a space walk released an object in space, it would float in the same position because there would be no forces on it. If the object was moving slightly when the astronaut let it go, it would keep going at the same speed and in the same direction.

Key vocabulary

prediction
action force
reaction force

Understanding stretch and compression

We are learning how to:

- Explain the relationship between an applied force and the change of shape of an object.
- Investigate forces involved in compressing and stretching 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.

FIGURE 1.5.6a: The angler benefits from elastic materials.

Comparing materials

All materials can **compress** (squash) or **stretch** 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, this 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.

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 1.5.6. Write a list of features that a correctly plotted graph to show this data should include.
5. Plot a line graph to display the data in Table 1.5.6. Describe what your graph shows about how the force applied affects the spring.

TABLE 1.5.6: How a compressing force affects a spring

Force applied (N)	Compression of spring (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.

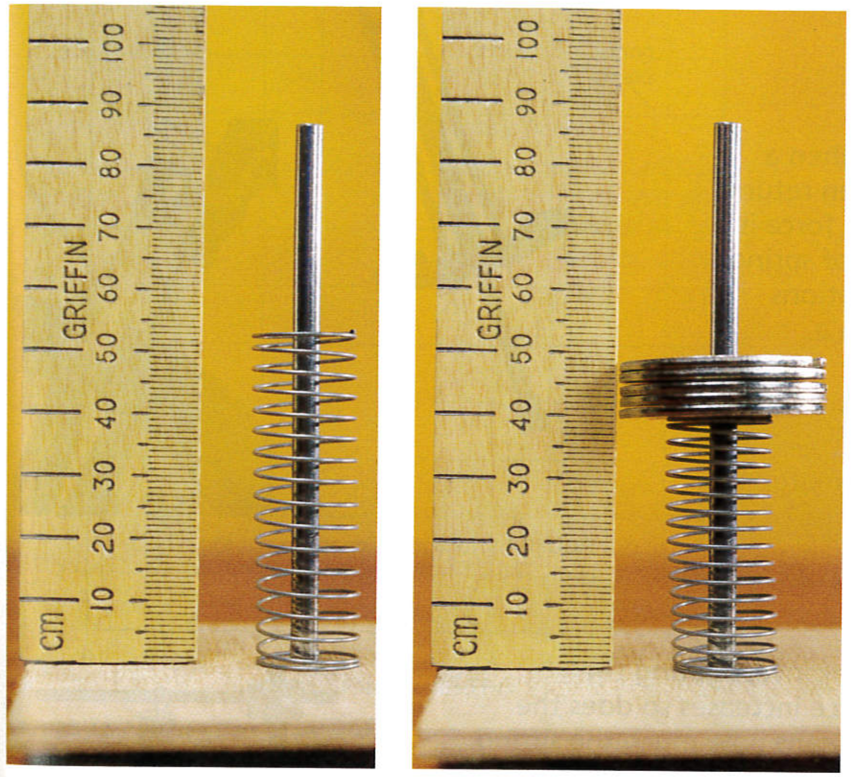


FIGURE 1.5.6b: The behaviour of a spring under an applied force allows us to measure weight.

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.

Key vocabulary

compress
stretch
elastic behaviour
elastic limit
brittle

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.

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.

FIGURE 1.5.7a: Springs in action

Investigating how a force stretches a spring

Figure 1.5.7b 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. 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**.

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.

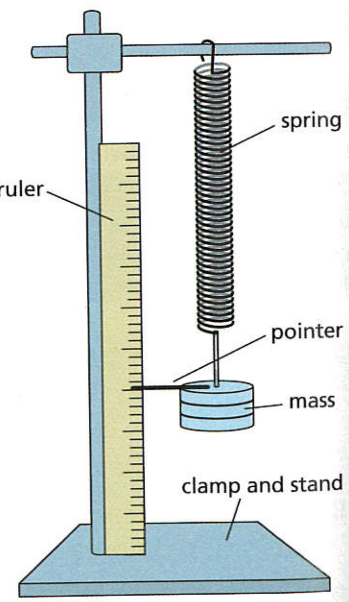


FIGURE 1.5.7b: Investigating Hooke's Law

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.

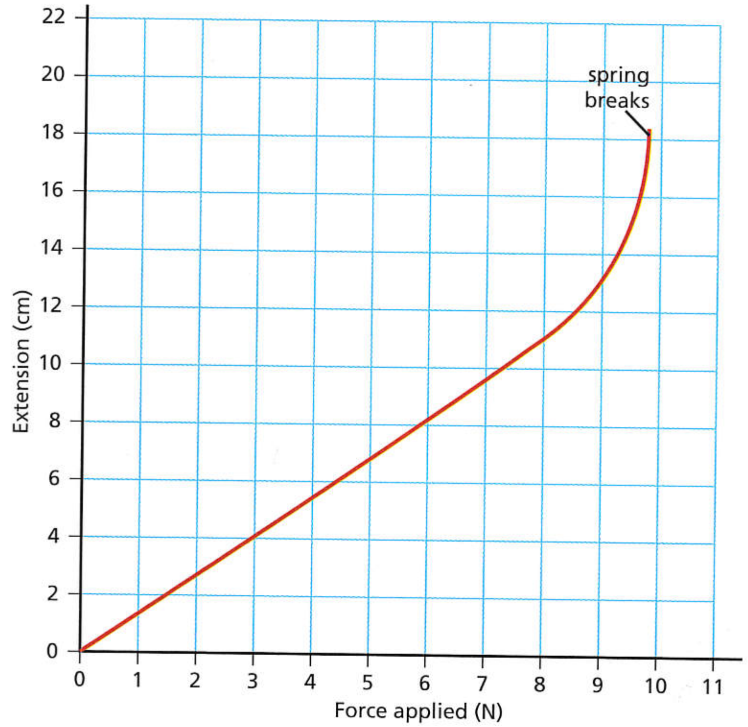


FIGURE 1.5.7d: The effect of a stretching force on a spring

5. Look at Figure 1.5.7d. 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 1.5.7c: 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*.

Key vocabulary

extension

Hooke's Law

elastic limit

Understanding friction

We are learning how to:

- Identify the force of friction between two objects.
- Describe the effects of friction.
- Understand that friction acts in the opposite direction to the direction of movement.

Whenever there is movement, there is almost certainly friction. Friction is always working against movement.

Friction slows things down

The boy in Figure 1.5.8a is enjoying the thrill of the water slide. He picks up speed as he travels down so at the bottom he will make quite a big splash. The slide is designed so that **friction** doesn't slow people down too much.

- It's steep, so the boy's weight helps to overcome friction at the surface of the slide.
- The water pouring down the slide makes the smooth surface even more slippery.

1. What features of a water slide help people to travel fast? Explain your answer.
2. List three situations in which friction acts to slow something down.

FIGURE 1.5.8a: Is the friction on this slide large or small?

Friction is a force

Friction is a **contact force** that exists when two surfaces touch one another. Friction opposes movement. This means that the force of friction always acts in the opposite direction to movement, so it causes moving objects to slow down. When an object is stationary it will not move until the pushing, pulling or turning force is big enough to overcome the force of friction resisting movement.

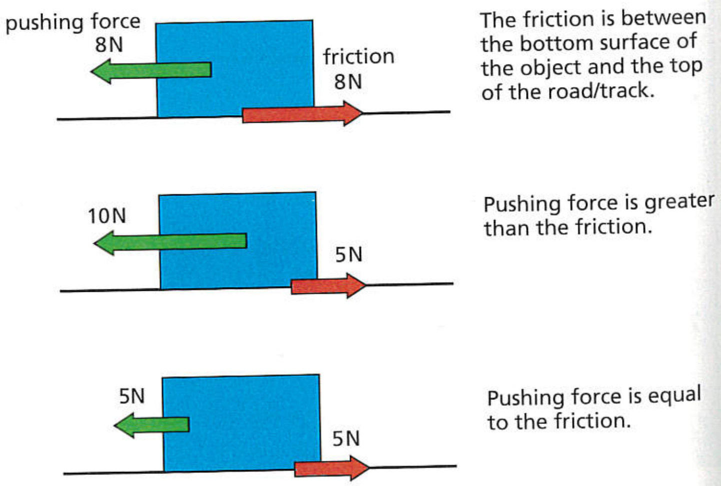


FIGURE 1.5.8b: Will the object move?

3. In general, in what direction does the force of friction act?
4. Look at Figure 1.5.8b. Assuming that in all three cases the object is stationary to start with, state in which case, if any, the object might move. Explain your reasoning.

Explaining friction

No surfaces are completely smooth, so when two surfaces touch each other the tiny bumps and ridges on one surface can rest in the hollows of the other. For the surfaces to slide across each other the bumps and ridges must ride up out of the hollows, and this needs force. The smoother the surfaces, the less force is needed to make the surfaces slide across each other.

Engineers take steps to reduce friction in machines. For example:

- they use a **lubricant** such as oil or wax to create a smooth sliding layer between moving parts
- they make surfaces as smooth as possible by special machining and polishing.

FIGURE 1.5.8c: The engine has to produce enough force to overcome friction.

5. Draw a diagram with labels to explain how friction occurs between two surfaces.
6. Draw an outline of a car in the middle of a sheet of paper. Around the outside add labels to identify where friction could occur. Add details to the diagram to make your descriptions clear.
7. Suggest some problems that friction could cause in a machine – for example a car or a bicycle.

Did you know…?

The oil in a car engine is very highly engineered to lubricate an engine, and so reduce friction between the moving parts. Engine oil has to work when the engine has just started on a freezing winter's day, and also at over 100 °C when the engine is hot. It has to withstand the constant pounding of all the moving parts in the engine.

Key vocabulary

friction

contact force

lubricant

Exploring the benefits of friction

We are learning how to:

- Describe applications that make use of friction.
- Design procedures for investigating the force of friction.

Friction, although frequently undesirable, can also have many benefits. In certain situations designers deliberately try to make friction high.

Situations in which sliding is bad

Without friction, many everyday activities would be very difficult.

- Your feet would slide backwards when you tried to walk.
- Cars could not accelerate, brake or go round corners because the tyres would slip.
- Clothes would slip through pegs on a washing line.

Friction resists movement when two surfaces might slide across each other, so it helps to provide grip.

1. Describe what might happen if you tried to open a door in a world without friction.
2. Explain whether friction is useful or unwanted in these situations:
   a) skiing
   b) rock climbing
   c) driving on a wet road
   d) pedalling a bicycle.
3. Draw force diagrams to illustrate the forces in action in the situations in question 2.

Increasing friction

Buckles for webbing straps rely on friction of the strap against itself. The harder you pull on the strap the better it grips, because the two layers of webbing are forced together.

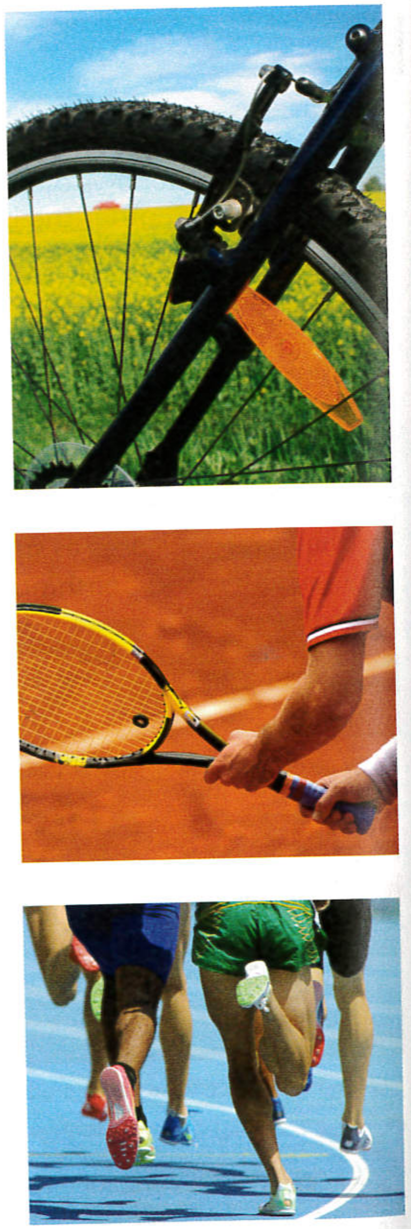


FIGURE 1.5.9a: How is friction helping in these examples?

In racing cars the brake discs are made of carbon ceramic. Friction causes so much heat during heavy braking that the discs glow red-hot. As the brakes get hotter, the friction of the carbon ceramic material increases. In wet weather the brake discs don't get hot enough to work well, so steel discs need to be used instead.

4. Explain how a webbing strap uses friction to stop itself coming undone.
5. Suggest why carbon ceramic disc brakes are more suitable for a racing car than for a family car.

FIGURE 1.5.9b: Why is the strap looped back through the buckle?

Comparing grip

The friction between an object and a ramp can be measured. If the friction is low, the object will start to slide when the ramp is raised slightly. If the friction is higher, the ramp must be raised higher before the object will start to slide. To compare different surfaces and get reliable results, a scientist must take care with the planning of the investigation.

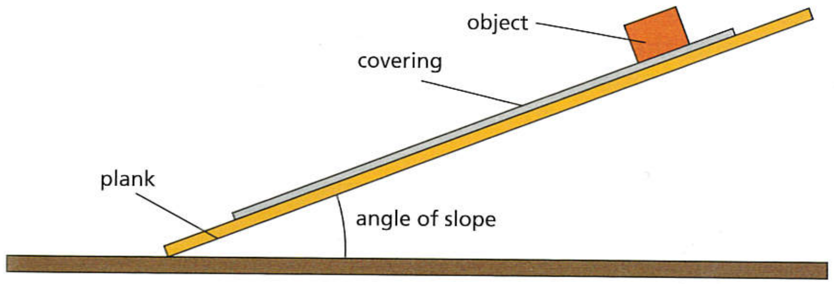


FIGURE 1.5.9c Measuring friction

6. Look at the apparatus for an investigation in Figure 1.5.9c.
   a) Identify the **independent variable**, the **dependent variable**, and any **control variables**.
   b) Explain how the experimenters could judge whether the results were **reliable**.
   c) State what **safety** considerations should be taken into account.

Did you know ...?

When a car brakes, if the braking friction is too high it will overcome the friction that allows the tyres to grip the road. When this happens the car will skid. Once a car is skidding, it will stop quicker if the brakes are released briefly and re-applied. This allows the the tyre to regain grip on the road surface.

Key vocabulary

independent variable
dependent variable
control variables
reliable
safety

Understanding air and water resistance

We are learning how to:

- Link frictional forces between surfaces to 'drag' between objects in a fluid.
- Discuss examples of frictional drag in air and in water.
- Consider the effects of friction on sky divers.

If you open a car window when travelling at speed, you will notice how the air exerts large forces. Any object travelling fast has to overcome drag forces caused by the air. The faster you go, the greater force you must overcome.

Explaining air and water resistance

When you walk slowly, you may not notice the force that the air exerts on you. When you move faster you have to overcome more friction from the air. This force is also known as **air resistance** or 'drag'. When a car reaches its top speed, the air resistance is so large that it prevents the car going any faster. The pushing force from the engine is equal to the force of air resistance. The two forces are in balance so the speed cannot increase.

FIGURE 1.5.10a: The top speed of this car is limited by the power of the engine and the drag from the air.

Water resistance works in a similar way. Water is denser than air so the drag is larger.

1. What type of force is air resistance?
2. In what direction does air resistance act?
3. Why does air resistance limit the top speed of a vehicle?
4. What is the main difference between air resistance and water resistance?

Terminal velocity

FIGURE 1.5.10b: The sky diver's speed initially increases because the weight force is larger than the force from air resistance.

When a sky diver steps out of a plane, he or she falls with increasing speed because of the force of gravity. As the sky diver falls faster, the air resistance increases. Eventually air resistance is so great that it balances the downward force of weight, and the sky diver reaches a steady speed known as **terminal velocity**.

When the sky diver opens the parachute, the air resistance increases greatly. The sky diver slows down dramatically and reaches a much slower steady speed.

5. At what point(s) during a sky dive are all the forces in balance?
6. When during a sky dive is the downward force of weight larger than the force of air resistance?
7. a) When during a sky dive is air resistance larger than the downward force of weight?
   b) Draw a force diagram to show the situation in part a).

Colliding particles

Air is mixture of gases and consists of **particles**. When an object travels through air, it **collides** with the particles. These collisions make it more difficult for the object to move through the air. This is the cause of air resistance.

A fast-moving object collides with more particles than a slow-moving one, so the air resistance is larger at higher speeds.

8. Suggest why you cannot feel the collisions of the individual air particles on your skin.
9. Using the idea of particles, explain why it is much harder to run through water than through air.

Did you know…?

The fastest recorded sky dive was by Felix Baumgartner in 2012. He hit a peak speed of 1343 km/h after jumping from a helium balloon in the middle of the stratosphere. He reached such a high speed because the air is much less dense at the high altitude he jumped from, so there was little air resistance.

Key vocabulary

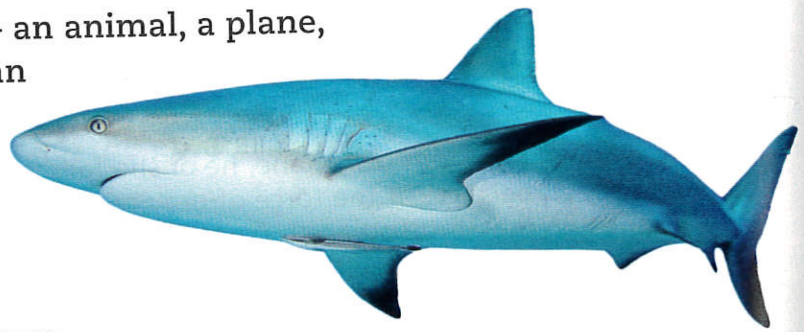
air resistance
water resistance
terminal velocity
particle
collide

Discovering streamlining

We are learning how to:

- Recognise natural and man-made examples of streamlining.
- Link streamlining to fuel efficiency in vehicles.
- Evaluate the use of data collected from investigations of drag.

Friction from air and water is a serious matter for anything that moves at speed – an animal, a plane, a car or a boat. Streamlining can increase speed and save fuel.



Streamlining in nature

Compare the shapes of the fish in Figure 1.5.11a. The shark is a predator that relies on speed to hunt in open water. The angel fish does not have the same need for speed because it feeds and hides in coral reefs. The shark's narrow, smooth shape, tapered at both ends, helps it to slip easily through the water with very little friction. We say that the shark's shape is **streamlined**.

FIGURE 1.5.11a: Compare the shapes of these two fish.

If you compare the shapes of cars designed for high top speed with those that only travel slowly, you will find that fast cars are more streamlined. As well as increasing the top speed, streamlining means that less energy is needed to travel at a particular speed. Less energy is wasted.

1. What features does a streamlined shape have compared to a less streamlined one?
2. State two benefits of streamlining.
3. Explain the effect of streamlining on friction.

Investigating streamlining

It is possible to compare the drag that happens with different shapes by timing how long it takes for objects to fall through a liquid. Using a thick liquid, such as wallpaper paste, means that the drag is high and the object will sink slowly. This makes it much easier to measure accurately than if we were dropping the objects through air or water.

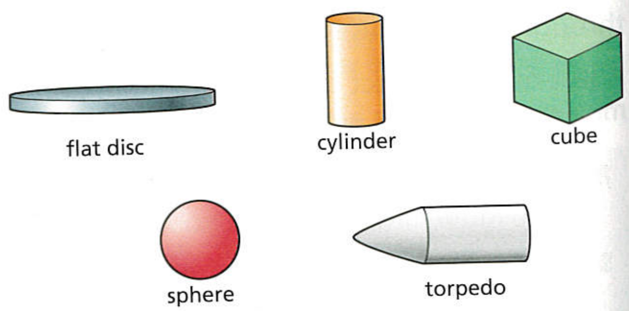


FIGURE 1.5.11b: Possible shapes to investigate

TABLE 1.5.11: Times taken for different shapes to sink

Shape	Trial 1: time taken to sink (s)	Trial 2: time taken to sink (s)
disc	19.4	25.1
cube	15.2	12.8
sphere	8.1	7.8
torpedo	8.9	9.6

4. Refer to the data in Table 1.5.11. Which shape is the most streamlined? Explain how you know.
5. **Evaluate** the data in Table 1.5.11.
   a) First suggest how reliable the results are.
   b) Now suggest factors that could have affected the results.

Using wind tunnels

Scientists and engineers use wind tunnels to investigate how the air flows over different shaped objects. Trails of smoke or tiny strips of paper show how the air is flowing. To get the best streamlining, the flow needs to be as smooth as possible. Where the flow has to change direction suddenly, **turbulence** is created and this increases drag. Drag can be reduced by having a smaller area meeting the air flow.

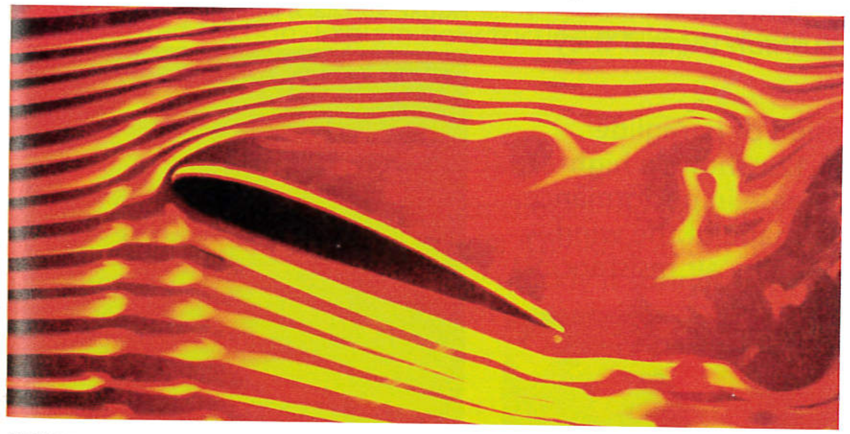


FIGURE 1.5.11c: Where is the flow streamlined and where is it turbulent?

6. Suggest two ways in which the choice of shape can reduce drag.
7. In designing a streamlined shape, why might the rear of the shape be important as well as the front?
8. What are the advantages to car designers of using wind tunnels to help design the shape of a car?

Did you know…?

Fluid dynamics is the study of how liquids and gases flow. This is very important in a wide range of situations:

- designing aircraft, boats and cars
- studying the oceans
- predicting weather patterns
- planning many industrial processes.

Key vocabulary

streamlined
evaluate
turbulence

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 get a bit more challenging.

Adventure sport

The photographs show people doing the sport of paragliding. They launch from hillsides and glide through the air, like a paper aeroplane does. At its most basic, the sport involves flying from a high point downwards, at a constant speed, to a landing field a few kilometres away. More experienced paragliding pilots aim to fly as far as possible. They do this by finding rising currents of air, which they use to gain height. They can then glide further in search of more rising air. The world distance record stands at over 500 km for a single flight.

Figure 1.5.12a shows a person launching. They lay the paraglider on the ground and put on the harness. They then pull the glider up into the air and run down the slope. After a few steps, the glider has enough speed to fly and the pilot glides off the slope.

The harness is designed so that the pilot can sit comfortably and it also contains protective padding. Normally paraglider pilots land gently on their feet, but the padding helps to cushion them if they misjudge a landing.

Figure 1.5.12b shows a basic design of paraglider, as used by beginners. Figure 1.5.12.c shows a high-performance paraglider. The increase in performance is due to an improvement in the shape of the wing and a reduction of the drag caused by air resistance.

FIGURE 1.5.12.a: A paraglider launching

FIGURE 1.5.12b: A basic paraglider

FIGURE 1.5.12c: A high-performance paraglider

Task 1: Forces on a paraglider

Describe the forces acting on paraglider as it flies down at steady speed. What is important about the size of the forces if the speed and direction are not changing?

Task 2: Force diagram

Draw a force diagram to show the forces on a paraglider. Use the side-view diagram in Figure 1.5.12d as a basis. One of the force arrows has been drawn for you.

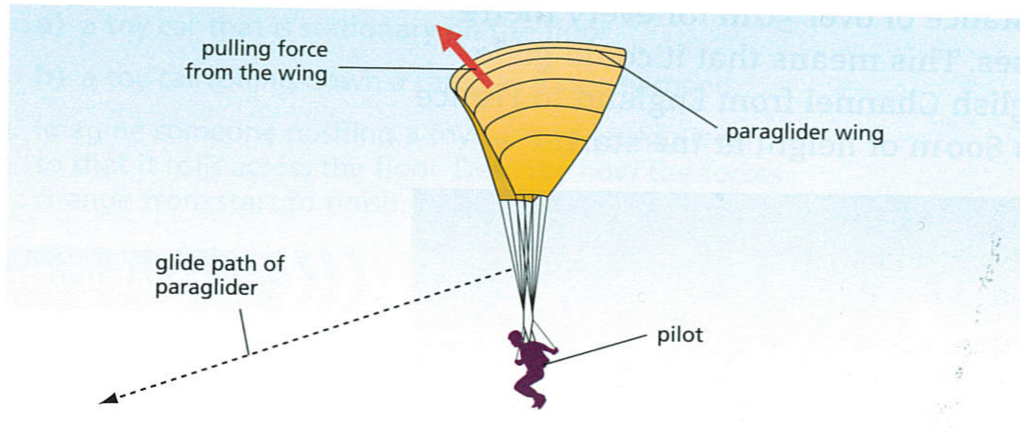


FIGURE 1.5.12d: Side view of a paraglider gliding

Task 3: Friction

Friction is essential to a paraglider pilot in many ways, but there is also unwanted friction. Explain how friction could be useful and where it is unwanted.

Task 4: Choosing the right elasticity

The designers must be careful to choose the right material for the protective padding in the harness. Thinking about how easy it is to compress the materials and how quickly it springs back – what might happen if the materials were not appropriate?

Task 5: Improving the performance of a paraglider

Suggest what features could improve the performance of a paraglider. Think about all the possible ways of reducing drag. There are other forces at work as well – could any of these help performance to be improved?

Task 6: Adding an engine

It is possible to have a harness with a small propeller engine on the back. This allows the pilot to gain height as they fly along. Explain how the forces on the wing might change and how this would affect flight.

Exploring forces and motion

We are learning how to:

- Recognise that for an object to start moving there must be a force applied.
- Describe the effects of balanced and unbalanced forces.
- Explain the significance of balanced and unbalanced forces on a moving object.

The glider in Figure 1.5.13a has no engine. It can glide a distance of over 50 m for every metre of height it loses. This means that it could glide across the English Channel from England to France with less than 800 m of height at the start.

FIGURE 1.5.13a: What forces are involved to allow this glider to glide long distances?

Forces in balance

Three forces are at work on a glider:

- a force from the wings which pulls on the glider in an upwards and forwards direction
- a downward force from the glider's weight
- a backward drag force caused by the glider's movement through the air.

Once the glider is flying, these three forces become **balanced**. The glider continues to glide on the same path at the same speed. Unless there is a change in any of the forces acting on the glider, its motion does not change. It will continue gliding until it reaches the ground.

1. What are the three forces that act on a glider as it flies?
2. What features does the glider in Figure 1.5.13a have that help it to fly as far as possible?

Did you know…?

Wings do not work in space because there is no air. With no air flow over them, the wings are incapable of producing any lift force. This is why spacecraft don't often have wings. One exception is the space shuttle – it needs wings to fly when it re-enters the Earth's atmosphere.

When forces are out of balance

If any of the forces on an object do not cancel out we say they are **unbalanced**.

- If the object is at first stationary, it will start to move.
- If the object is already moving, it will change its speed or its direction, or both.

3. Identify the similarities and differences between the forces acting in these situations:
   a) a toy car that is stationary on the floor
   b) a toy car rolling down a ramp at a steady speed.
4. Imagine someone pushing a toy car and letting it go so that it rolls across the floor. Describe how the forces change from start to finish.

A new balance

All the forces on the bridge in Figure 1.5.13b are in balance. The downward action force of the weight of the bridge is balanced by the upward **reaction force** of the ground, acting through the bridge supports. If a lorry parked on the bridge, the total downward force would increase. However, it would still be balanced, because the upward reaction force would now be larger. If the load was too great the bridge would collapse, or the compression force could break the supports.

FIGURE 1.5.13b: Engineers need to ensure all forces are in balance.

5. Sketch a road bridge, without any vehicles on it, and add arrows to show the forces acting.
6. Sketch your bridge again, now with a lorry parked on it. Add the force arrows for this new situation.
7. The bridge in Figure 1.5.13b spans a fast-flowing river. Describe or draw the additional force(s) that this creates.

Key vocabulary

balanced (forces)
unbalanced (forces)
reaction force

Exploring how forces affect speed and direction

We are learning how to:

- Recognise that the size of a force determines its effect.
- Recognise that the direction of a force determines its effect.
- Provide examples to illustrate where a force of precise strength and direction is needed.

If you could throw a ball on the Moon, it would follow a different path to the one it would follow on Earth. Doing the same in outer space would result in a different outcome again. Even if the ball was thrown with the same force, the forces acting on it in flight would be different in each case.

FIGURE 1.5.14a: An expert golfer can hit a ball into a small hole from many metres away.

Precise forces in action

In many situations, the speed and the direction of a force must be carefully controlled. A car driver controls the size of the pushing force from the engine using the accelerator pedal. The direction in which the force acts is controlled by the steering wheel. Many ball sports involve great control of the size of a force applied and its direction.

1. Why would a footballer want to use a different size of force in different situations?
2. What could go wrong if a person could not control the direction and size of the force when driving a car?

Hitting the target

When an arrow is fired, the pushing force comes from the bow. Once the arrow has left the bow, two forces act on it as it flies through the air – the frictional force due to air resistance and the downward force of the arrow's weight. Air resistance is very small for an arrow because it is so thin and streamlined.

3. When an arrow is fired straight ahead (horizontally), what effect will the downward force of weight have?
4. What effect will air resistance have on the flight of the arrow?

FIGURE 1.5.14b: How does the archer know the direction in which to fire the arrow, so that it hits the target?

Horizontal and vertical movement

When an arrow is fired **horizontally**, as it flies through the air it moves **vertically** downwards as well as horizontally. The combined effect of this is a curved path, as shown in Figure 1.5.14c. The downward motion gets faster until the arrow hits the target or the ground.

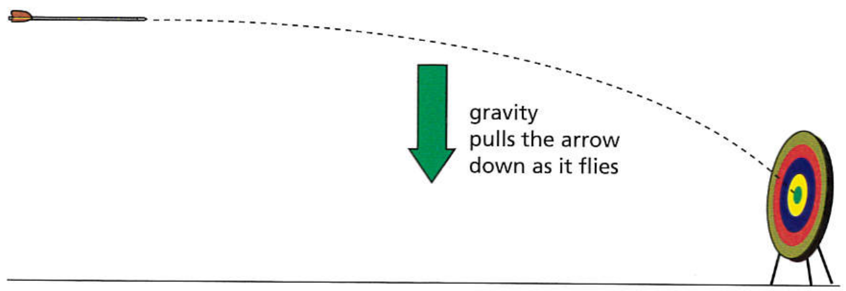


FIGURE 1.5.14c: Something that moves through the air and is affected by the force of gravity is called a projectile.

Imagine the same arrow being fired on the Moon. Here the weight of the arrow is lower so although the arrow's path would still curve downwards, it would do so more gradually. Also, on the Moon there is no atmosphere to create air resistance, so the horizontal speed would stay the same as when it was fired.

5. Describe the motion of an arrow that is fired vertically upwards. Describe the force(s) that act after the arrow is fired.
6. Why does pulling the string on the bow affect how far the arrow flies?
7. What similarities and differences might there be between the flight of an arrow propelled by a bow and the flight of a football thrown by a person? Explain your answer.

Did you know…?

In Olympic archery, the athletes fire at a target from a distance of 70 m. The bull's eye of the target is 12.2 cm in diameter, and they frequently hit this.

In 2010 a 14-year-old boy broke the record for firing an arrow the furthest distance. Zak Crawford's shot was nearly 500 m.

Key vocabulary

horizontally

vertically

Understanding speed calculations

We are learning how to:

- List the factors involved in defining speed.
- Explain a simple method to measure speed.
- Use the speed formula.

On Britain's busy roads, there are speed limits to make them safer. Driving too fast is one of the factors that causes accidents. Cameras that measure the speed of vehicles were introduced in the 1960s. In 2012 the number of deaths on Britain's roads was the lowest it had been since records began.

FIGURE 1.5.15a: This roadside camera measures the speed of a car.

Distance and speed

When you travel on a journey, it takes a certain amount of time to travel the **distance**. The **speed** of a vehicle is worked out from how how far a journey is and how long it takes. There are different **units** used for measuring speed:

- kilometres per hour (km/h)
- metres per second (m/s)
- miles per hour (mph).

When travelling fast your speed is high. You cover a longer distance in a certain time – you travel more kilometres in each hour, compared with travelling slower.

1. What does speed measure?
2. Which two quantities are needed to work out the speed at which something is travelling?
3. If car A travels 45 km in 1 hour and car B travels 55 km in 1 hour, which one has the higher speed?
4. Motorbikes C and D both travel 100 km. C takes 2 hours and D takes 3 hours. Which has the higher speed?

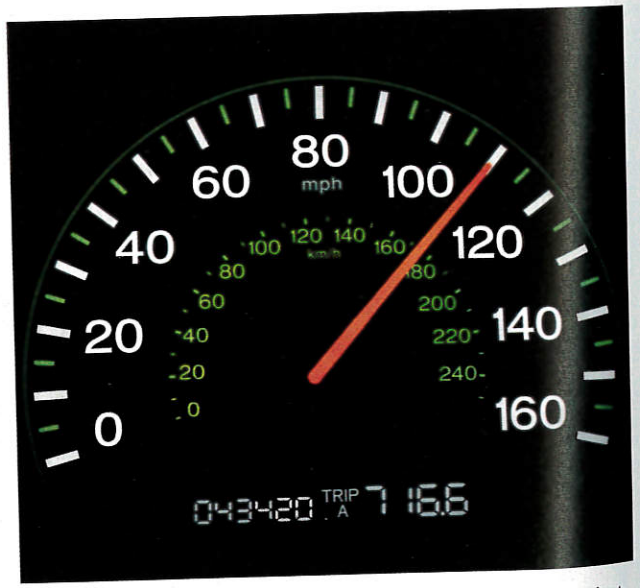


FIGURE 1.5.15b: A car's speedometer shows the car's speed at each instant.

Calculating speed

We use a **formula** to calculate speed: speed = distance travelled ÷ time taken

The units of speed depend on which units were used for measuring the distance and the time.

Example calculation:
Usain Bolt from Jamaica won the 2012 London 100 metre final in a time of 9.63 seconds.

speed = distance travelled ÷ time taken

Usain's speed = 100 ÷ 9.63 = 10.38 m/s
This is equivalent to over 37 km/h or over 23 mph.

5. Use the speed formula to calculate the speed of a cross-country runner who runs steadily for an hour and a half and covers 15 km. Show your working.
6. A mouse runs 2 metres in 4 seconds. What is its speed?

Did you know…?

Some scientists have measured the force that an athlete's legs can produce, and how quickly the force can be transferred. From this they have worked out that it might be physically possible for the best athletes to run at over 60 km/h. We do not know if this will ever be achieved.

Average speed

FIGURE 1.5.15c: For an Olympic sprinter the distance is measured in metres (m) and the time is measured in seconds (s), so the speed is calculated in metres per second (m/s).

When Usain Bolt won the Olympics sprint in 2012, his speed varied during the race. At the start it took a while to get up to full speed. The speed of 10.38 m/s that we calculated is his **average** speed over 100 metres. His top speed was over 12 m/s.

Some speed cameras work out a car's average speed over a distance of a kilometre or so, while other types work out speed almost in an instant. A car's speedometer displays the exact speed at any moment.

7. Explain why your average speed and your top speed over a car journey will be different.
8. What benefit to road safety may there be when cameras work out average speed over a distance, rather than in one spot?

Key vocabulary

distance
speed
unit
formula
average

Understanding turning forces

We are learning how to:

- Describe the forces acting on a see-saw.
- Understand that the forces turn about the fulcrum.
- Explain how to balance different weights on a see-saw.

When children play on a see-saw, they can balance each other by producing equal and opposite turning forces. Turning forces are involved in many situations – opening a door, riding a bike, driving a car, using a spanner.

Push and turn

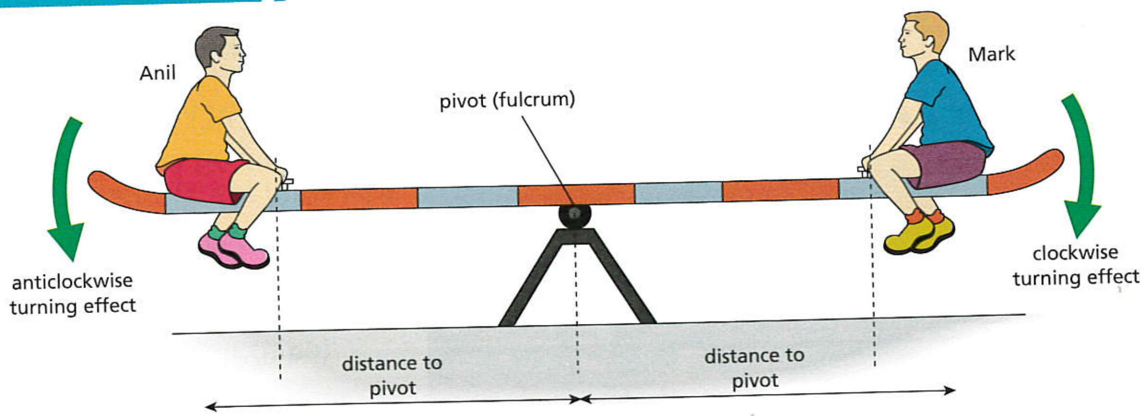


FIGURE 1.5.16a: Turning forces on a see-saw. Anil, on the left, causes an anticlockwise turning effect. Mark, on the right, causes a clockwise turning effect.

A see-saw changes a pushing force into a **turning force**. The force of the weight of a person sitting on the see-saw acts vertically downwards. This becomes a turning force because the middle of the see-saw sits on a **pivot**, also called a **fulcrum**.

For a door the fulcrum is the hinge. On a wheel the fulcrum is the axle at the centre of the wheel – a fulcrum does not change its position.

1. In what direction does the weight of a person act?
2. How does a see-saw change a vertical force into a turning force?
3. What acts as the fulcrum in a windmill?

Large and small turning forces

The size of the turning force on a see-saw depends on the distance of the person from the fulcrum. A small pushing force can produce a large turning force when it is applied a long way from the fulcrum. When a large pushing force is applied close to a fulcrum it produces a relatively small turning force.

4. What would happen if the larger child on the balanced see-saw in Figure 1.5.16b moved closer to the fulcrum? Explain your answer.
5. If another two children, of equal weight, got on the see-saw in Figure 1.5.16b, in what positions could they sit and still get the see-saw to balance?

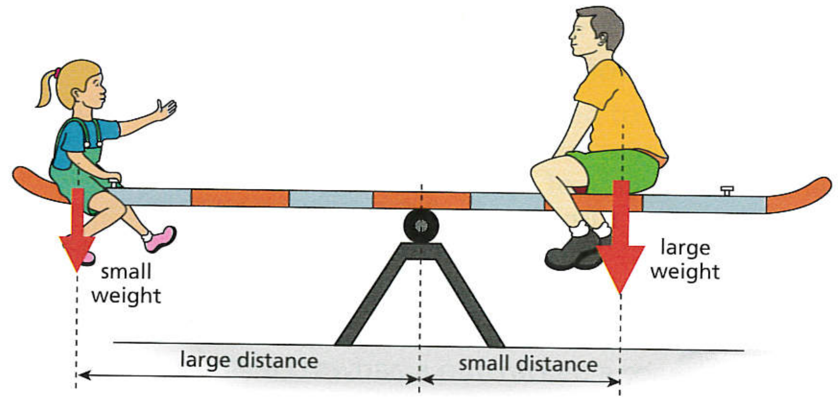


FIGURE 1.5.16b: The small force balances the large one because it is further from the fulcrum.

Force diagrams

Straight arrows are always used to represent forces, even when they they result in a turning effect. The reason that a force acting in a straight line produces a turning motion is because of the fulcrum. The fulcrum, which is some distance from where the force is acting, acts as a fixed point. The turning motion occurs around the fixed point.

6. Draw and label forces diagrams for:
   a) a person pushing open a door
   b) a spring 'door-closer' closing a door
   c) a person forcing a door open against a spring-closer.
7. Explain why a person pushing with a smaller force than the spring can still open the door in question 6.
8. Give some examples of turning forces in action in a science laboratory.

Did you know…?

By positioning the forces and the fulcrum carefully, jacks allow people to raise a heavy car by using just one hand to apply a force. This works because where the person pushes is a long distance, compared to the distance of the car, from the fulcrum.

Key vocabulary

turning force
pivot
fulcrum

Discovering moments

We are learning how to:

- State and use the law of moments.
- Describe how turning forces can be increased.
- List some examples of levers used as force multipliers.

A turning force is known in physics as a 'moment'. By understanding moments we can use levers to produce large turning effects.

Working out a moment

The size of a **moment** depends on the the size of the force used and on the distance of the force from the fulcrum. The equation for working out the size of a moment is:

moment = size of force × distance of the force from fulcrum

The unit is newton metres (Nm).

On a see-saw there are two moments at work. One of them turns the see-saw clockwise and the other turns it anticlockwise. For a balanced see-saw:

clockwise moment = anticlockwise moment

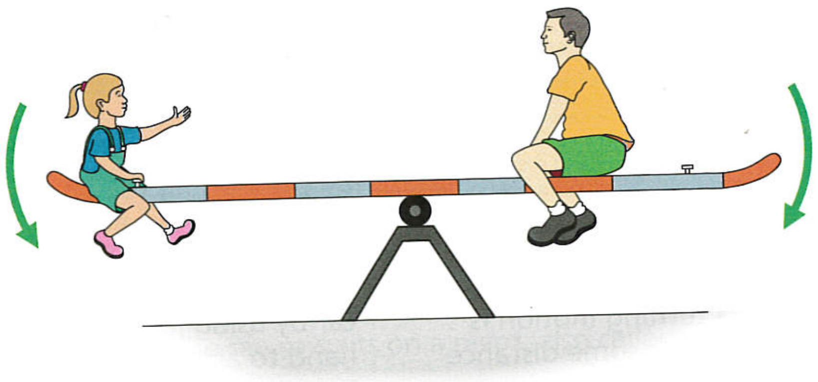


FIGURE 1.5.17a: When the clockwise and anticlockwise moments have the same value, the see-saw balances.

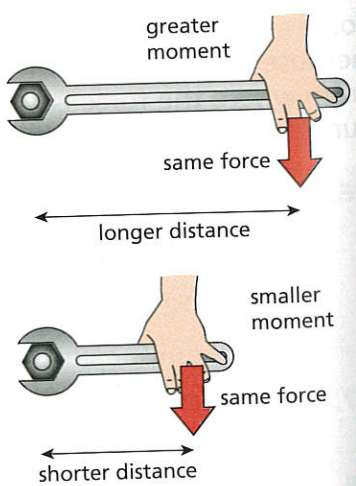


FIGURE 1.5.17b: How a spanner works

1. What does the scientific term 'moment' mean?
2. What two quantities do we need to know to be able to work out the size of a moment?
3. Look at Figure 1.5.17b. Explain why it is easier to undo a nut with a long spanner than with a short one.
4. A force of 20 N is pushing on a see-saw 2 m from the fulcrum. Calculate the size of the moment.

Levers

A **lever** is an example of a very simple machine. Levers use moments to produce large forces.This means that a large **load** can be moved by a smaller **effort**.

In Figure 1.5.17c the person's downward push gives an anticlockwise moment on the left of the fulcrum and this balances a clockwise moment on the righthand side.

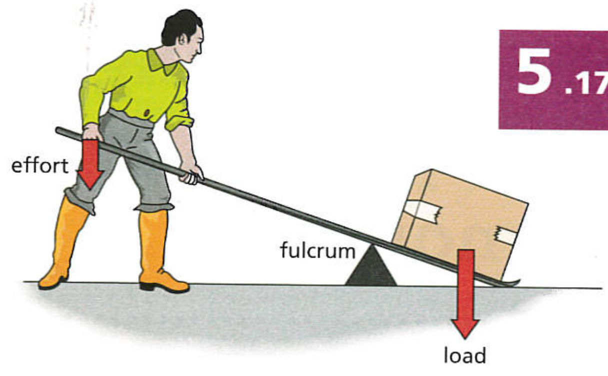


FIGURE 1.5.17c: A see-saw being used as a lever

5. In Figure 1.5.17c, the load is 1 m from the fulcrum and gives a downwards force of 20 N.
   a) What is the size of the anticlockwise moment caused by the load?
   b) What moment must the person produce to overcome the moment of the load and lift it?
   c) What force would the person need to push down with if they were 2 m from the fulcrum?

Simple machines

Levers that work like the one in Figure 1.5.17c act as **force multipliers**. These simple machines make a job easier. Examples include: a crowbar, a nutcracker, a spanner, long-handle garden cutters, a wheel barrow.

FIGURE 1.5.17d: Examples of levers used as force multipliers

6. Explain why a lever can be called a 'force multiplier'.
7. Explain how garden cutters work as a lever. Use the key words and a force diagram in your explanation.
8. A nutcracker works slightly differently. Try to draw a force diagram for one. What is the difference between this and the other levers?

Did you know ...?

The strongest human bite recorded in the Guinness Book of Records produced a force of 4337 N. The load at the teeth is very close to the fulcrum of the jaw, so the effort from the jaw muscle produces a big effect.

Key vocabulary

moment
lever
load
effort
force multiplier

Understanding the application of moments

We are learning how to:

- Link the law of moments to the design of cranes.
- Explain why counterweights are needed by cranes.
- Investigate the lifting capacity of a crane.

Engineers use their understanding of moments to design many types of machine – cranes are one example of this. Cranes make many tasks easier in building work. Ancient structures such as the Egyptian pyramids and Stonehenge are all the more remarkable for the fact that they were built without the use of such modern machinery.

FIGURE 1.5.18a: The pyramids were built without using cranes.

Keeping cranes stable

The larger the load that a crane lifts, the more it is in danger of toppling over. Also, the further crane has to reach to lift a load, the greater the risk of toppling. This is because of the size of the moment caused by the load. The tower crane in Figure 1.5.18b has a **counterweight** on the non-lifting end, to balance the load. This allows the crane to lift much bigger loads safely.

1. Why are tower cranes at risk of toppling over?
2. Describe one feature of a tower crane that helps in stopping it from toppling over.
3. Why is the size of the counterweight important?

Adjustment for different loads

A crane is often required to lift different-sized loads. This could unbalance the crane, because the size of the moment changes. By moving the counterweight to a new position along the jib, the clockwise and anticlockwise moments can be balanced.

A crane may sometimes have to reach further out than at other times. Again in this situation the position of the counterweight needs to be adjusted to keep the crane balanced.

4. Explain why a moveable counterweight is necessary on a crane.
5. A crane has just lifted a small load. In what direction does the counterweight need to be moved if the crane now has to lift a larger load?
6. A crane has picked up a load from the far limit of its reach and now needs to release it near to the base of the crane. How can the crane be kept balanced?

Exact position of the counterweight

For all the different lifting work that a tower crane does, it is important that the counterweight is always moved to the correct position along the jib. By calculating the clockwise and anticlockwose moments, engineers can work out the exact position for the counterweight.

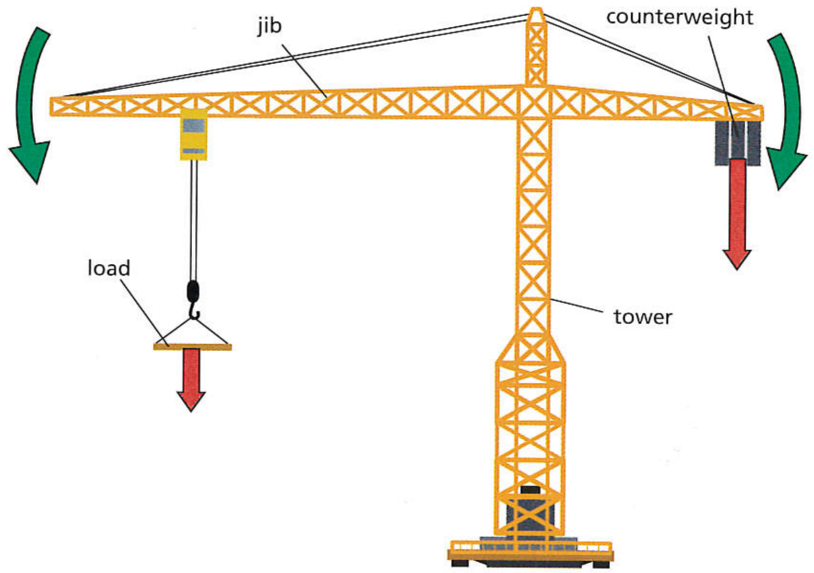


FIGURE 1.5.18b: Forces and their turning effects on a tower crane

7. What causes the anticlockwise moment on the crane in Figure 1.5.18b?
8. If the counterweight weighs 1000 N and each side of the jib is 20 m long, calculate:
   a) the maximum possible clockwise moment
   b) how big a load could be lifted when the counterweight is 5 m from the tower and the load is 10 m from the tower.
9. If the load and the counterweight were kept perfectly balanced, what other factors could affect the maximum lifting capacity of a crane?

Did you know …?

A crane in a shipyard in China can lift over 20 000 metric tonnes, which is 20 000 000 kg. This is roughly the weight of 15 000 medium-sized family cars.

Key vocabulary

counterweight

Checking your progress

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

- List types of force and represent forces using force diagrams; use newtonmeters.
- Describe the size and direction of forces using force diagrams.
- Explain how the size and direction of forces determines their effects.

- Identify gravity as a pulling force and distinguish between mass and weight.
- Describe what is meant by mass, explain how gravity forces affect weight, explain why weight varies from planet to planet and explain the term 'weightless'.
- Explain weight as a gravitational attraction between masses which decreases with distance; use scientific concepts to explain the difference between mass and weight.

- Know that forces can lead to changes in shape and investigate the change of shape of a spring.
- Explain the relationship between the amount of change in shape and the size of the force, and use data to state Hooke's Law.
- Collect accurate data about forces changing the shape of an object, recognise when shape changes regularly with force size, and explain behaviour when the elastic limit is exceeded.

- Identify some situations in which forces are balanced and recognise that unbalanced forces are needed for a change to take place.
- Identify forces acting in pairs, and apply understanding of forces to explain how a force can cause a change in speed and direction.
- Identify different examples of forces and reaction forces, and predict the changes of speed and direction that different forces can cause.

- Recognise that friction is a force that slows objects down or stops them from moving.
- Explain that friction is a contact force opposing the direction of movement.
- Provide a detailed explanation of friction between surfaces.

- List examples in which friction is useful and when it is unwanted, recognise that drag forces slow things down, and recognise that streamlining helps objects move through air or water.
- Compare contrasting situations involving friction, explain how friction can be increased or reduced, explain air and water resistance, and explain how streamlining reduces such resistance.
- Explain air and water resistance in terms of frictional drag, explain the forces on flying or falling objects, and explain streamlining using scientific vocabulary.

- Explain how to find the speed of an object.
- Explain the concept of speed and use an understanding of speed to explain how the equation for speed is derived.
- Independently derive the equation for speed and use understanding of the speed equation to explain how speed cameras work.

- Describe the balancing of a see-saw with different loads, recognise situations in which balance is important, and describe the effect of increasing the length of a lever.
- Explain how a fulcrum allows a turning motion, explain the effect of changing the size of a force or its distance from the fulcrum, and use and apply the law of moments.
- Explain moments using force diagrams and the law of moments, explain how levers can act as force multipliers, and explain and demonstrate the design principles of a crane.

Questions

Questions 1–7

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

1. Which is the best description of gravity? [1]
   - a) It pushes you towards the Earth.
   - b) It is a pulling force between two objects.
   - c) It is force that is stronger if you are on a planet with less mass.
   - d) It is a pushing force between two objects.

2. What is the speed of a cyclist who covers 7 m in 1 second? [1]
   a) 70 km/h b) 7 km/h c) 7 m/s d) 700 m/s

3. What is the correct unit for measuring force? [1]
   a) metre b) newton metre c) newton d) centimetre

4. 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.

5. Describe the forces acting on a trolley as it rolls down a ramp. [2]

6. Describe why streamlining is important for a car. [2]

7. Explain the forces involved when two people of different weights balance each other on a see-saw. [4]

Questions 8–14

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

8. Two people are pushing either side of a door. One is pushing with a force of 80 N, 100 cm from the hinge. The other is pushing 50 cm from the hinge. Which size of force must this second person push with to balance the other? [1]
   a) 160 N b) 40 N c) 800 N d) 8 000 N

9. Which of these statements is true about your weight and mass on a planet that has twice the gravity of Earth? [1]
   - a) Weight is the same, mass is double.
   - b) Weight and mass are both the same.
   - c) Weight and mass are both double.
   - d) Weight is double, mass is the same.

10. A speedboat takes 8 seconds to pass from one buoy to another 56 m away. Which of these is the speed of the boat? [1]
    a) 448 m/s b) 7 km/h c) 7 m/s d) 448 km/h

11. For a large object dropped onto a trampoline, which of these statements is *not* true? [1]
    - a) The trampoline shows elastic behaviour.
    - b) The object's weight exerts a downward force on the trampoline.
    - c) The trampoline exerts an upward force on the object.
    - d) The trampoline exerts a downward force on the object.

12. Draw and label a diagram to show the forces acting on an object that has just been dropped from a hot air balloon. [2]

13. Draw a diagram to show the forces acting on an object falling towards Earth at terminal velocity. Explain why the object is at terminal velocity. [2]

14. The soles of running shoes are made from an elastic material. Explain what is meant by 'elastic' and how this helps the runner. [4]

Questions 15–16

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

15. Evaluate the following statement, stating the extent to which you agree with it: 'A jack designed to lift a car could be strong enough to lift a lorry'. [2]

16. Crash-helmet padding is compressed as a force is applied. This protects the head because the squashing reduces the effect of an impact. Figure 1.5.20 shows how three different types of padding for motorcycle crash helmets gets compressed when different forces are applied. Evaluate the three types, suggesting which is most suitable. [4]

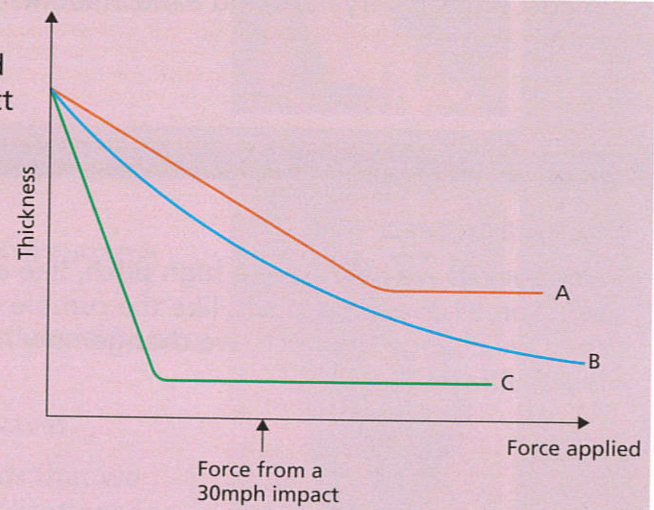


FIGURE 1.5.20: A graph to show the effect of thickness of crash-helmet padding when different forces are applied.