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FOR NSW STAGE 4

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2ND EDITION

SAMPLE CHAPTER

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CONTENTS

FORCES

Why does an object's motion change?

2

*** Have you ever wondered …**

- Why do we not slip over when we walk on smooth surfaces?
- Why do our feet get hot if we drag them along carpet?
- Why do cars sometimes deform in car crashes?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify changes that take place when particular forces are acting
- predict the effect of unbalanced forces acting in everyday situations
- describe some examples of technological developments that have contributed to finding solutions to reduce the impact of forces in everyday life, e.g. car safety equipment and footwear design
- analyse some everyday common situations where friction operates to oppose motion and produce heat
- investigate factors that influence the size and effect of frictional forces.

Check your Student obook assess for these digital resources and more:

Quizlet Live

Compete in teams to test your knowledge of key concepts in this chapter.

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Quizlet Live

Launch a quiz for your students on key concepts in this chapter.

2.1 A force is a push or a pull

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Key ideas

In this topic, you will learn that:

> unbalanced forces act on everything, causing objects to move or stop moving, or change speed, shape or direction.
> the unit used to measure a force is a newton (N).

force
push or pull that, if unbalanced, can cause a change in an object's motion

calibrate
to check the accuracy of a metre against known measurements

newton
unit used to measure force; symbol N

A **force** is a push or pull that happens when two objects interact. Sometimes forces are easy to identify and describe, such as a foot kicking a ball. Other forces are harder to identify and describe; for example, the force that keeps you on the ground.

Forces in action

Forces act on everything around us. Usually, more than one force is acting on any object at one time, but often we do not notice them. You have many forces acting on you at the moment. For example, when you sit on a chair, gravity is pushing you down. The chair is pushing back against you. Because these forces acting on you are in balance (the same strength but opposite directions), you do not move.

When you kick or throw a ball, you need to push the ball. This push force causes the ball to move. When you catch a ball, you are still giving it a push. This time, the push force causes the ball to stop moving.

Forces act on everything around us all the time. They cause objects to:

> begin to move
> speed up
> slow down or stop moving
> change direction
> change shape
> remain still.

Examples of these forces are shown in Figures 2–7.

Measuring forces

One way to 'see' a force at work is to measure it. Push forces can be measured with a set of scales like the ones you might find in a kitchen or bathroom. Pull forces can be measured using a **spring balance**. As shown in Figure 1, a stiff spring in the balance stretches when an object pulls on it.

spring balance
device consisting of a spring and a scale, used to measure forces in the laboratory

The distance the spring stretches represents the amount of force applied. This distance is measured by a marker on the spring balance. A rubber band can measure the size of forces in a similar way to a spring balance. Before we can use a rubber band to measure a force, it must be **calibrated**. This means we need to match the stretch of the rubber band to the force pulling on it.

The unit used to measure forces is called a **newton** after English physicist Isaac Newton (1642–1727), who first described the force used to pull an apple from a tree. Spring balances are also known as newton meters. Scientists around the world have agreed to this standard measurement so that they can communicate with one another. In every country, the force of 100 grams being pulled to the centre of the Earth is about 1 newton (N). This is about the same as one large chocolate bar sitting on your hand.

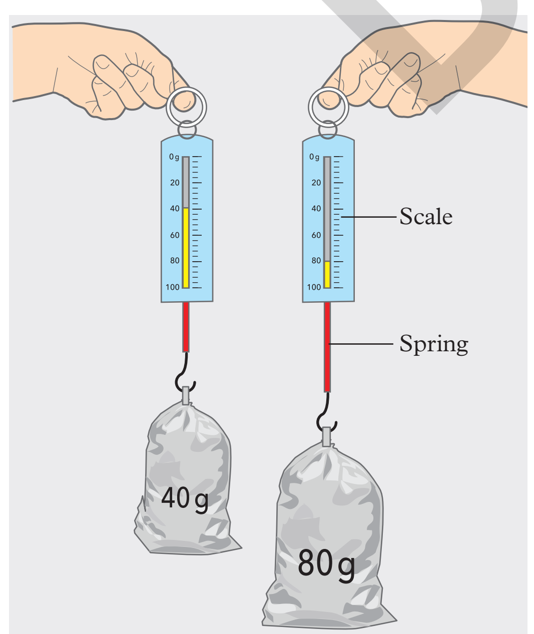

Figure 1 Spring balances are used to measure force.

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SKILLS LAB
2.1: Measuring forces
Go to page 15.

Figure 2 Begin to move. The golf club pushes the ball. The club exerts a force on the ball, causing it to begin to move. If the club misses the ball, there is no additional force on the ball from the club and the ball stays still.

Figure 3 Speed up. When the skateboarder wants to move faster, they use their foot to exert a force on the ground.

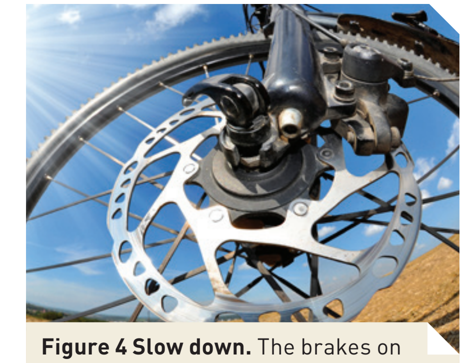

Figure 4 Slow down. The brakes on this bicycle wheel push down on the tyre, causing the tyre to slow down. This in turn brings the bicycle to a stop.

Figure 5 Change direction. The tennis racquet pushes the ball in a different direction.

Figure 6 Change shape. The fingers push the plasticine into a different shape. When the fingers stop pushing, the plasticine no longer changes.

Figure 7 Remain still. The forces acting on this ball stop it from moving.

Check your learning 2.1

Recall and explain

1 **Define** the term 'force'.
2 **Recall** six things that forces do.
3 **Recall** the unit used to measure force.

Apply and analyse

4 **Order** these forces from biggest to smallest.
 a A truck hitting a pole
 b A rocket being launched
 c Typing one letter on a computer keyboard
 d Kicking a soccer ball
5 **Compare** the spring balances used for weighing a bag of flour with those used for weighing a spoon of baking powder.

Evaluate and communicate

6 Can you see a force? Always, never or sometimes? **Justify** your answer in the format of your choice, such as paragraph, poster or speech.

Skills builder: Planning investigations

7 A student was using the force measurer from Skills Lab 2.1 (see page 15) when the rubber band broke.
 a **Identify** the aim of Skills Lab 2.1. (THINK: Why was the student using the force measurer?)
 b **Suggest** why the original force measurer might have broken. (THINK: What needs to change to make it work?)
 c **Propose** a new way to conduct Skills Lab 2.1. (THINK: Could a different rubber band be used with the same scale?)

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2.2 An unbalanced force causes change

Key ideas

In this topic, you will learn that:

> when forces acting on an object are balanced, the object's motion does not change

> forces acting on an object are unbalanced when there is a change to the speed, direction of motion, or shape of an object.

Forces always come in pairs. Forces are balanced when they are pushing or pulling equally in opposite directions. If one of the push or pull forces is larger than the other, the object will change its speed, direction of motion or shape. When this happens, the forces are said to be **unbalanced**.

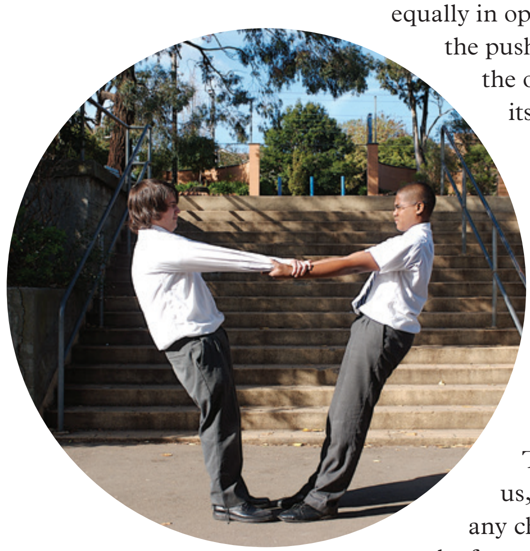


Figure 1 Forces can balance each other.

Balanced forces

Pushing on a brick wall does not usually cause the brick wall to move. This does not mean your force did not exist. There are many forces around us, but most of them do not cause any change in motion. This is because the forces are balanced. It means they are equal in size but opposite in direction. If the forces of the two people in Figure 1 balance each other, the people stay still. This is because they are pushing or pulling with equal and opposite forces. **Balanced forces** are very important. Two tug-of-war teams will be balanced if they pull with the same amount of force but in opposite directions.

balanced forces
two forces equal in size and opposite in direction

Unbalanced forces

Unbalanced forces are also very important. Consider the forces acting on the barbell in Figure 2. The barbell stays in the air at a particular height because the forces on it are in balance. The weightlifter is pushing the barbell up with exactly the same amount of force as the Earth is pulling down. To move the barbell up, the weightlifter must use a stronger force than the Earth's pull. This will make the forces on the barbell unbalanced.

unbalanced forces
two or more forces that are unequal in size and direction and therefore change an object's speed, direction or shape

Evidence of an unbalanced force

There are three ways you can tell if a force is unbalanced. Forces are unbalanced if there is a change in an object's:

> speed

> direction

> shape.

Figure 2 A weightlifter applies a force to lift the barbell.

CHALLENGE
2.2: Design a ball whacker
Go to page 16.

If a ball is resting on the ground, then all the forces acting on it are balanced. If two people are pushing equally on a stationary object in opposite directions, then the forces are balanced and the object does not move. If one person starts pushing harder, then the object will start to move. There is a change in motion because the forces are unbalanced.

Consider a soccer ball rolling towards the goal. If the goalkeeper kicks it away, then the ball will change direction because the goalkeeper's kick unbalanced the forces.

Playdough sitting on the bench will not change unless you add a push force with your finger. The evidence for this unbalanced force is a change in shape.

Contact forces

Contact forces involve two objects touching each other. Some forces make objects move because of a direct push or pull. It is much easier to move a pencil if you push it with your finger. Your finger has to touch the pencil or be in contact before the pencil will move. This is called a contact force. Friction is also an example of a contact force, which you will learn more about later in this chapter.

If an object is able to push or pull another without touching, it is called a **non-contact force**. Magnetism and **gravity** are examples of non-contact forces.

Figure 3 This door is opened by applying either a direct push or pull force (contact).

Worksheet
Predicting the effect of forces

contact forces
forces that occur when two objects are touching each other

non-contact force
force that operates between two objects when they are not touching each other, e.g. gravitational force

gravity
force of attraction that objects have on one another due to their masses

Check your learning 2.2

Recall and explain

1 **Identify** an example of balanced forces acting on an object.

2 **Describe** how the forces acting on the objects in the following situations are unbalanced.
 a Pushing down the lever on the toaster
 b Jumping on a trampoline
 c A car starting to move

Apply and analyse

3 **Examine** Figure 2. What are the forces acting on the barbell?

4 **Explain** why weightlifters get tired when they hold heavy masses in the air.

5 **Explain** why a brick wall does not fall over when you push it. Why can a bulldozer push it over?

6 Jack pushes a trolley quickly down a supermarket aisle. He builds up speed and then stops, letting go of the trolley.
 a **Predict** what would happen to the trolley.
 b **Explain** your answer in terms of the forces acting on the trolley.

Skills builder: Questioning and predicting

7 Sam wants to investigate if having more people on one side of a tug-of-war will affect the result of the game. He has created this scientific question for his investigation: 'Is it good to have lots of people for tug-of-war?'
 a **Identify** what is wrong with Sam's question. (THINK: Is this question specific enough and easy to test?)
 b **Propose** your own scientific question for Sam's investigation. (THINK: How does your question improve on Sam's question?)

2.3 Forces can be added together

Key ideas

In this topic, you will learn that:

> forces can be added together to calculate the net force working on an object
> force diagrams use arrows to represent the direction and strength of a force.

If you tried to lift a heavy object such as a piano, you would not succeed because the upward force you exerted on the piano would be too weak. But if a few of your friends helped you by adding their force to yours, the combined upward forces would be stronger than the downward pull of the Earth. The **net force** is the combination of all the forces acting on the piano. If the piano is lifted up, the forces are unbalanced and the net force on the piano is upward.

net force
combination of all the forces acting on an object

If an object is stationary (not moving) or moving at a steady speed in the same direction, then the net force acting on that object is zero. All the forces are balanced. If an object changes its speed (by speeding up or slowing down), shape or direction, then a net force must be acting on it.

In tug-of-war (see Figure 1), if one team pulls with more force, the rope will move towards them. If the rope stays in the same place while both teams pull, the net force acting on the rope must be zero.

Drawing force diagrams

Force diagrams show all the forces acting on an object. There is one arrow to represent each force. The arrows on a force diagram can tell you information about the forces being exerted:

> The length of the arrow shows the size of the force. For example, a short arrow shows a weak force and a long arrow shows a strong force.
> The direction of the arrow shows the direction of the force.

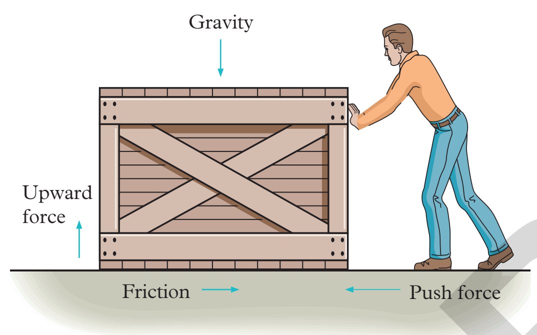


Figure 2 The arrows in this diagram show the forces acting on the box as it is moved.

More than one force is usually acting on an object at a time. Figure 1 shows a tug-of-war between two teams. The arrows show the pull force they are exerting on the rope. The arrow for the 200 N force is twice as long as the arrow for the 100 N force, but they are showing opposite directions. One team is much stronger than the other team. Which team will win? What evidence will you see in real life that this team is stronger?

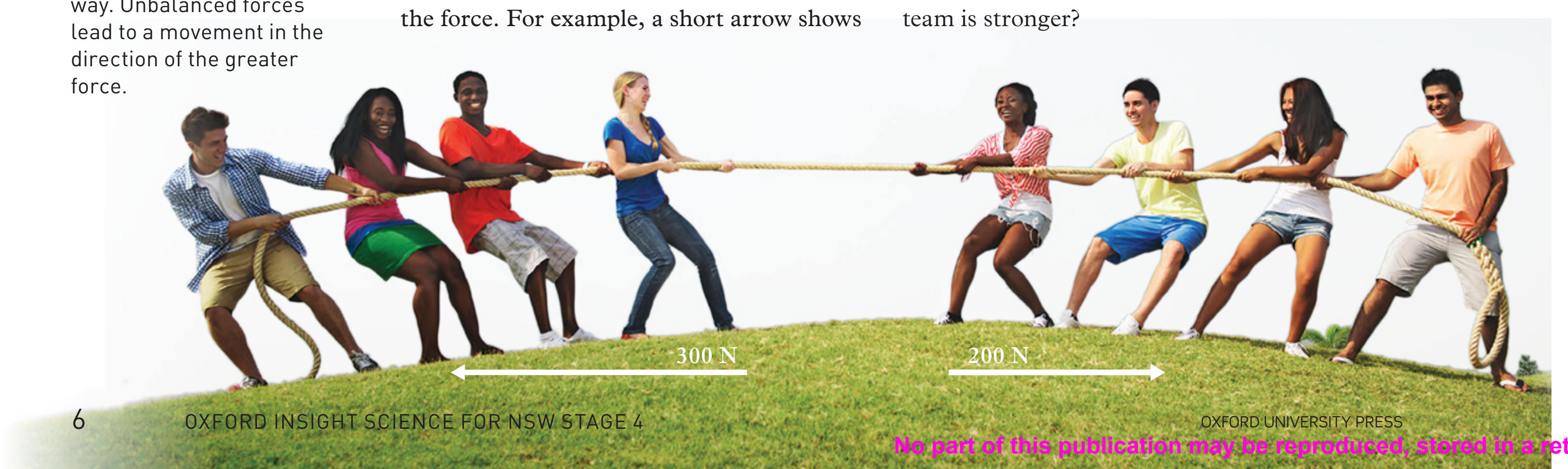


Figure 1 When forces are unbalanced, a change in motion will occur, with the greatest force 'winning'. In a game of tug-of-war, if one team pulls with a force of 200 N to the right and the other team pulls with a force of 300 N to the left, the net force is 100 N to the left. The team on the left will win the game because both teams will move that way. Unbalanced forces lead to a movement in the direction of the greater force.

Worked example: Drawing force diagrams

Question

Construct a force diagram to represent the car being pushed in Figure 3.

Figure 3 When one of these people tries to push the car, they are not strong enough. But their combined net force is enough to move the car.

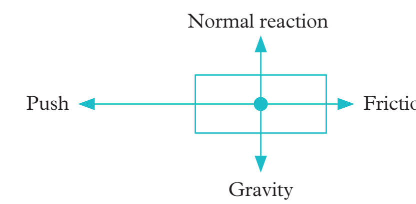
Solution

Step 1 Draw a box or dot to represent the car.

Step 2 Identify all the forces acting on the car, and in which direction they are acting. In this example, the forces are the people pushing on the car, the friction acting in the opposite direction to the movement, gravity acting down on the car and the force of the ground pushing upward (called normal reaction).

Step 3 Draw an arrow for each of these forces. Use a ruler to draw straight lines. The push causes the car to move so it must be an unbalanced force. Therefore, the arrow for the push force should be longer.

Step 4 Label the arrows.



Worksheet
Drawing force diagrams

Check your learning 2.3

Recall and explain

1 **Define** the term 'net force'?

2 **Identify** two examples where forces cancel each other out (net force = 0) and where two forces add together.

3 **Explain** what the arrows represent on a force diagram.

Apply and analyse

4 If Sally can push with 150 N and Marilla with 200 N in the same direction, **calculate** the force they push with together. **Calculate** the net force if they push in opposite directions.

5 **Construct** a diagram of two people having a tug-of-war. Give them names and draw arrows to show the force they are exerting on the rope. Identify the winner.

6 **Construct** a force diagram for the following examples.
  a A broken-down car being pushed
  b A ball being thrown
  c Laying still on the grass

Evaluate and create

7 **Identify** if the forces acting on a car are balanced or unbalanced in each step. **Justify** each of your answers.
  a A car is stationary.
  b It then starts moving and keeps travelling at a constant speed on a straight road for 5 minutes.
  c It next turns right.
  d Then it continues to travel at straight road.
  e The driver sees a dog crossing the road, so he brakes and the car stops after 1 minute.

Skills builder: Communicating

8 Your classmate does not understand why his team lost a tug-of-war, even though he had more people on his side.
  a **Construct** a force diagram to demonstrate the forces in the tug-of-war. (THINK: What kind of representation is normally used to demonstrate forces?)
  b Label your force diagram. (THINK: What does your classmate need to know about what heat?)

2.4 Friction slows down moving objects

Key ideas

In this topic, you will learn that:

> friction resists motion between objects
> friction produces heat.

What is friction?

friction
force that acts to oppose the motion between two surfaces as they move over each other

Friction is the force that resists movement between two objects in contact. In other words, friction slows down moving objects. Friction happens as surfaces rub together or try to slide across each other. For example, it is much easier to slide along ice than along a gravel road. This is because the friction of the gravel road slows the forward motion.

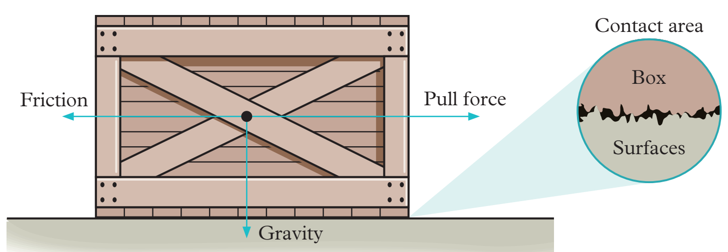


Figure 1 Friction between the box and the carpet on the ground makes it harder to slide the box around.

Friction acts in the opposite direction to movement. The greater the friction, the more the movement slows down and eventually stops. Any time a movement is slowed down, it is because of friction.

Imagine that you need to move a heavy wooden box across a carpeted room (see Figure 1). It would require more force to slide the box along carpet than a smoother surface such as floorboards. This is the because the carpet generates more friction.

Resource
STEM Project:
What a drag!

Friction produces heat

When you rub your hands together quickly, you can make your hands feel warmer. The friction between them produces heat. All friction forces produce heat as the surfaces of objects rub together.

Think about the way some people can start a fire just by rubbing two sticks together or striking a match. The friction from such movement can create enough heat to produce a flame.

Figure 2 The friction from rubbing two sticks quickly together can produce enough heat to start a fire.

Aboriginal and Torres Strait Islander peoples developed different methods for creating fire with friction. One method, sometimes called the fire drill, involves a flat piece of a wood and a long stick. The long 'drill' stick is held upright with one end placed on the flat piece of wood. The drill stick is then twirled quickly, causing friction. The saw dust that collects in this process can ignite to become fire.

How to decrease friction

The size of friction depends on how easily two surfaces rub over each other. Smooth surfaces move easier over each other than coarse surfaces. Therefore, the friction between smooth surfaces is smaller than the friction between coarse surfaces. To reduce friction, we need to find ways to make movement between surfaces easier.

Rollers or balls are one way to reduce friction. Because the balls roll across the ground, it is much easier than if they were dragged along. Tiny balls are often used as bearings to allow two surfaces to slide over one another easily.

INVESTIGATION 2.4: What if the amount of friction was changed? Go to page 17.

Hovercrafts and air pucks have low friction because they use a layer of air to glide over a surface. There is no contact between the surfaces and almost no friction as a result.

Lubricants, such as oils and grease, also reduce friction. This is called **lubrication**. If a kitchen drawer sticks, you can use candle wax or soap to lubricate it. Lubricants work by coating the surface with an oily or waxy substance, which makes them slippery. Putting oil on bicycle chains and grease on the wheel axles makes the wheels spin more easily and with less friction.

Air resistance, or **drag**, is the friction between a moving object and the air it is moving through. Air resistance limits the speed of an object in the air. Air resistance is necessary for parachutes, but it is a problem for cars and trucks. **Streamlining** (making the surface smooth and rounded) helps overcome air resistance.

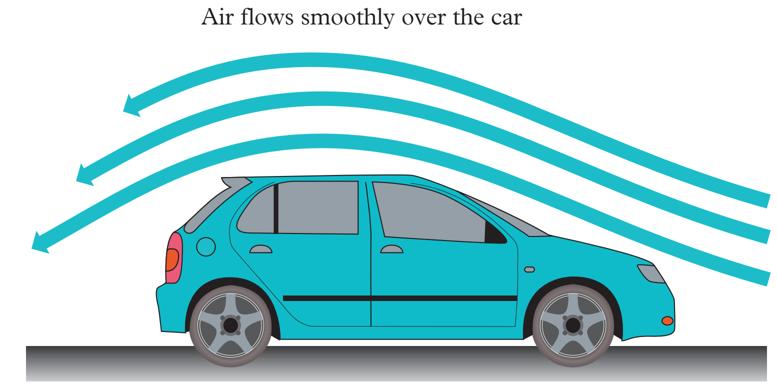


Figure 3 Streamlining reduces friction.

Footwear for friction

When buying sports shoes, many people look for shoes with good grip. This grip prevents the shoes from sliding when they run and stop. The grip provides friction between the ground and the wearer. When you start walking, you rely on the shoe rubbing against the ground so that you can push forward. When you try to stop, you rely on the friction between the shoe and the ground to stop your movement. Without friction, your feet would just slip over the ground. It would be like trying to walk on ice.

Footwear has also developed to reduce the impact of your feet hitting the ground.

Figure 4 Friction between the shoe and the ground stops a person from sliding around.

lubrication
using a lubricant, such as oil or grease, to decrease friction

air resistance
friction between a moving object and the air it is moving through

drag
see air resistance

streamlining
making a surface smooth and rounded to reduce friction

Check your learning 2.4

Recall and explain

1 **Recall** three examples where friction is useful, and three examples where friction is a problem.
2 **Explain** how speed and friction are related.
3 **Identify** two examples of friction slowing down an object.

Analyse and apply

4 Using the examples of friction you identified in Question 3, **analyse** how these examples slow down an object and how they produce heat.
5 Why does the tread on the tyres of your bike wear down over time? **Explain** this in terms of force.
6 In a world without friction, **predict** what would happen if you tried to:
 a go down a slide in a playground
 b play tenpin bowling
 c tie your shoelaces.

Skills builder: Processing and analysing

7 Vivienne used the same pushing force on her textbook to slide it across different surfaces. She recorded her results in the table below.

Surface	Distance the textbook travelled (m)
Floorboards	1.2
Carpet	0.9
Linoleum	1.6

 a **Identify** what kind of graph you would use to represent this information. (THINK: Would you use a bar chart or a line graph?)
 b **Construct** a graph for this data using your answers from parts a and b. (THINK: What other features should a graph have? Remember to label your x and y axes and include a title.)

2.5 Seatbelts and safety helmets save lives

Key ideas

In this topic, you will learn that:

> technological developments, such as seatbelts and helmets, reduce the impact of forces in everyday life.

When objects are stationary or moving at a constant speed, the forces are balanced. When the forces are unbalanced, they can cause a change in speed, shape or direction. When cars or push bikes stop suddenly, passengers or riders can experience unbalanced forces. Australian government regulations mandate the wearing of seat belts or safety helmets to prevent these unbalanced forces causing damage to passengers.

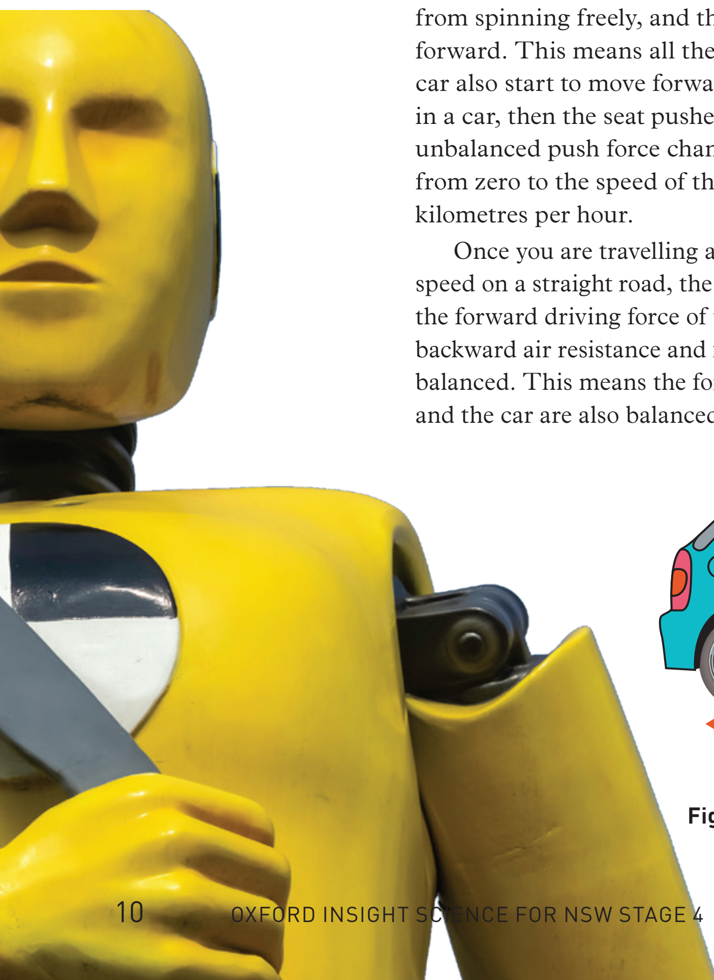
Seatbelts and car safety

When a car starts to move, the engine provides a driving push force on the wheels. The friction between the road and the wheel stops the wheel from spinning freely, and the car starts to move forward. This means all the other parts of the car also start to move forward. If you are sitting in a car, then the seat pushes you forward. This unbalanced push force changes your speed from zero to the speed of the car, such as 100 kilometres per hour.

Once you are travelling at a constant speed on a straight road, the forces between the forward driving force of the car and the backward air resistance and friction forces are balanced. This means the forces between you and the car are also balanced. Balanced forces mean there is no change in speed, shape or direction. Often, when you are in a moving car, you might not notice that you are moving at 100 kilometres per hour. If you stop to think about it, you might realise that 100 kilometres per hour is the same as running a 100 metre race in 3.6 seconds. Yet you do not notice the forces involved because they are balanced.

You do notice the forces when the car stops suddenly. Most cars stop when the engine stops its driving force and the brakes prevent the wheels from moving. Because the car is still moving forward, there is friction between the wheels and the road. This means there is more force stopping the car than there is pushing it forward. The unbalanced forces change the cars speed from 100 kilometres per hour to 0 kilometres per hour. But what stops you?

As a passenger, your speed will only change if there is an unbalanced force exerted on you. The friction between the wheels and road stop the car; however, it does not stop you. You need a force to stop you moving forward. Fortunately, the laws in Australia encourage everyone to wear a seatbelt.



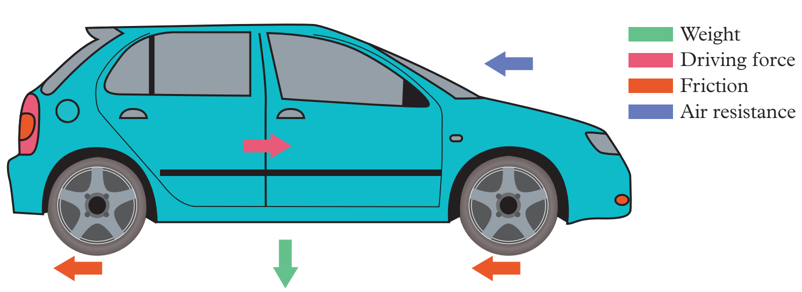


Figure 1 There are many forces acting on a moving car.

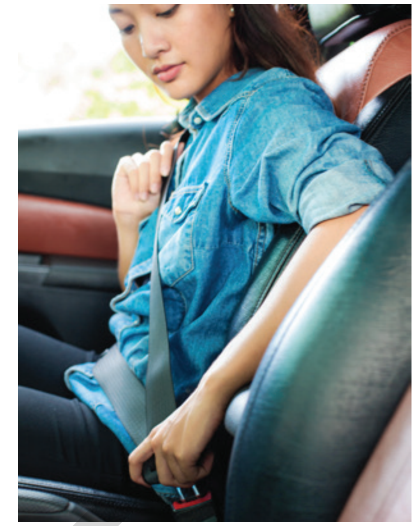


Figure 2 Seatbelts hold us in place when a car stops suddenly.

Figure 3 The unbalanced forces in a car crash can cause a change in speed and shape.

When the car stops, the seatbelts attached to the car also stop. These seatbelts then provide an unbalanced force to change your speed from 100 kilometres per hour to 0 kilometres per hour.

Just imagine what would happen if you were not wearing a seatbelt? The car would stop, and you would keep going at 100 kilometres per hour until a force slowed you down. This could be the seat in front of you, the windscreen or the road in front of the car. This type of unbalanced force would change not only your speed but also your direction and shape.

Safety helmets

Safety helmets are an essential item when riding a bike, and the wearing of them is strictly regulated by Australian law. Just like a passenger in a car, a cyclist can experience unbalanced forces when stopping suddenly. In an accident, such as hitting a car door, the unbalanced force stops the bike; however, the cyclist keeps moving forward until their forces become unbalanced. The unbalanced force results in a change in the rider's shape and speed. As bicycles do not have seatbelts, the movement of the cyclist is often unstopped when they hit the road. A helmet can help prevent direct contact between the cyclist's head and the road while spreading the force over a greater surface area. For this reason, Australian regulations require all cyclists to wear an appropriate safety helmet.

Check your learning 2.5

Recall and explain

1 **Identify** the forces on a car travelling at a constant speed of 100 kilometres per hour on a straight road.

2 **Explain** why you do not notice how fast you are travelling when you are a passenger in a car travelling at 100 kilometres per hour on a straight road.

Evaluate and create

3 **Identify and describe** how one technological development is reducing the impact of forces for car safety.

4 **Investigate** the rules in New South Wales around bike safety to reduce the impact of forces. Present your findings as an A4 poster.

Skills builder: Problem-solving

5 **Investigate** Australian government regulations about wearing seatbelts when in a moving car.

   a **Identify** the problem that seatbelts are trying to solve. (THINK: Why do we need to wear seatbelts?)

   b **Evaluate** the rules around wearing seatbelts when in a moving car. (THINK: Do you think these rules work? Are these rules enough?)

Figure 4 A safety helmet spreads the force of an impact to the head across a great surface area.

*REVIEW

Multiple choice

1 **Identify** which of the following is an example of a pull force.
A Kicking a soccer ball
B Diving into a swimming pool
C Dragging a box toward you
D Pushing a shopping trolley

2 **Identify** how you would describe the net force of a barbell being lifted.
A Upward net force
B Downward net force
C Zero net force
D Sideways net force

3 **Identify** the balanced forces.
A A ball flying through the air after it was thrown
B A book sitting on a table, not moving
C A piece of modelling clay being moulded into a different shape
D A car slowing down for a stop sign

Recall and explain

4 **Identify** two examples of a push force.

5 **Identify** two examples of a pull force.

6 Think back to the start of your day. **Describe** the forces that you experienced from the time you got up to the time you arrived at school.

7 **Explain** which of the following involve forces, and which of the following do not.
a Opening a window
b Turning a screw with a screwdriver
c Smelling food cooking
d Modelling clay
e Standing on a diving board
f Watching a candle burn

8 **Explain** the difference between a contact force and a non-contact force.

9 **Outline** the effects of balance and unbalanced forces on an object.

10 **Outline** three ways to reduce friction.

11 **Describe** how one technological development has reduced the impact of forces to make cars safer.

Apply and analyse

12 **Examine** Figure 1.
a **Describe** the net forces acting on the ball.
b **Predict** what will happen to the ball.
c Draw a force diagram of forces acting on the ball to support your prediction.

Figure 1 The force of Benji Marshall kicking the ball is easy to identify and describe, but what force is pulling him towards the centre of the Earth?

13 **Analyse** the following in terms of friction.
a Gymnasts putting chalk on their hands
b People driving cars on ice or snow putting chains on their tyres
c A car using more petrol when it has a load on the roof
d A person having difficulty running across ice

14 **Calculate** the size and direction of net force in the diagrams below.

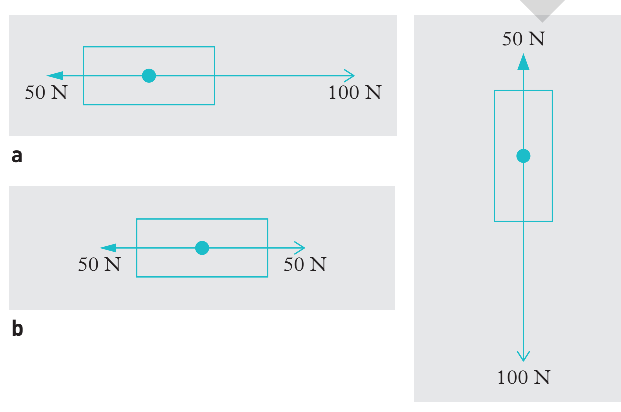


Figure 2 Net force diagrams

15 Two students worked together to investigate the effect of the mass of objects on the size of the friction force. They pulled different weights with the same size force on the same surface. Their results are in the table below.

Mass (kg)	Friction Force (N)
0.25	0.63
0.50	1.30
1.00	2.50
2.00	5.00
3.00	7.50

a **Identify** the independent and dependent variables.
b **Identify** one controlled variable.
c **Construct** an appropriate graph using the data in the table.

16 You are camping in a remote area, but you have left your matches at home. **Explain** how you can start a fire for cooking.

17 Use your understanding of forces to **account** for a row of dominos falling over.

Figure 3 The forces acting on the dominos become unbalanced when one domino in the chain is pushed.

Evaluate and create

18 **Determine** which of the following cars would be better as a racing car? **Account** for your answer.

Figure 4 Two cars

19 Think about how far a toy car and a marble would roll along a flat bench.
a **Predict** which would have the least friction. **Justify** your response.
b **Predict** which would roll the furthest. **Justify** your response.
c **Explain** the connection between rolling and friction.

20 **Discuss** why surfers often wax their surfboards.

21 If you used the same pushing force in each of the following cases, **determine** which surface an object would move over the fastest: sand, wood, or metal coated in oil. Justify your answer.

22 **Propose** three things that are more difficult, and three things that are easier, to do without friction. **Account** for your answer.

Critical Thinking

23 Matilda fills her car with petrol and drives 100 kilometres along a freeway. She then turns off the freeway and travels 100 kilometres along country roads, one of which is very rough.
a **Identify** which part of the trip the car would use more petrol.
b **Justify** your answer using your knowledge of forces and friction.

24 Harry is pushing a full shopping trolley up a steep hill. He pushes the trolley with all of his might, but it goes nowhere.
a **Explain** what is happening to the trolley in terms of forces.
b **Construct** a force diagram to represent the forces acting on the trolley.
c Suggest a solution that might help Harry to get the trolley and all of its groceries to the top of the hill..

Go further

25 Imagine that you want to move a big box across a room. Your friend comes to help you and he pushes down on the box.
a **Identify** if he would make your work easier or more difficult.
b **Justify** your answer.

26 Think about a car travelling at a constant speed around a roundabout. **Explain** if the forces acting on the car are balanced or unbalanced.

Research

27 Choose one of the following topics to research further. Present your findings in a format that best fits both the information you have found and the understandings you have formed.

»Seatbelts

The wearing of seatbelts in cars became compulsory in Australia in 1970. Research the materials that are used to make seatbelts. Use your knowledge of forces to explain how seatbelts prevent injury in a car accident.

»Aeroplanes

There are always forces acting on objects. What are the push and pull forces acting on an aeroplane? How do these push and pull forces change as an aeroplane takes off, flies and lands? Research the forces acting on an aeroplane and draw a labelled diagram to show the forces.

»Footwear for friction

Investigate how different types of footwear have been designed to reduce friction. What type of footwear do you think is the best for reducing or increasing friction? What features have designers included to manage friction? Draw a diagram of one shoe and label how it has been designed to improve the impact of friction.

Reflect

Now that you have completed this chapter, reflect on your ability to do the following:

	I can do this.	I cannot do this yet.
Identify changes that take place when particular forces are acting.	☐	☐ Go to pages xxx - xxx
Predict the effect of unbalanced forces acting in everyday situations.	☐	☐ Go to pages xxx - xxx
Describe some examples of technological developments that have contributed to finding solutions to reduce the impact of forces in everyday life, e.g. car safety equipment and footwear design.	☐	☐ Go to pages xxx - xxx
Analyse some everyday common situations where friction operates to oppose motion and produce heat.	☐	☐ Go to pages xxx - xxx
Investigate factors that influence the size and effect of frictional forces.	☐	☐ Go to pages xxx - xxx

2.1 Measuring forces

SKILL

Aim

To measure a variety of forces in common situations.

Risk assessment 2.1 Measuring forces

Lab tech notes 2.1 Measuring forces

Materials

- Rubber band
- Thin strip of timber (or a ruler)
- Mass carrier and masses
- Pen

Method

A rubber band can measure the size of forces in a similar way to a spring balance. But before it can, the rubber band must be calibrated. This means matching the stretch of the rubber band to the number of newtons pulling on it.

1 Calibrate the rubber band on the strip of timber, as shown in Figure 1.

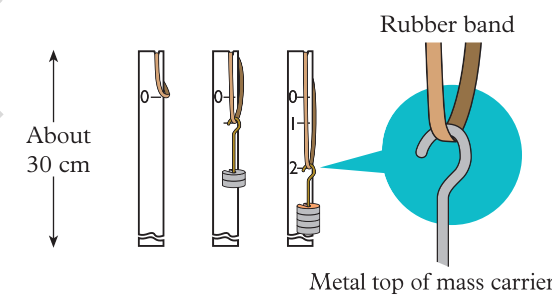


Figure 1 Calibrating the force measurer

2 Mark the distance that the rubber band is stretched on the timber when the mass carrier holds a 100 gram mass. Remember: The weight force of 100 grams equals 1 newton of force.

3 Repeat for masses of 200 grams, 300 grams, 400 grams and so on, marking the timber each time.

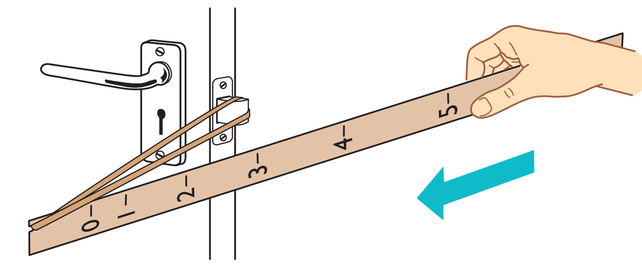


Figure 2 Measuring the force needed to open a door

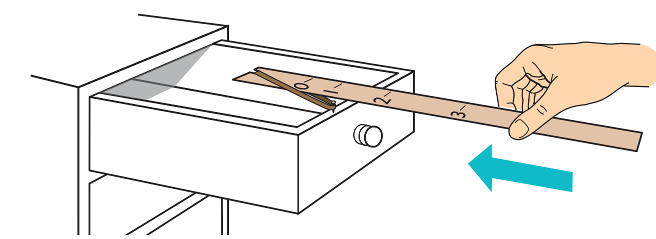


Figure 3 Measuring the force needed to close a drawer

4 Use your measuring device to measure the force needed to:

a open the door to a room
b drag a chair across the floor
c close a drawer in the laboratory
d move your pencil case
e pull up your sock
f carry out three movements of your choice.

Results

Draw a column graph showing the amount of force needed to move each object.

Conclusion

What do you know about the force required to move different objects?

2.2 Design a ball whacker

CHALLENGE

Design brief

Design equipment that uses a block of wood to hit a tennis ball. A block of wood from home or the woodwork room is ideal.

Risk assessment
2.2 Design a ball whacker

Lab tech notes
2.2 Design a ball whacker

Questioning and predicting

> How will you create a contact force between the wooden block and the ball?
> How will you make the wooden block swing?
> How far do you want your ball to move?

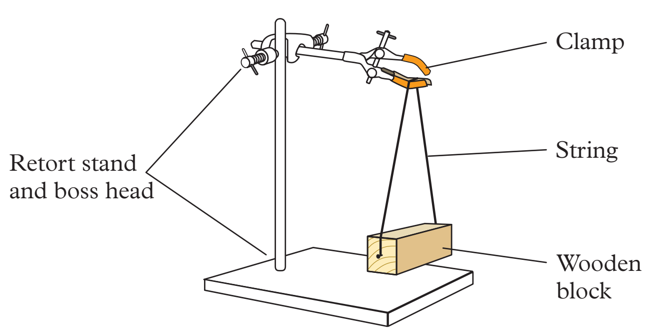


Figure 1 A possible design for the experiment

Planning and conducting

Figure 1 shows one way to set this experiment up. You must use only the force of gravity – you cannot push the wooden block.

Processing, analysing and evaluating

1 What changes did you have to make to move the ball further?
2 What was the most successful feature of your ball whacker? What was the least successful?
3 Is a heavy block better than a light one?
4 Is there any practical use for a 'whacker' like this?
5 If you were doing this experiment again, how would you modify your device? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

2.4 What if the amount of friction was changed?

INVESTIGATION

Aim

To investigate how friction may be reduced.

Investigation
2.2 What if the amount of friction changed?

Risk assessment
2.4 What if the amount of friction changed?

Lab tech notes
2.4 What if the amount of friction changed?

Materials

> Force measurer (see Skill Lab 2.1) or spring balance
> Thick textbook
> Wooden rollers (round pencils)
> Book
> Sand

Method

1 Use your force measurer to measure the friction of your textbook being dragged along the table. (Hint: Drag it at constant speed.)

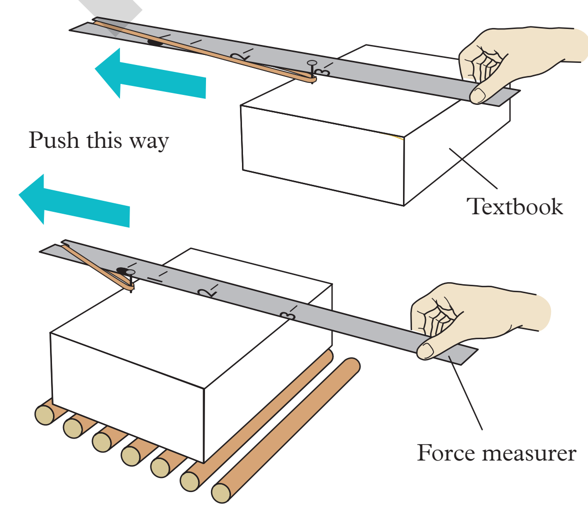


Figure 1 Measuring the friction of a textbook

2 Place two books on top of each other and measure the friction.

Inquiry: Choose one question to investigate

1 What if rollers were placed under the textbook?
2 What if sand was placed under the textbook?

- Write a hypothesis for your inquiry.
- What (independent) variable will you change from the first method?
- What (dependent) variable will you measure/observe?
- What variables will you need to control to ensure a fair test? How will you control them?

Results

1 Record your results in a table like the one below.

Object	Force needed to make it move (N)			
	Trial 1	Trial 2	Trial 3	Average
Textbook				
Textbook with a second book on it				
Textbook with rollers under it				
Textbook with sand under it				

2 Draw a column graph showing the effect of sand/rollers on the object's friction.

Discussion

Compare your results with those of others in the class.

1 What was the best way to reduce friction?
2 Would 5 rollers be better than 2 for reducing friction?
3 Would 10 rollers be better than 5 for reducing friction?
4 Would bigger or smaller rollers be better for reducing friction?
5 What are some problems with using rollers?
6 Write down a practical example of rollers being used to reduce friction.
7 Why would square rollers not be any good?
8 Would fine sand or coarse (large-grained) sand be better for increasing friction?
9 Write down a practical example of sand being used to increase friction.
10 What are some problems with using sand for this purpose?

Conclusion

What do you know about how to reduce friction?

A scuba diver observing a rusted and overgrown shipwreck in the Red Sea.

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