7 Forces

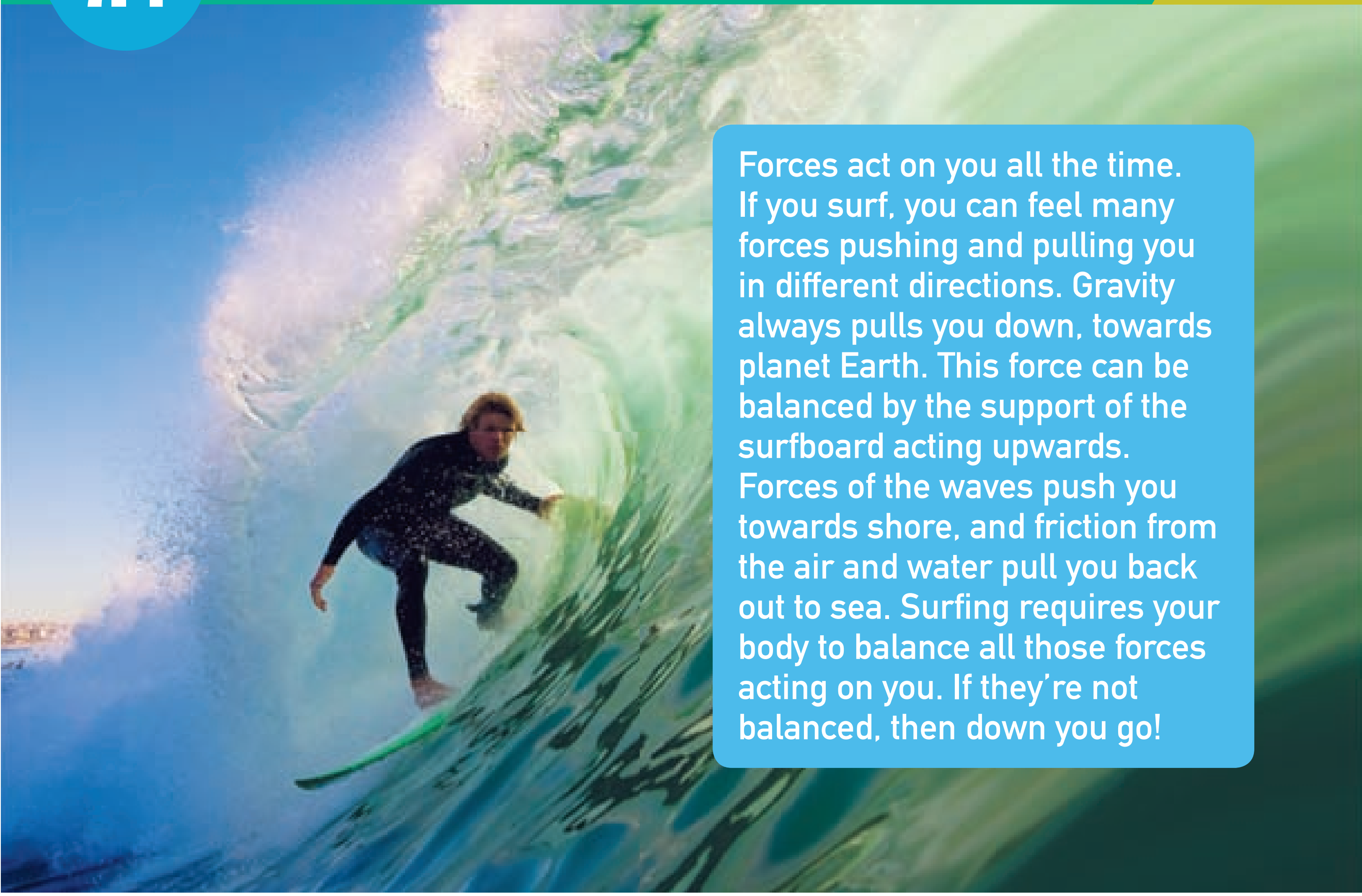
HAVE YOU EVER WONDERED...

- why your stomach feels funny on a rollercoaster?
- why you lean sideways when turning a sharp corner in a bus?
- why a feather falls more slowly than a stone?

After completing this chapter students should be able to:

- identify whether forces acting upon an object are balanced or unbalanced
- recall that change to an object's motion is caused by unbalanced forces acting on the object
- investigate the effects of applying different forces to familiar objects
- investigate common situations where forces are balanced, such as stationary objects and unbalanced, such as falling objects
- identify how wearing a seatbelt offers protection to a person in a car accident
- explain how sports scientists apply knowledge of forces in order to improve performance
- discuss beneficial and unwanted effects of friction
- recall that the Earth's gravity pulls objects towards the centre of the Earth
- discuss how gravity explains the motion of the planets and why objects fall
- recall that a magnet will attract certain materials within a magnetic field
- explain how an object becomes charged and describe the effects of electrostatic forces.

7.1 What are forces?



Forces act on you all the time. If you surf, you can feel many forces pushing and pulling you in different directions. Gravity always pulls you down, towards planet Earth. This force can be balanced by the support of the surfboard acting upwards. Forces of the waves push you towards shore, and friction from the air and water pull you back out to sea. Surfing requires your body to balance all those forces acting on you. If they're not balanced, then down you go!

What is a force?

A **force** is a push, a pull or a twist. This is shown in Figure 7.1.1.

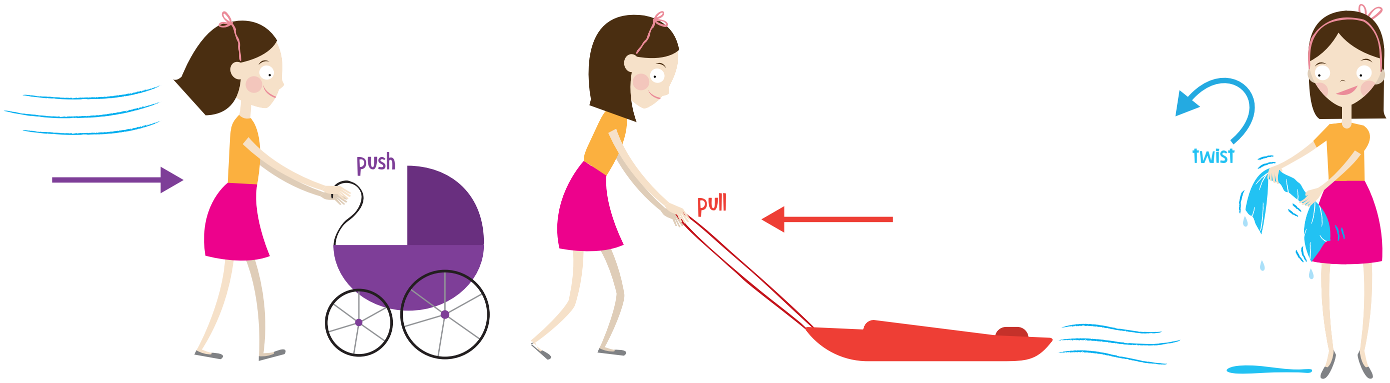


Figure 7.1.1 A force is applied when something is pushed, pulled or twisted.

What can forces do?

All around you, things move, or are in motion. Whenever there is a change in motion, a force has acted. Some examples are shown in Figure 7.1.2.

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A force can...
start something moving or speed it up. When something moves faster, we say that it accelerates, or undergoes **acceleration**.

A force can...
stop or slow an object's motion. When something slows down, we say that it decelerates, or undergoes **deceleration**.

A force can...
cause an object to change direction.

A force can...
change the shape of something.

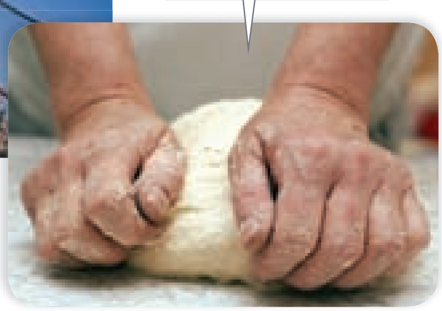


Figure 7.1.2 Forces are needed to cause a change in the motion of an object. Here are examples of the ways motion can change around you.

Measuring forces

A spring balance can be used to measure a force. The larger the pulling force, the more the spring is stretched and the higher the reading on the scale. The spring balance shown in Figure 7.1.3 operates in this way. Bathroom scales use a spring that is squashed or compressed to measure force.

Force is measured using a unit called the **newton** (symbol **N**). This is named after the 17th-century English scientist, Sir Isaac Newton. It takes a force of about 1 N to lift an apple.

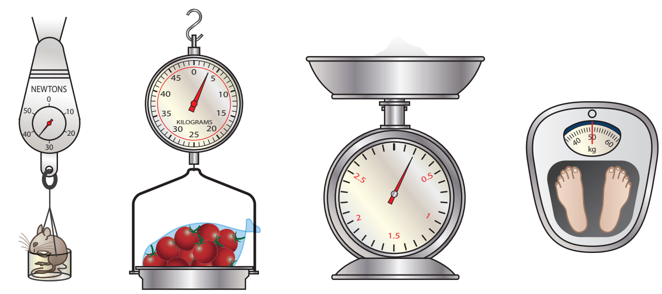


Figure 7.1.3 The ability of springs to stretch and squash allow a weight force to be measured.

SKILL BUILDER

Drawing forces

Many forces can act on an object at the same time. You can show these forces in a diagram such as Figure 7.1.4 by representing each as an arrow.

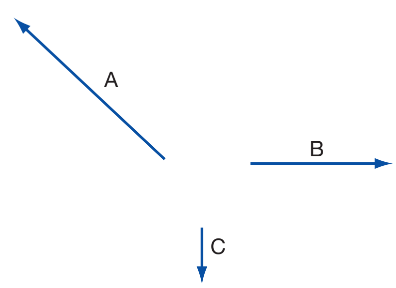


Figure 7.1.4 Forces are represented by arrows that show the direction in which the force acts. The size of the arrow represents the size of the force, so the bigger the arrow, the bigger the force. Force **A** is the largest of these three forces and force **C** is the smallest.

Balanced forces

The forces acting on an object can be balanced or unbalanced. When sitting on a chair, the force of gravity pulls you downwards, towards Earth. A support force from your chair acts upwards and balances the downwards force of gravity. This balancing act is shown in Figure 7.1.5.

Figure 7.1.5

The downwards force of gravity is balanced by the upwards support force from the chair. The forces acting on this person are balanced.

Balanced forces don't always mean that the object is stopped: it might be travelling at the same speed without changing directions. Consider Nishika, about to ride her bike. To take off, Nishika must accelerate, pedalling fast and hard to produce a force large enough to push her forwards. She needs to overcome the friction caused by the roughness of the road and by the air that she pushes through. To speed up, Nishika keeps accelerating. Her pedalling needs to provide a driving force that is bigger than the force of friction acting in the opposite direction. As Nishika continues her journey, she may travel at a constant speed without slowing down or speeding up. When this happens, the forwards force from her pedalling is cancelled out by the friction forces pushing her backwards. At this stage, her motion is constant and all of the forces acting on her are balanced, as shown in Figure 7.1.6.

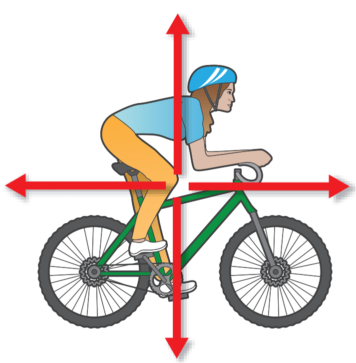


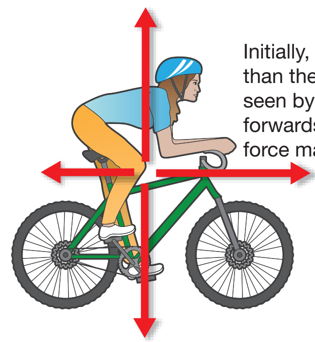
Figure 7.1.6

At this stage of the ride, Nishika travels at a constant or even speed. All of the forces acting on her are balanced. This is indicated by the red arrows being the same length in each direction.

Unbalanced forces

Whenever the forces acting on Nishika are unbalanced, her motion will change. Motion always changes in the direction of the unbalanced force, as can be seen in Figure 7.1.7. This means that the forces are unbalanced when Nishika:

- starts moving (by pedalling fast and hard)
- speeds up (by pedalling faster and harder)
- slows down (by using the brakes)
- comes to a stop (by using the brakes)
- changes direction (by turning the handlebars).



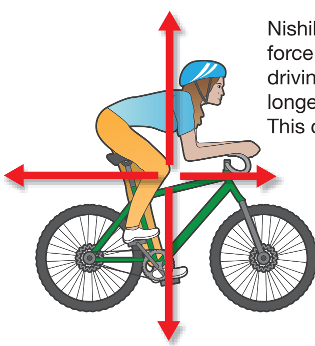


Figure 7.1.7

Nishika's motion will change whenever the forces acting are not balanced.

7.1

Inertia

If you put your schoolbag down in your bedroom, it will stay there until something happens to it. Someone could lift it, push it or pull it to make it move; but if left alone, your schoolbag will stay as you left it. This ability of the schoolbag to remain unchanged is called its **inertia**. Everything and everyone possesses inertia. Inertia can be described as the tendency to resist any change in motion.

INQUIRY **science 4 fun**

Marble motion

Can you design and build a device that will apply different forces to a marble?

Yes

Collect this ...

- an arrangement of objects, such as elastic bands, wooden ramps, springs, balloons, cardboard boxes, cardboard tubes, funnels, icy pole sticks
- a marble

Do this ...

1. Design a device so that once a marble is dropped onto or into your device, it will speed up, slow down, change direction and finally come to a stop.
2. Build your device and test it out.

Record this ...

Describe what happened to the marble's motion after it was dropped.
Explain why you think this happened.

Figure 7.1.8 In a front-on collision, although the car has stopped, the motion of its passengers continues due to the effects of inertia.

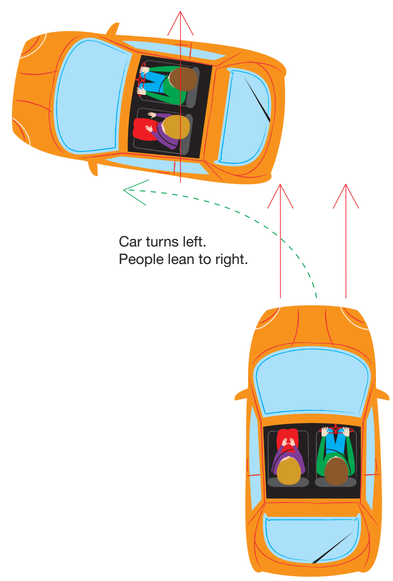


Figure 7.1.9 When travelling forwards in a car that suddenly turns left, you may lean to the right. Although the steering force changes the direction of the car, you continue to move straight ahead.

Sir Isaac Newton proposed some statements to explain the way things move. These are called laws of motion. Newton's first law of motion states that:

- anything that is not moving will stay that way unless a force makes it move
- anything that is moving will keep moving at the same speed and in the same direction unless a force makes it change.

This law explains why Nishika needed to apply an unbalanced force in order to change her motion. Figure 7.1.8 shows what happens to crash-test dummies the instant after a car hits a wall at 56 km/h. The motion of its passengers continues until something else stops them. Similarly, when travelling in a car or bus turning a corner, your body continues to travel in a straight line. As a result, you lean to one side as the vehicle turns, as shown in Figure 7.1.9.

Wearing seatbelts while travelling in a car and wearing a helment while riding a bike help to protect you from the effects of inertia.

The effect of mass

The more massive something is, the greater its inertia. This means it takes greater force to change its motion. It takes a far smaller force to stop a pebble rolling down a hill than to stop a massive rock. Similarly, it takes a smaller force to get the pebble moving in the first place.

SciFile

Pumpkin helmets

Operators of the many motorcycle taxis used as cheap transport in Nigeria were unhappy about a new law forcing them to wear helmets. Complaining that the helmets were expensive and were often stolen, many riders protested against the law by wearing helmets made from pots, pans, plastic or even dried pumpkin shells. Authorities were not pleased and their motorbikes were confiscated.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Car safety features

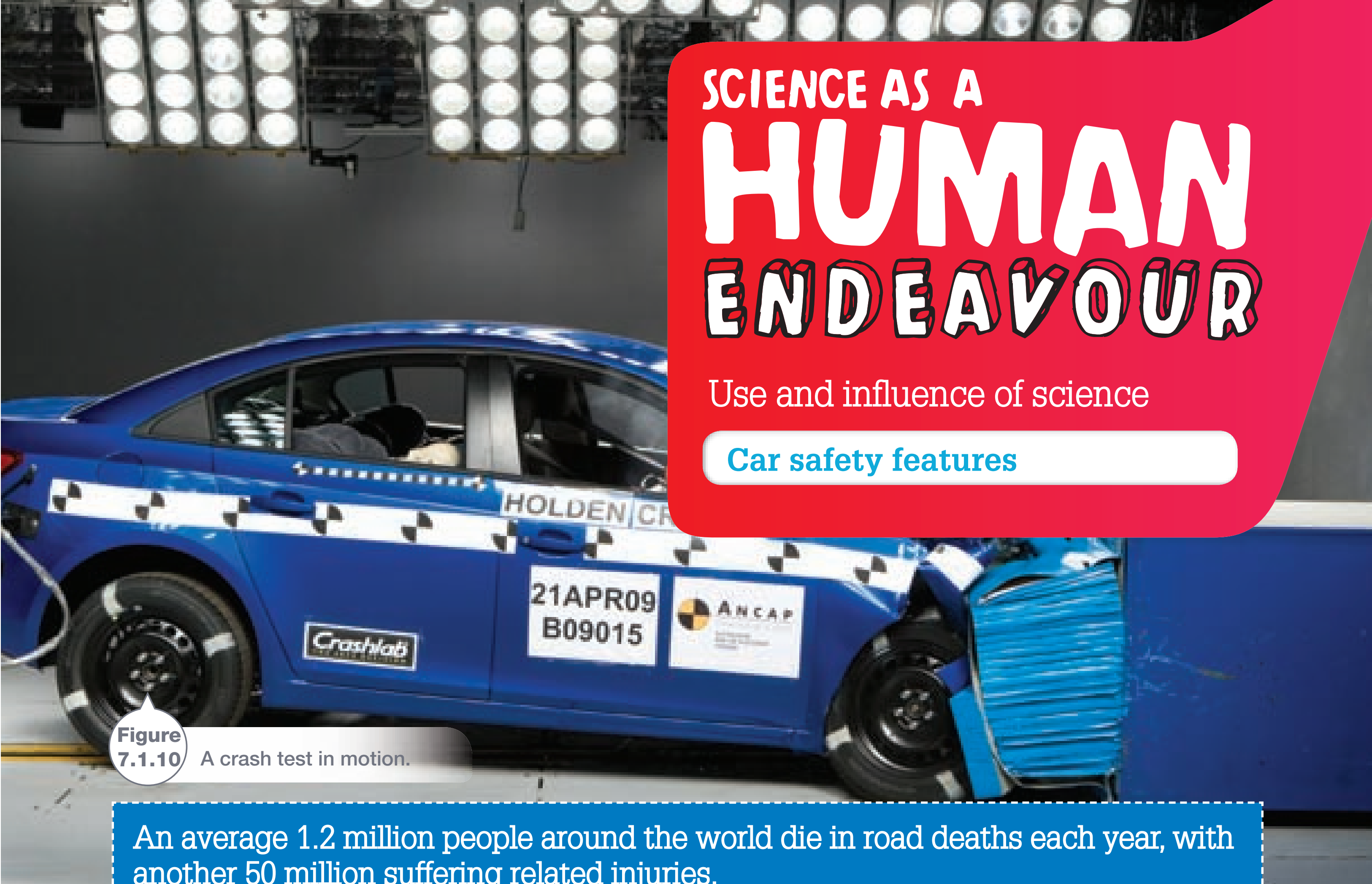


Figure 7.1.10 A crash test in motion.

An average 1.2 million people around the world die in road deaths each year, with another 50 million suffering related injuries.

ANCAP (Australasian New Car Assessment Program) provides information to consumers about the level of protection afforded by all new cars on the market. A system of star ratings, from 1 to a maximum of 5 stars, is used to indicate how safe a car will be in an accident.

If a car stops suddenly, its passengers continue to move forward until they hit something that stops them. If they stop by hitting the windscreen, dashboard or steering column at this speed, they can be seriously injured or killed. Crash testing helps develop safer cars and inform consumers of the safety rating of new cars on the market.

INQUIRY science 4 fun

Starting and stopping

What happens to your body as a car starts and stops?

Yes

Collect this …

- a skateboard or toy truck
- a petri dish or jar lid
- masking tape
- a marble

Do this …

1. Tape the petri dish to the skateboard or toy truck.
2. Put a marble or ball bearing in the dish.
3. Observe what happens to the marble when you push the skateboard/truck forward, stop it, or push it around a corner.

Record this …

Describe what happened to the marble in each case.
Explain why you think this happened.

Figure 7.1.11 illustrates some of the active and passive safety features found in many new cars. Active safety features are designed to reduce the chance of an accident. They include:

- good quality tyres inflated to correct pressure
- functioning headlights
- an effective braking system
- reversing cameras
- reversing sensors
- ABS (anti-lock brakes)
- traction control
- ESC (electronic stability control)
- night vision
- brake assist.

Passive safety features lessen the possible damage to the occupants of a car in an accident. They include:

- correctly adjusted three-point seatbelts and seatbelt reminder lights
- front and side airbags
- crumple zones (shown in Figure 7.1.12)
- side impact protection systems
- no sharp features protruding from the dashboard of the car.

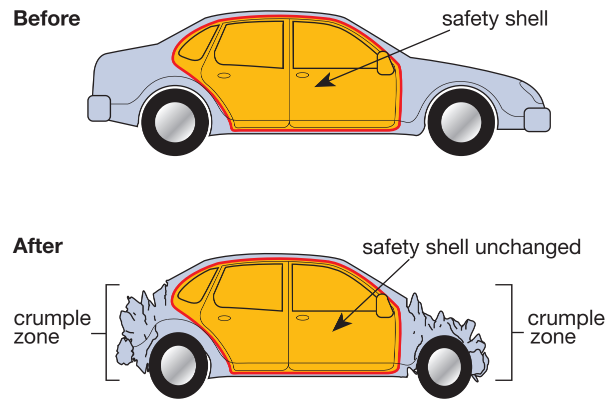


Figure 7.1.12 The passenger shell of a car is usually made from steel to protect its passengers. The engine compartment and the boot, however, are designed to collapse in a collision. This increases the time the car takes to come to a stop, which reduces the force of the impact.

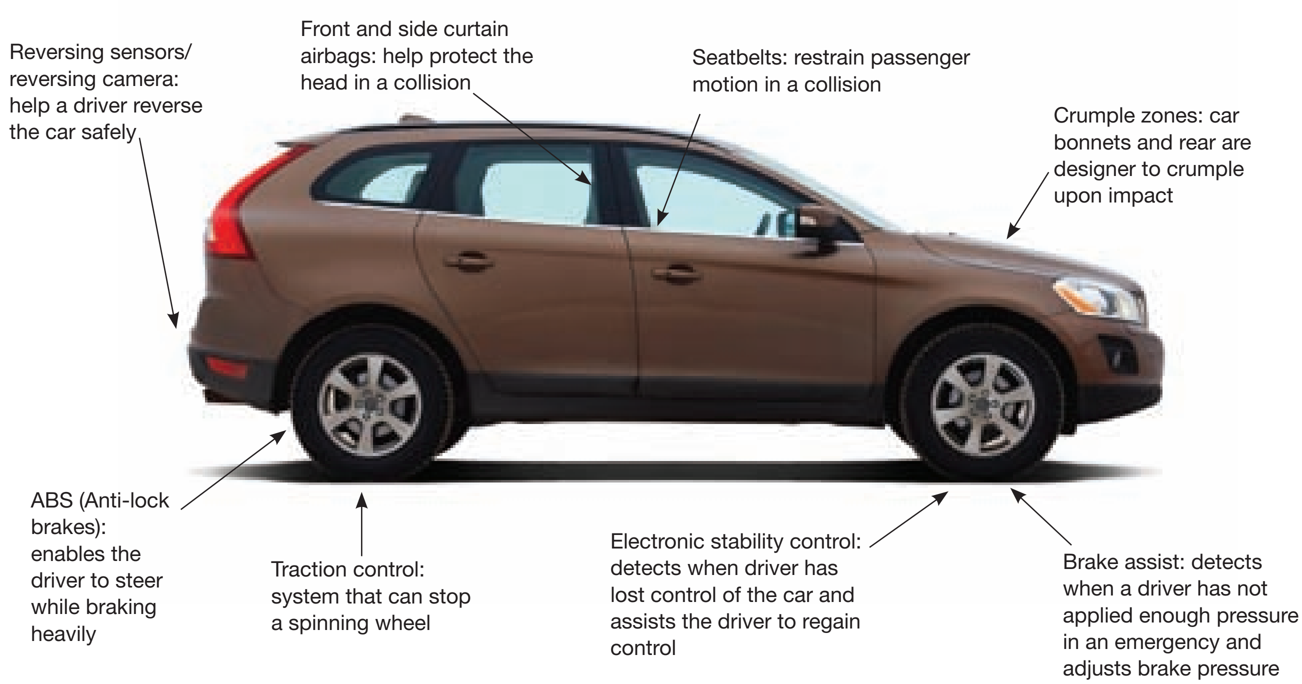


Figure 7.1.11 These are some of the active and passive safety features that can be found in a car.

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7.2

ENDEAVOUR

7.1 Unit review

Remembering

1 **State** which word from the list below correctly completes each statement.

push motion newton force spring

- **a** All around us, things move or are in ____.
- **b** Whenever there is a change in motion, a ____ has acted.
- **c** A force can be a ____, a pull or a twist.
- **d** A force can be measured using a ____ balance.
- **e** The unit used to measure force is called the ____.

2 **List** five ways a force can change motion.

3 **State** whether the following are true or false.

- **a** If the forces acting on an object are balanced, then it is not moving.
- **b** You supply a force when you squeeze a tube of toothpaste.
- **c** Inertia describes the tendency of an object to change its motion.
- **d** The less mass an object has, the greater its inertia.

Understanding

4 **Describe** an example of a force that:

- **a** speeds up an object's motion
- **b** changes an object's direction.

5 **Explain** how a spring balance is used to measure force.

6 The grocery and bathroom scales shown in Figure 7.1.3 on page 246 both use a spring to measure the size of a force. **Outline** how the spring is used in each case.

7 Refer to Figure 7.1.6 on page 247.

- **a** **Name** the forces acting on Nishika when she travels at a constant speed.
- **b** **Explain** why the arrows on this force diagram are shown to be equal in size.

8 **Describe** the role of each of the following safety features in protecting passengers of a car in an accident: airbags, anti-lock brakes, reversing sensors, electronic stability control and seatbelts.

9 **Explain** why cars are designed with crumple zones.

Applying

10 **Identify** the direction of movement of objects acted upon by these forces:

Force to left (N)	Force to right (N)	Force upwards (N)	Force downwards (N)	Direction of movement
10	10	10	0	
20	30	0	0	
25	5	15	15	
30	30	10	50	
40	40	100	100	

11 Figure 7.1.13 shows forces acting upon four boxes, labelled A, B, C and D.

Use an arrow to **demonstrate** the size and direction of the overall force acting on boxes A, B, C and D.

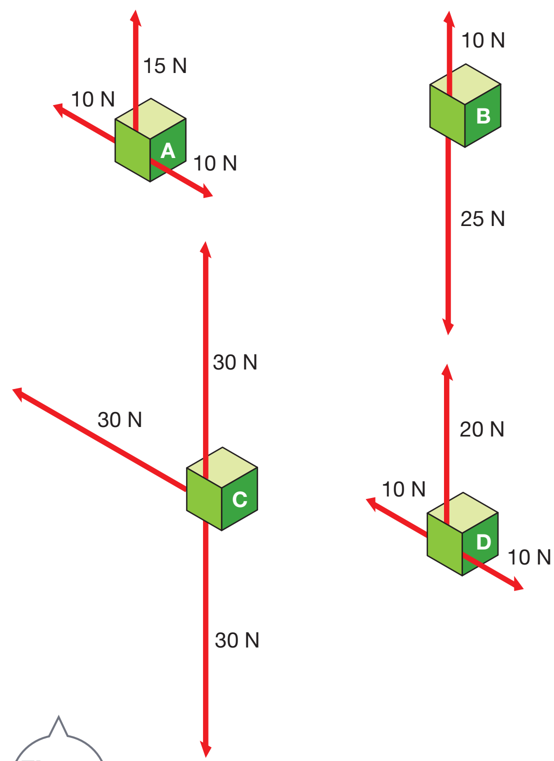


Figure 7.1.13

7.1 Unit review

12 **Use** your understanding of inertia to **explain** the following situations.

a Mien is rollerblading along the footpath. Upon hitting a small stone, he falls forward, grazing the palms of his hands and his knees.

b Madeline brakes suddenly when driving to work because she failed to notice that the driver in front was slowing. Some china plates resting on the back seat fall forward and some break.

c Carl loses his balance and falls backwards while standing in a train as it leaves a station.

Analysing

13 **Classify** each of these actions as a push, pull or twist force.

a Sweeping the floor

b Dragging a heavy sports bag along the floor

c Throwing a cricket ball

d Hitting a golf ball

e Tightening wheel nuts on a car

f Closing your front door from the inside of the house

g Closing your front door from outside your house

14 Forces can be represented by arrows.

a **Compare** the forces shown in Figure 7.1.14 by stating which:

i force is the largest

ii two forces are the same size

iii two forces act in the same direction.

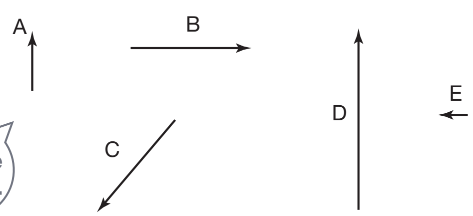


Figure 7.1.14

b If forces B and E acted on an object, **predict** which direction the object would move.

Creating

15 Bob uses an old yo-yo for a trick called 'around the world'. Unfortunately, the string breaks as the yo-yo reaches point X (Figure 7.1.15).

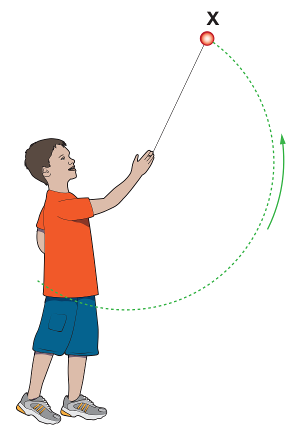


Figure 7.1.15

a **Construct** a diagram to show the path you think the yo-yo will take immediately afterwards.

b **Justify** your answer in terms of its inertia.

Inquiring

1 Sir Isaac Newton (1642–1727) used mathematics to develop theories to help us understand the world better. Research his life and work. Construct an illustrated timeline in which you outline major events and discoveries in his life.

2 Compare the:

- number of airbags installed
- features of the airbag system

for three different models of cars.

Recommend which of the three cars would provide greatest protection in an accident.

3 Design and construct a device that can measure the size of a force. Explain how your scale works and describe how this measurement can be converted into newtons.

4 Design and conduct an experiment to examine the effects of inertia on a moving object. For example, you could study what happens as you swing a bucket of water in a vertical loop. You could use a mobile phone or video camera to record and analyse changes in the object's motion.

7.1 Practical activities

1 Looking at forces

Forces act all around us, all of the time. Whenever the shape or motion of an object changes, we know that an unbalanced force has acted.

Purpose

To observe a range of forces in action.

Materials

- textbook
- table tennis ball
- balloon
- woollen fabric
- magnet
- paper clip
- plastic straw
- plasticine
- tennis ball
- plastic cup
- pencil case
- ruler
- bucket

Procedure

Complete each of the tasks in the table, recording your observations as you go.

Results

1 Copy the table into your workbook.

2 Record all your observations in the appropriate columns.

Discussion

1 A force was acting in each task. **Explain** how you knew.

2 **List** any objects that changed shape as a result of the force.

3 **State** whether any of these changes in shape were permanent.

4 **State** whether the tennis ball changed its shape at any stage of its journey.

5 **Discuss** whether a table tennis ball could remain stationary even when two people blow air on it from two straws.

Task	Changes observed in the motion or shape	What produced the force?
a Prop up one end of a textbook to make a ramp. Roll a tennis ball down it.		
b Rub woollen fabric against an inflated balloon, and bring the balloon towards someone's hair.		
c Point an end of a bar magnet towards a paper clip.		
d Drop a tennis ball and try to catch it when it bounces.		
e Blow a table tennis ball across a bench using a plastic straw.		
f Use a straw to blow bubbles in water in a cup. (Do not drink it.)		
g Push your pencil case across the bench using a ruler.		
h Squash a lump of plasticine.		
i Push an inflated balloon into a bucket of water and then let the balloon go.		

2 Crash test dummies

Purpose

To model crash-test dummies and describe their motion in different types of collisions.

Materials

- trolley
- about 50 g of plasticine
- toothpicks
- talcum powder
- block of wood
- ruler or measuring tape
- ramp
- some books or bricks to make ramp and a barrier
- video camera or mobile phone

Procedure

Part 1: Collision with a barrier

1. Construct a model crash-test dummy of a person from plasticine and toothpicks.
2. Set up a ramp to a height of about 50 cm. Place a brick 30 cm in front of the ramp as shown in Figure 7.1.16.
3. Place crash dummy A on a trolley. Lightly powder the dummy with talcum powder to prevent it sticking to the trolley.
4. Release the trolley from the top of the ramp, and watch the motion of dummy A carefully (or record its motion) as it hits the brick.
5. Repeat the test three times and record your observations.

Part 2: Collision between two vehicles

6. Join with another group. Remove the brick and place one trolley and dummy B in its place.
7. Release dummy A from the top of the ramp and record what happens to dummies A and B when the trolleys collide.
8. Repeat this test three times.

Discussion

1. Part 1: Collision with a barrier
   a. **Describe** changes in the motion of dummy A on impact.
   b. **Explain** these changes in terms of inertia.
   c. **List** any safety features that would protect dummy A in this impact.
2. Part 2: Collision between two vehicles
   a. **Describe** changes in the motion of dummy A on impact.
   b. **Explain** these changes in terms of inertia.
   c. **List** any safety features that would protect dummy B in this impact.

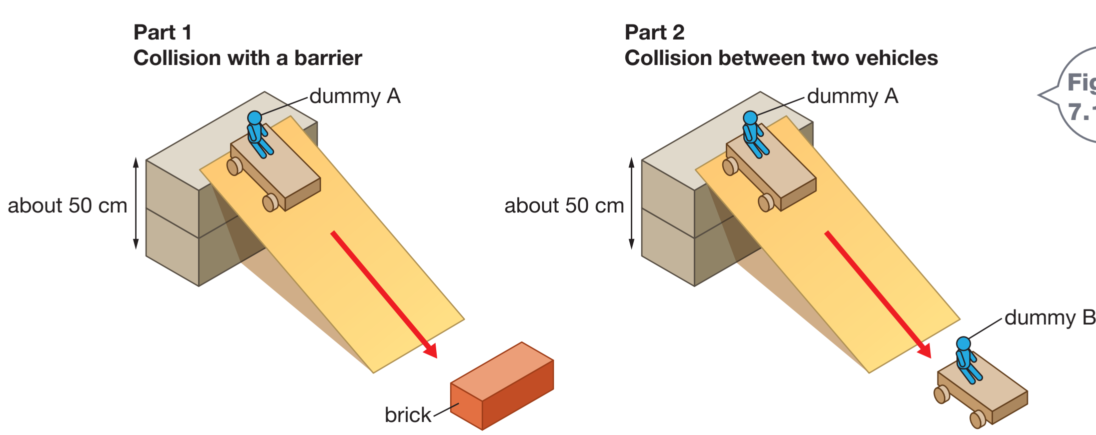


Figure 7.1.16

7.2 Friction—a contact force

According to Newton's first law, things that are moving will continue to do so unless a force makes them stop. The force that makes most moving objects stop is friction. Friction exists whenever two surfaces are in contact. Friction is the force that provides the grip needed by cars, bikes, trucks and your shoes to get moving, change direction and slow down. Friction can be a problem. It causes machines with moving parts to heat up, which wastes energy.

INQUIRY science 4 fun

Warming up

Yes

Collect this ...

- block of wood
- piece of sandpaper

Do this ...

1 Rub your hands together as quickly as you can for a minute. How do they feel?

2 Now rub a piece of sandpaper back and forth over a piece of wood for a couple of minutes. Feel the surface of the wood.

Record this ...

Describe what happened in each case.

Explain why you think these observations happened.

What is friction?

If you roll a soccer ball along a patch of open grass, then it will slow down and eventually stop. The force that slows it down is **friction**. Friction occurs whenever one object tries to move over another. Because it occurs between surfaces in contact, friction is called a **contact force**. Friction acts in an opposite direction to motion, as shown in Figure 7.2.1.

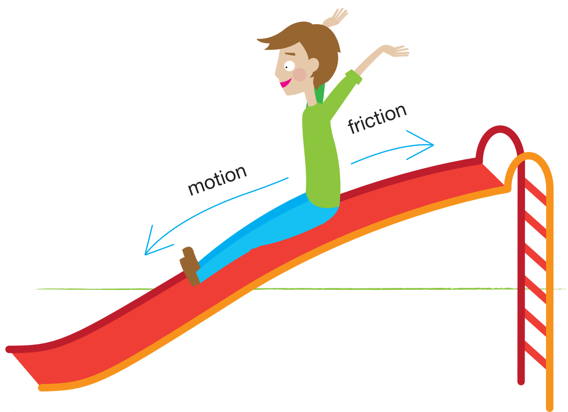


Figure 7.2.1 Friction always acts in the opposite direction to motion.

Two sheets of sandpaper will appear to 'stick' when you try to slide them over each other. This is because the grit on one sheet grabs and catches bumps on the other. This causes friction, and collisions between these bumps create heat.

All surfaces have bumps on them, even 'smooth' materials such as glass or steel. Figure 7.2.2 shows the microscopic bumps on the 'smooth' surfaces of a contact lens. An ice sheet is a very smooth surface (Figure 7.2.3). Try to walk on ice and you will slip because the friction is so low. You may have already worked this out and suffered a few bruises as a result!

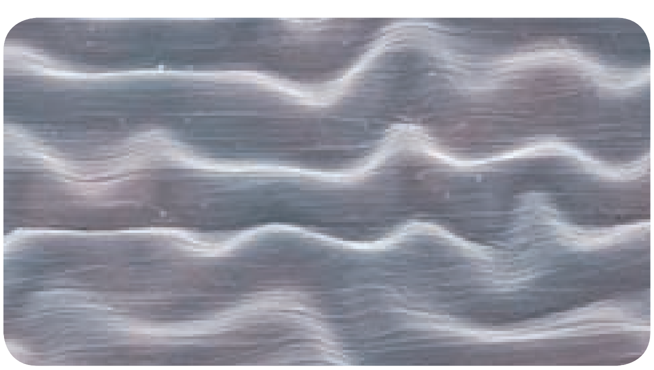


Figure 7.2.2 These ridges are microscopic bumps on the surface of a plastic contact lens, viewed with an electron microscope.

Figure 7.2.3 The puck used in ice hockey will travel long and fast along the ice unless it is blocked. This is because of the low friction between the ice and the puck.

What affects friction?

Friction depends on:

- how rough the surfaces in contact are
- how hard the surfaces are pushed together.

7.3

1 p261

The greater the weight of a sliding object, the greater the force of friction, as shown in Figure 7.2.4.

Figure 7.2.4 Greater friction exists between the heavier box and the floor than between the lighter box and the floor. This makes the heavier box harder to move.

Useful friction

When you walk, you push your foot backwards against the ground. The force of friction acts in the opposite direction to push you forward. For this to happen, there must be enough traction, or grip between your feet and the ground, or else you slip. This is shown in Figure 7.2.5. Without friction, you could not pick things up, walk, run, ride a bike or travel in a car.

Figure 7.2.5 Friction enables us to walk.

Figure 7.2.6 The ridges and grooves seen in your fingerprints increase the friction between your fingers and the objects you grasp.

Unwanted friction

You rely on friction in your daily life, but it also has some unwanted effects. Moving parts, such as those in a machine, are gradually made thinner, or worn away, by friction. Friction also produces heat. Much of the energy put into a machine, such as a car, aircraft, a mixer or an electric knife, is converted into heat. This makes the machine less efficient and wastes energy, because it is not being converted into the useful forms of energy required. A car radiator absorbs heat produced by the friction of moving parts in a car engine.

Friction between an object and the air around it slows its motion. This type friction is called **air resistance**, or drag. A wind tunnel, such as that shown in Figure 7.2.7, can test how well an object cuts through the air.

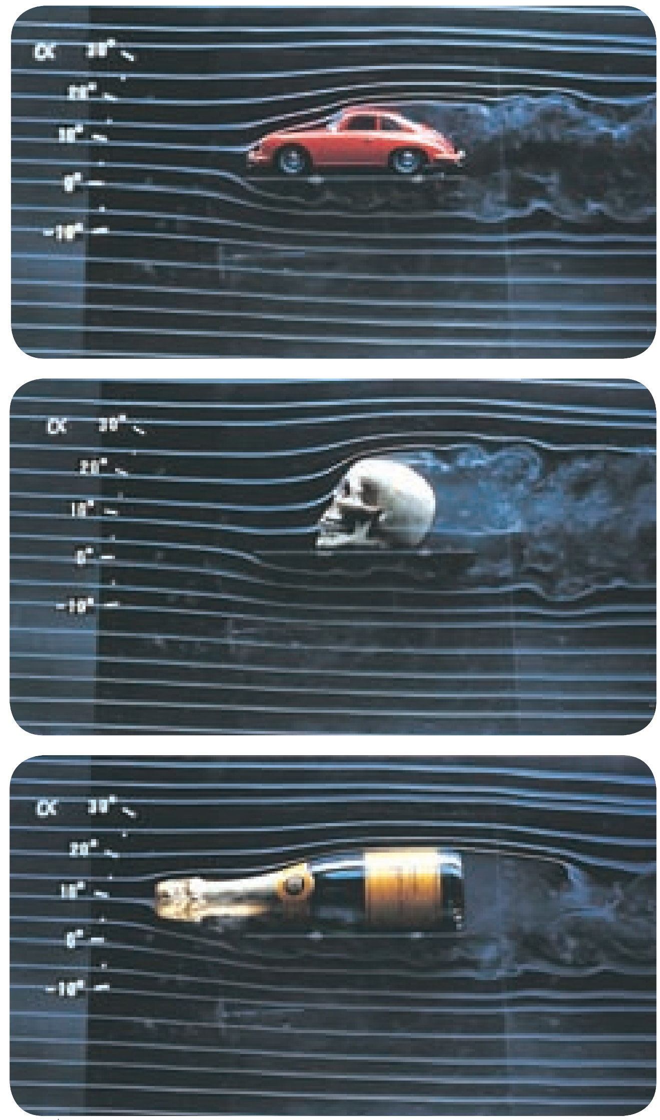


Figure 7.2.7 Studying the air flow over these objects reveals that drag occurs at the front of an object where air bunches up as it moves forward, and also behind it, where there is a space needing to be filled.

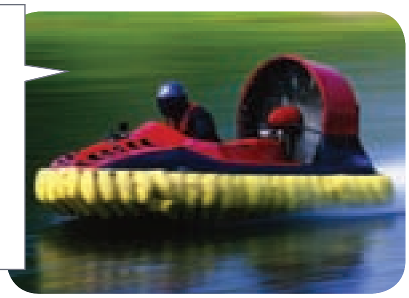
Reducing friction

Reducing friction makes machines more efficient, cheaper to run and longer lasting. Friction can be reduced by a number of different methods (see Figure 7.2.8).

2 p262

Removalists use trolleys to shift refrigerators because rolling surfaces produce less friction than sliding surfaces. Skateboards and rollerblades have ball bearings inserted into the hub of their wheels, allowing them roll more freely over the axle.

An effective way to reduce friction is to stop moving parts being in contact with each other. A hovercraft travels on a blanket of air with very little friction.



You may have slipped on spilt grease or oil at home. These substances are called **lubricants**. By adding grease to ball bearings, or putting oil into a car, we reduce the friction between moving parts. Polishing a surfboard helps to make its surface smoother and will reduce friction.

Vehicles such as cars and aircraft are all designed to have a streamlined shape. These shapes allow air to flow over and around them more freely, and reduce drag.

Figure 7.2.8 There are a number of ways friction can be reduced.

SciFile

Low-drag shark

These are shark scales. Each is made from dentine, is coated in dental enamel and measures about a half a millimetre. The base of each scale is made from bone and attaches the scale to the shark's skin. The shark's scales reduce churning of the water as the shark moves, and allow it to glide more smoothly as it seeks its prey.

SciFile

Swimsuit friction

Swimmers have always tried to reduce their friction with the water. Men shave their heads, legs and chests and swimmers often wear full-body swimsuits. In 2009, swimmers competing in the World Titles in Rome were allowed to wear hi-tech polyurethane swimsuits, resulting in 43 new world records. These suits are now banned in competition.

7.4

7.2 Unit review

Remembering

1 **State** three everyday activities you couldn't do without friction.

2 **Name** which surfaces are in contact when friction acts:
- a when you kick a football
- b when you swim at the beach
- c as you walk down the street
- d as two people push a broken-down car.

3 **State** whether the following are true or false.
- a Friction acts in the same direction as an object's motion.
- b The greater the weight of the sliding object, the less the force of friction it experiences.
- c Friction makes a machine more efficient.

Understanding

4 In your own words, **explain** why friction exists.

5 Without friction, you could not pick up an apple. **Explain** why.

6 **Explain** why a car needs a radiator to operate effectively.

7 **Explain** why it is easier to push a toy chest along the floor when it is empty than when it is full.

8 **Explain** why ball bearings are used within the hubs of skateboard wheels.

9 Your grandmother has asked you to shift her refrigerator to the other side of the kitchen. **Describe** three ways you could reduce friction to make the task easier.

10 A mountain bike is designed to be considerably heavier than a road bike. **Explain** why this is the case, considering the typical surfaces each is used on.

Analysing

11 Figure 7.2.9 shows an ice-skater performing a routine on ice.
- a **Compare** the level of friction that would be present on the ice and on a footpath.
- b **Discuss** how this difference allows the ice-skater to move differently on the ice.
- c The base of an ice skate is a narrow blade. **Explain** how this shape helps to lessen friction.

Figure 7.2.9

12 **Analyse** the following and rate them in order from those that would experience the most friction to those that would experience the least.
- A couch being dragged across carpet
- A waxed pair of skis travelling on snow
- An ice-hockey puck hit across the ice
- A child's tricycle being pulled along the footpath

Evaluating

13 A minibus is travelling along a flat road. **Use** Figure 7.2.10 to answer the questions below.

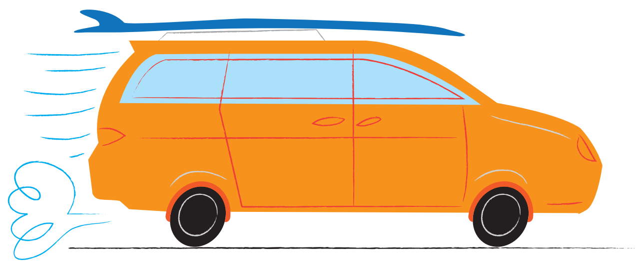


Figure 7.2.10

- a **Name** two sources of friction that are acting on the vehicle.
- b **State** the direction in which these forces act.
- c **Describe** what the driver should do to maintain the speed of the minibus.

- **d** The surfboard is now removed from the roof-rack.
  - **i** **Explain** whether the friction acting on the car would increase or decrease.
  - **ii** **Justify** your answer.
- **e** **Predict** what would happen if the tyres on the minibus were not properly inflated. Use friction to **justify** your answer.

14 The blades of an electric mixer are hot after beating some cream. **Justify** why this had happened in terms of friction.

15 Weighlifters rub chalk onto their hands before attempting a lift. The chalk absorbs any sweat on the weightlifter's palms.

- **a** **Propose** why weightlifters use this chalk.
- **b** **Predict** what could happen if they use too much chalk on their hands.

Creating

16 Imagine that you wake up one morning and the force of friction no longer exists. **Create** a role-play or a story or **construct** a flowchart in which you **describe** what happens when you attempt five everyday tasks, such as getting dressed, brushing your teeth, cooking and eating your breakfast, getting to school, and sitting in class.

Inquiring

1 Describe how disc and drum brakes use friction to slow and stop a car. Present your findings as a labelled poster.

2 Investigate the friction that exists within three objects in your home. For example, you could investigate a doorhandle, a suitcase on rollers or the mechanism of a sliding door or drawer.

- Describe how the mechanism works and state where friction is experienced.
- Propose how this friction can be reduced.

3 Using a cardboard box, an electric fan, streamers or wool and some sticky tape, construct a wind tunnel to test the aerodynamics of at least five objects. Describe which shapes you find to be the most aerodynamic.

4 Identify and describe the way the body coverings of three different animals assist them by reducing friction as the animals move.

5 Identify the structure of a polar bear's foot, shown in Figure 7.2.11. Explain how this increases friction between the bear's foot and the ice.

Figure 7.2.11 The underside of a polar bear's foot

7.2 Practical activities

1 Friction and mass

Purpose

To investigate how increasing mass affects the size of friction.

Materials

- wooden block with hook
- spring balance or force sensor
- 200 g masses

Procedure

1. Place the wooden block on a bench top.
2. Attach the spring balance to the block of wood as shown in Figure 7.2.12.

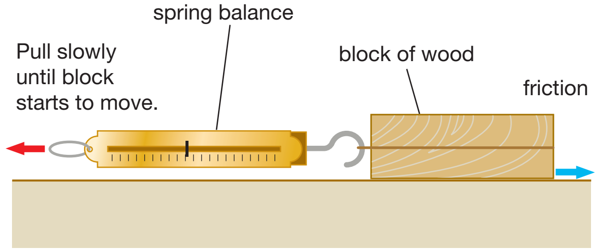


Figure 7.2.12

3. Measure the size of the force needed to keep the block moving at a constant speed. This is equal to the force of friction. Record this in your results table.
4. Repeat step 3 twice and record the results.
5. Add a 200 g mass on top of the block of wood. Measure the friction between the block and the bench top three times and add these results to the table.
6. Repeat the friction measurements for 400, 600, 800 and 1000 g (1 kg) masses on the block, recording three results for each test.

Results

1. Copy the table below into your workbook.
2. Calculate the average of your results in the table. (Add the three forces and divide by three.)
3. Construct a line graph showing your results. Place mass added to the block on the horizontal axis (0, 200, 400, 600, 800, 1000 g) and the friction force on the vertical axis (in newtons).

Discussion

1. **Describe** what happened to the size of the force of friction as the mass on the wooden block increased.
2. **Discuss** a situation in which you have noticed this link between friction and mass.
3. **Propose** any improvements that could be made to the design of this experiment.

Object moving	Friction force measured (N)			Average friction (N)
	Trial 1	Trial 2	Trial 3	
Wooden block				
Wooden block + 200 g				
Wooden block + 400 g				
Wooden block + 600 g				
Wooden block + 800 g				
Wooden block + 1000 g				

2 Reducing friction

Purpose

To reduce the force of friction between a block of wood and a wooden ramp.

Materials

- wooden block
- wooden ramp
- various materials to place on the ramp, such as:
  - linoleum square
  - carpet square
  - sandpaper
  - waxed paper
  - other materials as approved by your teacher
- protractor
- 3 pieces of dowel

Procedure

1. In your results table, enter the details of each surface you are testing in the second column. With permission, you may also test the block on 2 tablespoons of cooking oil.
2. Predict in which experiment there will be the most friction between the block and the ramp, and in which there will be the least.
3. Place the wooden block on a marked position near the end of a plank of wood.
4. Slowly lift the end of the plank that the block is on, holding the other end of the plank on the bench top as shown in Figure 7.2.13.

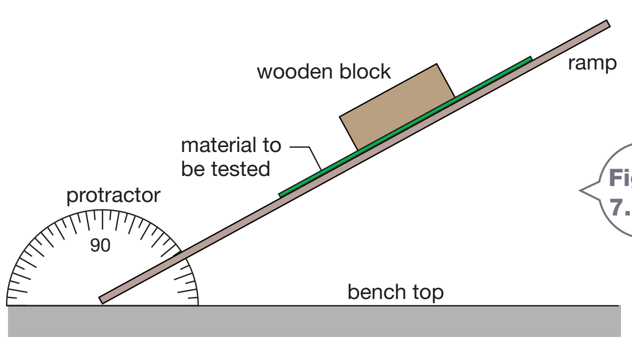


Figure 7.2.13

5. Use the protractor to measure the angle at which the block first starts to slide down the plank.
6. Repeat the test using the wooden dowels as rollers, and then test each surface you have available.

Results

1. Copy the following table into your workbook.

Experiment number	Set-up of equipment	Angle at which block starts to slide down ramp
1	Wooden block on ramp	
2	Wooden block placed on dowel rollers on ramp	

2. **Construct** a bar or column graph that compares the angle at which the block started to slide for each surface.

Discussion

1. The larger the angle at which the block started to move, the larger the friction between the block and the ramp. **Assess** whether you were correct in predicting which block experienced the most friction.
2. **Assess** whether you were correct in predicting which had least friction.
3. **Construct** a diagram on which you label the direction of friction acting on the block.
4. **Identify** two examples where lubricants, rollers or waxing are used to reduce the force of friction.