13 Space science

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Main ideas

Chapter 13 crossword

Review

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Essential Learnings for Chapter 13

Essential Learnings	References		
	Student book (page number)	Workbook (page number)	Teacher Edition CD (Assessment task)
Knowledge and understanding *Energy and change* An unbalanced force acting on a body results in a change in motion	pp. 308–314	pp. 100–101 p. 107	
Objects remain stationary or in constant motion under the influence of balanced forces	pp. 315–318	pp. 103–104 p. 107	
Science as a human endeavour People from different cultures contribute to and shape the development of science	Wan-hu p. 307		
Ways of working Reflect on learning, apply new understandings and justify future applications	Activity p. 326	Problem solving p. 107	Assessment task 13 A student in space
Communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats	Maths equations pp. 308–314	p. 106	Assessment task 13 A student in space

QSA Science Essential Learnings by the end of Year 9

Vocabulary

artificial gravity
astronauts
balloon
cosmonauts
demineralisation
geostationary
gravitational
microgravity
oxidiser
satellite
thrust
weightless

Focus for learning

Discuss the motion of objects in space (page 306).

Equipment and chemicals (per group)

Activity page 310	heavy ball (eg medicine ball), skateboard or skates
Experiment page 311*	**Part A:** nylon fishing line (about 20 m), sausage-shaped balloon, masking tape, drinking straw
	Part B: empty plastic bottle (eg washing-up liquid), one-holed rubber stopper to hold tyre valve and fit in bottle, tyre valve with extension tube, retort stand, ring clamp, bicycle pump, commercial water rocket (optional)
Investigate 31 pages 315–316	65 m length of nylon fishing line, plastic tubing (about 15 cm long), one-holed rubber stopper, brass hanger and some brass masses

* Students to list the equipment they will need, which may be different from what is listed here.

13 Space science

Getting Started

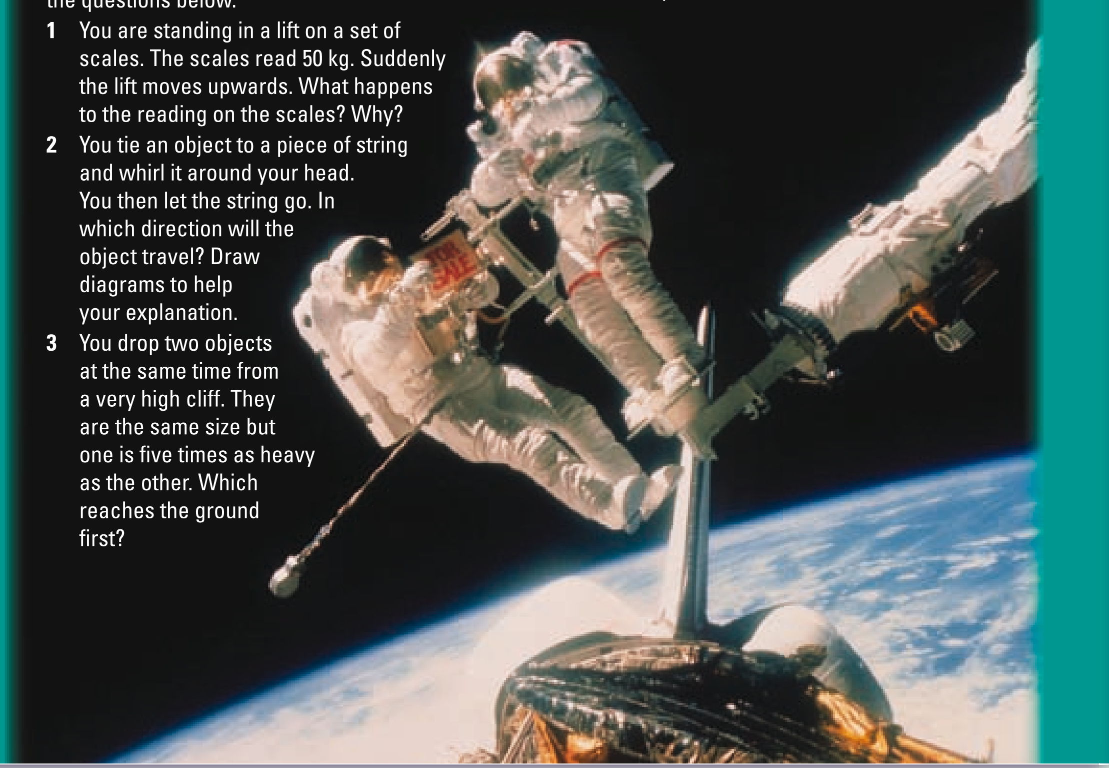
Form a group of three or four people and discuss the questions below.

1 You are standing in a lift on a set of scales. The scales read 50 kg. Suddenly the lift moves upwards. What happens to the reading on the scales? Why?

2 You tie an object to a piece of string and whirl it around your head. You then let the string go. In which direction will the object travel? Draw diagrams to help your explanation.

3 You drop two objects at the same time from a very high cliff. They are the same size but one is five times as heavy as the other. Which reaches the ground first?

4 You are on a space walk alongside the Shuttle's cargo bay 400 km above the Earth. You let go of the handrail. Will you fall back to Earth? Explain.



Starting point

1 Consider having students write their responses to the Getting Started questions on four separate sheets of paper. Collect each group's response and evaluate them. During the chapter—after the material relating to each question is covered in class—give students the opportunity to attempt the same Getting Started question. Then hand back their original answer to the question so that they can do a self-evaluation of how their learning has improved. For example, question 1 can be attempted again after page 309.

2 Our knowledge and understanding of the solar system is continually changing because of new discoveries. Encourage students to set up an astronomy blog, on which they can discuss interesting findings, ask each other questions and comment on the science that they have learned in class. Hyperlinks to their favourite astronomy sites, or examples of the electronic work they have produced throughout the chapter can be added to make the site interesting. Organise a team of students to create the blog page. Your school's ICT department should be able to help out if students are unsure of how to do this.

3 This is a good chapter to get the students to design a concept map. Allow students to work on this map progressively until the end of the chapter. When they have finished their maps, collect and assess them. This learning tool could be used to find out what students already know by having them complete it as a pre-test. However, return it to them after marking so that they can continue to make additions. Have students generate the class word list. Suggest they flick through the chapter for possible words, and recall any information from previous topics that links to this chapter (eg Chapter 3 Light and Sound, Chapter 4 Communications Technology, Chapter 5 Road Science, etc).

4 There are many commercial DVDs on astronomy which can be used throughout the chapter. Make sure to preview any before showing them to the class to determine if they are appropriate, and prepare worksheets for the students to fill in.

5 Consider organising an excursion to a planetarium or an aerospace centre. These centres will often organise a program to suit the year level and subject matter. Starlab is a portable planetarium, and it is well worth organising for it to come out to the school. There are many programs to choose from.

13.1 Getting into space

How high can you jump vertically when you stand on the ground with your feet together? Fifty centimetres? The reason why you cannot jump any higher is because the force of gravity attracts you to the Earth. To get into space you have to overcome this force. To do this, rocket engines have to supply a force greater than the downwards force of gravity. When the engines in a rocket ignite, the force generated by the engines accelerates the rocket upwards.

Science in action

The first rocketeers

The Chinese are credited with the invention of rockets, which were used in warfare and in religious ceremonies. The rockets were made of bamboo tubes filled with gunpowder. In warfare they were attached to arrows, and in ceremonies they were attached to bamboo sticks to help them steer a straight course.

The legend of Wan-hu

Legend has it that Wan-hu, a lowly government official in the Ming Dynasty (early 16th century), was intrigued with rocketry, and he thought rockets could be used for transportation. Wan-hu was also a keen astronomer and dreamed that rockets could take him to the stars.

He built a special chair with 47 rockets and two kites attached to it. At the appointed time, Wan-hu sat in the chair and gave the order for his assistants to light the fuses. Moments later there was a massive explosion. When the smoke and dust cleared, Wan-hu and the rocket chair were gone. The world's first want-to-be astronaut was gone.

Busting the myth of Wan-hu

The *Mythbusters* team decided to try to recreate the Wan-hu rocket chair using the same sort of materials available to Wan-hu. They used a crash test dummy instead of a human.

The chair exploded on the launch pad and the dummy suffered severe burns. The team then tried modern rockets, but the chair only rose a few metres before going out of control and crashing. The team concluded that rockets cannot supply enough force to lift a rocket chair very far away from the Earth's surface.

<WEBwatch>

Go to www.scienceworld.net.au and follow the links to the websites below.

Brief history of rockets

An interesting, easy-to-read account of the history of rocketry from early times to the present.

Chinese fire-arrows

The story of Wan-hu, and links to the history of rocketry and other sites.

The History of Rocket Science

Detailed information on the history of the science of rockets and rocket design.

Hints and tips

- Because this chapter has a lot of text, make sure you are monitoring students who experience language difficulties. Where appropriate, suggest their note taking is in point form, with clear page references, or suggest they do concept drawings to display information. Spend extra time with these students and monitor their progress through the topic to ensure they have grasped the main concepts. It may be appropriate to encourage ESL students to write definitions in their native language. Students who prefer an auditory learning style could make their own podcast or audio file of the text and revise the material this way.
- There are many interactive applications on the internet which can be used throughout this chapter. Try compiling a list of web addresses which could be handed out to the students for exploring in their own time. These addresses could be hyperlinked in the astronomy blog.

Learning experience

For the more confidently literate students, this passage could be rewritten into a play and then performed. More information can be found by following the Webwatch links. Ensure that students correctly cite any references they use.

Learning experience

Most days in the media there is some sort of report describing an astronomical event: satellites docking, comets close to the Earth, and so on. Ask the students to collect articles related to space science and bring them into class to discuss. They could compile a journal of articles as an ongoing homework exercise throughout the chapter. They should write the date of each article, a summary outlining the main points and an explanation of how it relates to space science. This task promotes science awareness, literacy and critical thinking.

Hints and tips

- Revise Newton's first and second laws of motion and how they relate to this chapter. Can students remember what they are? How do they think each can be applied in the context of space science? Before teaching the theory have a class discussion.
- Students often misinterpret the acceleration due to gravity with the force of gravity. Explain the difference.

Force, mass and acceleration

When the engines in a rocket ignite, the force generated by the engines accelerates the rocket upwards. How quickly a rocket lifts off depends on the mass of the rocket and the force generated by its engines.

In Chapter 5 you learnt that the acceleration of an object is directly proportional to the force acting on it and inversely proportional to its mass. That is:

$$\text{acceleration} = \frac{\text{force}}{\text{mass}}$$

$$a = \frac{F}{m}$$

$$\text{or} \quad F = ma$$

For example, the upwards force produced by a rocket of mass 10 000 kg being accelerated at 10 m/s^2 is:

$$\begin{aligned} F &= ma \\ &= 10\,000 \text{ kg} \times 10 \text{ m/s}^2 \\ &= 100\,000 \text{ N} \end{aligned}$$

Fig 4 The force generated by a rocket's engines accelerates the rocket upwards.

Weight is a force

If you hang an object on a spring balance the spring stretches. This shows that there is a downwards force. If a larger mass is hung on the balance the spring stretches further, showing that the force is greater. F = ma can be rewritten as:

$$W = mg$$

where **W** is the weight force and **g** is the accelaration due to gravity

Acceleration due to gravity

When you hang a 1 kg block on a Newton spring balance, the dial reads 9.8 N. This means the weight of the 1 kg block is 9.8 N. If the block is unhooked from the spring balance, it will fall to the ground. The acceleration of the block is:

$$\begin{aligned} g &= \frac{W}{m} \\ &= \frac{9.8 \text{ N}}{1 \text{ kg}} \\ &= 9.8 \text{ m/s}^2 \end{aligned}$$

So the acceleration due to gravity at the Earth's surface is 9.8 m/s^2.

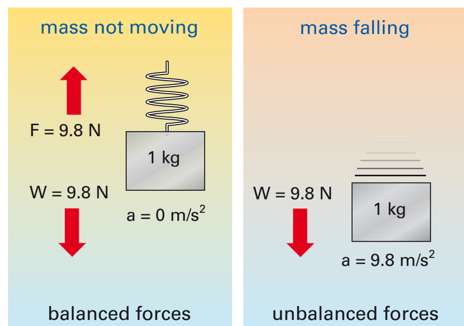


Fig 5 When the mass is hooked on the spring, the forces are balanced and there is no motion. When it is unhooked it falls with an acceleration of 9.8 m/s^2.

Homework

Ask students to define mass and weight, and explain how they are different in the context of space science.

Learning experience

Organise students into teams of about five students each, and have them work through this chapter as a 'space science mission'.

Each team needs to come up with a name for their 'space science mission'. They are to present their work as a logbook of investigations, including theory, and a record of how each team member contributed to the mission. At the end of each lesson, teams need their logbook signed by you to authenticate work.

Throughout their journey, teams can be challenged by giving presentations to the whole class about particular theoretical concepts and how they are applied to space science. As the teacher, you can direct which area of study each team presents. Students will need to do the Activities and Investigates in this chapter so that the theory they present is supported with 'evidence'. At the end of the chapter, each team will have to complete a final assessment task, highlighting the main points about space science.

Sets of challenge questions or problem-solving tasks can be given to teams, and 'fuel' points awarded for accuracy and presentation as they progress through the chapter. (The Check! and Challenge questions in the text could be used.) Once teams have gained enough 'fuel' points, they could be awarded a completion certificate for their 'mission'.

What happens if a 2 kg block falls to the ground? When the block is attached to the spring balance it reads 19.6 N. If the block is unhooked from the balance, the acceleration of the 2 kg block is:

$$g = \frac{16.9\ \text{N}}{2\ \text{kg}}$$
$$= 9.8\ \text{m/s}^2$$

The heavier block still falls with the same acceleration as the lighter one. In general, the acceleration due to gravity is the same for all objects on the Earth's surface. Why then does a tennis ball fall faster than a piece of paper? Falling objects are slowed down by friction due to the air around the Earth, and the amount an object is slowed down depends on its shape. So in real life, different objects do not all fall with the same acceleration.

The acceleration due to gravity is not the same everywhere. It decreases as you move away from the Earth. So when the force of gravity decreases, the acceleration also decreases. This means that if you travel away from the Earth your weight will decrease. The table below shows how gravity and weight decrease with increasing distance from Earth for a 50 kg person.

Location of 50 kg person	Acceleration (m/s^2)	Weight (N)
On the Earth's surface	9.8	490
100 km above Earth	9.6	480
500 km above Earth	8.3	415
1000 km above Earth	6.8	340

The force of gravity also depends on the mass of the planet or moon. You can investigate the differences in the acceleration due to gravity on different planets in the activity below.

Activity

Suppose you are on the surface of Planet X and you are curious to find out how the weights of various masses on the surface of this planet are different from those on Earth.

The table below shows the results for Planet X.

Mass (kg)	Weight (N)
2	39.2
4	78.4
6	117.6
8	156.8

- Use the formula W = mg to find the acceleration due to gravity on Planet X.
- Suppose you took the four masses in the table back to Earth. Find the weights of the masses on the Earth's surface.
- The acceleration due to gravity on Jupiter is 25.5 m/s^2. Calculate the weights of the 2, 4, 6 and 8 kg masses in the table.
- Write a generalisation about the relationship between weight and gravity.
- If the force of gravity is directly proportional to the mass of the planet, work out which planet (X, Jupiter or Earth) has the smallest mass and which has the greatest.
- How much would you weigh on Planet X? How much would you weigh on Jupiter?

Hints and tips

Remind students that the SI unit for force is the newton, mass is kilogram, distance is metres and time is seconds. It might be worthwhile to quickly show how the unit for acceleration is derived. Remember that m/s/s is the same as m/s^2 and ms^{-2}.

Research

Galileo and Newton both contributed to our ideas about gravity and space science. Have students find out more about their contributions. How have their contributions helped with our understanding? When did they announce their findings? What other interesting information can students discover?

Students can research in groups or individually. Refer to the Activity notes on page 133 for a suggestion on how to set up the research groups. Have students present their information as a profile of either Galileo or Newton. They could write or perform an interview with one of them for a science program, write an article for a science textbook or newspaper, or write a practical experiment report explaining the scientist's methods, results and conclusions. Make sure to tell students to include a bibliography. Remind them how to write an internet bibliography: author name/s (if appropriate), title of site or web page (in italics/underlined), URL of site, date last updated.

Activity notes

This activity should reinforce for students that mass and weight are different.

Learning experience

Ask the students to find out some specific facts about gravity and prepare a fact sheet to share with the class. You could pin the sheets around the room for the students to read or post them on the school's intranet. Hyperlinks could be set up on the astronomy blog.

Alternatively, students could develop a set of questions and answers about gravity. For example, what is g-force, what does 8g mean, and can fighter pilots experience this?

Learning experience

Students could do a simple ticker timer or datalogging investigation to calculate the acceleration due to gravity.

- Clamp a ticker timer to a bench or retort stand so that it is vertical and at least 1 metre off the ground.
- Place a length of tape through the timer with a 50 g mass secured to it. Place some cushioning—a lab coat works well—at the bottom of the fall to 'catch' the mass so that it doesn't cause damage to the floor.
- All students should perform the investigation so that they all have a length of ticker tape to analyse. Refer to Investigate 12, pages 105–106, for further details on how to use ticker timers and analyse tapes.
- Students should calculate the average speed for each 0.1 s section, plot a speed versus time graph, and find the gradient of the line of best fit. This is the acceleration due to gravity. You might need to help them convert their units to m/s^2.

Hints and tips

Design an action–reaction worksheet, on which students draw or list examples of action–reaction pairs of forces.

Rocket science

The cartoon below illustrates Newton's third law of motion.

When the man fires the gun, the bullets go in one direction and the gun moves in the opposite direction. Newton's third law of motion states:

For every force there is an equal and opposite force.

The two forces in this law are often called the *action* force and the *reaction* force. You can investigate these forces in the activity below.

The action–reaction principle is used in rockets. Rockets shoot out hot exhaust gases from their engines. The force of the exhaust gases shooting out (the action) pushes the rocket forwards (the reaction). This is why rockets are sometimes called *reaction engines*. And the faster the hot exhaust shoots out, the faster the rocket moves in the opposite direction.

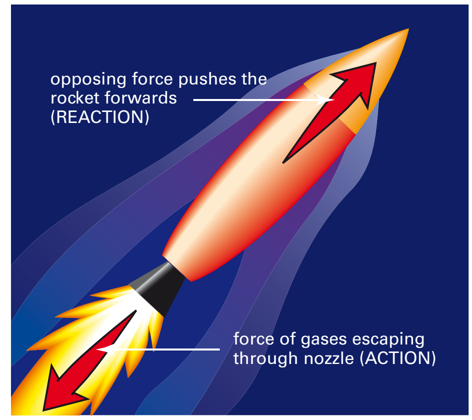


Fig 8 A rocket works on the principle of action and reaction.

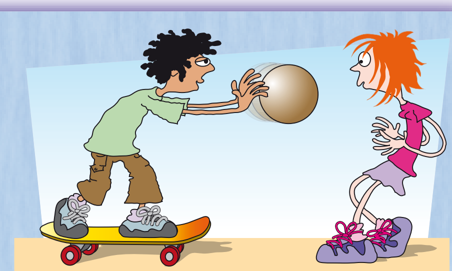
All aircraft use the action–reaction principle. The blades on propeller-driven aircraft spin rapidly and push the air backwards (action), thus pushing the aircraft forwards (reaction). The engines on jet aircraft take in air at the front. This is mixed with jet fuel, ignited, and then the hot exhaust gases are forced out of the back of the engine. This pushes the aircraft forwards.

Activity

For this activity you need a heavy ball (medicine ball) and a skateboard or skates.

1 Stand on the skateboard facing the front and hold the medicine ball at chest level.

2 Throw the ball horizontally to another person without bending your legs or pushing the skateboard.
   - Describe what happens.
   - In what way is this similar to the gun cartoon above?
   - Which is the action force and which is the reaction force?



3 Find out what happens when you throw the ball harder.
   - Interpret your results.

Activity notes

- If a skateboard is not available, a pair of roller blades works just as well.
- Another very simple way to demonstrate action–reaction pairs is to blow up a balloon and let it go. Students feel the air being expelled backwards and see the balloon move forwards.

Learning experience

A fun way to make a simple rocket is by using empty film canisters, baking soda and vinegar. Place some baking soda (or an Alka-Seltzer tablet) in the hollow inside the lid of the canister. Pour vinegar into the canister up to one-third full, quickly invert and seal the container, and place it (with the lid facing down) on the ground. Stand a reasonable distance away from the 'rocket', and wear safety glasses. As the carbon dioxide gas is released from the reaction between the vinegar and baking soda or Alka-Seltzer, so too does the pressure inside the canister, causing it to shoot upward. How does this relate to Newton's third law?

Learning experience

What is terminal velocity? Do all falling objects reach this? Devise some Think/Pair/Share questions for the class (or mission teams) to investigate.

Learning experience

Students could create a mural using space science images collected from magazines and newspapers. Keen photographers could take their own photos. The mural could be displayed in the classroom or a hallway.

Experiment
MODEL ROCKETS

Planning and Safety Check

- Carefully read through Part A and Part B. Work in a small group to design the tests for both types of rockets.
- Make a list of the equipment you will need for each part of the experiment.
- Design and draw up data tables for your results.
- Discuss the safety precautions necessary in this experiment. Draw up a risk assessment sheet listing all the safety hazards and the precautions you will need to take.

PART A
Balloon rockets

The task

Your task is to design an efficient balloon rocket which will be propelled along a length of nylon fishing line. The efficiency of the rocket will be tested in two ways:

- how far the rocket goes along the nylon fishing line
- how fast the rocket goes in the first 5 metres.

You are to use simple materials in your test—balloons, drinking straws, adhesive tape and nylon fishing line.

Discussion

1 Compile class results of the two tests.

2 Which design features are important in making a balloon rocket?

3 What caused the motion of the rocket?

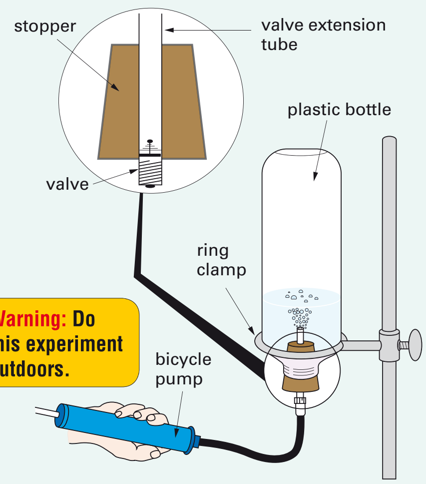
4 How well would your rocket go in space? Explain.

5 How would you design your rocket to test whether altering the size of the jet (where the air comes out of the balloon) has an effect on the speed of the rocket? Try it!

PART B
Water rockets

In this part of the experiment, your task is to find out which variables affect the motion of a water rocket.

Use the diagram below to build a water rocket. Your teacher will help you fit a car valve extension tube through a rubber stopper. (You can also purchase commercial water rockets.)



Warning: Do this experiment outdoors.

Experiment with the water rocket to find out how the following variables affect its motion.

- the amount of water in the bottle
- the size and shape of the container

Discussion

1 Write a report of your findings.

2 Explain in detail what caused the motion of the water rocket. In which ways is this similar to the motion of the balloon rocket? In which ways is it different?

3 Is water necessary for the operation of the water rocket? Test your prediction.

Lab notes

Part A

- The fishing line can be mounted horizontally or vertically.
- Long thin balloons (sausage-shaped) work best.
- Make sure students carefully position and secure the inflated balloon to the drinking straw before they let it go.

Part B

- This is a great activity but it needs to be done on an oval or playing field away from buildings.
- Students need to be wearing waterproof coats to avoid getting wet, so tell them to bring their coats to class. Coats can be shared around if all students do not have them.
- Make sure students wear safety glasses.
- A foot pump or electric pump is better to use than a bicycle pump.
- If you want to vary the design, make plastic fins and attach them to the bottle with duct tape.

Rocket motion

In Part A of the experiment the balloon rocket moved forwards (the reaction force) because air was forced out of the balloon in the opposite direction (the action force). The water rocket in Part B shot upwards (the reaction force) because the compressed air in the bottle forced water out of the mouth in the other direction (the action force).

In a space rocket, the fuel burns in a combustion chamber. The burning fuel produces hot gases which are forced out of the nozzle at great speed. The force of the escaping gases produces an equal and opposite reaction which pushes the rocket upwards. This force is called the **thrust**. Applying Newton's second law of motion (F = ma), the thrust of a rocket is equal to the mass of the escaping gases multiplied by the acceleration of the gases.

The net force accelerating the rocket from its launch pad is the thrust minus the weight of the rocket.

net force = thrust of engines − weight

For example, a 2 000 000 kg rocket has engines that develop a thrust of 69 600 000 N. What is the acceleration of the rocket at lift-off?

Weight of rocket	=	2 000 000 kg × 9.8 m/s^2
	=	19 600 000 N
Thrust of engines	=	69 600 000 N
Net force	=	thrust − weight of rocket
	=	69 600 000 – 19 600 000 N
	=	50 000 000 N
acceleration	=	$\frac{\text{net force}}{\text{mass of rocket}}$
	=	$\frac{50\,000\,000\ \text{N}}{2\,000\,000\ \text{kg}}$
	=	25 m/s^2

Space engineers design engines that develop as much thrust as possible, while at the same time they try to reduce the weight of the rocket.

Rocket engines

All rocket engines work on the same principle: they burn fuel to produce fast-moving exhaust gases which push the rocket forwards.

As well as the fuel, space rockets have to carry a source of oxygen because there is no air in space in which to burn the fuel. There are two types of rocket engine—the *solid-fuel engine* and the *liquid-fuel engine*.

The solid-fuel engine uses a solid fuel mixed with an *oxidiser* much like a fireworks skyrocket. A spark ignites the mixture and the explosive reaction produces gases which are forced out of the engine's nozzle. The solid-fuel engine is very simple in construction and very powerful for its weight, and is used mainly in booster rockets to lift heavy payloads into space. However, like the skyrocket, it suffers one major disadvantage—once ignited it cannot be extinguished until the fuel has been used up.

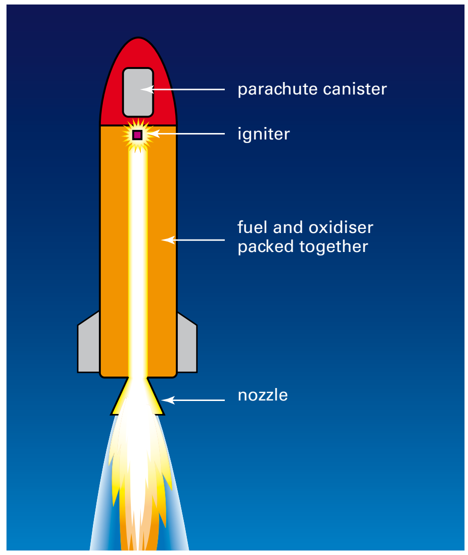


Fig 11 A solid-fuel rocket engine has solid fuel and oxidiser packed together. When ignited, the fuel burns, sending high speed gases out through the nozzle. The parachute enables the rocket to be recovered for reuse.

Hints and tips

- Consider making a half-page worksheet so students can practise calculating net forces, masses or accelerations of rockets using Newton's second law: F = ma. They should be able to rearrange the formula algebraically. Include an example where the net force equals zero. What do they think this means?
- The cargo of a rocket launched into space is called its payload. In most cases, a rocket's payload is a satellite.

Research

A timeline showing the history of rockets is an interesting research activity for the class. Either in their teams, or as a class, students research the history of rockets and construct a timeline of events. They could start with Wan-hu (see page 307).

Homework

Are there any creatures that use 'rocket motion' to propel themselves forward? Give students a hint and suggest they think of some sea creatures, then make a list.

Learning experience

Students can investigate how lift-off for a rocket is achieved. Initially, the rocket sits on the launch pad and generates a lot of flames. It then begins to hover, and finally lifts off. In groups, have students describe these three stages in terms of forces (thrust and weight). This activity could be approached using the Round Table method.

The liquid-fuel engine needs complicated pipework and pumps to force the liquid hydrogen fuel and the oxidiser (liquid oxygen) into the combustion chamber. Here they are ignited and burn explosively. The advantage of this type of engine is that it can be throttled back, or turned on and off, to control the rocket's speed.

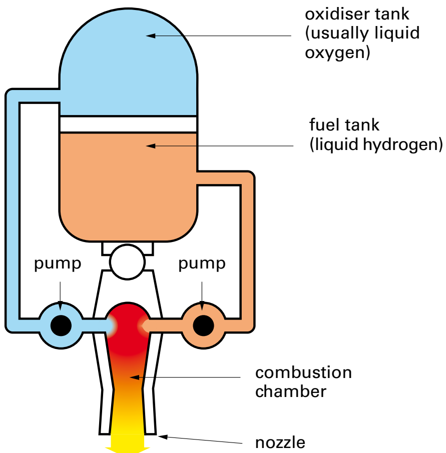


Fig 12 A liquid-fuel rocket engine. This engine is more complicated and expensive to build than the solid-fuel engine, but its thrust can be controlled.

Rocket designs

Since gravity is greatest at the Earth's surface, the most powerful engines in a rocket have to be used at lift-off. Space rockets usually use two to four solid-fuel booster engines alongside the main liquid-fuel engine. However, two minutes after lift-off the solid-fuel boosters have used up all their fuel. To reduce the mass of the rocket, engineers design parts of the rocket to fall away when they are no longer needed. Most rockets have this design and are called multistage rockets.

About 10 minutes after lift-off the main rocket engines also run out of fuel. This first stage, which is the largest part, then detaches and burns up in the atmosphere as it falls to Earth. Engines in the second stage then ignite and carry the rocket further into space.

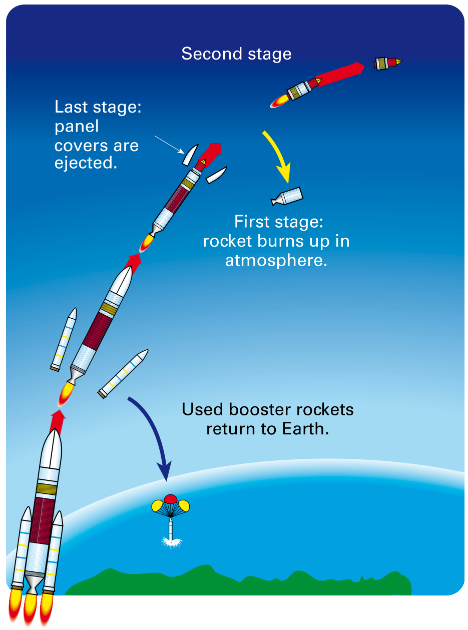


Fig 13 Sections of a multistage rocket detach and fall away after use. This helps to keep the mass of the rocket as small as possible while gaining maximum acceleration.

Check!

1. a You simultaneously drop a 2 kg rock and a 10 kg rock from a high cliff. Why should they hit the ground at the same time?
   b You then drop a piece of paper and a small pebble from the cliff at the same time. Will they hit the ground at the same time? Explain.
2. How does Newton's third law of motion explain how a rocket moves?
3. A bag of sand is attached to a spring balance. The dial reads 147 N. What is the mass of the bag of sand?

Hints and tips

Commercial model rocket kits can be purchased from most school suppliers. Consider organising a rocket launch day where each class has to make their own rocket, launch it and mathematically determine the greatest height it reached. This activity needs to be done on the school oval and well away from buildings. Proper safety precautions need to be adhered to, and a risk assessment is critical.

Check! solutions

1. a They should hit the ground at the same time because even though one rock has five times the mass of the other, it is acted upon by a gravitational force which is five times greater. This means that they will have the same acceleration and take the same time to fall.
   b No, they will not hit the ground at the same time because the piece of paper has a much greater surface area exposed to the air. This will cause more friction and slow down the paper as it falls.
2. Newton's third law states that the action and reaction are equal and opposite. In a rocket, the hot gases being pushed out of the exhausts are the action, and the rocket moving forward is the reaction.
3. You know that the formula is $W = mg$ and that g, which is the acceleration due to gravity, is $9.8\ m/s^2$
   Substituting $147\ N = m \times 9.8\ m/s^2$
   Rearranging $m = \dfrac{147\ N}{9.8\ m/s^2}$
   $= 15\ kg$

Learning experience

Posters and models of rockets could be made and displayed around the room. Rocket models look great, especially if they are placed near a ceiling fan so that they swish around when the fan is on. Can students find any rocket specifications and make a scale model, or a scale diagram of a rocket for their poster? Cardboard tubing, aluminium foil and coloured paper are useful items.

Learning experience

Have there been any rocket launches or missions where something went wrong? Find out more about *Apollo 13*. Ask students to write a newspaper report or make an audio report of what happened from the perspective of one of the NASA ground crew in charge of the mission. Alternatively, a role play could be performed showing what the astronauts of *Apollo 13* did to survive and how they might have felt. You might like to show the class the film *Apollo 13* after they have presented their work.

Learning experience

Flow charts are a useful way to simplify information. Have students construct a chart showing the stages of a rocket's journey to the moon, including its landing. Students with a visual learning preference could draw annotated diagrams.

Erratum

In earlier printings of the textbook, there is an error in the graph for Challenge 5. The weights on the vertical axis should be 0–50 N, not 0–5 N.

4 Look at question 1 in Getting Started.
 a What is the mass of the person?
 b How much does this person weigh?
 c Suggest why weighing scales are graduated in kilograms rather than newtons.
 d Why does the reading on the scales increase when the lift moves upwards?

5 Unlike jet aircraft, space rockets carry a source of oxygen as well as fuel. Explain why.

6 You tell a group of 8-year-old students that you lose weight when you go into space.
 a Suggest how the students might interpret this statement.
 b Write down your explanation of the statement.

7 Look at the photo of a helicopter.
 a Explain in terms of action–reaction how the helicopter can rise vertically from the ground.
 b How does the helicopter move forwards?

8 a Explain the difference between a solid-fuel rocket engine and a liquid-fuel engine.
 b The last stage of a multistage rocket contains a small liquid-fuel engine. Why is the engine small, and why does it use liquid fuel and not a solid fuel?

9 In this chapter and the last chapter you have learnt Newton's three laws of motion. In your own words write down these three laws. Check pages 117, 122 and 310.

challenge

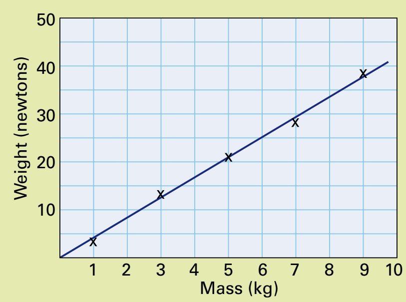
1 A man has a mass of 85 kg. Use the table on page 309 to calculate:
 a his weight on Earth
 b his weight 1000 km above the Earth

2 The rockets that carried the Apollo missions into space had a thrust-to-weight ratio of 12:1.
 a What does this statement mean?
 b Suggest what would happen to the acceleration of the rocket if the thrust-to-weight ratio was larger.

3 A lunar lander of mass 3000 kg lands on the Moon's surface. When they are ready for lift-off, the astronauts fire the lander's rockets which develop a thrust of 15 300 N. If $g = 1.6\ m/s^2$ on the Moon, calculate the acceleration with which the lander leaves the Moon's surface.

4 The Space Shuttle and the booster rockets pictured on page 307 have a combined mass of 2 200 000 kg. The acceleration on lift-off is maintained at 2.5 g for 50 seconds (g = acceleration due to gravity on Earth).
 a Calculate the net upwards force on the Shuttle at lift-off.
 b Find the thrust developed by the engines.

5 The graph below shows a plot of weight versus mass for a number of objects. Use the graph to work out whether the readings were taken on the Moon ($g = 1.6\ m/s^2$), on Mercury ($g = 4.1\ m/s^2$) or on Saturn ($g = 10.8\ m/s^2$). Explain how you arrived at your answer.



6 Leon stands in a lift and hangs a 5 kg bag of potatoes on a spring balance. The dial reads 42.5 N. Describe the motion of the lift. As a challenge calculate the acceleration of the lift.

Check! solutions

4 a The mass of the person is 50 kg.
 b This person weighs:
 $50\ kg \times 9.8\ m/s^2 = 490\ N$
 c Most scales are graduated in kilograms because this is the way it has always been done, and most people do not understand force and newtons.
 d If the lift moves upwards the scales will show an increased weight because the action of the acceleration of the lift provides a downwards reaction. This force is in addition to the force of gravity.

5 Space rockets need to carry a supply of oxygen for combustion of the fuel as well, because there is very little oxygen in the upper atmosphere and none in outer space.

6 a The 8-year-old students might think that you lose some fat tissue and get smaller.
 b When you go into space the force of gravity is less because you are further from the Earth. This means that your weight is less. In other words, you will not fall towards the surface of the Earth.

7 Looking at the photo:
 a The helicopter can rise vertically because the rotating blades exert a force (an action) downwards on the air, which produces an equal and opposite force upwards (a reaction). This force upwards lifts the helicopter vertically.
 b The helicopter can move forwards when the rotating blades are tilted forwards. When this happens the rotating blades cause an action backwards which produces a reaction forwards.

8 a A solid-fuel rocket engine has both the fuel and oxidiser mixed together. This is ignited by a spark and burns rapidly until all of the fuel is used up. A liquid-fuel engine has the fuel (usually liquid hydrogen) and oxygen in different tanks and their flow can be regulated. This means that this type of engine can be throttled back or turned off when not required.
 b The engine is small because only small forces are needed to make slight adjustments in the final stages. It is a liquid-fuel engine because it needs to be carefully adjusted and turned off, as explained in **a**.

9 Newton's three laws may be stated as:
 1 A body will remain at rest or keep moving with the same speed and direction unless acted upon by an external force.
 2 The force required to accelerate an object is directly proportional to the mass of the object and the acceleration produced (F = ma).
 3 For every force there is an equal and opposite force. This is called action and reaction.

Challenge solutions

1 For a man who has a mass of 85 kg:
 a His weight on Earth will be:
 $W = mg = 85\ kg \times 9.8\ m/s^2 = 833\ N$
 b His weight 1000 km above the Earth (see the table on page 309) will be:
 $W = mg = 85\ kg \times 6.8\ m/s^2 = 578\ N$

2 a The thrust is the amount of force that can be developed by the rocket engines. The weight is the result of the force of gravity on the rocket. If the weight is 10 000 N and the thrust is 120 000 N, then you can say that the thrust-to-weight ratio is 12:1.

13.2 Orbiting the Earth

If you look at the Moon on successive nights, you will see that its position in the sky changes. This is because of the Earth's rotation, and also because the moon revolves around the Earth in its orbit. An **orbit** is a path taken by an object as it moves around another object.

Satellites

Objects that orbit planets are called **satellites**. The moon is Earth's natural satellite. The first artificial satellite to orbit the Earth, called *Sputnik 1*, was launched in October 1957 by the then Soviet Union. Since then more than 4000 artificial satellites have been launched into orbit. Hundreds of communications satellites relay radio and television information between the continents on Earth 24 hours a day.

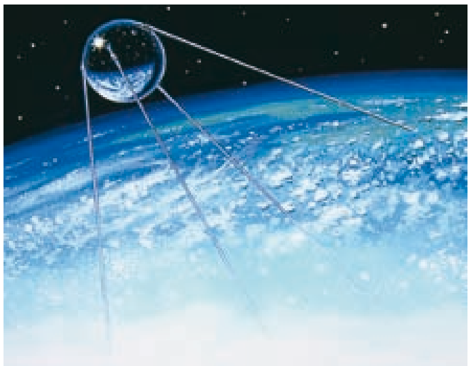


Fig 16 *Sputnik 1* was the Earth's first artificial satellite. It was relatively small with a mass of 84 kg and a diameter of 53 cm. Its four aerials beamed back information about the temperature and density of the upper atmosphere.

Investigate 31 ORBITS

Aim

To use a model to show the forces acting on a body in orbit.

Materials

- 1.5 m length of nylon fishing line
- plastic tubing (about 15 cm long),
- rubber stopper with a hole in it
- brass hanger and some brass masses

Planning and Safety Check

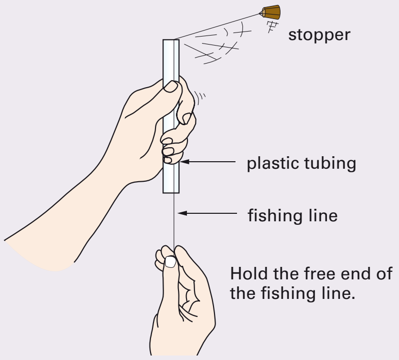
- Carefully read through the investigation. Then tell your partner what you have to do, what you have to record and what safety precautions you have to take.
- It is best to do this investigation outdoors.

Method

1 Tie the rubber stopper to the end of the fishing line. Thread the other end of the fishing line through the plastic tube.

2 Hold the end of the fishing line below the tube and whirl the stopper around in a circle as shown in the diagram below. Now let the fishing line go.

In which direction did the stopper travel? Draw a sketch to show this.



Hints and tips

- Do Investigate 31 before explaining the theory, as most students are more likely to remember by 'doing'.
- What is the definition of a satellite? Explain the difference between natural and artificial satellites. What are artificial satellites used for? Are there different types of satellites? Who owns them? Who launches them? Who uses them? Use questions like this to generate a class discussion about satellites.

Lab notes

- The outside casing of a ballpoint pen can be used as the plastic tubing.
- Nylon fishing line can tangle quite easily so thick nylon thread can be used instead.

Learning experience

How many artificial satellites are there orbiting the Earth: 10, 100, 1000 or more? See if students can find out approximately how many there are and what kinds of satellites they are. Have there been any reports of satellite collisions? Do satellites ever return to Earth or do they stay in space forever? Ask students to attempt these questions individually before working in teams. Can they come up with any of their own questions about satellites?

b If the ratio was larger, for example 15:1, the force upwards would be greater and this would cause a greater acceleration.

3 The weight or gravitational force downwards = mg = 3000 kg × 1.6 m/s^2 = 4800 N. The net force upwards is the thrust of the engines minus the weight of the vehicle = 15 300 – 4800 = 10 500 N. Using the formula a = F/m:
a = 10 500 N/3000 kg = 3.5 m/s^2

4 The weight of the Space Shuttle is: 2 200 000 kg × 9.8 m/s^2 = 21 560 000 N. The initial acceleration is 2.5 × 9.8 = 24.5 m/s^2

a The net upward force at lift-off = ma
= 2 200 000 kg × 24.5 m/s^2
= 53 900 000 N

b The thrust developed by the engines = upward force + weight
= 53 900 000 N + 21 560 000 N
= 75 460 000 N

5 Consider a mass of 5 kg. According to the graph it is acted upon by a force of approximately 21 N.

Using a = F/m you can calculate that the acceleration is approximately 4.2 m/s^2. This indicates that the readings were taken on Mercury (g = 4.1 m/s^2).

You could also calculate the slope of the graph: = 41 N/10 kg = 4.1 m/s^2

6 When the lift is stationary you would expect the spring balance to show a force of 5 kg × 9.8 m/s^2 = 49 N

The observation that the balance shows only 42.5 N indicates that the lift is moving *downwards*.

The net downwards force is 6.5 N. So the downwards acceleration is 6.5 N/5 kg = 1.3 m/s^2

Lab notes

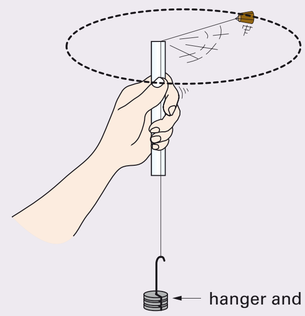
Beware of flying stoppers, and make sure students wear safety glasses.

Hints and tips

Give the class a quick quiz based on the material they have already learned. This will indicate any concepts that need to be revised. Ask the students to write the answers only (no need for the questions).

3 Thread the fishing line through the tubing again. Then tie the brass hanger to the free end.

4 Add some masses to the hanger and whirl the stopper so that it orbits at a constant distance and the masses do not move up or down. This may take a little practice.



Record the radius of the orbit.

5 Now speed up the orbiting stopper.

Record what happens to the masses.

6 Add masses to the hanger so that the stopper orbits at the same radius orbit as in Step 4.

7 What will happen if you decrease the speed of the orbiting stopper? Test your prediction.

Discussion

1 Why did the stopper fly off when you let the string go in Step 2?

2 What happens to the rotating stopper when its speed increases? How could you keep it rotating at the same radius of orbit?

3 What keeps a spacecraft in a circular path when it is in orbit?

In the investigation you just did, you should have concluded that the revolving stopper is being pulled towards the centre of the circle by the force along the fishing line. This force keeps changing the *direction* of the stopper's motion. And if this force disappears the stopper flies off in a straight line. The stopper is not pulled in towards the tubing, because it has sufficient orbital speed (inertia) to keep it in 'orbit'.

In the same way, the gravitational force pulls an orbiting satellite towards the centre of the Earth. The satellite does not fall to Earth, because it has sufficient speed to stay in orbit.

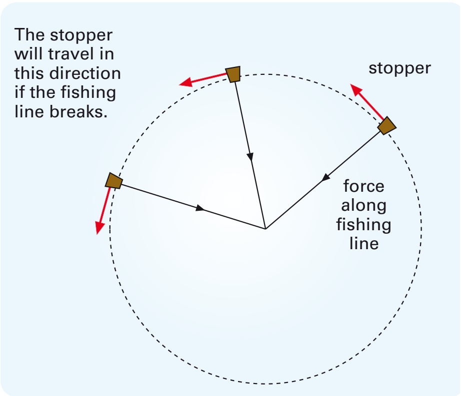


Fig 19 The inwards pulling force along the fishing line constantly changes the direction of the stopper's motion.

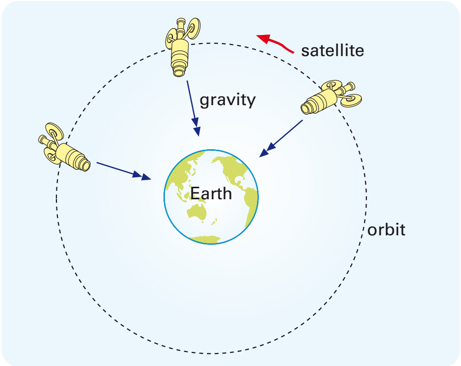


Fig 20 The satellite is being pulled towards Earth by the force of gravity, but its motion (inertia) keeps it in orbit.

Homework

Set students the task of finding out more about the first satellite that was successfully launched into orbit. What was it called? When was it launched? Who launched it? What was its purpose? How long did it orbit the Earth? What happened to it?

Learning experience

Take students outside to a grassy area, with plenty of free space. In pairs, have students hold hands at arm's length, but keep their feet close to the other person's feet. They should spin around fairly rapidly (but not too fast), then let go of their hands. Students will continue their motion in a straight line (tangent) rather than in a circle. If they spin close to each other, when they let go they are likely to fall inwards. Warn them not to spin too fast or they are likely to fall over and may hurt themselves.

Types of orbits

You found out earlier that the Earth's gravity is strongest at the surface and decreases with altitude. (In outer space gravity is zero.) This means that satellites in a low Earth orbit will experience a stronger gravitational pull than satellites in higher orbits. To overcome this problem, satellites in low Earth orbits have to have a greater orbital speed, otherwise they fall back to Earth. In general, the higher the altitude of the satellite the slower its orbital speed.

Low Earth Orbits

Low Earth Orbits (called LEOs) are usually at altitudes of about 400 km. At this height, 99.9% of the Earth's atmosphere is below you, so satellites avoid the problem of friction with the Earth's atmosphere. LEO satellites move at high speeds of about 8000 m/s, and include the Earth-monitoring and 'spy' satellites. Because of their low altitude, LEO satellites can take very clear pictures of objects as small as 3 m across on the Earth's surface. They usually have a much shorter life than other satellites because even the tiny amounts of gases in the upper atmosphere gradually slow them down. As the satellite's speed decreases it loses altitude and eventually falls to Earth where it burns up in the more dense atmosphere.

LEO satellites can be linked to form information networks in space. For example, twenty-four LEO satellites have been placed above the Earth to form the Global Positioning System (GPS). Sailors, airline pilots or even motorists driving along central Australian outback roads can find their position on the Earth's surface using a small portable receiver.

Even though LEO satellites have a much shorter life than high altitude ones, placing satellites in the lower orbit is much cheaper. This is because large, powerful and very expensive rockets are needed to launch the high altitude satellites. Sometimes the high altitude satellites are 'parked' in low orbit, before they are boosted into higher more useful altitudes.

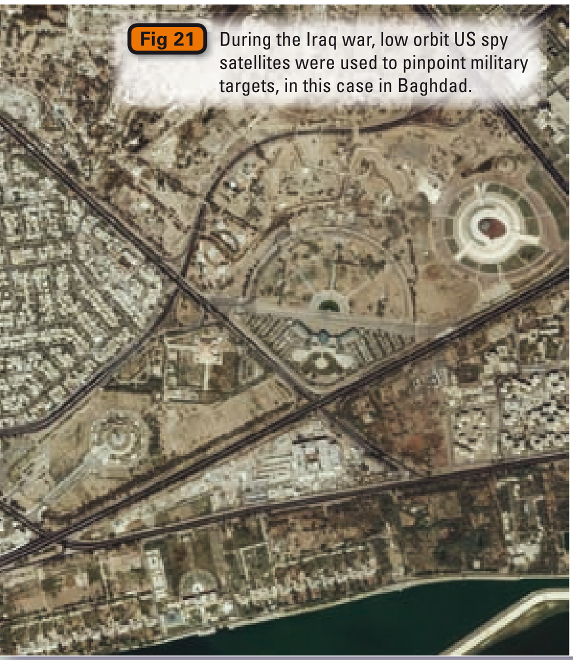


Fig 21 During the Iraq war, low orbit US spy satellites were used to pinpoint military targets, in this case in Baghdad.

Fig 22 This scientist in Antarctica is using a hand-held GPS receiver to accurately plot his position.

Polar orbiting satellites

Polar orbits are special low Earth orbits which carry satellites in a circle over the North Pole and South Pole. These high-speed satellites complete about 14 revolutions of the planet every 24 hours. As the satellite revolves from pole to pole, the Earth rotates beneath it. In this way, the satellite 'sees' every part of the Earth's surface at relatively close range.

Hints and tips

If you have access to a handheld GPS device, show students how you can locate and track a satellite. Discuss how GPS uses satellites. Can students think of any other communication devices that use satellites?

Learning experience

What are some current Australian satellites (*ARIES-1, FedSat 1, Optus*)? Find out their names, purpose, launch date, expected life and other interesting information. An electronic presentation would be an appropriate format so that graphics can be included. Software such as PowerPoint or Photo Story could be used. Gifted and talented students might like to research the names, purpose, launch dates and so on for important current satellites of the world. Is there a country that appears to dominate the skies?

Learning experience

Ask students to design a galactic board game. It could be designed so that it uses packs of cards with questions relating to rockets, satellites, space travel and 'wild cards' (general science knowledge). More sophisticated games could use a graded system and have a 'Superstar' level. Give the students enough time, but a limited amount, to create their games. Small groups work best. When they have finished, give them class time to swap and trial them.

Hints and tips

Revise this section by asking the students to write a paragraph about what they have learned so far and share it with the person next to them. Then choose a few students to read aloud their paragraphs to the class.

Geostationary orbits

A satellite placed in orbit 36 000 km above the Earth's equator takes exactly one day to complete an orbit. During this time, the Earth also turns once on its axis. This means that the satellite remains over the same point on the Earth's surface. Orbits at this altitude are called **geostationary orbits** or sometimes, geosynchronous orbits. Satellites in this orbit travel at about 3200 m/s, less than half the speed of the LEO satellites.

Geostationary satellites are used to beam everything from commercial radio and television broadcasts to navigational and weather information. However, there are so many satellites in this orbit that its use is now governed by international regulations.

Aussat and Intelsat satellites relay TV channels to subscribers all over Australia. To receive these broadcasts, subscribers have a satellite dish pointing towards a geostationary satellite above the equator.

Fig 24 An image from the GMS Japan geostationary satellite positioned in orbit to the north of Australia

Fig 23 A satellite dish on this school is used to receive TV channels from geostationary satellites.

The weather information that is continuously beamed down to Australian weather forecasters comes from one of five geostationary satellites that form a network around the equator. The GMS Japan satellite is positioned over the equator to the north of Papua New Guinea. This satellite sends information and pictures to forecasters who then send them on to radio and TV stations as well as newspapers.

WEBwatch

1 Weather satellites

You might like to look at some images from weather satellites. Go to www.scienceworld.net.au and follow the links to the websites below.

JCU MetSat

The lastest GMS Japan satellite image of Australian can be found on this website.

Australian Region Satellite Images

This Bureau of Meteorology site provides satellite images and state-by-state weather forecasts in Australia.

2 Google Earth

Would you like to see a satellite's view of your neighbourhood, or even a close-up of your house? Go to www.scienceworld.net.au and follow the links to **Google Earth**.

You can use this link to download the Google Earth application onto your computer. Then you can scan almost everywhere in the world and zoom in to see details of cities, mountains, lakes and oceans.

Issues

Space junk: what is it? Before they begin their research, have students list some questions about what they think space junk is. Once they have established the definition of space junk, they should list questions and issues surrounding it. It is important to allow thinking time so students, especially the more creative learners, can develop ideas. You might have students working in pairs or teams for this exercise, although gifted and talented students may like to complete the task individually. Students could present their information in a variety of formats, eg a poster, booklet, multimedia presentation, podcast or vodcast.

Learning experience

Do the Webwatch if you have access to computers in class. Have students investigate each site and write an evaluation of it. What was something they learned from it? What did they like about the site? Would they visit the site again or recommend it to others? Their evaluations could be added to the astronomy blog.

The Space Shuttle

The Space Shuttle is a reusable rocket about the size of a small airliner. Its cargo bay is large enough to carry a school bus. The original purpose of the Space Shuttle was to carry large instruments into space at a far cheaper cost than by conventional rocket. For example, the Space Shuttle can carry thirteen times the payload of a conventional Delta multistage rocket at only one and a half times the cost.

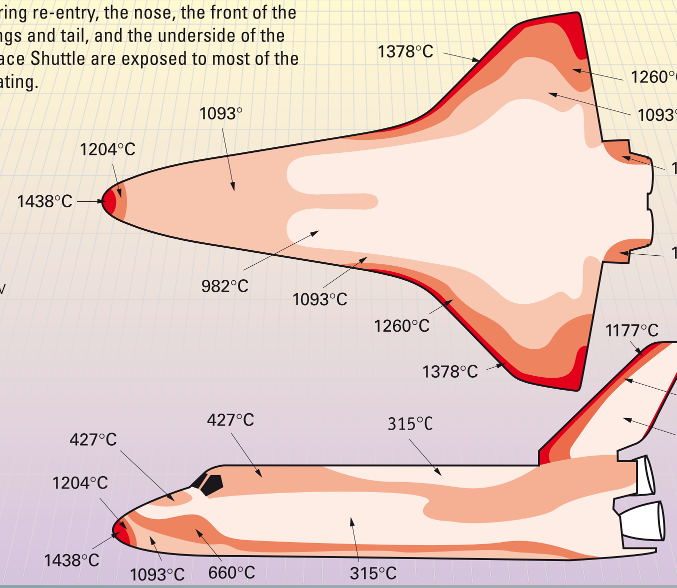
The main role of a Shuttle mission is to place satellites into orbit, retrieve and repair damaged satellites, and transport crew and parts to and from the International Space Station (ISS). For example, in August 2006, *Atlantis* delivered a second set of solar panels that will double the power output on the ISS.

After the mission, which lasts for up to 10 days, the Shuttle is ready for re-entry. Some of its 44 small rockets fire to slow the orbiter down from an orbital speed of 28 000 km/h. At an altitude of 120 km friction begins to generate a large amount of heat. The temperature on some of the Shuttle's surfaces can reach close to 1500°C, as shown in the diagram below.

The lightweight aluminium shell of the Shuttle is covered with thousands of heat-insulating tiles. The orbiter enters the atmosphere belly first, with the nose, the front of the wings and tail and the underside exposed to most of the heating. The tiles are designed to perform 100 missions before they are replaced.

There are four main types of tiles, each of them being able to withstand different temperatures. For example, composite carbon tiles can withstand temperatures of 1650°C before breaking down. These tiles are thick and reasonably heavy, and are costly to make. The tiles are designed to re-radiate heat so quickly that a tile heated in a kiln and glowing white-hot at 1250°C can be held in your hand 10 seconds after being removed from the kiln.

Fig 25 During re-entry, the nose, the front of the wings and tail, and the underside of the Space Shuttle are exposed to most of the heating.



Hints and tips

What is an STS mission (Space Transportation System, or Space Shuttle)? Is it only the USA that has launched shuttles into space? Present to the class some facts or interesting points about shuttles. The NASA website at <www.nasa.gov> is a useful place to start. Students could look at the 'Starchild' or 'Imagine the Universe!' sections of the site and work their way through some of the space science activities. Go to the *ScienceWorld 3* Webwatch for Chapter 13 and follow the links to 'Imagine the Universe!' and 'Starchild'.

Homework

Are rockets and space shuttles different? Ask students to explain. Encourage them to continue adding this information to the astronomy blog. (You might also like to use the blog to remind students of homework or upcoming class events.)

Learning experience

Colourful posters and flow diagrams are always a good way to summarise and simplify information. Get the class to make posters to display around the room, explaining the parts and operation of a Space Shuttle. They can use the information on this page or other resources.

Learning experience

Students might have made model rockets earlier in the chapter (see page 313). A similar activity could be done here, but have students construct scale models of shuttles. More adventurous students could construct large models that can be displayed in cabinets around the school or science room.

Activity notes

This is a good problem-solving activity and could be attempted in small teams.

Activity

In this activity, you need to imagine you are a space engineer. Your task is to determine where each of the four types of heat-insulating tiles will have to be placed on the Space Shuttle.

1. Trace the bottom-view and side-view outlines of the Shuttle on the previous page.
2. Use the information in the data table and the heat contour diagrams to indicate the position of each type of tile on your orbiter outlines.
3. When determining the distribution of tiles, remember that the tiles with the best heat insulation properties also are the heaviest and are the most expensive.

Type of material used in tile	Breakdown temp (°C)
heat resistance felt	370
light-weight silica	650
heavy-weight silica	1350
composite carbon	1650

Make a list of all the factors you have to take into account when deciding where to place the tiles.

Suggest why a metal skin (for example titanium alloy which was used in the *Apollo* spacecraft) is not used on the Shuttle.

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Office of Space Operations
Gives comprehensive information on the Space Shuttle, International Space Station, Questions and Answers, meet the space crews of the Shuttle missions and details of space missions.

The future of flight?
Gives details of the Crew Exploration Vehicle design by Lockheed Martin which is to replace the Space Shuttle.

Crew Exploration Vehicle
Has information on the proposed Crew Exploration Vehicle, and has links to other sites.

How the Orion CEV will work
Has interesting information on the proposed Crew Exploration Vehicle and launch rockets.

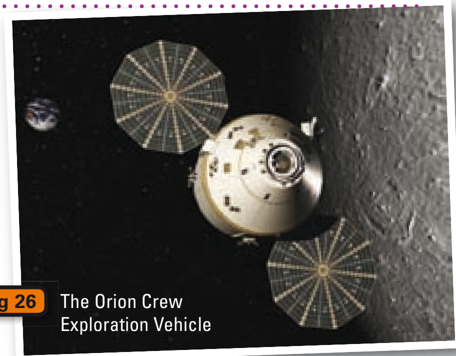
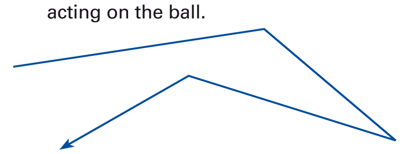


Fig 26 The Orion Crew Exploration Vehicle

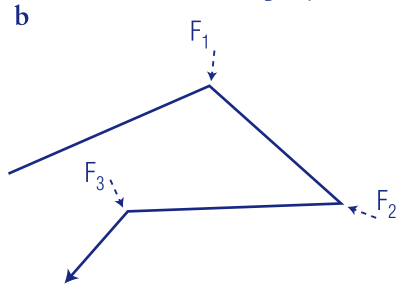
Check!

1. Explain in your own words what the words *revolve* and *orbit* mean.
2. a A force can change the speed of an object. What is the other thing a force can do?
   b Leon sketched the path taken by a ball rolling over a smooth horizontal surface. The ball started from rest and was struck three times during its movement. Copy the path in your notebook and show, using arrows, the direction of the forces acting on the ball.



Check! solutions

1. Revolve means to move around another object. For example, the planets revolve around the Sun. An orbit is the path taken by such a revolving body.
2. a A force can also change the direction of a moving object.
   b



Learning experience

Do the Webwatch if you have access to computers in class. Students could investigate these websites after doing the activity.

Erratum

In earlier printings of *ScienceWorld 3* there was an error in Check! 2b. It read 'and was struck four times…' instead of 'and was struck three times'.

Challenge solutions (page 321)

1. a The satellite(s) which would provide data for:
   - Sydney is GMS Japan.
   - Perth is GMS Japan.
   - New York is GOES-E USA.
   - Singapore are GOMS Russia and GMS Japan.
   - Hawaii is GOES-W USA.

   b The advantage of a geostationary satellite is that it can 'see' and take good-quality photographs of the same part of the Earth's surface continuously.

   c These satellites are unsuitable for use in areas near the poles (eg Norway and Alaska) because they must be in orbit near the equator. Information about these countries can be obtained from polar-orbiting satellites.

   d The equipment on the satellites is able to detect infra-red radiation, which is still present at night.

2. a The circumference = 2π r = 4π = 12.57 m

   The total distance travelled in 10 revolutions is 125.7 m.

   $v = d/t = 125.7 \text{ m}/8 \text{ s} = 15.7 \text{ m/s}$

   b The distance travelled by the ball is $10 \times 6\pi = 188.5$ m

   If the speed is 15.7 m/s

   $$t = \frac{188.5 \text{ m}}{15.7 \text{ m/s}} = 12 \text{ s}$$

3 Mariela whirls a tennis ball attached to a string around her head in a horizontal circle.
   a Explain in terms of force why the tennis ball moves in a circle.
   b What would happen to the ball if the string broke?

4 What is a geostationary satellite? How is it different from other types of satellites?

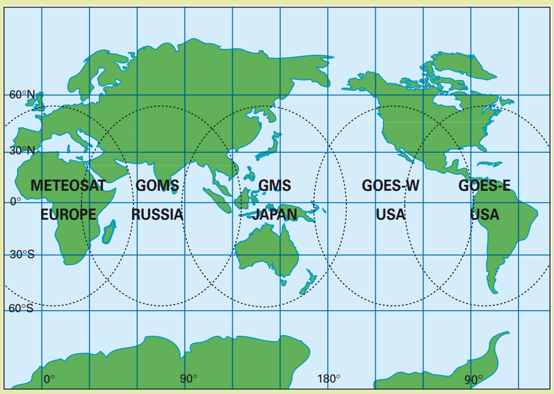
5 a A low Earth orbit (LEO) is usually about 400 km above the Earth's surface but very rarely below this altitude. Why?
   b Why do satellites in LEOs have to have high orbital speeds?
   c What is the main advantage of placing a satellite in LEO?

6 How is a polar orbiting satellite different from a geostationary satellite? What are the advantages of placing satellites in polar orbits?

7 What was the purpose of building the Space Shuttle?

8 a What causes the temperature on the Shuttle's surface to rise on re-entry?
   b Which parts of the Space Shuttle are reusable, and which have to be replaced before the next launch?

challenge



1 The map shows the five overlapping areas serviced by the geostationary weather satellites.
   a Which satellite's data would be used to determine the weather patterns for each of the following—Sydney, Perth, New York, Singapore and Hawaii?
   b What is the advantage of a geostationary satellite?
   c Why are these satellites unsuitable for obtaining weather data about Norway or Alaska? Suggest a way of obtaining data about these regions.
   d Geostationary satellites send weather data to Earth 24 hours a day. Suggest how they obtain weather data at night.

2 The tennis ball that Mariela is whirling around her head in Check 3 above does 10 revolutions in 8 seconds.
   a If the string is 2 metres long, how fast is the ball travelling in its circular path?
   b Calculate how long the ball will take to do 10 revolutions if it travels at the same speed but the string is 3 metres long.

3 It is cheaper to launch a satellite-carrying rocket in an easterly direction than in the opposite direction. Suggest why.

4 A satellite is moving with an orbital speed of 8000 m/s in a low Earth orbit at an altitude of 450 km. Assuming the Earth is circular with a radius of 6380 km:
   a calculate the time it takes for the satellite to orbit the Earth
   b find out how many times the satellite orbits the Earth in 24 hours.

5 *Columbia* was the first in NASA's fleet of Space Shuttles. It was launched on 9 April 1981 and landed again two days later. However, on 1 February 2003, it disintegrated on re-entry and all seven astronauts perished. Use your internet browser to research this Space Shuttle, and write a short story about its achievements.

Check! solutions

3 a The tennis ball moves in a circle because the force of the string on the ball continually changes the direction of the ball as it revolves.
   b If the string breaks, the ball will continue to move along a tangent to its path.

4 A geostationary satellite is one that remains above a particular point of the Earth's surface. It orbits approximately 36 000 km above the Earth and revolves at the same rate as that which the Earth rotates. Other satellites are in lower orbits and travel much more quickly.

5 a Satellites rarely orbit below this altitude because if they did, their motion would create friction with the atmosphere and this would slow them down and cause them to fall back to Earth.
   b These satellites must have high orbital speeds to balance the force of gravity, which is much greater at lower altitudes.
   c The main advantage is that these satellites are able to take good-quality photographs of objects on the Earth's surface or cloud formations in the lower atmosphere.

6 Polar-orbiting satellites travel in an orbit over both poles. They also travel very quickly, making about 14 revolutions every 24 hours. This enables them to see and photograph every part of the Earth's surface at very close range.

7 The purpose of the Space Shuttle is to take astronauts and equipment to and from space for a variety of reasons.

8 a The temperature rises because of friction with the air during re-entry to the Earth's atmosphere.
   b The Space Shuttle orbiter is reusable, whereas the booster rockets fall back to Earth during the launch and must be replaced.

3 It is easier to launch a rocket to the east because it is assisted by the rotation of the Earth, whereas this is not the case if it is launched to the west.

4 In this case:
   a The radius of the orbit = 6380 + 450
   = 6830 km
   The length of the orbit = $2\pi \times 6830$
   = 42 914 km
   The speed is 8000 m/s or 8 km/s, so
   $$t = \frac{42\,914 \text{ km}}{8 \text{ km/s}}$$
   = 5364 s = 1.5 h
   b The number of orbits per day = 24/1.5
   = 16 orbits

5 Here is some history of the Shuttle taken from the *Wikipedia* website.

Columbia was used for 28 missions from 1981 to 2003.

1981: First shuttle to travel into Earth orbit

1981–82: Used for the first five shuttle missions

1982: Deployed the first commercial satellite

1983: Deployed Spacelab (a mobile space station)

1999: Deployed Chandra X-ray laboratory

2002: Hubble Space Telescope service mission

Hints and tips

- Asking students to read the weightlessness article aloud not only keeps them focused but assists those who have a preference for auditory learning.
- Consider taking the class on an excursion to a theme park where students can experience a feeling of weightlessness or circular motion. Rides such as Dreamworld's Tower of Terror, where the seat you are in suddenly drops downwards, causes you to feel weightless. Not only is it a fun day but much physics can be learned!

Homework

If the microgravity suddenly increased in a shuttle or space station, what would be some possible consequences?

13.3 Living in space

As the giant rocket blasts off from the launch pad, the astronauts aboard the space module feel the effects of the tremendous force of the rocket engines. One hour later the space module is in orbit 400 km above the equator. At this altitude the astronauts feel 'weightless'. Outside the space module there is no air and no protection from the Sun's radiation. Let's look at some of the problems of living in space.

Fig 29 An astronaut catches a weightless sandwich during a snack on board the Space Shuttle *Atlantis*.

Weightlessness or microgravity

All objects on or near the Earth are attracted to it by the force of gravity. Your weight depends on your mass and the acceleration due to gravity. When an object is in outer space there is no gravity; that is, the acceleration due to gravity is zero. Therefore objects in outer space are weightless. However, at an altitude of 400 km there is still some gravity. Why then do you feel weightless here?

At an altitude of 400 km the reduced gravity still pulls the spacecraft towards the Earth. However, the spacecraft is moving fast enough to keep it moving in a circular orbit. So the spacecraft and everything inside it is effectively in free fall. This is why astronauts feel weightless when in orbit.

Weightlessness is not really the correct word for this effect. Objects in orbit still have some weight, although very small. **Microgravity** is a more precise word that describes the lack of weight.

Advantages of microgravity

You can move in any direction with just a little push in the opposite direction. You can work upside down without the feeling of blood rushing to your head. And you can sleep horizontally or vertically, although you have to be strapped into your bed to avoid floating away when you move in your sleep.

Disadvantages of microgravity

Astronauts often get space sickness. This is related to the motion sickness some people feel in a rocking boat or when travelling in a car. Space sickness may also be caused by the effects of microgravity on the balancing organs inside the ear.

Eating and going to the toilet also have their problems in space. You have to drink all liquids through a straw from a closed container. In an open cup the liquids form drops and float around the compartment. Food is packed in individual serving pouches on trays that have magnets on them to hold them firmly on a table or wall or wherever you wish to eat.

In the Shuttle toilet, air draws the faeces and urine into a bowl underneath the seat. Blades shred the solid wastes, which are then dried when exposed to the vacuum of space. Urine and other waste water is periodically dumped overboard where the material instantly vaporises in space.

Air and water

The air in the crew compartment of the spacecraft is similar to that on Earth. The air pressure is maintained at 1000 hectopascals (1000 hPa) —the same as at sea level.

The composition of the compartment's air is 79% nitrogen and 21% oxygen. Carbon dioxide, given off as a waste product of respiration, is monitored very closely. An excess of CO_2 in the air can make you drowsy and sleepy and this could be dangerous for the crew. Canisters filled with lithium hydroxide absorb the CO_2. The CO_2 reacts with the lithium hydroxide to form lithium carbonate and water vapour. Other canisters filled with activated charcoal absorb odours from the compartment.

Electrical power in the spacecraft is generated by fuel cells. In these devices, oxygen and hydrogen are chemically combined to produce electricity and about 3 litres of water per hour as a by-product. The water is stored and is used for drinking, for the toilet and for the air control system, which maintains the relative humidity at about 55%. Any excess water is dumped overboard where it vaporises and disperses into space.

Maintaining fitness

When you have been in space for a period of time, the microgravity affects your body in a number of ways.

1 One of the most noticeable effects is that the liquids in your body redistribute themselves. The liquids in the upper part of your body increase, causing your face to puff up and some stuffiness in your sinuses.
2 Your posture alters with the low gravity. When you relax, your arms float away from your body, your knees bend and your toes point, making walking difficult. To overcome this, you can wear suction cups on your shoes.
3 The microgravity affects your heart in a similar way to being bedridden for a long period of time. Your heart and pulse rates decrease, as does your blood pressure. To overcome this problem you have to exercise for at least 30 minutes each day on the treadmill or rowing machine.
4 The most serious problem for space travellers is the demineralisation of bones. Weightbearing bones lose calcium and phosphorus during long periods of microgravity, and this causes a weakening of the bones in the skeleton.
5 Long periods of microgravity also decrease muscle tissue. The Russian cosmonaut Yuri Romanenko lost 15% of the muscle tissue in his legs during an 11-month stay aboard the Mir space station.

Fig 30 Astronaut Jerry Ross exercising on a bicycle ergonometer on the Space Shuttle *Atlantis*.

Hints and tips

Devise a 'What am I?' quiz about space science. Get the students to guess if you are describing a rocket, type of force, type of satellite and so on. The students could make their own quiz question for you to collect and use in a compiled quiz to give to the class. Make sure they write their name on their question, and the answer to the question.

Issues

Should so much money be spent on space programs? How else could the money be used scientifically? There are people starving and homeless in the world—is this where money should be directed?

Ask students to present points about the money spent on space programs. Divide the class evenly into two groups. Ask the students in one group to work individually and jot down points for why money should be spent on space programs. The other group does the same but lists points *against* spending money on space programs. This could be extended into a class debate.

Alternatively, get the students to hold a 'Space Science Summit'. Appoint leaders and assistants for different countries. Each country must come up with their own space program policy. Then, as a class, the world leaders collaborate and form one policy to monitor what goes into space.

Another method that could be used to discuss the issue is the Four Corners strategy. It is useful for developing students' collaborative skills, encourages reflection, and helps students develop empathy and understanding of other people's viewpoints. The corners of the classroom represent 'strongly agree', 'agree', 'disagree' and 'strongly disagree'. Students reflect on their response to an issue, statement or question, and consider which of the corners best captures their perspective and opinion. Students then move to the relevant corner and pair up with another student in that corner to discuss their perspective on the issue. Students can also be paired with a student from the opposite perspective to discuss the issue.

Learning experience

Place some detailed information sheets about rockets, satellites and living in space around the room. Next to each information sheet, have another sheet where students record dot points about the information. This is the summary sheet. Pairs of students read the information sheet and then write a dot point on the summary sheet before rotating onto the next sheet. Each dot point has to be different—no two points can be the same.

Learning experience

What are some applications that have been used on Earth as a result of space science research or technology? Has our life been improved? Ask students to explain their views. Have them brainstorm some of the technologies we use that were originally designed for space missions. Are any of them everyday applications? A booklet called *Space science in everyday life* could be created to present their findings.

Hints and tips

Get the students to write a series of key sentences about each section of the chapter. They could use their sentences to make revision cards, a crossword or a multiple-choice quiz.

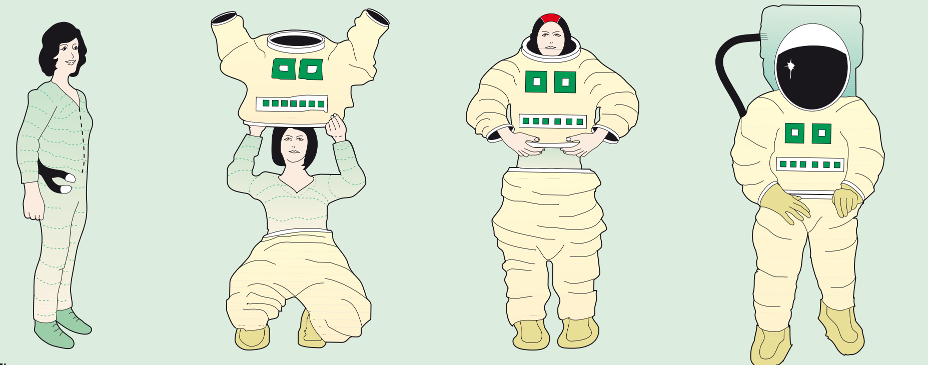
Research

Fuel cells were studied on pages 150 and 291. What types of fuel cells are used in spacecraft? What are they used for?

Heat and radiation

At an altitude of 400 km the temperature in space can be as high as 250°C in the sunlight and as low as –150°C in the shade. The crew compartment of the spacecraft is maintained at a constant temperature and pressure, but any space walks require special clothing. To overcome the extreme temperature changes in space, the undergarments of the spacesuits are equipped with water-cooling and ventilation.

On Earth, the atmosphere absorbs much of the harmful high-energy radiation from the Sun, but in space there is no such protection. This radiation can cause cancer and changes to the chromosomes in your sex cells. Spacesuits therefore have to be designed to reflect this dangerous radiation.



1 The spacesuit's undergarment is made from Spandex mesh with plastic tubing woven into it. The tubing circulates cool water from the life-support backpack.

2 The outer suit comes in two sections and can be put on in less than 5 minutes. The suit contains oxygen-filled pressure bladders that help to keep its shape.

3 When the torso section is put on, the cooling tubes from the undergarment are connected to the tubes that flow to the life-support backpack. The trousers are then joined to the torso section by a rigid aluminium ring.

4 The life-support backpack contains oxygen, water, batteries, and communication equipment. The space-suit is designed to be re-used and should last 15 years.

Activity

Astronaut's diary

Use the information on pages 322–324 to write a 24-hour diary in the life of an astronaut orbiting the Earth in a space station. For this task, work in a group of three or four people. Use the following ideas in your diary.

- How many hours do you allocate for sleeping, exercising, working and relaxing?
- List the difficulties you face when doing everyday activities in microgravity. For example, washing, cleaning your teeth, eating and drinking, and using the toilet.
- What are the problems of working in a spacesuit and doing jobs in space?
- Describe the experiences at lift-off from Earth and in re-entry.

Activity notes

An alternative activity is for students to draw a cartoon strip of a day in the life of an astronaut orbiting Earth in a space station. They should have 24 cartoon pictures—one picture per hour.

Learning experiences

1 Gifted and talented students, or those who like costume and design, could make their own authentic spacesuit. The school's drama department might be able to help out with materials.

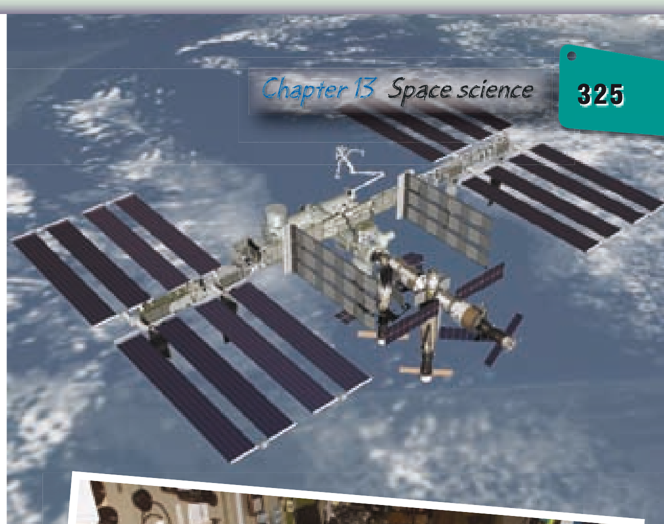
2 Students might like to make a model of a space station or design a futuristic one. Key features about the station need to accompany their model/design.

Learning experience

Living in space seems to affect the human body negatively. What are some health risks associated with living in space? Explain why it is important to wear appropriate clothing and to exercise. Have students make a list of the health risks and what causes them. Does living in space have any positive effects on the human body?

Learning experience

Get the students to draw a concept cartoon depicting what it is like to live in space, using the information in section 13.3. Minimal text in caption bubbles should be used to describe the ideas. This is a great task for students with language difficulties. It might be useful to title it 'An astronaut's view on living in space'.



Space stations

In early 1971 the Russian spacecraft *Salyut 1* became the first space station to be put into Earth orbit. Since that time a number of improvements have been made to make them more liveable for the astronauts who spend an extended period of time in them.

The unmanned *Salyut 6* space station was sent into orbit in 1978. Two months later, two cosmonauts on board a Soyuz spacecraft docked with the Salyut space station and entered it via the docking bay. Three months later they were visited by two other cosmonauts in another Soyuz supply vehicle. This was the first time a space station had been supplied with fresh provisions, and unwanted materials removed.

In 1988 Musa Manarov and Vladimir Titov became the first people to spend more than a full year away from Earth on board the Mir space station. But after nearly 15 years in space Mir crashed back to Earth in March 2001.

The International Space Station (ISS)

In 1998 a new space station was born. On 20 November, space scientists from 16 countries throughout the world watched as the Russian Proton rocket carried the first section of the International Space Station (ISS) to an orbit 400 km above the Earth. The ISS is the largest international space project in history.

The ISS is in orbit at an altitude of 360 km, and orbits the Earth every 92 minutes. By June 2006 it had completed over 42 000 orbits since its launch.

In 2006, additional solar panels were installed to increase electrical power, and further modules will be added until it is complete some time in 2012.

Fig 32 (*top*) The International Space Station in orbit 360 km above the Earth's surface
(*middle*) Russian ISS commander Pavel Vinogradov and other crew members in the Zvedna Service Module
(*bottom*) US astronaut flight engineer Susan Helms looking at Earth from a window in the ISS

Hints and tips

In March 2001, the Mir space station crashed back to Earth. It passed within 2000 kilometres of the northern Queensland coast. Most of it was burnt up in the Earth's atmosphere, while the rest plunged into the Pacific Ocean.

Learning experience

Ask students to find out more about the International Space Station (ISS). They could prepare a PowerPoint presentation with details of its dimensions, how it is powered, which countries are involved with it, and so on. Alternatively, information could be presented as a recording such as a podcast.

Homework

Set students the task of finding out about the Mars Exploration Program. Give students free choice of format for their final presentation.

Learning experience

Students are to imagine they have just returned from a space station. A TV show wants to interview them. The interviewer asks them the following questions:

- What was your mission called?
- Which space station did you visit?
- When did you go?
- How long were you away?
- What was the purpose of your mission?
- What was a highlight of the trip?
- What was the worst part of the trip?
- What did you learn from your stay in space?
- What changes did you observe in your body?
- How long will it take you to recover?
- What other interesting things from your trip can you share?

Students can present their work as a media article in the form of an interview. They might also like to act out the interview as a role play. If students are using a computer to write their article, remind them to use the spellcheck feature. You may need to give ESL students and students with language difficulties extra time to complete this task. Podcasts and vodcasts would work well as another presentation format.

Hints and tips

- Does Australia have a space science program? Find out more and give details to students—or, better still, have them investigate themselves. Suggest they start their inquiries with universities.
- Find out what Glen Waverley Secondary College in Melbourne contributed to the 2003 *Columbia* space mission. Link up with the school if you can via the internet and chat to some of their science teachers and students.
- This is a good time for students to complete the concept maps they started at the beginning of the chapter.

Activity notes

As an extension, students could consider the needs of both humans and wildlife in their space station. They should:

1 list the human needs
2 decide which type of habitat the space station wildlife lives in
3 list the needs of the wildlife
4 explain why this wildlife was chosen
5 determine how the space station can support both humans and wildlife.

Students will probably find surfing the internet to be the quickest research method, but remember that not all the information on websites is reliable.

Learning experience

What do students think the future of space science is? Is it likely that in the next few years there will be space tourism? How much do they think a trip into space will cost? How long do they expect a journey to take? What destination(s) do they think space travellers will choose to visit? Where do they think possible launch sites will be located? Ask them to explain their answer. Launches are easier when they are near the equator—why? (This is where the Earth's surface is travelling the fastest.) Is there a suitable place in Australia?

Artificial gravity

The one factor that causes most problems for humans in space is the lack of gravity. Serious health problems such as the demineralisation of bones, weakening of the heart and loss of muscle tissue occur when people spend long periods of time in space. Many of the experiments on board the ISS are designed to look at these problems, but they may only be solved if artificial gravity can be created in space stations. How can space stations be designed to create artificial gravity? Try the activity below.

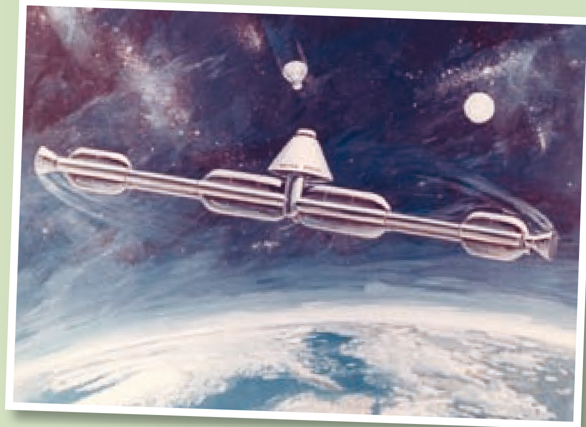


Fig 33 An artist's impression of a space station spinning around a central axis to create artificial gravity

Activity

Your task is to design a space station that will generate artificial gravity and will have facilities for an extended stay by the people on board. Use the internet, books and magazines to help you with this task.

Use the statements below as a guide in your design. As well as describing your design, write a report detailing the various features of the space station and how its inhabitants can survive in space.

- Describe the overall shape of the space station.
- Is it necessary to create artificial gravity in the space station? If not, how will the people on board overcome microgravity problems?
- How will light and electricity be provided for the occupants?
- How will the space station be built? Remember the present-day Shuttle can carry a maximum load of 20 tonnes.
- How will the space station be supplied with food, water, oxygen and fuel, and how will unwanted materials be removed?
- How will the space station be protected from radiation and from meteorites?

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Inside the space station
Has a description and tour through the different modules in the ISS.

International Space Station
Comprehensive information about the ISS.

Life on the Space Station
Interactive tour of the ISS, as well as an interview with an astronaut, and links to other sites.

Space Station
NASA's space station site.

Learning experience

Students could investigate the effects of demineralisation to explore what happens to an astronaut's bones. Place some clean chicken bones in a jar of vinegar and leave it for a couple of days. After two days pour off the vinegar and replace it with fresh vinegar. Leave for a further two days. Repeat this process for a total of eight days. Rinse the bones in water, then try to bend them—they will be rubbery!

Science in action

Andy Thomas: Australian astronaut

Andy Thomas is the only Australian to have orbited the Earth. He began his training with NASA in 1992 and flew his first flight into space on board the Space Shuttle *Endeavour* in May 1996.

In 1998 he spent 141 days and 2250 orbits of the Earth aboard the Mir space station and was the last US-trained astronaut to stay on Mir.

He blasted off into space again in 2001 on board the Space Shuttle *Discovery* along with three other crew, and headed towards the International Space Station. Three Space Station crew on board *Discovery* replaced three others who had been working on the ISS. Andy and fellow astronaut Paul Richards had to walk in space to attach a platform and pump to the outside of one of the modules on the ISS. In 2005 Andy visited the ISS again on board *Discovery*.

For more information about Andy Thomas, go to www.scienceworld.net.au and follow the links to these websites:

Andrew S. W. Thomas

Mission Specialist Andy Thomas

Fig 35 Andy Thomas gathers equipment in the cargo bay of Space Shuttle *Discovery* at the end of his space walk in March 2001.

Check!

1. What is meant by free fall? Where on the Earth's surface could you demonstrate free fall?
2. Explain the term *microgravity*. Are there any places in the solar system that would have zero gravity? Explain.
3. The photo on the right shows a handwashing station inside the Space Shuttle. Suggest reasons for the design of this piece of equipment.
4. In which ways is the air in a spacecraft's crew compartment similar to the air on Earth? In which ways is it different?

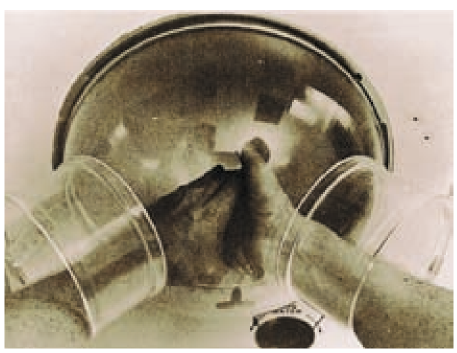


Fig 36 Washing your hands on the Space Shuttle

Check! solutions

1. Free fall means that you are apparently weightless and would not show any weight on a set of scales. You could experience free fall if you were in a lift in a high-rise building when the cable broke, or when skydiving before your parachute opens.
2. Microgravity is the term that describes the condition of apparent weightlessness such as that which occurs in a spacecraft. There would not be any places in the solar system where there is zero gravity. The sun has a very large mass and attracts planets and all other objects. However, there are places where the pull of gravity is equal in all directions and you would think that there is no gravity.
3. In the same way that human bodies appear to be weightless, so too are all other objects such as droplets of water. This basin is fully enclosed and water is squirted onto the hands because water will not form a puddle in the bottom of the basin as it does in your bathroom. The basin is emptied by reducing the air pressure in the outlet.
4. The air in the crew compartment is at the same pressure and contains nitrogen and oxygen in approximately the same proportion as that of the air on Earth. The main difference is that carbon dioxide, which is produced and breathed out by the crew, is removed by lithium hydroxide. Any other odours are removed by activated charcoal filters.
5. The Velcro pads are used to attach these utensils when they are not actually being used so that they do not 'float' around the cabin where they could cause injury or damage.
6. The level of carbon dioxide is controlled because if it rises it could cause drowsiness and this would be dangerous for the crew.
7. One way in which engineers save space is to compress these gases so that they form liquids. When the pressure is released the liquids form gases, which then react in a fuel cell to form electricity.
   The equation is $2H_2 + O_2 \rightarrow 2H_2O$

Learning experience

A 'wall of fame' for significant people in space science is a great way to end the chapter. Students make their own giant class poster. For each person, they should include:

- name
- date of birth (and death if appropriate)
- date and reason for their claim to fame
- any other interesting facts.

Students could start their wall of fame with Andy Thomas.

Learning experience

If students worked through this chapter on a 'space science mission', check that each team has gained enough 'fuel' points so that they can be awarded a completion certificate for their mission. Review teams' logbooks and final assessment item(s). Refer to the Learning experience on page 308.

Homework

Have students do some reflective thinking about this chapter. See Homework on page 146.

8 Important points to mention in your story are:
- You need to pass through an airlock, which is a compartment from which all air is pumped out and stored to prevent the loss of air, before the door is opened into space.
- You would need to check that your radio is working so that you can communicate with your colleagues in the spacecraft.
- You would need to check that you are connected to the spacecraft with a cable so that you do not float off into space.
- You would need to be sure that your tools are attached securely so that you do not lose them.
- Once you are in space you might comment on the intense light and variations in temperatures. You might also comment on the beautiful views of our planet from space.

5 All items of equipment, including knives and forks, pens and scissors, that are used during a space mission have small Velcro pads on them. What is the purpose of these pads?

6 Why is the level of carbon dioxide in the air of the crew compartment monitored carefully?

7 The fuel cells in spacecraft produce electricity when hydrogen and oxygen combine. The two gases would take up a huge amount of space on the spacecraft. Suggest how space engineers have overcome this problem.

8 You have put on your spacesuit and are now ready to go outside into free space to begin repairs to a damaged satellite. Write a short story about how you would get out of the spacecraft, and what it might be like outside in space.

challenge

1 The manned manoeuvring unit or MMU allows an astronaut to move from a spacecraft to other places, say, another orbiting satellite. The propellant is simply nitrogen gas.
  a Suggest how this propellant might move you through space.
  b How do you think you would be able to control the speed of the MMU?

2 a How is carbon dioxide removed from the air in a spacecraft?
  b Write a word equation for the reaction that occurs when carbon dioxide is removed from the air in the spacecraft using lithium hydroxide.

3 Suggest why the outside temperature at an altitude of 400 km can be as high as 250°C in the sunlight and –150°C in the shade.

4 Electrical power for the Space Shuttle is produced in fuel cells. Each cell generates 1.2 volts DC and there are 24 cells in each battery. Each cell produces about 20 watts of electrical power.
  a What is the total voltage produced by each battery?
  b What power (in watts) can be produced by each of the Shuttle's batteries?

5 Suggest why water vaporises immediately it is released into space from a spacecraft.

6 The International Space Station will cost about $150 billion to build. The Human Genome Project cost $45 billion.
  a Compare and contrast the benefits of these two science projects to humankind.
  b What is your opinion about the statement that these projects are examples of 'scientists spending money on themselves and not on the people who really need it'?

7 Use the internet and other library resources to write a brief history of space stations. Find out how many space stations have been built and put into orbit, what functions they served, and what has happened to them.

8 Before humans went into space, small Rhesus monkeys were placed in orbit for various periods of time. Even recently monkeys have been used in a number of space experiments.
Discuss with others the pros and cons of using animals in space experiments. You might like to organise a debate on this subject.

Challenge solutions

1 a When a valve is opened, some of the nitrogen gas will escape to the outside where the pressure is very low. The escaping gas is the action that will produce an equal and opposite reaction which moves you through space.
  b You could control the speed of the MMU by controlling how quickly the nitrogen gas escapes from its container.

2 a Carbon dioxide is removed from the air using lithium hydroxide.
  b Carbon dioxide + lithium hydroxide → lithium carbonate + water
  $CO_2 + 2LiOH \rightarrow Li_2CO_3 + H_2O$

3 On the surface of the Earth, the temperature is moderated by the atmosphere so that it does not usually fall far below 0°C or go much above 40°C. In space, however, there is no air present and the temperature can fluctuate dramatically.

4 a The total voltage produced by each battery is 24 × 1.2 = 28.8 V
  b The total power produced by each battery is 24 × 20 = 480 W

5 Water immediately changes from liquid to gas in space because there are no air molecules (no pressure) to hold the water molecules together. This means the molecules will move apart and diffuse away from each other or vaporise very rapidly.

6 a Sometimes the benefits of projects such as these are not immediately obvious. For example, the first microcomputer was built to assist the moon landing in 1969 and computers are now widely used in our lives.
  Possible benefits of the International Space Station are:
  - finding out more about where the Earth, solar system and universe came from
  - gathering information that might help humans live in outer space or on other planets
  - the possibility of 'unexpected' benefits such as microcomputers and Velcro, which were first developed for the moon landing in 1969
  - the usefulness of 'global' information, such as the warming of the oceans and the destruction of vegetation
  - spying on other countries for military advantage
  - manufacturing products (eg drugs) that require microgravity conditions.

  Possible benefits of the Human Genome Project are:
  - improved diagnosis and treatment of disease
  - manufacture of custom medicines and drugs
  - finding and fixing or replacing faulty genes.

  b There are many different opinions that may be given here including that space

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 There are a number of problems to overcome when living in space: you need a supply of air and water, protection from ______ and extremes of temperature, and dealing with 'weightlessness' or ______.

2 The weight of an object is a ______ and it is found by multiplying its ______ by the acceleration due to gravity.

3 The acceleration due to ______ on the Earth's surface is 9.8 m/s^2, and it ______ as you move away from Earth.

4 The force or ______ developed by a rocket's engines is due to the exhaust gases moving backwards (the ______) and pushing the rocket forwards with an equal force (the ______).

5 The net force on a rocket at lift-off is equal to the thrust of the engines minus the ______ of the rocket.

6 Gravity pulls a satellite towards the Earth, but its ______ (motion) keeps it in orbit.

7 ______ in low Earth orbits, where the gravity is stronger, have much greater ______ than satellites in higher orbits.

action
decreases
force
gravity
inertia
mass
microgravity
orbital speeds
radiation
reaction
satellites
thrust
weight

Try doing the Chapter 13 crossword on the CD. Working with technology

REVIEW

1 You are standing on some scales in a lift. The scales read 60 kg. The lift suddenly accelerates downwards. The reading on the scales will be:
- **A** 60 kg
- **B** less than 60 kg
- **C** more than 60 kg
- **D** 60 × 9.8 kg

2 In 1975 *Apollo 15* astronaut Scott Irwin dropped a hammer and a feather while standing on the Moon's surface.
- **a** Why did they both hit the ground at the same time on the Moon but not on the Earth's surface?
- **b** Would the hammer fall faster or slower on the Moon than on the Earth? Explain.

3 Jilly stands on ice wearing ice skates. She throws a heavy weight out in front of her.
- **a** In which direction does she move?
- **b** Explain what would have happened if Jilly had thrown the object with more force.

4 Which one of the statements is correct?
- **A** Liquid-fuel rockets are cheap to make and are very simple in construction.
- **B** Solid-fuel rockets have to carry a source of oxygen but liquid-fuel rockets do not.
- **C** Once ignited solid-fuel rockets cannot be extinguished.
- **D** Most liquid-fuel rockets burn hydrogen and nitrogen gas in the combustion chamber.

Main ideas solutions

1 radiation, microgravity
2 force, mass
3 gravity, decreases
4 thrust, action, reaction
5 weight
6 inertia
7 satellites, orbital speeds

Review solutions

1 B

2 a On Earth falling objects are slowed down by the friction due to the air. Because the feather has a large surface area, there is more air resistance and the feather falls more slowly than the hammer. On the Moon, where there is no air, the hammer and the feather fall together.

b The hammer (and the feather) would fall more slowly on the Moon because the acceleration due to gravity is less.

3 a Jilly moves backwards if she throws the heavy weight forwards. This is due to action and reaction. (See page 310.)

b If the action force increases, the reaction force also increases. Therefore, Jilly would have moved backwards much more quickly.

4 C

5 Satellite A is closer to the Earth and will experience a greater gravitational pull than satellite B. Therefore, to stay in orbit satellite A will have to have a greater orbital speed than satellite B.

stations and the Genome Project will have benefits for humankind, some of which are predictable and some of which are not. There is also a debate about who 'the people who really need it' are. For example, these might be people who are starving or people who could use satellite communication or people suffering from genetic disease. You will form your own opinion about this and it may change over time.

7 The first space station was the Russian Salyut in April 1971, then Skylab was launched by the USA in May 1973. It was used by several different crews, and returned to Earth and burnt up in 1979. The Russians also launched a series of Salyut space stations between 1974 and 1991. The Russian Mir space station was in orbit between 1986 and 2001. In 1998, the first part of the International Space Station (ISS) was launched and is currently being assembled with equipment taken up by the Space Shuttle and several Russian space vehicles. It is planned that this space station will be used until 2016. Space stations are designed to do experiments in space and, perhaps, to launch missions to the Moon or other planets. Eventually, they are slowed down by friction, pulled back to Earth by gravity and burnt up on re-entry.

8 Pros (arguments for) include:
- Monkeys are quite similar to humans and will respond in many of the same ways.
- Using monkeys means that human lives are not endangered during experiments.
- Sending monkeys into space is not as expensive as sending humans.

Cons (arguments against) include:
- Monkeys are not able to send back as much information as humans.
- Monkeys are not able to manage the spacecraft.
- If the experiments involve pain or suffering for the monkeys, then they would be cruel.

6 **a** There is no oxygen in space in which to burn the fuel. Therefore oxygen has to be carried.

b The solid-fuel rocket engine is more powerful than a liquid-fuel engine of equivalent weight.

c The Shuttle uses a liquid-fuel engine because it can be adjusted or turned off and on to control the Shuttle's speed.

7 Microgravity causes the heart and pulse rates to decrease as well as blood pressure to decrease.

The bones tend to lose calcium and phosphorus during long periods in space. This causes a weakening of the bones.

Because of the lack of exercise of the weight-bearing bones, the body's muscle tissue tends to decrease. This is a similar effect to being bedridden for a long period of time.

8 **a** In microgravity, the blood and other liquids in your body flow to places like the neck and the head, causing puffiness and fullness in these parts.

b In the Shuttle there is no 'down' because the spacecraft is in 'freefall'. Therefore drinks will not flow 'downwards' and can be drunk in any position.

c When you sneeze in microgravity, the action of the air being forced out of your mouth in one direction pushes your body in the opposite direction.

d As the Shuttle enters the Earth's atmosphere, the friction of the air created by the speed of the Shuttle causes the tiles on exposed surfaces such as the nose to glow red hot.

9 **a** Mars (4.1 m/s^2)—since the acceleration due to gravity is about half that on Earth (9.8 m/s^2)

b Use the formula W = mg to find Ziro's mass.

$$W = mg, \quad \text{so} \quad m = \frac{W}{g} = \frac{88\ \text{N}}{1.6\ \text{m/s}^2} = 55\ \text{kg}$$

His mass is 55 kg on Mars (or anywhere else). On Uranus his weight is:

$$W = mg = 55\ \text{kg} \times 8.9\ \text{m/s}^2 = 489.5\ \text{N}$$

c Weight of rocket on Ganymede:

$$W = 75\,000\ \text{kg} \times 3.9\ \text{m/s}^2 = 292\,500\ \text{N}$$

Net force accelerating rocket—

$$F = 75\,000\ \text{kg} \times 5\ \text{m/s}^2 = 375\,000\ \text{N}$$

Net force = thrust – weight

so, thrust = net force + weight

= 375 000 N + 292 500 N

= 667 500 N

d On Uranus the rocket's weight is—

$$W = 75\,000\ \text{N} \times 8.9\ \text{m/s}^2 = 667\,500\ \text{N}$$

The weight of the rocket is equal to the thrust, so there is zero net force and the rocket will not be able to leave the surface of Uranus.

10 **a** On Earth the weight of the astronaut is 110 kg × 9.8 m/s^2 = 1078 N

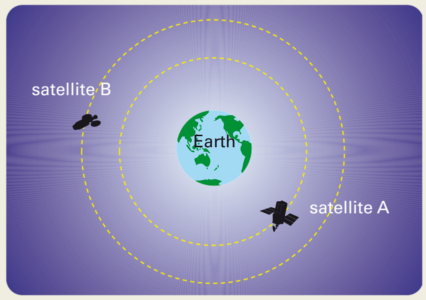
b $a = \frac{F}{m} = \frac{9\ \text{N}}{110\ \text{kg}} = 0.08\ \text{m/s}^2$

c The total thrust developed by the 24 rockets is 24 × 9 = 216 N. This is much less than the astronaut's weight (1078 N), so the rockets would not lift her off the ground.

d On the Moon the astronaut's weight is 110 × 1.6 = 176 N. This is less than the total thrust developed by the rockets, so she would lift off from the Moon's surface.

REVIEW

5 Two satellites are in orbit around the Earth. Satellite A is at an altitude of 400 km while satellite B is at an altitude of 900 km. Explain why satellite A has to have a greater orbital speed than B.



6 You are in the Shuttle ready for lift-off. The engines that fire for lift-off are solid-fuel engines. The last stage is powered by liquid-fuel engines.

a Why do space rockets have to carry their own source of oxygen as well as the fuel?

b What is the advantage of using solid-fuel engines for lift-off?

c The engine in the Space Shuttle is a liquid-fuel type. Suggest why this type of engine is used.

7 Spending long periods of time in microgravity causes problems for the heart, weight-bearing bones and muscle tissues. Describe how microgravity affects these parts of the body.

8 Imagine you are a crew member of Shuttle mission STS-120 to the International Space Station. You make the following observations:

a When the Shuttle reaches the ISS in orbit, you notice that your face and neck become 'puffy' and you feel a fullness in your head.

b In the ISS crew compartment, you can drink liquids upside down as easily as right-side up.

c Inside the orbiting ISS, you sneeze and you crash backwards into the compartment wall.

d During re-entry you notice the tiles on the nose of the orbiter glow red hot.

Write an inference for each observation.

9 The table gives the acceleration due to gravity for a number of bodies in our solar system.

Planet or moon	Acceleration due to gravity (m/s^2)
Mars	4.1
Earth's moon	1.6
Saturn	10.8
Pluto	0.3
Ganymede (moon of Jupiter)	3.9
Uranus	8.9

a On which planet would your weight be about half of what it is on Earth?

b Astronaut Ziro's weight is 88 N on Earth's moon. What is his mass on Mars? What is his weight on Uranus?

c A rocket of mass 75 000 kg blasts off from Ganymede with an acceleration of 5 m/s^2. Calculate the thrust developed by the rocket's engines.

d Will the same rocket be able to lift off from the surface of Uranus? Explain.

10 An astronaut in a manned manoeuvring unit (MMU) or 'space scooter' has a total mass of 110 kg. Each of the twenty-four jet nozzles around the base of the MMU can produce a thrust of 9 newtons.

a What would the astronaut's weight in newtons be on Earth?

b The astronaut goes for a space walk and fires one jet nozzle. How fast would she accelerate?

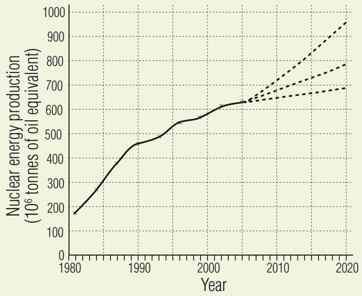
c If the astronaut stood on the Earth's surface and fired all the jet nozzles downwards, would the MMU develop enough thrust to lift her off the ground?

d Would the astronaut lift off if she fired all the MMU's jets on the Moon?

Check your answers on pages 339–340.

Challenge solutions (page 134)

1 a



b After 1987 the slope of the graph decreases, meaning that the rate of increase of energy production decreased. The reason for this might be that after the Chernobyl disaster in 1986 some plans for building new nuclear reactors were scrapped.

c Extending the graph or extrapolating the data as shown (top line), you can estimate that the amount of nuclear energy that will be produced in 2010 will be approximately 680 million tonnes of oil equivalent, and will be about 780 million tonnes in the year 2020.

d The prediction for 2010 is more accurate than for 2020 because it isn't as far into the future. Depending on many other factors, the present trend may either continue (middle line), slow down (bottom line) or speed up (top line).

e You can do this in your group and you will find a considerable variation as shown with the other lines on the graph.

f Factors that might increase the use of nuclear fuel are the limited availability and high cost of fossil fuels. Another factor will be the state of the atmosphere and whether greenhouse gas emissions are causing major problems. Factors that will decrease the use of nuclear energy will be whether or not governments decide that it is safe to mine, transport, use and dispose of radioactive material. Another factor will be whether other methods such as solar energy have been developed to generate electricity.

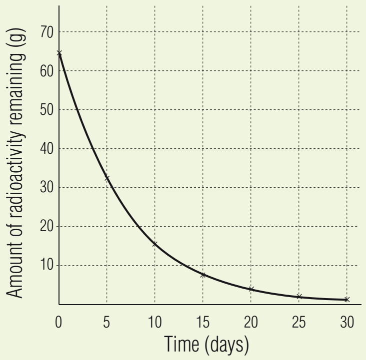
2 Referring to Fig 6 on page 131:

a Wastes are produced at stages 1, 3, 6 and 7.

b At Stage 7 spent fuel is reprocessed to separate wastes and some uranium is recovered. High-level wastes are solidified in glass and some plutonium is used to make new fuel rods.

c The longest stage is Stage 9, which will take tens of thousands of years.

3



It will take 30 days to reduce to 1 g, as shown in this graph.

4 With this and all such issues there will be arguments for and against. There are two things that are certain. First, the biosphere is changing because of human activities and, second, the fossil fuels are finite and running out. During your lifetime, humans will need to learn to do things differently and it would be better if this is the result of choice before things reach the point of disaster, where there might not be many choices!

5 Using various websites:

a The 'greenhouse effect' is perfectly normal and makes life on Earth possible because it moderates temperatures. The problem is that because of an increase in the levels of CO_2 and other gases in the atmosphere, this effect has been speeded up or 'enhanced' with effects on the local weather and the global climate.

b An international conference was held in Kyoto in Japan in December 1997. Some agreement was reached about limiting the emissions of greenhouse gases, and the emissions targets were called a protocol. Australia signed this protocol in December 2007, but the USA has not signed.

c One of the proposals is that countries are required to plant a certain number of trees to remove some of the carbon dioxide that is produced by their industries. These are called carbon credits and if the country is not able to plant enough trees they can pay other countries to do it for them, which is called 'carbon emissions trading'.

Challenge solutions (page 265)

1 a You would expect barium to be more reactive because these metals become more active as you go down the group.
b You would expect sodium to be more reactive because the metals on the left of the periodic table are more reactive.
c You would expect oxygen to be more reactive because the non-metals become more reactive as you move to the right of the periodic table.
d You would expect fluorine to be more reactive because these metals become more active as you go down the group.

2 Points that you could mention in your paragraph include:
- Scientists are able to recognise patterns with the properties of elements and make predictions.
- Scientists are able to predict which elements or compounds are likely to be suitable for particular uses.
- Scientists can predict which elements will react to form compounds and what the formulas of these compounds are likely to be.

3 An atomic number of 112 would place the new element in the same group as zinc, cadmium and mercury. It would probably be most similar to mercury.

4 Imagine that a Russian spy named Mr 'H. HeLi BeBCNOF' found his girlfriend 'NeNa' unconscious after she drank too much of a Russian beverage called 'ClArKCa' and he called the police. Later in an interview 'H. HeLi BeBCNOF' said 'NeNa, MgAl, SiPS ClArKCa'. You may have thought of a different jingle, acronym or mnemonic, otherwise remember this one.

5

		Number of electrons …			
Elements	*Atomic number*	*first shell*	*second shell*	*third shell*	*fourth shell*
hydrogen	1	1			
helium	2	2			
lithium	3	2	1		
beryllium	4	2	2		
boron	5	2	3		
carbon	6	2	4		
nitrogen	7	2	5		
oxygen	8	2	6		
fluorine	9	2	7		
neon	10	2	8		
sodium	11	2	8	1	
magnesium	12	2	8	2	
aluminium	13	2	8	3	
silicon	14	2	8	4	
phosphorus	15	2	8	5	
sulfur	16	2	8	6	
chlorine	17	2	8	7	
argon	18	2	8	8	
potassium	19	2	8	8	1
calcium	20	2	8	8	2

a The elements with only one electron in their outer shell are hydrogen, lithium, sodium and potassium. They belong to Group I, which are the 'alkali metal' group.
b The elements that need only one electron to fill their outer shell are fluorine and chlorine. These belong to Group VII, which are the 'halogens'. Their valency is 1–.
c The elements that have a full outer shell are helium, neon and argon. They belong to Group VIII, which are the 'noble gases'.
d An oxygen atom needs to react with two hydrogen atoms to form a molecule of water, which has the formula H_2O.
e Each nitrogen atom will need to react with three atoms of hydrogen to form a molecule of ammonia, which has the formula NH_3.
f The two elements that have properties similar to beryllium are magnesium and calcium. You know this because they have the same number of electrons (two) in their outer shell.
g Each magnesium atom needs to react with two chlorine atoms to form magnesium chloride, which has the formula $MgCl_2$.