12

Earth, moon and sun

By the end of this chapter you will be able to …

Science understanding

- compare times for the rotations and orbits of the Earth, sun and moon
- model the relative movements of the Earth, sun and moon to show how phases of the moon and eclipses occur
- relate the tides to the positions of the Earth, moon and sun

Science as a human endeavour

- examine Aboriginal and Chinese stories about eclipses and day/night

Science inquiry skills

- accurately map the positions of objects in the sky
- evaluate the claim that the Apollo 11 moon landing was a hoax

LITERACY FOCUS

axis	gibbous	orbit	solstice
azimuth	hydrosphere	penumbra	Southern Hemisphere
crescent	lunar eclipse	phases of the moon	spring tides
Dreamtime	meteors	rotation	umbra
elevation	neap tides	solar eclipse	zenith

Focus for learning

The Aboriginal people have been in Australia for at least 40 000 years. Different tribes had different stories or legends to explain what they saw in the sky. This one is about an eclipse of the sun.

A long time ago in the Dreamtime, an Aboriginal tribe had plenty to eat and were free and happy. They had rules to live by and for many moons they lived in peace and harmony with the land.

Then there came an unsettled time. People did not help each other. The young ones disobeyed their parents and took no notice of their elders. There were evil spirits about and everyone was unhappy. The Good Spirits decided to teach the people a lesson by blocking out the sun. This made it dark and cold. The plants began to die and the animals became scarce.

The people asked the Kadaicha Man what was happening. He told them that the Good Spirits were angry because the tribe was not obeying the rules. So to make the Good Spirits happy the people started to help one another again. Even though the sun was still dark, they began to live in peace as they had before.

Then one day the sun became bright and the sky turned blue again. The Good Spirits had given them back the sun and sky, but the Kadaicha Man told the people to remember the lesson they had been taught. 'Keep the rules or the Good Spirits will block out the sun forever. And just to make sure you remember, they will block out the sun again every now and then.'

INQUIRY 1 *Dreamtime legend*

- Suggest why the Aboriginal people were so frightened when the sun was blocked out.
- What do you think is the purpose of this Aboriginal legend?
- Is the legend scientifically accurate? For the purposes of the legend, does this matter?

A system within a system

The sun and the planets that orbit around it form the solar system. In this chapter you will learn to explain day and night, the seasons, phases of the moon, eclipses and tides. To do this you will need to consider the Earth, moon and sun as a sub-system within the solar system. Because the Earth, moon and sun are so large you will use models to represent them.

PROBLEM SOLVING *Apollo 13*

Like the Aboriginal people, we tell stories to explain what happens in our world. Our stories are told through movies, TV and books. Look at the movie *Apollo 13*. Your task is to make a list of things in the movie that are scientifically correct and another list of things that are incorrect. Use what you learn in this chapter. Researching the *Apollo 13* mission will help too.

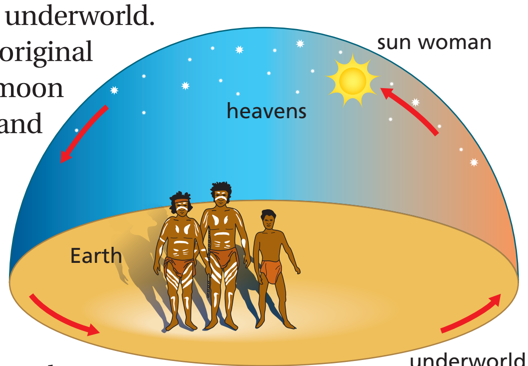
Have a class discussion about the things you notice. Would the movie be as good if Hollywood didn't 'bend' the truth a little?

12.1 How the Earth moves

The Aboriginal people believed the Earth was created during the Dreamtime by god-like beings such as the Rainbow Serpent. The Earth was a flat disc and above this was the dome of the heavens. The stars in the sky were the campfires of the god-like beings. Underneath the Earth was the cold, dark underworld.

In many Aboriginal tribes the sun was a woman who travelled across the sky looking for her lost son. She had a camp in the east and each morning she lit a fire and made a bark torch which she carried with her. She covered her body in ground-up red-coloured rock (ochre). She spilt some of this ochre and that is why the sky is orange-red at sunrise. When she reached the western horizon she spilt more ochre—creating the sunset. She then travelled back under the Earth through the underworld.

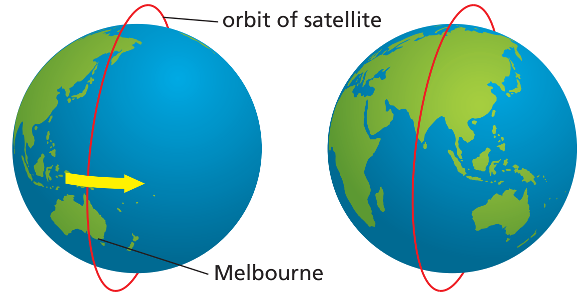
To the Aboriginal people the moon was a man, and when the sun woman and the moon man came together an eclipse occurred.



The Aboriginal people were not the only people who thought the Earth was flat. Five hundred years ago Christopher Columbus, the Italian-Spanish explorer who discovered the United States, decided to sail around the world to show that the Earth was not flat. At this time many sailors were scared to go far from land in case they fell off the edge of the world. If the world was round Columbus would sail back to the place he started, and this is what happened.

The Earth's rotation

Today we can see the Earth from space and have much more information than ancient people to help us understand our world. From a satellite in orbit above the poles, it can be seen that Australia moves from west to east as the Earth spins. As a result the sun appears to move from east to west. The Earth spins at 1700 km/h but you don't notice it because everything around you is moving at the same speed. You would only notice it if the speed suddenly changed.

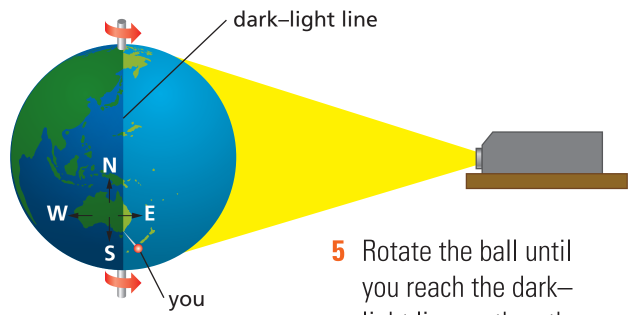


The Earth rotates from west to east.

INQUIRY 2 Day and night

You will need: polystyrene ball (about 7 cm diameter), pin, cooking skewer or knitting needle, projector

1. Push the skewer through the centre of the ball.
2. Draw a rough sketch of Australia in the bottom half of the ball (the Southern Hemisphere). Also mark in the directions north, south, east and west. Represent yourself by a pin stuck in the place where you live.
3. Turn on the projector and hold the ball in the light. Look at the ball from the side.
   - What happens as you rotate the ball from west to east?
   - What length of time does one rotation of the ball represent?
4. Hold the ball in the light so that your pin is on the dark–light line as shown.
   - What time of day is this?
   - In which direction does the sun rise?



5. Rotate the ball until you reach the dark–light line on the other side of the ball.
   - What time of day is this? In which direction does the sun set?
6. In Perth, does the sun rise before or after it rises in Melbourne? How is the time different?

Keep your model for Inquiry 4.

Rotation and revolution

The Earth moves in two different ways.

1 It spins or rotates on its **axis**—an imaginary line through the centre of the Earth from pole to pole. The rotation time is 24 hours—an Earth day.

2 The Earth *revolves* around the sun. The path it follows is called its **orbit**. This orbit is an ellipse—an oval shape.

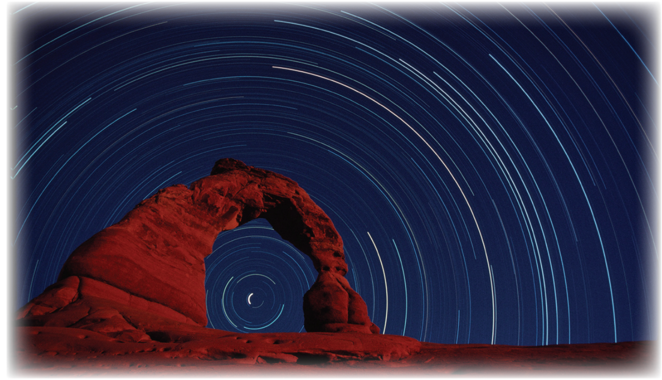
It takes one year for the Earth to revolve around the sun. During this time the Earth rotates on its axis 365¼ times. This means there are 365¼ days in a year. On our calendar it is impossible to have a quarter of a day. We consider each year as having just 365 days, and every fourth year the four quarter days add up to one extra day. We call this a leap year, and the extra day is 29 February.

The Earth's axis is not at right angles to the plane of the Earth's orbit around the sun. (See the diagram below.) The axis is tilted at an angle of 23½° and always points to the same place in space. This point is called the *South Celestial Pole*, and it is near the Southern Cross.

The Earth rotates on its own axis and at the same time revolves around the sun. To give perspective to the diagram below, the Earth's orbit has been drawn as much more of an oval shape than it really is.

On a clear night, go outside and watch the stars by sitting with your head resting on the back of a chair, or by lying on the ground. If you fix your eyes on a star that appears close to some object such as a house, you will soon see that the star either disappears behind the house or appears to move further away from it. It appears that the stars are moving from east to west, like the sun and moon. However, it is the Earth that is rotating—the stars don't move.

The photo top right was taken by pointing a camera towards the South Celestial Pole and leaving

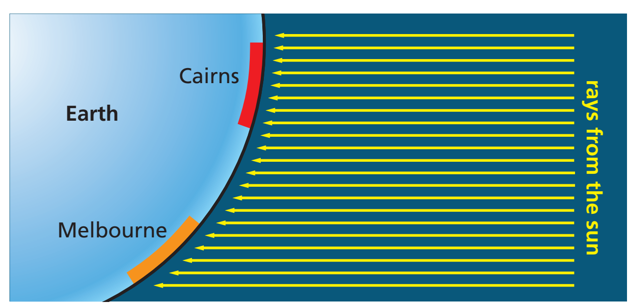


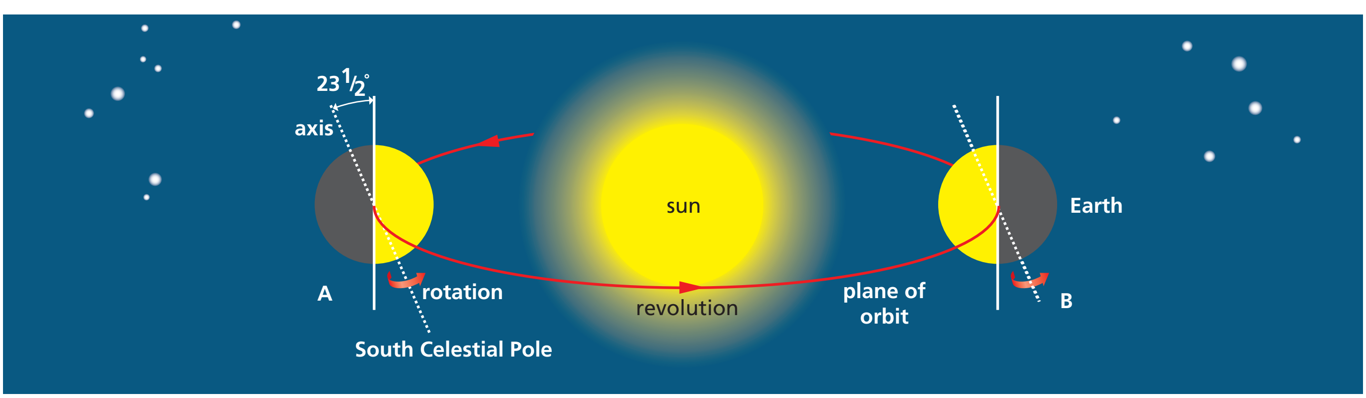
the shutter open for many hours. As the Earth spins on its axis the stars produce circular star trails.

Because the Earth revolves around the sun, our view of the stars changes during the year. Look at the diagram at the bottom of the page. When the Earth is in position A, the stars you see are different from those you see when it is in position B.

Why is Melbourne cooler than Cairns?

The Earth is warmed by heat rays from the sun. Depending on the angle at which the rays hit the Earth, some places are warmer than others. Look at the diagram below. The horizontal lines show heat rays from the sun hitting the curved surface of the Earth. Count the rays that hit each area. From this you can see that the more a surface is tilted away from the sun, the fewer rays hit it and therefore the cooler it is.





INQUIRY 3 Heading by the sun's rays

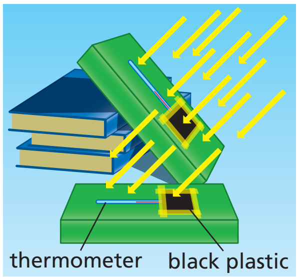
You will need: torch, sheet of paper, about 5 books, 2 thermometers, black plastic, adhesive tape

Part A

1. Shine a torch straight down onto a sheet of paper. Mark the size of the lighted area.
2. Now hold the torch at an angle. Notice that the light spreads over a larger area.

Part B

1. Set up the equipment as shown. Predict which thermometer will get hotter.
2. Wait about 5 minutes and compare the temperatures on the two thermometers.



- What conclusion can you draw from this inquiry?

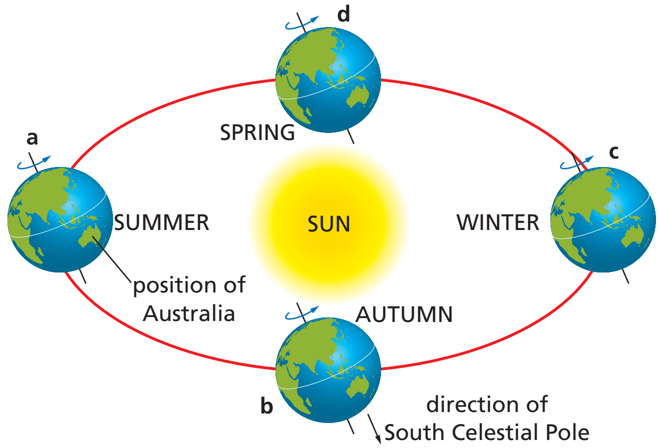
The seasons

Because the cycle of the seasons takes one year, you might guess that the annual revolution of the Earth around the sun is the cause of the seasons. This is true, however, only because the Earth's axis is tilted in relation to the Earth's orbit and always points to the South Celestial Pole. If the axis wasn't tilted, there would be no seasons.

Look at the diagram top right. With the Earth in position A it is summer in Australia. This is because the Southern Hemisphere is tilted towards the sun. This means that the sun's rays hit the Earth almost at right angles to the surface, making it warm. More than half of the Southern Hemisphere is in sunlight at any one time. This means that the days are longer than the nights. The longest day is 22 December, and is called the *summer solstice*.

Six months later the Earth is at position C on the other side of its orbit. The tilt of the axis hasn't changed, but in this position the Southern Hemisphere is tilted away from the sun. It is now winter in Australia and the days are shorter than the nights. The shortest day is 21 June, the *winter solstice*. In autumn (B) and spring (D) the days and nights are about the same length.

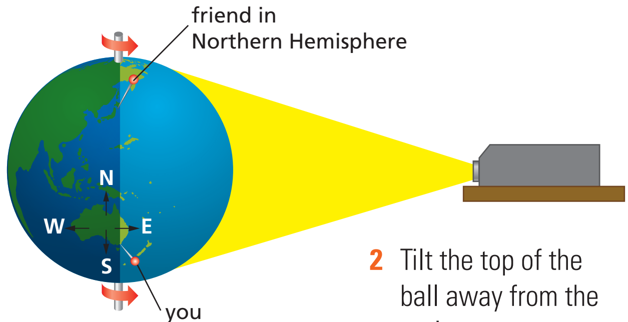
In the Northern Hemisphere the seasons are the opposite of those in the Southern Hemisphere.



INQUIRY 4 The seasons

You will need: polystyrene ball (from Inquiry 2), cooking skewer or knitting needle, projector, 2 pins

1. Hold the ball in the light from the projector with the axis upright. Use a second pin to represent a friend in the Northern Hemisphere. Place the pin so that both pins are on the dark–light line in the sunrise position, as shown.
   - Is the day the same length for both people?



2. Tilt the top of the ball away from the projector.
   - Where does the sun rise first—at your place or at your friend's place?
3. Keeping the ball tilted at the same angle, rotate it to the sunset position.
   - At whose place does the sun set first? Who has the longest day?
   - With the axis tilted like this, is it summer or winter in Australia?
   - Is there anywhere on Earth where the sun doesn't set? Is there anywhere the sun doesn't rise?
   - How would you need to change the positions of the ball and projector to show winter in Australia? (Remember, you can't change the tilt of the ball.)

INQUIRY 5 Comparing planets

Use the planetary data in the following table to answer the questions below.

Planet	Time to orbit sun (Earth years)	Time to spin on axis (h = hours, d = days)	Tilt of axis (degrees)
Mercury	0.2	59 d	0
Venus	0.6	243 d	177
Earth	1	24 h	23½
Mars	1.9	25 h	25
Jupiter	11.9	10 h	3
Saturn	29.5	11 h	27
Uranus	84	17 h	98
Neptune	165	16 h	30

- Which planet takes the longest time to orbit the sun?
- Which planet has the shortest year? How do you know?
- Write a generalisation linking the length of a planet's year to its distance from the sun.
- Which planet has the shortest day?
- On which planet would a day be about the same length as a day on Earth?
- Draw a diagram showing how all the planets are tilted.
- Which planets have seasons similar to those on Earth? Explain your reasoning
- Would there be seasons on Mercury? Explain.
- The axis of one planet is so tilted that it spins on its side. Which one? What would the seasons be like on this planet?

Over to you

1 In which direction does the sun move across the sky? What makes it appear to move this way?

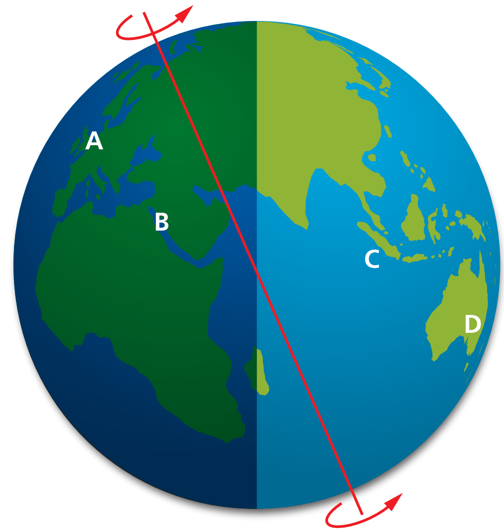
2 Explain in your own words what causes day and night. Use a diagram to help you explain.

3 **a** Use a diagram to explain the difference between the revolution and the rotation of the Earth.

b How long does it take the Earth to complete one *rotation*?

c How long does it take the Earth to complete one *revolution*?

4 Look at the diagram below showing four different places on Earth, marked with the letters A–D.



a Which places are in the Southern Hemisphere? Which are in the Northern Hemisphere?

b In which of these places is it daylight with the Earth in this position?

c In which places is it night?

d Of the places in daylight, which one will have sunset first?

e Of the places where it is night, which will have sunrise first?

f Which places are experiencing summer?

g Which place will have the longest day? The shortest day?

5 People once thought the sun moved around the Earth.

a Why do you think it is possible for people to have this idea?

b How do we know that this idea is wrong?

6 Why is the sunshine stronger in summer than in winter?

7 Places on Earth where the sun doesn't set during summer are called the Land of the Midnight Sun. Where are these places?

8 What would be different in our lives if:

a the Earth rotated in 50 hours

b the Earth took only half as long to complete its orbit around the sun

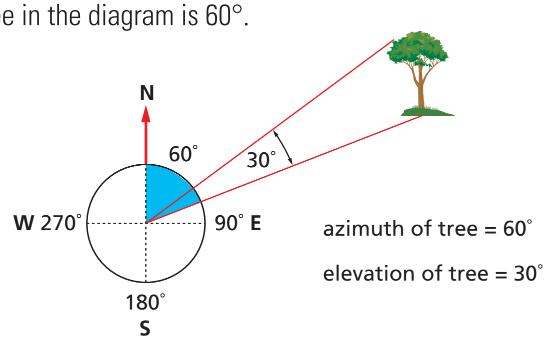
c the Earth's axis was not tilted?

9 What causes the length of daylight to change during the year?

SKILL

Mapping the sky

When you observe the sun, moon and stars you need to be able to describe their position in the sky. To do this you need a compass. Rotate the case of the compass until the pointer is over the letter N (north). You can then find the direction of any object by using the compass markings. The number of degrees clockwise from north is called the *azimuth* (AZ-ee-muth) of the object. So north is 0°, east is 90°, south is 180° and west is 270°. The azimuth of the tree in the diagram is 60°.

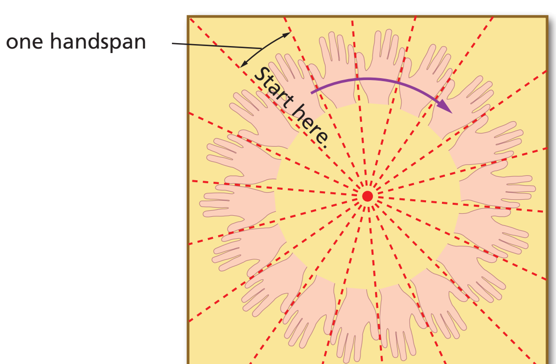


How far an object is above the horizon is called its *elevation*. This is also measured in degrees. For example, the top of the tree above has an elevation of 30°. The elevation can vary from 0° on the horizon to 90° directly above you. The point directly above you is called the *zenith*.

An easy way to measure azimuth and elevation is to use the handspan method. Stretch your arm out straight. Hold your hand flat and stretch out your fingers and thumb. The distance between the tip of the little finger and the thumb is called your handspan. Each person's handspan is slightly different.

Measuring your handspan in degrees

1. Stand in the centre of the room. Line up your thumb with one corner of the room and note where your little finger is pointing.
2. Now move your hand so that the thumb points where the little finger was pointing.



3. Keep going around the room like this until you reach the corner where you started. Count the number of handspans it took to go all the way round the room.
4. Suppose it took 18 handspans to go around the room.

$$\text{Then degrees in handspan} = \frac{360^\circ}{\text{number of handspans}} = \frac{360^\circ}{18} = 20^\circ$$

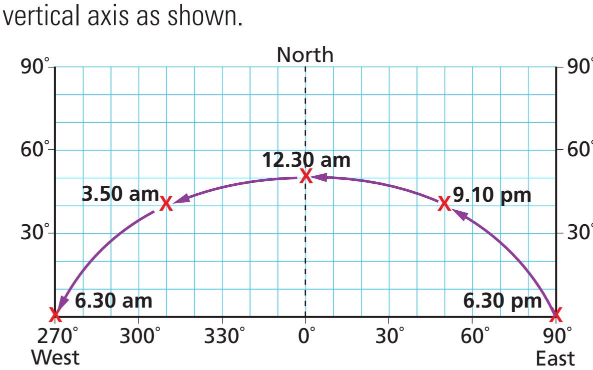
Estimating azimuth and elevation

1. Choose a tall object in the school yard, such as a tree, a pole or the top of a building.
2. Use a compass to find north.
3. Count the number of handspans it takes to go clockwise from north to the tree.
4. Multiply the number of handspans by the number of degrees in your handspan. For example, if the tree is 5 handspans to the right of north and your handspan is 20°, then its azimuth is 100° (just past east). If the tree is to the left of north you need to go all the way round. Or you can subtract from 360°. For example, a 20° handspan left of north would be 340°.
5. Use handspans to find the elevation of the object.

Making a star chart

You can use star charts to map the position of the sun, moon and stars. You can think of the sky as a big dome over your head. On this dome you can map the azimuth and elevation of stars. To record their position, divide the sky into two—the northern and southern halves. Then imagine each half dome flattened out onto a graph. The half dome you see when you look north has 0° in the middle, as shown. The half dome looking south has 180° in the middle.

If the moon rises in the east at 6.30 pm, it has an azimuth of 90 ° and an elevation of 0 °. You can plot its azimuth on the horizontal axis and its elevation on the vertical axis as shown.



12.2 The changing moon

For as long as people have been looking at the sky they have wondered about the moon. What is it? Why does it appear at different times each night? Why does it change its shape? (See the diagram at the bottom of the page.)

Diana the moon goddess

People all around the world made up stories about the moon. For the ancient Romans, Diana the Huntress was the goddess of the moon. She used the crescent moon as a bow and her arrows were moonbeams. The ancient Greeks believed the moon goddess had different faces depending on her moods. The Bushmen of southern Africa told the story of a sun goddess and a moon god. When the sun goddess was angry with the moon god she pierced him with her rays, until his face gradually disappeared. Then a new moon grew. The Arunta Aborigines of central Australia believe the sun is in love with the moon and pursues it across the sky each day.

The cycles of the moon became linked with the cycles of birth, growth and death. The new moon grows to a full moon, then grows thinner and thinner until it disappears. Then after about 30 days it is born again as a new moon.

The word *month* was originally spelt *moonth*, and Monday was *Moon's day*. There is always a full moon at Easter, and the Easter bunny brings eggs, symbolising new life. This relates back to an old tradition when people in the Northern Hemisphere said they could see the outline of a rabbit on the face of the full moon.

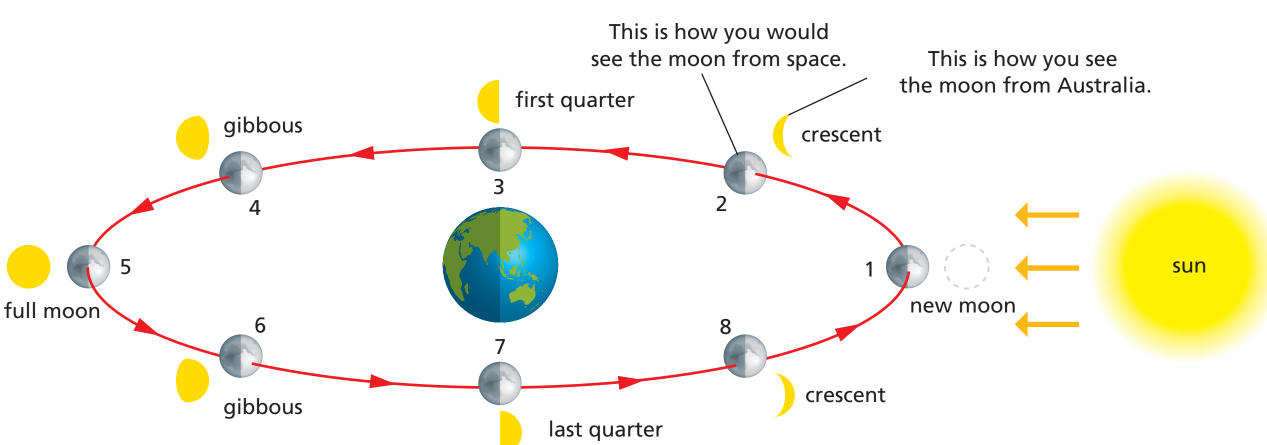
There have always been superstitions about the moon. One was that sleeping in the moonlight would cause you to go insane. The word *lunatic* comes from a Latin word meaning 'moonstruck'.

Phases of the moon

Only one side of the moon is lit by the sun. As the moon orbits the Earth you see varying amounts of this half-lit face. The changing faces you see are called **phases of the moon**.

Look at the diagram below. It shows the phases of the moon as seen in Australia. In position 1 the moon is between the sun and the Earth. Sunlight is shining on the side of the moon facing away from the Earth. In this position almost none of the moon's surface is visible from Earth. This is called the *new moon* and is when the nights are darkest.

As the moon moves to position 2 you see a *crescent moon*. At this stage you can often see the faint outline of the whole moon. As the moon continues in its orbit around the Earth the lit part gets larger. The moon is said to be *waxing*. In position 3, half of the side facing the Earth is lit, so the moon is said to be in its *first quarter*, because we can see only one-quarter of the moon. In position 4 nearly the whole half facing the Earth is lit. The moon in this position is said to be *gibbous*, from a Latin word meaning 'humpbacked'. In position 5, the whole hemisphere is lit and we have a *full moon*. The sun and the moon are now on opposite sides of the Earth. So as the Earth rotates, the sun sets and the full moon rises, and as the sun rises, the full moon sets.



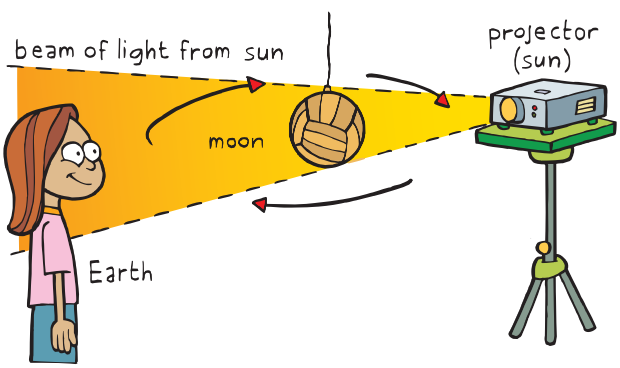
After the full moon, the lit part begins to decrease or *wane*, passing through another gibbous phase (position 6), the *last quarter* (position 7) and finally another crescent phase (position 8). Note that the crescent faces in the opposite direction to the one in position 1.

The whole cycle from one new moon to the next, or from one full moon to the next, takes 29½ days—about a month. Like the sun, the moon rises in the east and sets in the west. It rises about 50 minutes later each night.

INQUIRY 6 Moon phase model

You will need: white ball or blown-up balloon, thread, projector

1. Hang the ball or balloon in a darkened room in front of a projector. The projector represents the sun, the ball is the moon and you are observing from the Earth. Notice that one side of the moon is lit up by the beam of light from the sun.



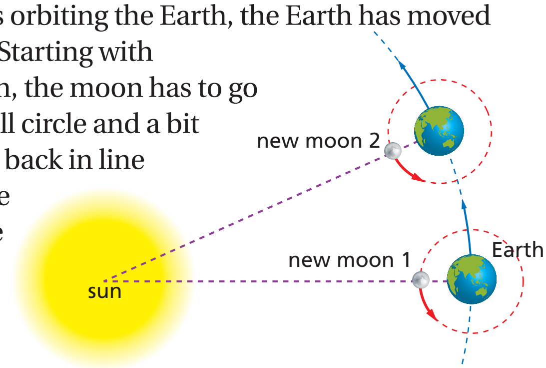
2. Move around the moon in a circle and note how the part that is lit changes shape in a regular pattern.
3. On an overhead projector transparency, draw a diagram to show the relative positions of the sun, moon and Earth when a full moon occurs. Show this to the rest of the class.
4. Draw a diagram to show the positions for a new moon when none of the lit part is visible.
5. Draw a diagram to show the position for a quarter moon when only half the lit part is visible.

Note that in this model the Earth orbits the moon instead of the moon orbiting the Earth, but you still get the same changing moon shapes.

Why we see only one side of the moon

The moon is a *satellite* of the Earth, which means it is held in place by the gravitational force attracting it to the Earth. It rotates on its axis once every 27⅓ days. It also revolves around the Earth every 27⅓ days. As a result it seems that the moon does not rotate because the same side always faces the Earth. The far side of the moon can never be seen from the Earth and is sometimes called the dark side.

This diagram explains why it takes 29½ days rather than 27⅓ days from one new moon to the next. While the moon is orbiting the Earth, the Earth has moved in its orbit. Starting with a new moon, the moon has to go around a full circle and a bit more to get back in line between the sun and the Earth.



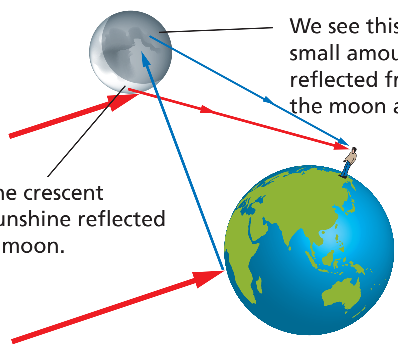
INQUIRY 7 Moon model

You will need: 2 oranges, apples or balls

1. Put one orange on the table. It represents the Earth. Mark the other orange with an **x**. This represents some feature on the moon. Place the moon orange on the table about 20 cm away from the Earth orange, with the **x** facing the Earth.
2. Now slowly move the moon around the Earth, keeping the **x** facing the Earth all the time.
   - Did the Earth see only one side of the moon?
   - Did the moon rotate as it orbited the Earth?
   - How many times did the moon rotate in one orbit of the Earth?
   - How long is a day on the moon?
   - Is it correct to call the far side of the moon the dark side? Imagine you are the sun and use the model to answer this question.

Why the moon shines

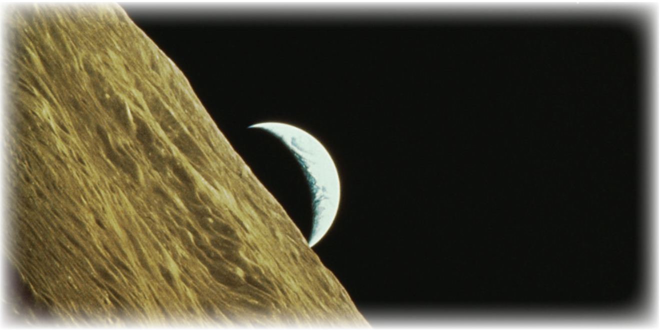
The moon produces no light of its own. It reflects light from the sun so it appears to shine. Just after the new moon, you see only a thin crescent shape due to reflected sunlight, but if you look carefully you can see the faint outline of the rest of the moon, as shown in the photo. This is due to earthshine, where light from the sun is reflected from the Earth to the moon and back to your eyes.



Do the planets show phases?

If you could view the Earth from the moon it would go through phases just like the moon does from Earth. Look at the diagram at the bottom of page 254. Imagine you are on the moon. In position 1 the whole side of the Earth is in sunshine, so you would see a full Earth. In position 5 the lit side is hidden, so you would see a new Earth. Between position 1 and position 5 you would see gibbous, quarter and crescent Earths.

From the Earth, phases of the planets Mercury and Venus can be seen because they are between us and the sun.



The crescent phase of the Earth, taken from the moon by the Apollo *astronauts*

Over to you

1. The shape of the moon changes from day to day. Sometimes it appears as a full round moon, and at other times it is a thin crescent. Why is this?
2. Draw a simple diagram showing how we see the moon by reflected sunlight.
3. Name the following moon phases.

4. Draw diagrams to show the positions of the sun, Earth and moon when the moon is new, in its first quarter, full and in its last quarter.
5. During which phase of the moon is it:
   a between the sun and the Earth
   b on the opposite side of the Earth from the sun?
6. Are these statements true or false? Rewrite the false ones to make them true.
   a The moon revolves around the Earth in 24 hours.
   b The moon produces no light of its own.
   c There is a full moon every 29½ days.
   d During a new moon the sunlit side of the moon faces the Earth.
   e A moon day is the same length as a moon year.
7. Why do you always see the same side of the moon from Earth?
8. **a** In an Arnhem Land Aboriginal creation story the moon is described as getting sick and becoming very thin. Relate this description to the phases of the moon.
   b Write your own story to describe the moon phases.
9. At what time of day does a full moon rise?
10. Record the position of the moon in the sky using azimuth and elevation (see the Skill box on page 253). You could observe it as it rises and moves across the sky. Or you could observe it at the same time each night (or day).

PROBLEM SOLVING

Have you watched the movie *Apollo 13* yet? From what you have learnt in this section, does the movie show the moon correctly? And does it show the Earth correctly from the moon?

12.3 Eclipses

Solar eclipses

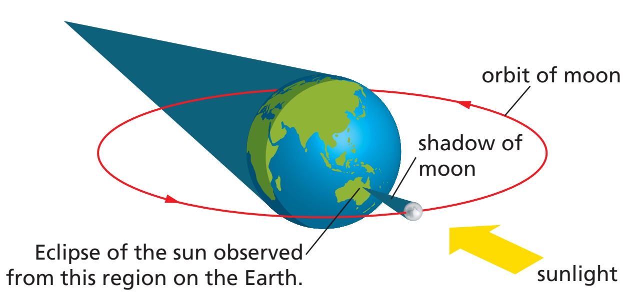
The series of photos above show an eclipse of the sun as it gets smaller and smaller and sometimes disappears altogether. This sight terrified ancient people. In China they thought there was a giant invisible dragon that ate the sun. Whenever there was an eclipse the people would run outside shouting, banging on pots and pans and firing arrows into the sky. They thought this would frighten the dragon and cause it to spit out the sun, which the dragon always did.

We now know what causes a **solar eclipse**. The moon blocks the light from the sun and casts a shadow in space. At the time of the new moon, the moon is between the sun and the Earth. Normally the moon's shadow misses the Earth, but sometimes it touches it as shown below. This causes an eclipse of the sun in this part of the world. The sun is blocked by the moon, and it appears black. If the moon blocks out the whole of the sun a *total eclipse* occurs. If the moon blocks out only part of the sun a *partial eclipse* occurs. Total eclipses are quite rare and can only be seen in certain places. For example, on 14 November 2012, there will be a total solar eclipse in Australia, which will be seen along a path from Kakadu National Park in the Northern Territory to Cairns in north Queensland. The eclipse will last about 2 minutes. Keen astronomers and photographers travel the world to catch rare glimpses of total solar eclipses.

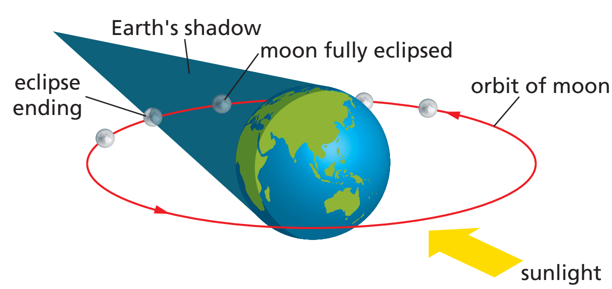
Lunar eclipses

In the year 1504 Christopher Columbus was forced to land in Jamaica in the West Indies. He soon ran out of food and the native people wouldn't give him any. Columbus was interested in astronomy and knew that in a few days there would be an eclipse of the moon. On the day of the eclipse he warned the natives that God would take away the moon if they didn't bring him food. When the eclipse began the natives became frightened. They agreed to give Columbus food if he could make the moon shine again. This he did when the eclipse was over.

At the time of the full moon, the Earth is between the sun and the moon. When this happens the Earth's shadow sometimes falls on the moon, causing an eclipse of the moon (a **lunar eclipse**). This doesn't happen every month because the sun, Earth and moon don't usually line up properly. If the entire moon passes through the Earth's shadow a total eclipse occurs. If only part of the moon passes through the Earth's shadow a partial eclipse occurs. As the moon passes through the Earth's shadow the lit part of the moon gets smaller and smaller and darker and darker. However, it doesn't turn black, but a reddish colour. The Earth's shadow is so wide it sometimes takes the moon several hours to pass through it.



A solar eclipse



A lunar eclipse

INQUIRY 8 Eclipse model

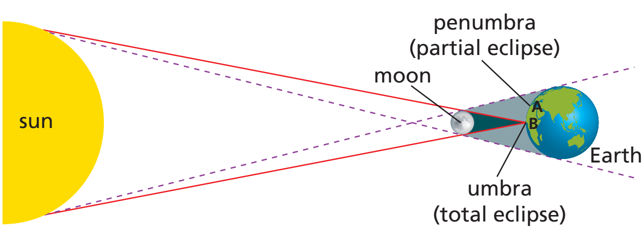
You will need: desk lamp with 100 W frosted bulb to represent the sun, large ball to represent the Earth, small ball to represent the moon

Use the lamp and the two balls to show how solar and lunar eclipses occur.

- Draw diagrams showing the positions of the sun, Earth and moon for a solar eclipse and for a lunar eclipse. What is the phase of the moon in each position?
- Did you notice that the shadow was darker in the centre than on the outside?

Explaining partial and total eclipses

In Inquiry 8 you may have noticed that during an eclipse the shadows on the balls were darker in the centre, and not so dark on the outside. The dark inner part is called the *umbra*, from the Latin word meaning 'shadow'. The lighter part on the outside is called the *penumbra*. *Pen* means 'almost', so the penumbra is the area that is 'almost shadow'.

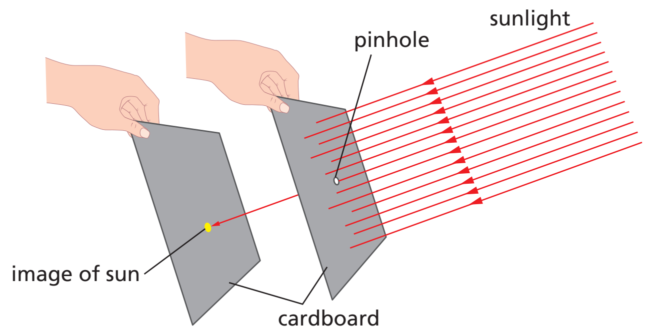


Look at the diagram above. At A, which is in the umbra, the sun is completely blocked, so there is a total eclipse in this part of the world. At B only part of the sun is blocked. Some rays of sunlight get around the edges of the moon into the penumbra, so there is only a partial eclipse in this area.

Astronomers are particularly interested in total solar eclipses because the outer part of the sun, called the *corona*, is visible at this time. The corona is hot gas boiling off the sun and streaming outwards into space. Normally the corona cannot be seen because of the brightness of the sun.

Viewing eclipses

Never look at the sun during a solar eclipse. This could cause permanent eye damage. Sunglasses should not be used either. The safest way to view a solar eclipse is to use two pieces of cardboard, one with a pinhole in it, as shown. It is safe to look at the moon during a lunar eclipse.



Over to you

1 Copy and complete these sentences.
  - **a** During a solar eclipse the shadow made by the ________ falls on the ________. A solar eclipse can occur only during the ________ moon phase.
  - **b** During a lunar eclipse the shadow made by the ________ falls on the ________. A lunar eclipse can occur only during the ________ moon phase.

2 Draw diagrams to show:
  - **a** how a lunar eclipse forms
  - **b** how a solar eclipse forms

3 What is the difference between a total eclipse and a partial eclipse of either the sun or the moon?

4 Look at the series of photos of a solar eclipse at the top of the previous page. How did the ancient Chinese explain this?

5 What is the safe way to observe a solar eclipse?

6 Why don't eclipses occur every month?

7 Jesus Christ was crucified during the Jewish Passover, which takes place at Easter during the full moon. The Bible says 'At noon the whole country was covered with darkness for 3 hours.' Could this darkness have been caused by a solar eclipse? Explain your answer.

8 Play a game of *Real or not*. Go to the library and find a story or legend told by ancient people about what they saw in the sky. Alternatively you can use what you find out to make up your own story. Read the story to the class and they must decide whether it is a real story or whether you made it up.

12.4 Tides

Both the sun and the moon exert a gravitational pulling force on the Earth. The force of the moon is greater, because it is much closer to the Earth. This force pulls the water of the oceans towards the moon, creating a bulge.

Look at the diagram on the right. The moon attracts the water nearest it, producing a high tide at A. The bulge on the opposite side of the Earth at B is caused by the moon pulling the Earth away from the water on that side. The bulges at A and B draw water away from C and D, causing low tides there.

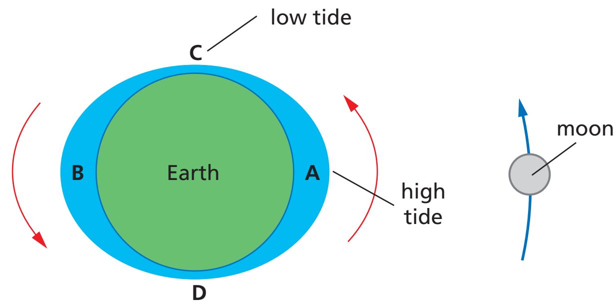
As the Earth rotates, the tidal bulges stay roughly in the same place relative to the moon, because the Earth rotates much faster than the moon revolves. As the Earth rotates, each place on Earth usually passes through two high tides and two low tides each day.

INQUIRY 9 Tide tracks

The tides are very important if you are going fishing or surfing. That is why tide times are given on the news each night.

Use the tide track below to answer these questions.

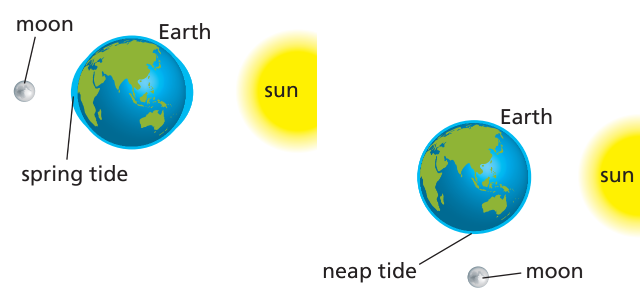
- What do the peaks on the graph represent? What do the troughs represent?
- How many high tides are there each day? How many low tides?
- What time is the high tide Tuesday night? How high is it?
- What is the height difference between the low tide Tuesday afternoon and the high tide Tuesday night?
- What pattern can you see in the times of the high tides over the two days?
- How long does the tide take to come in? How long does it take to go out?



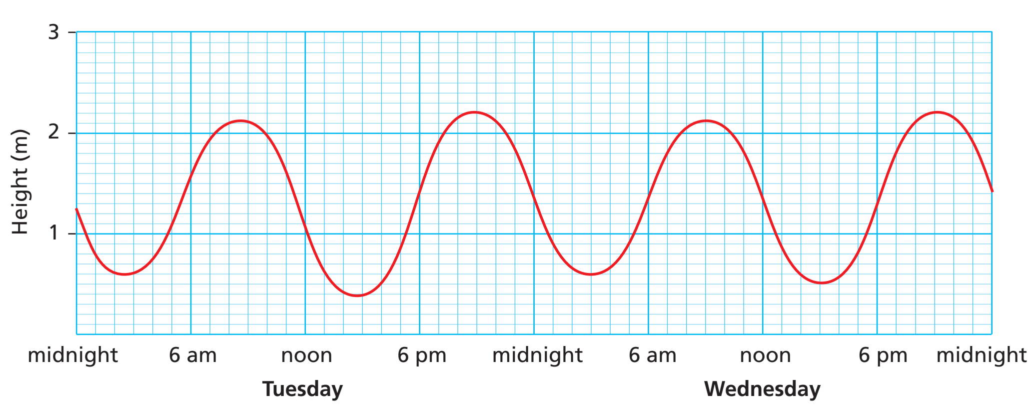
Note: The tidal bulges have been exaggerated.

Larger tides occur when both the sun and moon pull in the same direction. This happens whenever the sun, Earth and moon line up during a full moon or a new moon. These larger tides are called **spring tides**, although it has nothing to do with the seasons. The largest spring tides are called *king tides*.

Between spring tides we have small tides called **neap tides**, where the water doesn't come in as far or go out as far. These tides occur when the sun and moon are at right angles to each other as shown, and pull against each other. This happens at the first quarter and last quarter phases of the moon.



Because the moon is in orbit around the Earth, the Earth does slightly more than one rotation before the second high tide. This takes 24 hours and 50 minutes, so the high tide is about 50 minutes later each day. For the same reason the moon rises 50 minutes later each day.



How the tides vary

In most places there are two high tides each day, with a difference of 1–2 m between high tide and low tide. However, the tides are very complicated and depend on the shape of the coastline and unusual currents. For example, tides around Melbourne are larger than those around Sydney and Brisbane. This is because the water tends to pile up as it is funnelled through Bass Strait. The tides along the north-west coast of Australia can be as high as 10 m. In some places there may be only one tide per day.

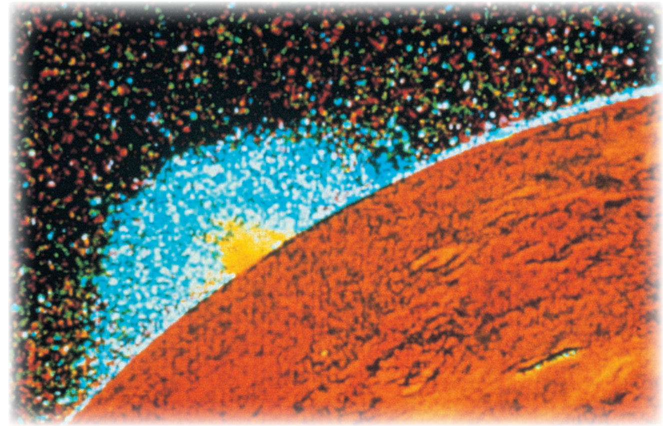
Tidal forces

Gravitational forces exist between all bodies in space. With large bodies close together, like the Earth and the moon, these forces are much larger. They are then called tidal forces. For example, in 1992 a comet almost collided with the planet Jupiter. There were such large tidal forces between Jupiter and the comet that the comet broke into 21 fragments, each of which collided with the planet two years later.

As well as pulling the Earth's oceans up and down, the pull of the moon can also distort the continents, moving the land up and down by as much as 2 cm. These same tidal forces act on the moon, causing it to distort. Scientists infer that these tidal forces cause moonquakes on the moon, but not the earthquakes on Earth.

The tidal bulges on the Earth create friction, which acts like a brake. This has slowed down the Earth's rotation, making our day 16 seconds longer every million years. At the same time the moon is getting further away from Earth. Using a mirror left on the moon by the Apollo missions, scientists have estimated that the Earth–moon distance is increasing by almost 4 cm every year.

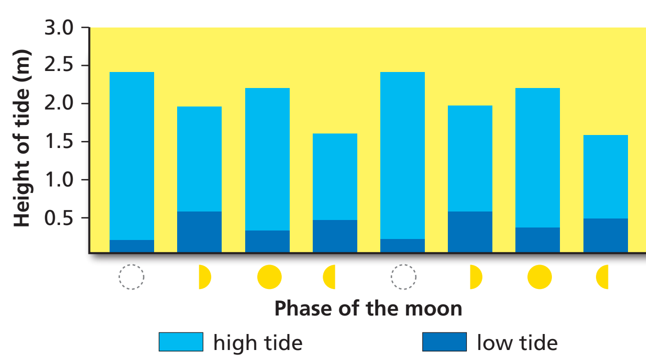
Because Jupiter is so large, there are huge tidal forces between it and its nearest moons. Each time Jupiter's moon, Io, rotates, its surface is pulled up and down and in and out by up to 10 m. Astronomers infer that this motion has heated the interior of this moon, just as a paperclip becomes warm if you bend it back and forth rapidly. This would make Io's interior molten and would explain why the surface is covered in volcanoes. Jupiter's second moon, Europa, is covered with a thick layer of ice with cracks in it. Astronomers have predicted that if tidal forces have caused this ice to melt, there could be extraterrestrial life under the surface of Europa.



Tidal forces between Jupiter and its moon 'Io' may have caused the volcanoes on the surface of Io.

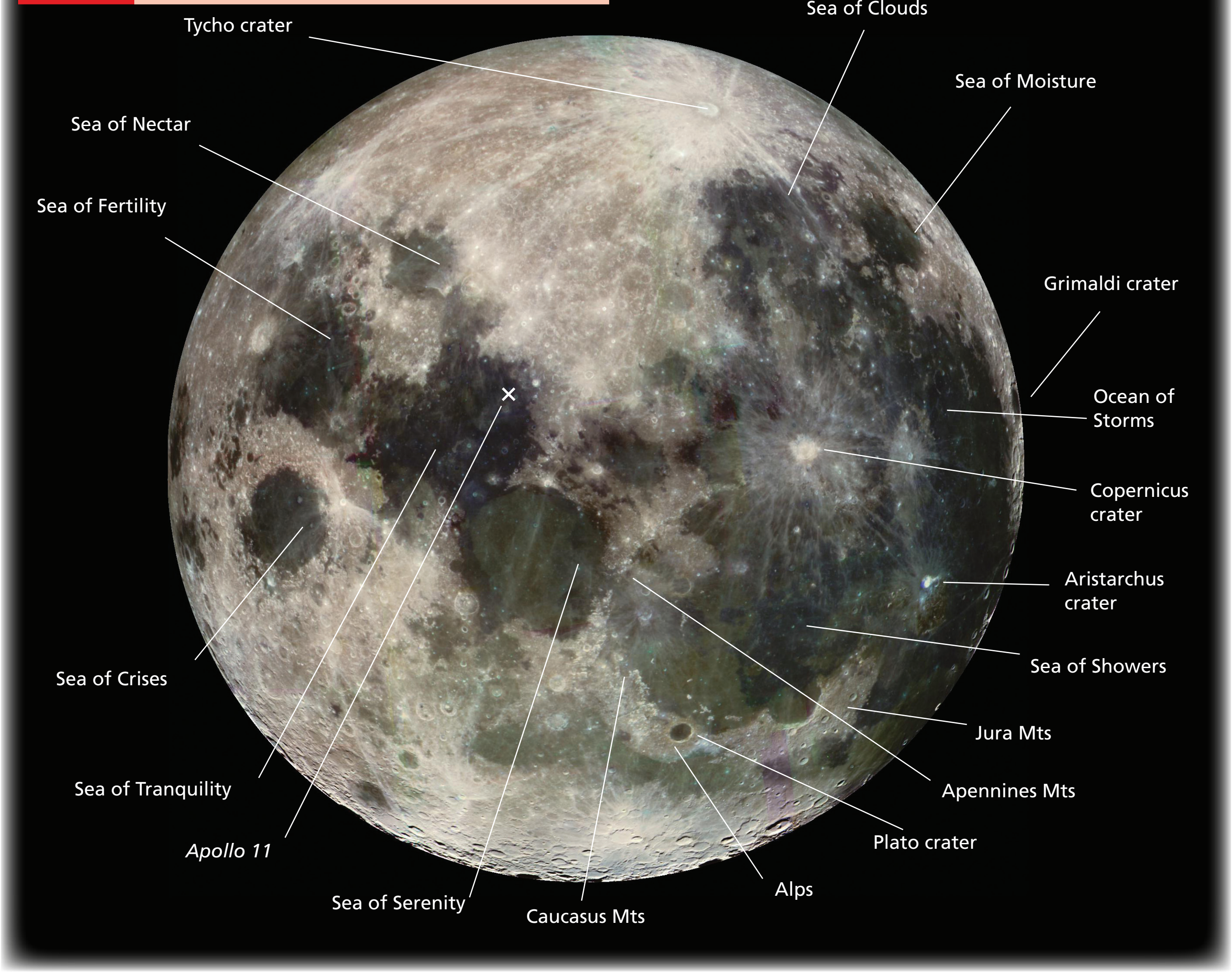
Over to you

1. What do you think the word **hydrosphere** means. Use a dictionary to check if you are correct. How is the hydrosphere affected by the moon?
2. If the sun is bigger than the moon, why doesn't it have a greater influence than the moon on the tides?
3. Why are there usually two high tides and two low tides in a 24-hour period?
4. Draw diagrams to show the relative positions of the sun, moon and Earth to produce:
   - **a** spring tides
   - **b** neap tides
5. Carlos said, 'If the moon's gravitational force causes the tides, then high tides can occur only at night when you see the moon.' Write a paragraph to convince Carlos that he is wrong. You may need to draw diagrams.
6. What does this bar graph tell you about the relationship between the tides and the moon?



7. Why are tides at the end of a long harbour later than at its mouth?
8. If there was no moon would there still be tides? If so, how would they be different?
9. How do tidal forces affect the moon?

12.5 On the moon



INQUIRY 10 *Moon gazing*

1 It is difficult to see the craters and mountains on a full moon because at that time they don't cast shadows. It is better to observe the moon when about half of it is visible. If possible use a pair of binoculars or a small telescope. You can hold the binoculars steady by resting your elbows on something.
- Can you see a 'man in the moon', a rabbit or something else?
- Try to identify the seas (dark areas), mountains and craters marked on the photo above.

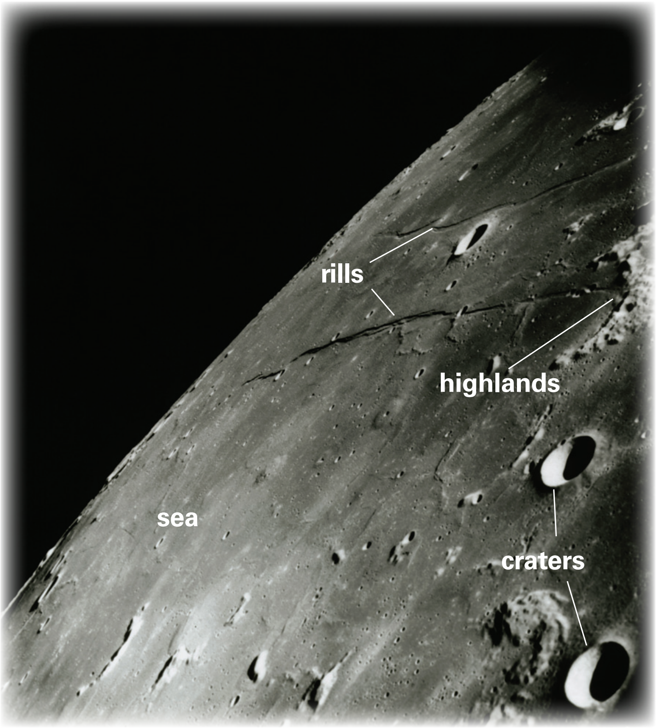
2 Make a rough sketch of what you see and label any features you were able to identify.

The surface of the moon

The moon is much smaller than the Earth—its diameter is about the distance across Australia. We only ever see the near side of the moon. The far side was unknown until it was photographed by the Russian spacecraft *Luna 3* in 1959.

The barren surface of the moon has three main features. First, there are millions of craters ranging in size from a few metres to over 200 km across. They are named after famous astronomers. For example, Tycho, the large crater at the top of the moon, is named after Tycho Brahe, a famous Danish astronomer.

Astronomers infer that most of the *craters* were formed when meteors collided with the moon. On Earth most meteors burn up in the atmosphere before they hit the ground. This is due to the heat produced



by friction between the meteor and the air. However, the moon does not have an atmosphere to protect it from meteors. The near side has fewer craters than the far side, because the Earth gives it some protection. Craters such as Copernicus have bright rays radiating from them. Astronomers infer this is material spattered around when the meteor thudded into the moon.

The large dark rounded areas are called *maria* (MA-ree-a) or seas. The early astronomers who studied the moon thought they were the same as the seas on Earth, but they are not. The Sea of Serenity is about the size of Victoria. The Apollo missions brought back rocks from the moon and many of these are basalt, which is formed from lava. Astronomers infer that the areas we call seas were once huge craters which filled with lava. This may have happened when meteors crashed through the moon's crust, opening up cracks that allowed lava to flow out over the moon's surface. After the lava hardened into rock, smaller meteors crashed into it, forming many smaller craters in its surface.

There are also long narrow valleys called rills. One of these is more than 500 km long. Astronomers are not sure how rills were formed. One theory is that they are cracks partly filled by molten material. Another theory is that they are lava tunnels, like those on Earth, whose roofs have collapsed.

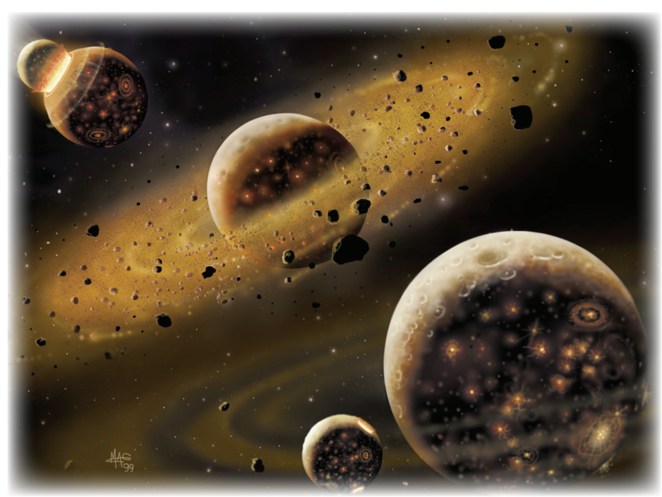
The light areas of the moon's surface are mountains or *highlands*, probably formed by volcanic activity. Some of these are as high as the Himalayas on Earth. The highlands are very old and exactly the same as they were when they were formed. This is because there is no air or liquid water on the moon, so no weathering and erosion can occur.

The whole surface of the moon is covered by a thick layer of broken rock and dust. This too has been produced by meteor collisions. The footprints left by the *Apollo 11* astronauts are still there in the moon dust after more than 30 years, because there is no wind or rain to erase them.

How was the moon formed?

Scientists infer the moon was formed about 4.5 billion years ago, at about the same time as the Earth. This is the age of the oldest rocks so far found on the moon. There have been three theories to explain the formation of the moon. The first theory says the moon was formed at the same time as the Earth when gas and dust clumped together to form the solar system. The second theory says that the moon was somehow split off from the Earth, perhaps pulled out by the tidal force of a passing star. For example, some people have suggested the moon may have come from the area now filled by the Pacific Ocean. The third theory says that the moon was captured by the Earth's gravity.

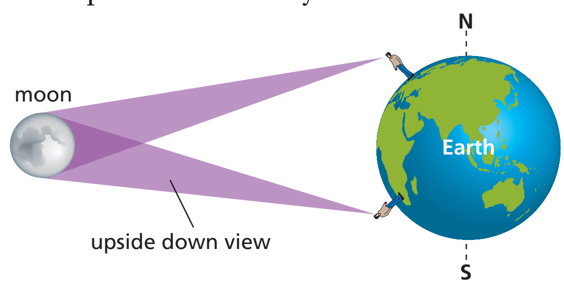
However, as a result of studying the moon rocks, scientists now favour a fourth theory—the 'Big Whack' theory. A Mars-sized body collided with the Earth, throwing huge amounts of debris into orbit around the Earth. Some of this debris eventually came together to form the moon, as shown below.



A Mars-sized body collided with the Earth, throwing huge amounts of debris into orbit. Some of this debris came together to form the moon.

The land down under

The features we see on the moon are upside down compared to what is seen by people in the Northern Hemisphere. It's like standing on your head to look at the moon. The constellations we see are also upside down compared to what they see.



Landing on the moon

The Earth and the moon are both moving in space, so it is not possible to travel in a straight line from one to the other. A rocket first puts a spacecraft into orbit around the Earth. The spacecraft is then boosted onto a path towards the moon. Once it reaches the moon the spacecraft goes into orbit around the moon, and from here a lunar module can be sent to land on the surface. To understand why this complicated path is necessary, try Inquiry 11.

On the moon

Imagine stepping out of a spacecraft onto the surface of the moon. Probably the first thing you notice is the low gravity. You weigh only one-sixth of what you weigh on Earth. Because you are not used to this low gravity you tend to leap off the surface with every step.

The low gravity means there is no atmosphere, so you need a bulky spacesuit with an air supply to breathe. The spacesuit also protects you from harmful UV rays and tiny meteors, as there is no atmosphere to protect you as there is on Earth. There is no air to carry sound, so your suit also contains a radio for communication.

The sky is black, not blue, because there is no atmosphere and therefore no air molecules to scatter light from the sun. The sun is very bright and the shadows are much darker and sharper than on Earth. The stars are visible during the day. There is no wind or clouds and it never rains.

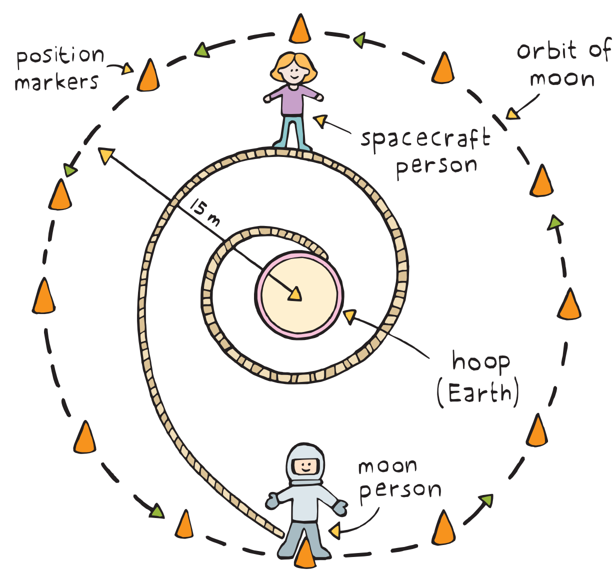
One day on the moon is 27⅓ Earth days, so daylight lasts almost 14 days and so does the night. Due to the long day and the lack of atmosphere, temperatures in the middle of the day reach 100 °C—hot enough to boil water. During the long night temperatures fall to about –150 °C.

Until recently astronomers thought there was no water on the moon, but recent space probes have found large amounts of ice near the poles. This makes it more likely that humans will some day be able to live on the moon.

INQUIRY 11 Moon trip

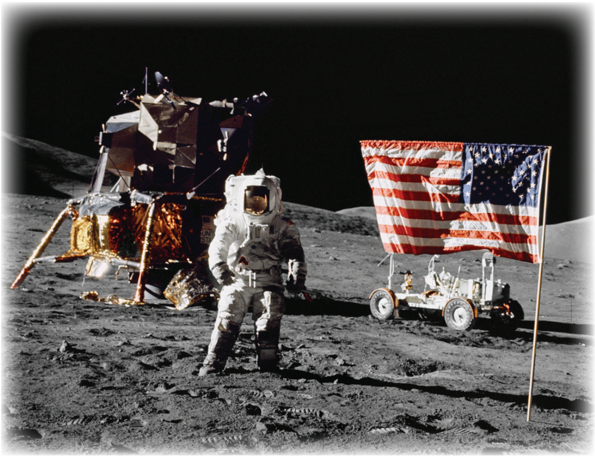
You will need: hoop, long rope (about 2 m), measuring tape, position markers

1. With a partner, use the measuring tape and position markers to mark out a large circle about 15 m in radius. This represents the orbit of the moon around the Earth.
2. Put the hoop in the centre of the circle. It represents the Earth. Place the rope so that it spirals out from the Earth and eventually reaches the moon's orbit. This represents the path of the spacecraft from the Earth to the moon.



3. One person represents the moon by walking at a steady pace around the large circle. A second person is the spacecraft launched from Earth. They walk along the rope at a steady pace to reach the person representing the moon. You will probably need to try this several times until you work out the correct time to launch.
4. Have a third person walk at a steady pace around the hoop to represent a landing site on the Earth. Work out when to launch from the moon so as to land at this spot on the Earth.
   - Why can't you launch a spacecraft in a straight line from the Earth to the moon?

INQUIRY 12 **Moon landing hoax**



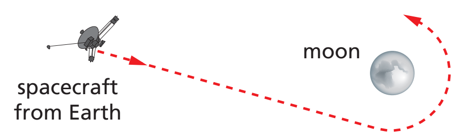
In July 1969, millions of people around the world stopped what they were doing to watch Neil Armstrong take the first steps on the moon, during the *Apollo 11* mission. However, there have been several TV programs that claim that American astronauts did not land on the moon, and that the trip was a hoax. The programs claim that NASA faked the landing in order to win the space race against Russia, and that the video of the landing was made in a movie studio on Earth.

Those supporting the hoax ask 'Why is the flag fluttering when there is no wind on the moon (as in the photograph)?' and 'Why are there no stars in the sky as there should be?' There is an enormous amount of information on the internet—both for and against the hoax. Your job in this activity is to consider this evidence and make up your own mind.

1 Your teacher will place signs in the four corners of the classroom: strongly agree it is a hoax, unsure but think I agree, unsure but think I disagree, strongly disagree. Move to the corner that applies to you.
2 Everyone now has a chance to convince others to swap corners. When everyone has had a chance to speak, the winning corner is the one with the most people in it.

Over to you

1 Why do astronauts need to wear spacesuits on the moon?
2 You can jump much higher on the moon than you can on Earth. Why is this?
3 What are the dark areas you can see on the moon? How were they formed?
4 Name at least six ways in which conditions on the moon are different from those on Earth.
5 What sort of weather would you expect on the moon?
6 Are these statements true or false? Rewrite the false ones to make them true.
   a The moon orbits the Earth in 27⅓ days.
   b On the moon the sky is black.
   c Daylight on the moon lasts almost 14 Earth days.
   d The moon is much younger than the Earth.
   e Gravity on the moon is six times greater than it is on Earth.
   f The far side of the moon is always dark.
7 Daytime on the moon is two Earth weeks long. Why is this?
8 How do scientists now think the moon was formed?
9 Write inferences to explain
   a how the craters on the moon were formed.
   b why there are more craters on the moon than on Earth.
   c why there are more craters in the mountains of the moon than in the maria.
10 If you weigh 60 kg on Earth, what will you weigh on the moon?
11 As a spacecraft nears the moon its path automatically curves as shown. Why do you think this happens?



12 What would be the benefits to us of having a space colony on the moon?
13 Suggest why no life has been found on the moon.
14 The moon is totally silent, even during a moon landing. Why is this? (Think back to Chapter 8.)
15 Draw a diagram that explains why we always see the same side of the moon.

PROBLEM SOLVING

Have you viewed the movie *Apollo 13* and written your list of what is scientifically correct and what is not? Now that you know more about the moon you should find this a little easier to do.

SCIENTISTS AT WORK

The Dish

Have you seen the Australian movie *The Dish*? It tells the story of how the Parkes Radio Telescope in western New South Wales was used to receive the TV images of Neil Armstrong landing on the moon on 21 July 1969 during the *Apollo 11* mission.

The Parkes Radio Telescope is 64 m across—large enough to play cricket on, as they did in the movie. It is used to track radio signals from space and can be rotated and tilted. NASA had three tracking stations to communicate with *Apollo 11*—one in California, one at Honeysuckle Creek outside Canberra, and Parkes. A last minute change of plans meant that NASA was relying on Parkes to receive the TV pictures of the moon landing.

The lunar module from *Apollo 11* landed on the moon at 6.17 am eastern Australian time. The astronauts were scheduled to rest for 10 hours before attempting to walk on the moon, but Armstrong decided to go immediately. This meant that Parkes would not be able to receive the TV signals. The moon hadn't yet risen there and the telescope couldn't 'see' the moon. To make matters worse a storm hit Parkes and 110 km/h winds threatened to damage the telescope. Fortunately it took the astronauts many hours to get ready and at 12.56 pm when Armstrong stepped down the ladder onto the moon's surface, Parkes was ready.

Six hundred million people in 49 countries around the world watched the live coverage of the event on TV. Parkes had the clearest pictures and Australians actually saw them a fraction of a second before anyone else. The live broadcast through Parkes continued for 2½ hours.

Parkes also played an essential role in the recovery of the *Apollo 13* astronauts in 1970 when an explosion in the spacecraft meant they had to survive the return trip to Earth in the lunar module, before re-entering the spacecraft for splashdown. Parkes also helped track the *Voyager II* mission to Uranus and Neptune in 1986–87 and the *Galileo* probe to Jupiter in 1997. The telescope has also been used in the Search for Extraterrestrial Intelligence (SETI).

In 1963 Parkes helped identify the first quasar—a very distant star-like object associated with a very large black hole. The telescope has detected magnetic fields in space and has located more pulsars than any other telescope in the world. Pulsars are extremely dense neutron stars formed by the collapse of large stars. They send out pulses of radio waves that can be detected by the telescope. The Parkes Radio Telescope is still in use today.

Questions

1 What was the plot of the movie *The Dish*?
2 How many people watched the live TV coverage of the moon landing?
3 Besides *Apollo 11*, which other NASA missions has Parkes been involved with?
4 How long ago did Neil Armstrong walk on the moon?
5 What time would it have been in the United States on the east coast when Armstrong walked on the moon?
6 Why couldn't Parkes receive a TV picture until the moon rose?
7 How could the Parkes telescope be used in the search for extraterrestrial life?
8 Why do you think they made a movie about the Parkes Radio Telescope?

THINKING SKILLS ?

1 Why does someone standing at the Earth's equator spin with the Earth faster than someone in Antarctica, even though they don't notice it?

2 Eloise was looking at the stars in the sky during summer and noticed that they were different from those she saw during winter. How can you explain this?

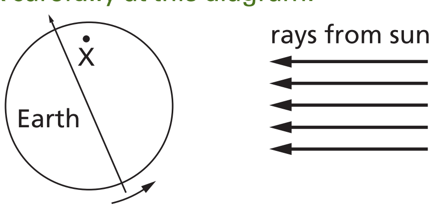
3 In winter the sun is lower in the sky as it crosses the sky than it is in summer. Why is this?

4 **a** Why can't you see much of the moon during a new moon?

b Why do new moons usually occur during the day? (Hint: Use the diagram at the bottom of page 254.)

5 Why don't the stars twinkle when seen from the moon?

6 Look carefully at this diagram.



a What time of day is it at the place marked X? Explain your answer.

b Would X be experiencing summer or winter?

c Copy the diagram and shade in the area of the Earth that would be dark for 24 hours. Explain.

d Shade in the area where there would be a 'midnight sun'.

7 What phase of the Earth would you see from the moon when the Earth experienced:

a a lunar eclipse **b** a solar eclipse?

8 Why is it that lunar eclipses are more common and last longer than solar eclipses?

9 How would the tides be different if:

a there was no moon

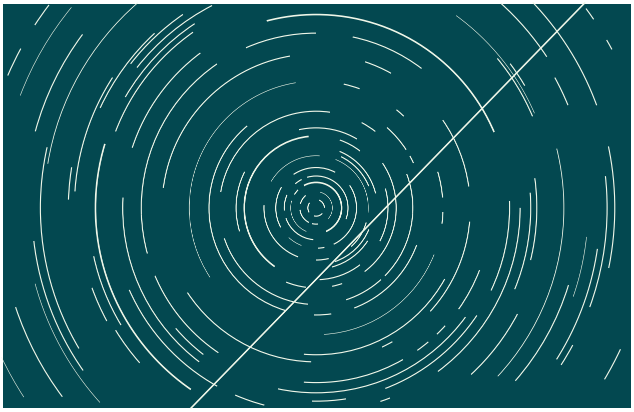
b the Earth had two moons

c the Earth did not rotate? (Assume the moon continues to orbit the Earth.)

10 **a** Research what the saying 'once in a blue moon' means.

b What is a 'blue moon'?

11 The illustration below recreates a photograph that was taken with a camera pointed into the sky with the shutter open.



a What are the curved lines? Explain.

b In which direction was the camera pointed?

c What do you think caused the straight line?

d Estimate how long the shutter was left open.

12 Imagine you see the moon as shown in the diagram.

a In which direction would the sun be?

b Draw a diagram to show where the sun, Earth and moon would have to be for you to see a moon like this.

13 Galileo was the first to observe the moon through a telescope. He said 'All the Earth sees one half of the moon. Only half the moon sees all the Earth.' What do you think he meant when he said this?

14 Does the same side of the moon always face the *sun*? Use a diagram to explain your answer.

15 In a group of 4 people, design a role-play to explain one or more of the following to a group of primary school children.

a day and night

b the revolution of the Earth around the sun and the moon around the Earth

c the phases of the moon

d solar and lunar eclipses

e the seasons

f the tides

You will need three people to represent the sun, Earth and moon, and a fourth person to be the narrator.

Knowing and Understanding

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

1 The Earth rotates upon a tilted ________. Because of this rotation the sun appears to rise and set every day.

2 The Earth revolves around the sun every 365¼ days. This is called a ________. This revolution and the fact that the Earth's axis is tilted causes the ________.

3 Because of the rotation of the Earth the ________ appear to move across the night sky. The ________ of the Earth around the sun explains why we see different stars at different times of the year.

4 The moon does not produce any light of its own, it only reflects the light from the ________. Over a month the moon passes through ________, from a new moon to a full moon and back to a new moon.

5 One complete revolution of the moon takes 27⅓ days. One ________ of the moon occurs in the same time. This is why the moon always keeps the same ________ towards the Earth.

6 An eclipse of the sun (________ eclipse) occurs when the moon casts a ________ on the Earth. An eclipse of the moon (lunar eclipse) occurs when the Earth casts a shadow on the ________.

7 The gravitational pull of the moon (and the sun) causes the oceans on the Earth to bulge, producing ________.

axis
face
moon
phases
revolution
rotation
seasons
shadow
solar
stars
sun
tides
year

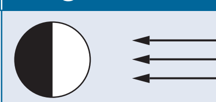
Self-management

Cause and effect

In everyday life and in science there are reasons for things happening. Suppose you are so tired you can't stay awake in class. This is the effect—what you see happening. Perhaps the cause of this is that you were up late doing your homework. In this way you relate the cause (the reason) to the effect.

1 Throughout this chapter there are many examples of cause and effect. Copy the table, leaving plenty of space for the diagrams. Complete the table by adding the missing causes or effects and drawing a diagram to explain the link between the cause and the effect, as shown in the first example in the table.

2 Check through the chapter and write your own cause or effect, different from the ones here. Then ask someone else to complete your example.

	Cause	Effect	Diagram
1	sun shines on only half of Earth at any one time	day and night	
2	moon passes through Earth's shadow		
3		two high tides and two low tides each day	
4		stars appear to move from east to west	
5	moon revolves around Earth in 27⅓ days and rotates on its axis in 27⅓ days		
6		moon seems to disappear at new moon phase	
7		solar eclipse	

Checkpoint

Remember to look at
www.OneStopScience.com.au
for extra resources

1 The dark-coloured parts of the moon's surface are

A craters formed by meteor impacts.

B mountain ranges.

C oceans.

D plains of basalt.

2 The sun and stars appear to move across the sky because

A the Earth's axis is tilted.

B the Earth is rotating on its axis.

C the Earth is orbiting the sun.

D the sun and stars are orbiting the Earth once each day.

3 The planet Mars rotates on its axis in 25 hours. This means that

A seasons on Mars and Earth are about the same.

B a Martian year is about the same length as a year on Earth.

C a Martian day is about the same length as a day on Earth.

D temperatures on Mars are about the same as those on Earth.

4 Which one of the following is *incorrect*? On the moon an astronaut

A would be weightless.

B would need to carry a supply of air to breathe.

C would need protection from heat and cold and UV radiation.

D could not be caught in a thunderstorm.

5 How long does it take for

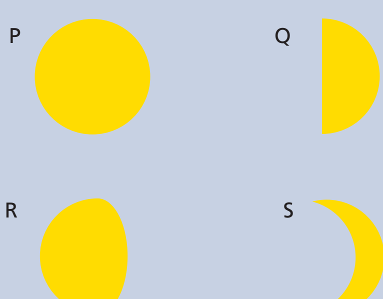
a the Earth to turn on its axis?

b the Earth to orbit the sun?

c the moon to orbit the Earth?

6 **a** Name the four moon phases below.

b Put the four phases in the order we see them, starting with the full moon.



7 Which of the diagrams below show the positions of the sun, Earth and moon for

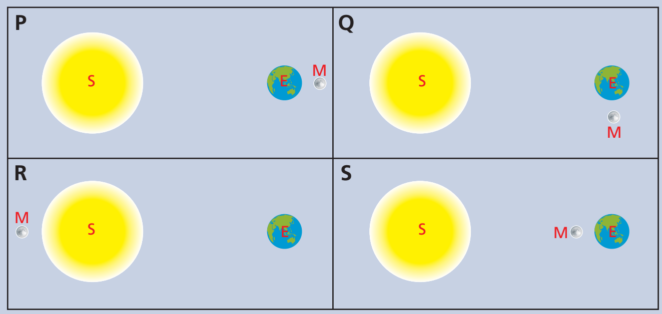
a a full moon?

b a quarter moon?

c a solar eclipse?

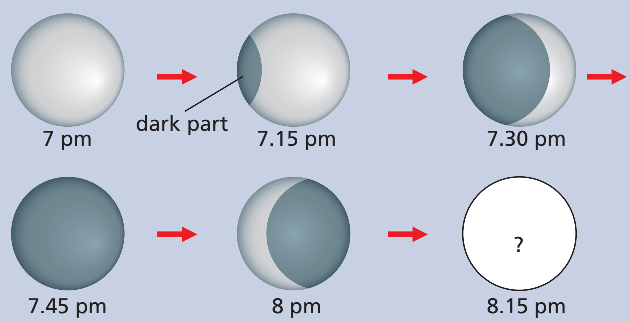
d a lunar eclipse?

You may need to use an alternative more than once.



8 Draw two possible arrangements of the sun, Earth and moon that could cause a spring tide.

9 The drawings show an eclipse of the moon, from 7 pm to 8 pm. Draw what you predict the moon will look like at 8.15 pm.



10 We never see the far side of the moon. Would a person on the far side of the moon ever see the Earth? Explain your answer.

11 Write down how life on Earth would be different in each of the following situations.

a If the Earth did not rotate

b If the Earth did not revolve around the sun

c If the time taken for the Earth to complete one rotation was the same as for one revolution

Explain your answers in each case. There may be more than one effect for each cause.