

# TOPIC 6

## The Earth in space

### 6.1 Overview

Earth is just a tiny speck in a vast universe. It's one of eight planets in the solar system, and the sun is one of more than a billion, billion stars in the universe. But life on Earth is very much controlled by events in our own 'neighbourhood'. The seasons, day and night, the tides and the phases of the moon are the results of Earth's orbit around the sun, the rotation of the Earth and the orbit of the moon around the Earth.



**assesson**

#### 6.1.1 Think about the Earth

- What causes the seasons?
- Why is there more daylight in summer than winter?
- Why does the same side of the moon always face the Earth?
- Which step was 'one giant leap for mankind'?
- What causes the phases of the moon?
- Why do coastal communities experience high and low tides?
- Why are total solar eclipses so rare?
- Which famous scientist was imprisoned for arguing that the planets revolved around the sun?

#### LEARNING SEQUENCE

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## 6.1.2 Your quest

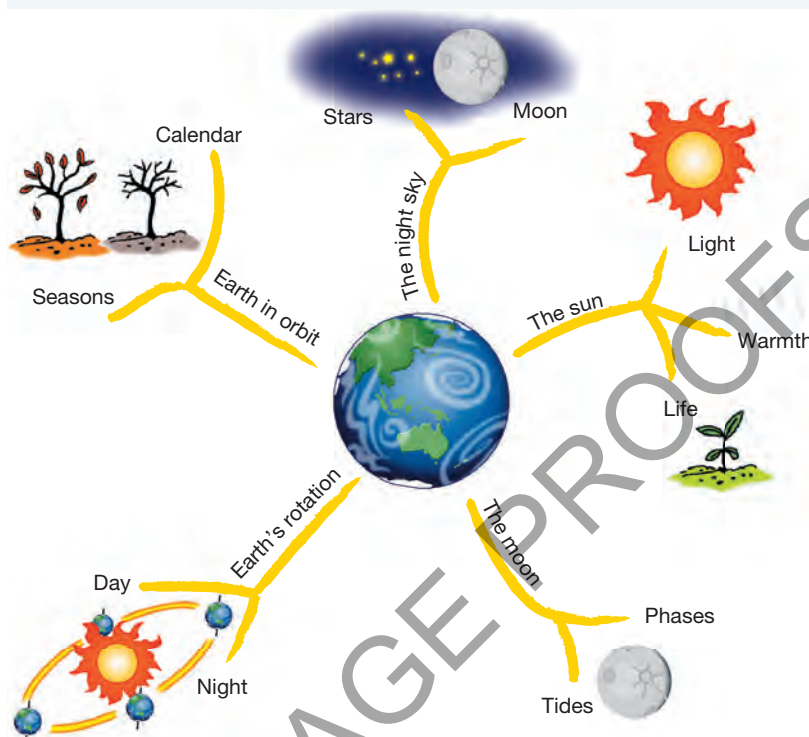
### Earth from space

#### Imagine

In a group of two to four, brainstorm what you know about planet Earth and then draw a mind map to summarise the ideas and information you have collected.

To start your mind map, draw the Earth in the centre of a large sheet of paper. Then use words, pictures and colour to add your own ideas.

An example of a mind map



### INVESTIGATION 6.1

#### Day and night

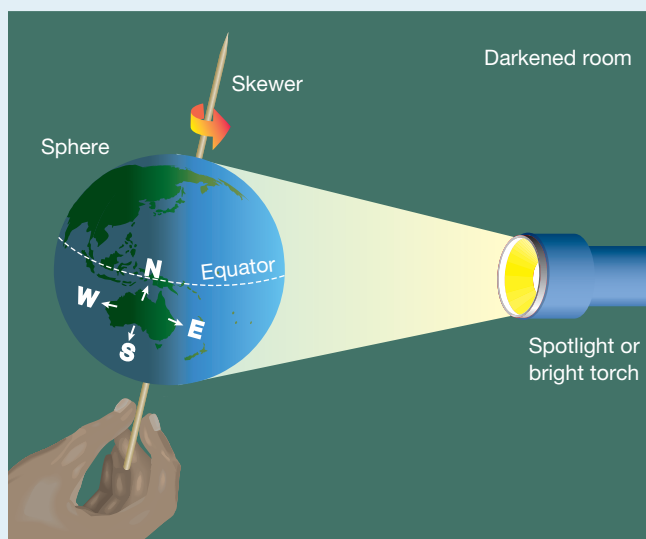
**AIM:** To model the cycle of day and night

#### Materials:

polystyrene (or similar) sphere  
spotlight or bright torch  
skewer

#### Method and results

- Your sphere represents the Earth. Draw a line around the centre to represent the equator. Label the Northern and Southern Hemispheres and mark in the North and South Poles.
- Draw an outline of Australia and Africa on your sphere. Use an atlas to check the positions and approximate shape of each continent. Also note the position of north.
- Mark the four compass directions — north, south, east and west — around the outlines of each continent.
- Gently push a skewer through the centre of your sphere from bottom to top through the 'polar regions'. This represents the Earth's imaginary axis.
- Turn on the spotlight in a darkened room. Its light represents the sun's light. Hold the skewer so it leans a little away from the vertical. This represents the Earth's tilt.
- Turn your sphere very slowly in the light, making sure you keep the skewer slightly tilted all the time. Turn it in an anticlockwise direction (as seen from above). Watch what happens from side on.



### Discuss and explain

1. In which direction is the 'Earth' rotating — from east to west or west to east? Check the compass directions you marked on your sphere.
2. In which direction does the 'sun's' light seem to move around the 'Earth'? How does this explain the apparent movement of the sun across the sky?
3. Where is Africa when Australia is lit up? Where is Australia when Africa is lit up? Explain why these continents experience daylight at different times.
4. How does this model help to explain why night falls in Perth about two hours later than in Sydney and Melbourne?

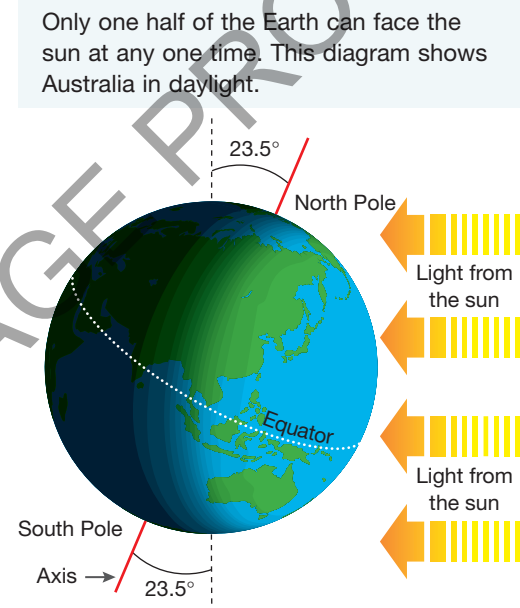
## 6.2 Sunrise, sunset

### 6.2.1 Night and day

Each day, the sun rises in the east, moves across the sky and sets in the west. The ancient Egyptians believed that the sun god Re sailed a boat across the sky each day. The ancient Greeks explained the movement of the sun as the daily journey of the sun god Helios across the sky in a chariot. It is not surprising that early astronomers explained day and night by suggesting that the sun moved around the Earth.

In fact, the sun doesn't move **across** the sky at all. It is the rotation of the Earth that makes it look like the sun is moving. The Earth rotates on its own axis, as do all the other planets.

The Earth's axis is an imaginary straight line between the South Pole and the North Pole. The axis is tilted at an angle of  $23.5^\circ$  from the vertical, as shown below. It takes 24 hours to complete each **rotation**. As the Earth rotates from west to east, the sun appears to move from east to west. At night the moon and planets also appear to move in this direction, seeming to travel from east to west.



### 6.2.2 The sun and the seasons

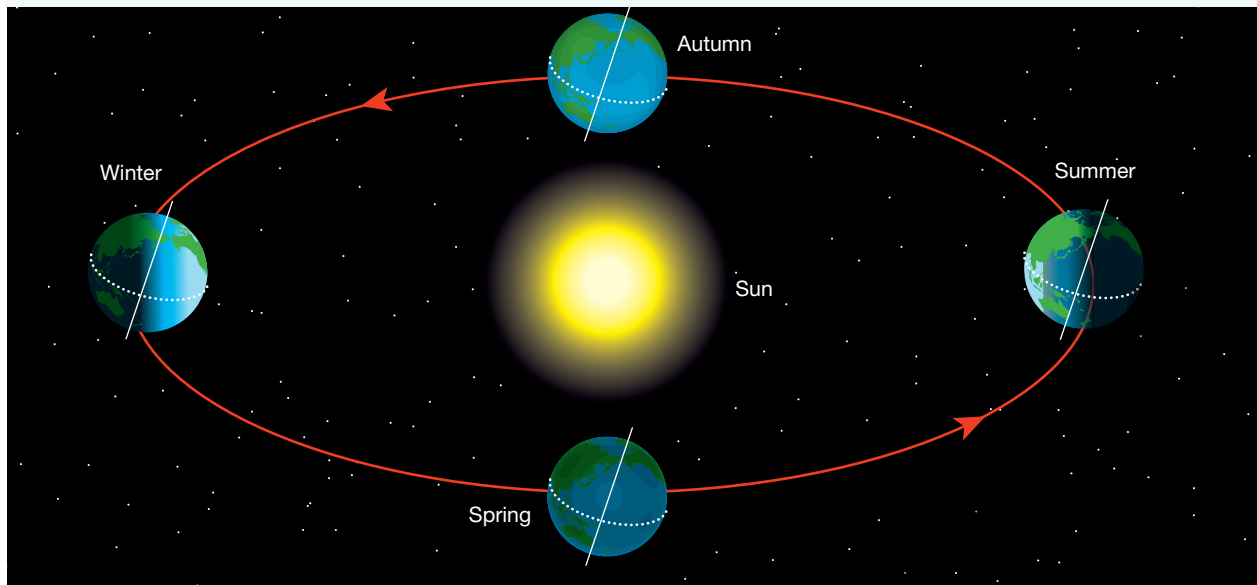
The Earth takes  $365\frac{1}{4}$  days to complete one **revolution** around the sun. This period is called a calendar year. To make the calendar simpler, we make each year 365 days with every fourth year being a leap year, 366 days. Over four years that averages out at  $365\frac{1}{4}$  days.

As the Earth orbits the sun, the tilt of its axis remains the same. The diagram below shows that, for one part of Earth's **orbit**, the Southern Hemisphere is tilted towards the sun. For the other part of the orbit, the Southern Hemisphere is tilted away from the sun. The opposite is true for the Northern Hemisphere.

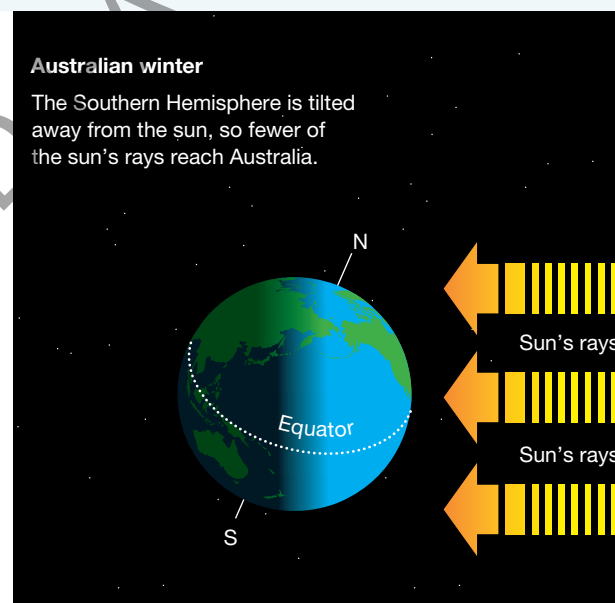
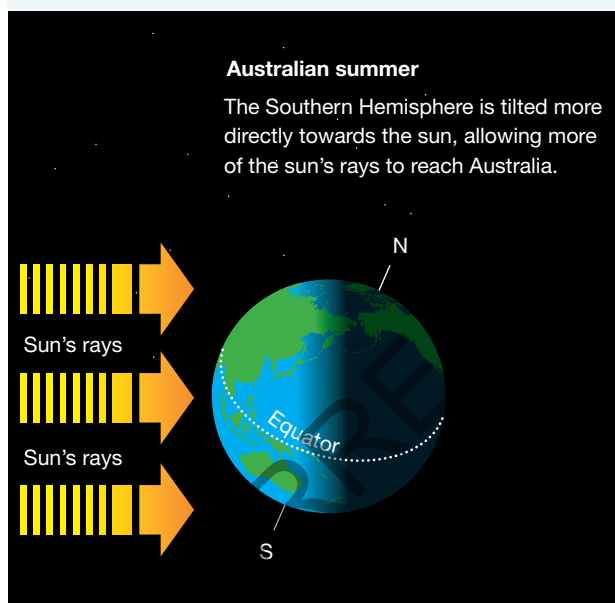
The Southern Hemisphere experiences summer when it is tilted towards the sun. During summer, the South Pole is in constant daylight. At the same time the Northern Hemisphere experiences winter because it is tilted away from the sun. The North Pole is in constant darkness. The Southern Hemisphere experiences winter when it is tilted away from the sun. It's cooler than summer because the sun's energy is spread out over a larger area.

While it's winter in the Southern Hemisphere it's summer in the Northern Hemisphere. Between summer and winter, neither hemisphere is tilted towards the sun. This happens during autumn and spring.

As the Earth orbits the sun, the seasons change. This diagram shows the seasons as they are in the Southern Hemisphere.



The tilt of the Earth's axis and its path around the sun help explain the seasons.



## INVESTIGATION 6.2

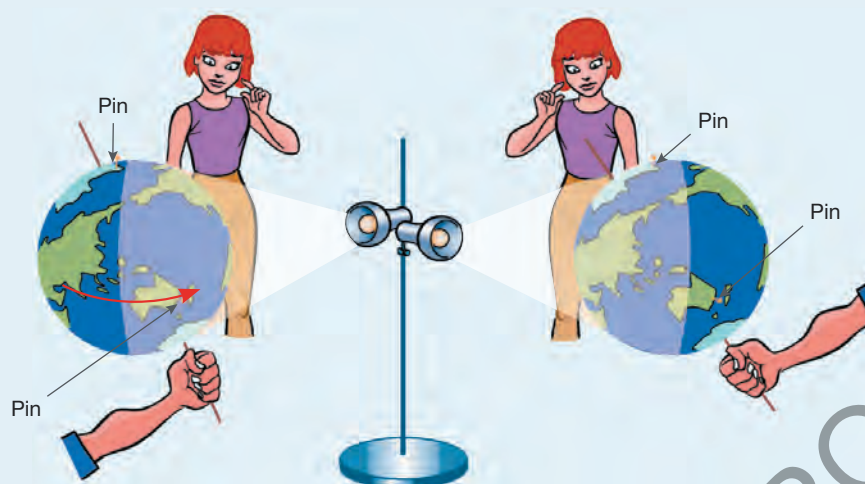
### Long days, short days

**AIM:** To model the cycle of the seasons and explain the variation in daylight hours

**Materials:**

*the equipment used for Investigation 6.1*

*2 pins with coloured heads*



### Method and results

- Hold the skewer vertically. Push two pins into your sphere — one about where Sydney is and the other directly above it at the top of the sphere, near the skewer.
- Set the spotlight up in a central place (such as on a table you can move around). Darken the room.
- Stand to the left of the spotlight. Hold the skewer so it leans to the left from the vertical. The southern half of your sphere should be leaning more towards the light.
- Slowly turn your sphere in the light, making sure you keep the skewer slightly tilted. Turn it in an anticlockwise direction. Watch what happens from side on. Watch the side of the sphere you can see as you turn it. A partner should watch the other side.
- Now stand to the right of the spotlight holding your skewer tilted to the left as before. This time the northern half of your sphere should be leaning more towards the light. Repeat what you did in the previous step.
- Repeat the whole procedure above two more times. The first time, look at what happens at each of the poles. The second time, look at what happens at the equator.

### Discuss and explain

1. Which pin comes into the light first when the southern half of the sphere leans towards the light? Ask your partner which pin moves out of the light first.
2. What does this tell you about the number of daylight hours in each hemisphere when the Southern Hemisphere tilts towards the sun?
3. Which pin comes into the light first when the northern half of the sphere leans towards the light? Ask your partner which pin moves out of the light first.
4. What does this tell you about the number of daylight hours in each hemisphere when the Northern Hemisphere tilts towards the sun?
5. What is the approximate length of day and night at the equator in each season?
6. Suggest why the sun never sets at certain times of year at the North and South Poles. What season is the Southern Hemisphere experiencing when the South Pole has several months of darkness?

## 6.2.3 The longest day of the year

The longest day of the year is called the summer solstice and occurs in late December in Australia. Some people mistakenly think that it occurs because the Earth is closer to the sun; however, that is not true. The seasons are determined not by the distance of the Earth from the sun but by the angle at which the sun's rays strike the Earth. In summer the sun is high in the sky. In winter the sun is low in the sky and rises late in the morning then sets early in the afternoon. Your shadow is at its longest on the shortest day of the year, the winter solstice, at midday. This happens in June.

## WHAT DOES IT MEAN?

The word *solstice* comes from the Latin words *sol*, meaning 'sun', and *sistere*, meaning 'to stand still'.

## HOW ABOUT THAT!

A day on Jupiter is less than 10 hours. This means it takes under 10 hours to complete one rotation. But this giant planet, made mostly of gas, is about 13 000 times bigger than Earth. So when it rotates, its outermost clouds move at close to 45 000 kilometres every hour!



## 6.2 Exercises: Understanding and inquiring

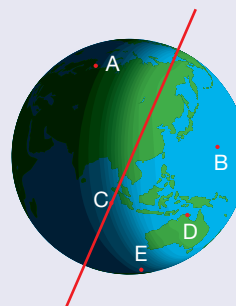
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### Remember

1. Explain the difference between the revolution and rotation of the Earth.
2. How long does it take the Earth to complete one:
  - (a) rotation
  - (b) revolution?
3. Explain why we experience day and night.
4. Why does the sun rise in the east and set in the west?
5. During which season does Australia tilt towards the sun?
6. Explain why it is usually warmer on a summer's day than on a winter's day.
7. Explain why there are 365 days in most years but 366 days in every fourth year.

### Think

8. Explain, with the aid of a diagram, why the South Pole is in darkness during the Southern Hemisphere's winter.
9. Use the diagram below to answer the following questions.
  - (a) Which of the locations A, B, C, D and E:
    - (i) are in daylight
    - (ii) are experiencing summer
    - (iii) are experiencing the longest day
    - (iv) are experiencing the shortest day?
  - (b) In which of the locations that are in daylight will the sun set first?
10. Explain why both the time and position of sunrise and sunset are not the same every day.



### Brainstorm

11. In a small group, brainstorm to compile a list of occupations in which day-to-day work is affected by seasonal changes. Provide a brief description of how each occupation is affected.



### Investigate and think

12. Observe the position of the shadow of a tree trunk or vertical pole from time to time on a sunny day.
- Explain how the shadow moves during the day from sunrise to sunset.
  - How do you think prehistoric people have explained the movement of the shadow?
  - What does the shadow tell you about the sun and the Earth?
  - How would you expect the length of the shadow to change from summer to winter?
  - In ancient times a vertical stick was used as a daylight clock. It was called a sundial. Describe the disadvantages of sundials.

### Investigate

13. Use the internet or other resources to find out when and where the astronomer Al-Battani lived and worked, and what contribution he made to an understanding of the seasons.

## learn on RESOURCES — ONLINE ONLY

 **Try out this interactivity:** Day, night and time zones  
Searchlight ID: int-0006

## 6.3 The moon

### Science as a human endeavour

#### 6.3.1 A face in space

From Earth, the moon is, by far, the brightest object in the night sky. Its presence and changing appearance have raised questions, inspired myths and legends, shaped our calendar and even determined the dates of some religious holidays.

The moon takes the same time to complete one full turn about its own axis as it takes to orbit the Earth. For this reason only one face of the moon can be seen from the Earth. The face seen from Earth is much less mountainous and rugged than the other side. Because the moon wobbles a little during its orbit around Earth, we sometimes get a view of the edges of the far side. However, 41 per cent of the moon's surface is never visible from the Earth.

Unlike the Earth, the moon has no atmosphere. There is no air. There is no sign of water on the surface. There is no wind and no rain. This means that there is no erosion.

#### 6.3.2 Getting to know the moon

From the time of the invention of the first telescope in 1608, it was possible to see some detail in the features of the moon's surface. In 1609, Galileo Galilei used his homemade telescope to study the moon, planets and stars.

While observing the moon's surface, Galileo observed:

- large, dark and flat areas that he called maria (Latin for seas)
- dark shadows that appeared to be made by mountains up to 6 kilometres high
- numerous craters.

Each of these features can be seen in the photograph at right.



Until 1959, when the first television pictures were transmitted from space, our knowledge of the moon depended on what could be seen through telescopes from Earth. The table below lists some of the important events that have occurred in the quest for knowledge about the moon.

The most significant event since Galileo's use of a telescope in 1610 to observe the moon occurred on 20 July 1969. On that day, astronaut Neil Armstrong stepped down from the lunar landing craft *Eagle*, and as his foot touched the lunar soil he uttered the words: 'That's one small step for a man, one giant leap for mankind'.

Indian, Russian, Chinese and USA space agencies are all planning further missions to explore the moon during the next decade. There are also some private companies planning missions.

### PROFILE OF THE MOON

- Natural satellite of the Earth
- Distance from Earth: 385 000 km (three days by spacecraft)
- Diameter at equator: 3475 km (Earth's diameter is 12 750 km)
- Period of orbit around Earth: about 29½ days
- Period of rotation about its own axis: about 29½ days
- Surface gravity: about one-sixth that of Earth
- Surface temperature: ranges from -175 °C in darkness to 125 °C in sunlight

The lunar rover *Yutu* (also known as Jade Rabbit) exploring the moon's surface in December 2013



### INVESTIGATION 6.3

#### Observing the moon's surface from Earth

**AIM:** To observe the moon's surface using a telescope or binoculars

**Materials:**

*binoculars or small telescope*

#### Method and results

- Observe the moon with a pair of binoculars or a small telescope. The best time to observe the moon is when about half of it is visible. Craters and mountains are difficult to see when there is a full moon because they do not cast shadows.
- Try to identify the seas (dark, smooth areas), mountainous areas and craters.

1. Sketch and label what you see.

#### Discuss and explain

2. Which features were easiest to locate?
3. How do you think the craters were formed?

Probing the moon: some important events

Year	Event
1609	Galileo Galilei used a telescope to observe the moon.
1850s	Astronomers took the first photographs of features of the moon.
1959	<i>Luna 2</i> (USSR) became the first space probe to reach the moon when it crashed into the surface.
1964	Space probe <i>Ranger 7</i> (USA) took the first close-up pictures of the moon.

(continued)



Year	Event
1966	<i>Luna 9</i> (USSR) became the first space probe to make a soft landing on the moon and take pictures from the surface.
1969	<i>Apollo 11</i> (USA) carried three astronauts to and from the moon. Astronauts Neil Armstrong and Buzz Aldrin became the first humans to walk on the moon. They spent three hours collecting soil and rocks, performing experiments and setting up equipment for further experiments.
1969–1972	Apollo missions 12 and 14–17 (USA) successfully reached the moon, enabling more experiments to be completed. <i>Apollo 13</i> failed, stranding the three astronauts in space. The movie <i>Apollo 13</i> shows how the astronauts were able to return safely to Earth by using the fuel and oxygen stored in their lunar lander.
2008	<i>Chandrayaan-1</i> (India) discovered evidence of water and a large cave beneath the surface that could provide a location for human settlement on the moon.
2013	<i>Chang'e 3</i> (China) landed with a six-wheeled lunar rover, called <i>Yutu</i> , with a mission to explore 3 square kilometres of the lunar surface. It used cameras and scientific instruments to send data back to Earth.

## 6.3 Exercises: Understanding and inquiring

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### Remember

1. Why does the same side of the moon always face the Earth?
2. Why is there no erosion on the moon?
3. What are the large, dark, flat areas on the moon that are visible from Earth?

### Think

4. How would you expect the mountains on the moon to be different from those on Earth?
5. As Neil Armstrong stepped down from the lunar landing craft onto the lunar soil, his now-famous words were heard by the millions of people watching the event live on television. Why do you think that this step was such a 'giant leap for mankind'?

### Imagine

6. It is likely that, in the not-too-distant future, people will be living and working on the moon for long periods. Before that happens, a lot of scientific investigations need to be carried out. The lack of gravity, fresh food, water and oxygen are just a few problems that need to be solved. Make a list of the types of scientist that need to be involved and what they would need to investigate to ensure that people could maintain healthy lives.

## 6.4 Systems: Phases of the moon

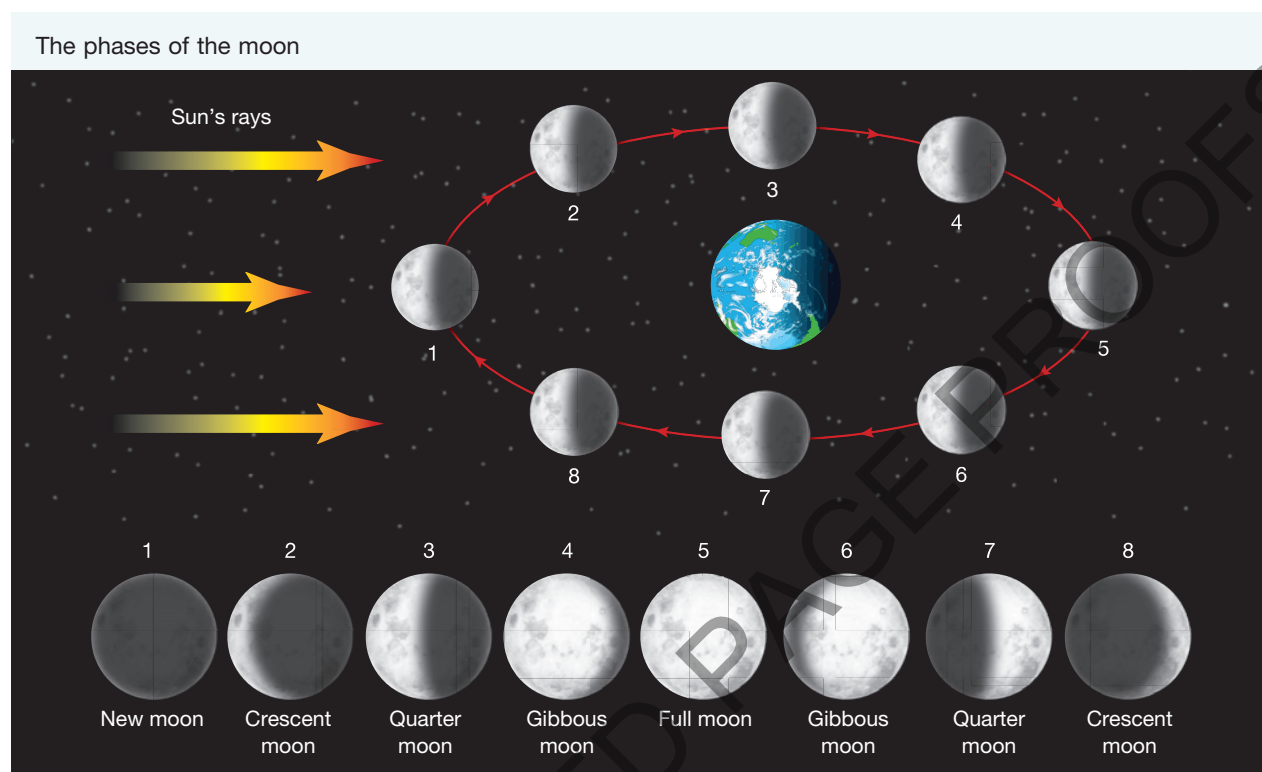
### 6.4.1 Phases of the moon

The moon is visible from Earth only because it reflects light from the sun.

As the moon orbits the Earth, it turns so that the same side of the moon always faces the Earth. At night, when you are in darkness, this side of the moon is sometimes completely bathed in sunlight. You then see a **full moon**. When the moon is between the sun and the Earth, its near side is facing away from the sun and in complete darkness. You are then unable to see the moon. When the near side of the moon is partially bathed in sunlight and partially in shadow, you see only the part that is in sunlight. The different shapes of the moon that you see from Earth are called **phases**. The diagram on the next page shows how the phases change during the 29½-day period between one new moon and the next. The view of the moon from Australia at each of the numbered positions is shown at the bottom of the diagram. The actual appearance

of the moon varies a little depending on where exactly in Australia you are. The closer you are to the equator, the more the phases will be like the ones in the diagrams.

During the period between a new moon and a full moon, the moon is said to be **waxing**. As the phases change between the full moon and the new moon, it is said to be **waning**.



## INVESTIGATION 6.4

### The changing moon

**AIM:** To observe and explain the phases of the moon

#### Method and results

- Copy the start of the table below into your workbook.
  - Observe the moon every third or fourth evening over a period of at least two weeks. Observations over one whole month would be best. Try to make your observations as close to sunset as possible so that you know where the sun is.
1. Record the date, the time and the shape of the sunlit part of the moon in your table.

#### Discuss and explain

2. Each time you make an observation, make a comment about the position of the sun and suggest why the moon has the shape that you have observed.

Observing the phases of the moon

Date	Time	Shape of moon	Comment about the position of the sun and the shape of the moon

## INVESTIGATION 6.5

### Modelling the phases of the moon

**AIM:** To model the phases of the moon

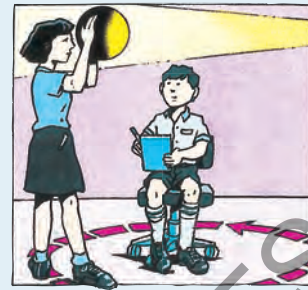
**Materials:**

projector

large, light-coloured ball

**Method and results**

- Select one student to act as the Earth and another to hold the ball representing the moon.
  - Darken the room and aim the projector (the sun) at the ball (the moon). The student holding it walks around the 'Earth' slowly in an anticlockwise direction, holding the same side towards the 'Earth'.
  - Try to identify each of the eight phases of the moon, as they are seen by the person representing the Earth. Stop rotating briefly when each of the phases is identified so that the positions of the 'sun', 'Earth' and 'moon' can be recorded.
1. Draw a diagram to show the positions of the 'sun', 'Earth' and 'moon' that result in:
    - (a) a full moon
    - (b) a gibbous moon
    - (c) a quarter moon
    - (d) a crescent moon
    - (e) a new moon.
  2. Describe the positions of the sun, Earth and moon when there is:
    - (a) a full moon
    - (b) a new moon.



## WHAT DOES IT MEAN?

The word *month* comes from the Old English word *mona*, meaning 'moon'. In early calendars, a month was the length of time between full moons. This period is called a lunar month. The modern calendar was not worked out until the sixteenth century by Pope Gregory XIII. The Islamic, Hebrew and Chinese calendars are still based on the lunar month.

## 6.4 Exercises: Understanding and inquiring

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### Remember

1. 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?
2. What is a lunar month?

### Think

3. Explain, with the aid of a diagram, how a quarter moon occurs.
4. Why is the phase in which half the moon is visible called a quarter moon?
5. Sometimes the moon is visible during the day.
  - (a) What phases of the moon would you be most likely to see during the day?
  - (b) Would it be possible to see a full moon during daylight hours? Explain your answer.

### Create

6. Draw a large poster to show how the phases of the moon occur.

### Investigate

7. What is a harvest moon?
8. The moon has been the subject of many poems and songs. As a class, see how many songs you can list with the word 'moon' in the title. Many of them are quite old, so you might need to ask music-minded adults for some help.

## 6.5 A lunar attraction

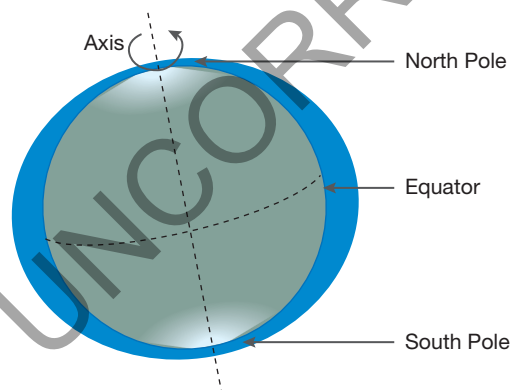
### 6.5.1 Changing tides

If you have lived near or visited coastal areas, you will know that the level of the water rises and falls. These changes in the water level are called **tides**.

Because the Earth rotates on its axis, the oceans bulge near the equator. This bulge is shown in the diagram below. This effect is just like that in the spin-dryer of a washing machine. As it spins, the water is flung towards the outside.

The oceans are not flung completely off the Earth because they are pulled back by the Earth's gravity. The size of the bulge would always be the same if it were not for the sun and the moon.

The rotation of the Earth would cause a permanent bulge all the way around the equator if it were not for the sun and the moon.

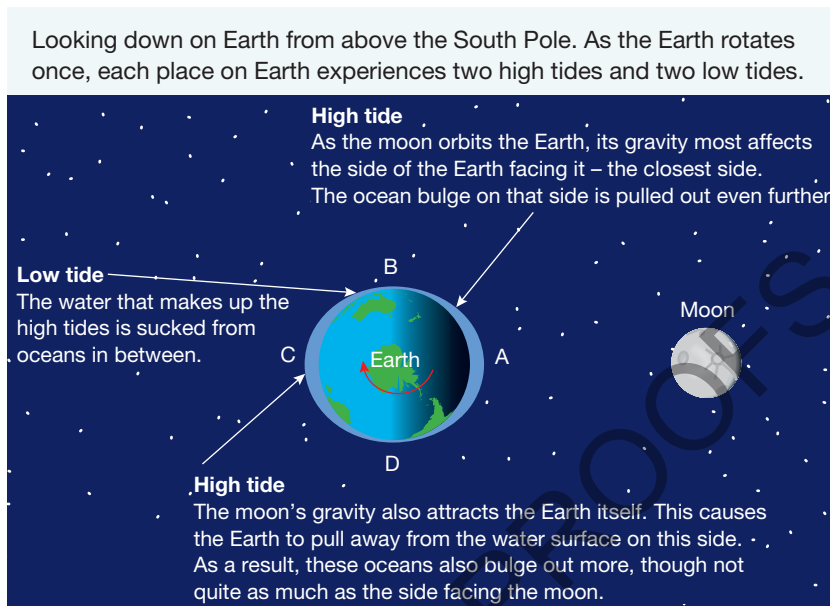


High and low tides at Lorne, Victoria. Between these two tides the water level rose vertically by 2.6 m, but stretched horizontally much further along the beach.



## 6.5.2 Tides and the moon

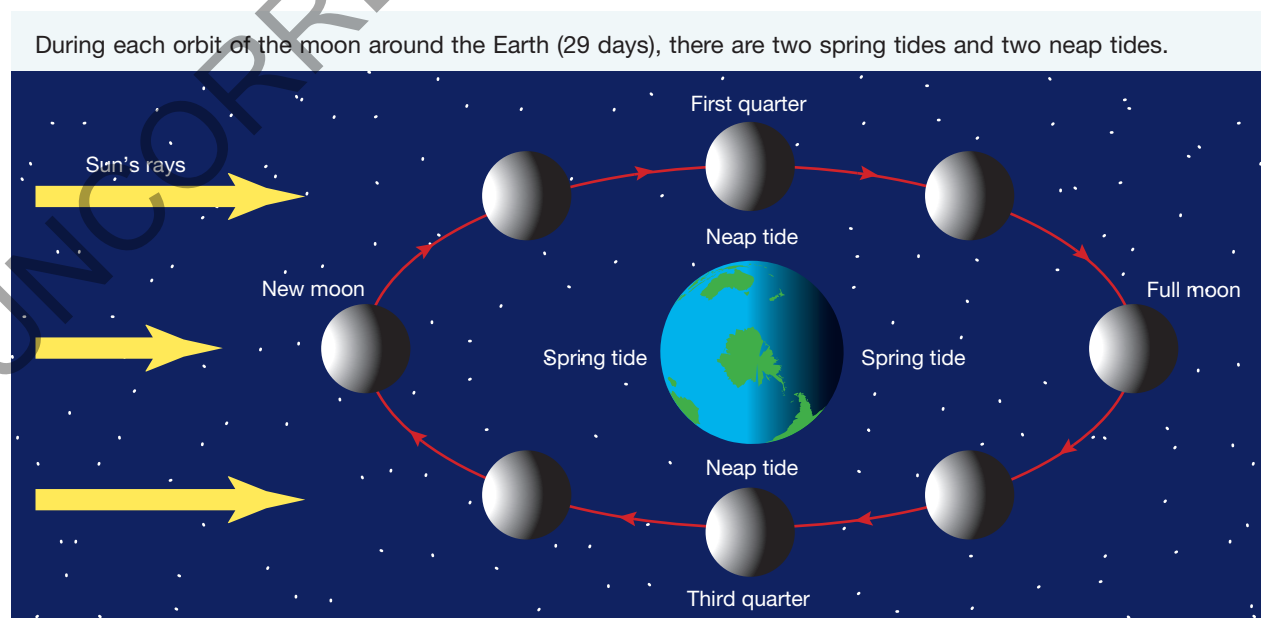
Tides are mostly caused by the gravitational pull of the moon. The diagram at right shows a view of the Earth from above the South Pole. The arrow shows the direction of the Earth's rotation. The oceans at A, closest to the moon, are pulled more strongly towards it, taking water away from B and D. The oceans at C, furthest from the moon, are pulled less strongly than the rest of the Earth. The result is that A and C are regions of high tide while B and D are regions of low tide. As the Earth rotates, different places on Earth experience high and low tides. During one day, each place on the Earth experiences two high tides and two low tides.



## 6.5.3 The effect of the sun

The sun also influences the tides. However, because it is further away, its gravity has much less effect than the moon's. Even though the mass of the moon is 27 million times less than that of the sun, its gravitational pull on the Earth is greater because it is so much closer to Earth. When the sun is on the same side of the Earth as the moon, or on the opposite side, higher tides than normal are experienced. These tides are called **spring tides**. They occur when there is a full moon or a new moon.

About seven days after a spring tide, the sun and the moon are no longer in the same line as the Earth. The gravitational pull of the sun is at right angles to the gravitational pull of the moon. The pull on the oceans of the sun and the moon are working against each other. The high tides are not as high as usual. The low tides are not as low as usual. These 'weaker' tides are called **neap tides**.





## 6.5 Exercises: Understanding and inquiring

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### Remember

1. What is the major cause of tides on Earth?
2. Why are there two high tides and two low tides in a day?
3. Even though the sun is much larger than the moon, it has much less effect on the tides. Why?

### Think

4. Explain why the highest tides occur during a new moon or a full moon.
5. If the moon did not exist, would there still be tides? If so, how would they be different?
6. How would the tides be different if the Earth did not rotate? Explain your answer with diagrams showing the Earth, sun and moon.
7. On any given day, one high tide is higher than the other one. Suggest a reason for this.

### Draw

8. Draw a diagram that shows one arrangement of the sun, moon and Earth that would cause a neap tide on the side of the Earth closest to the sun.

### Create

9. Design and act out a role-play that shows how the orbits of the Earth around the sun and the moon around the Earth cause tides. The role-play should involve at least four people, including a narrator to provide a commentary.

## learnON RESOURCES — ONLINE ONLY

- ✦ **Try out this interactivity:** Tides  
Searchlight ID: int-0225
- ✦ **Complete this digital doc:** Worksheet 6.2: Surf's up  
Searchlight ID: doc-19836

## 6.6 Lunar and solar eclipses

### 6.6.1 Lunar eclipses

A **lunar eclipse** occurs when the moon passes into the Earth's shadow. This can happen only during a full moon, when the Earth lies between the sun and the moon.

Lunar eclipses occur more often than solar eclipses. However, the moon's orbit around the Earth is tilted, so it does not pass through the Earth's shadow every time there is a full moon.

### 6.6.2 Solar eclipses

Any object that you cannot see through casts a shadow when the sun shines on it. The Earth and moon both cast shadows into space. Sometimes, when the moon passes between the Earth and the sun, the moon's shadow falls on the Earth. If this happens during the day, the part of the Earth in the shadow experiences a **solar eclipse**.

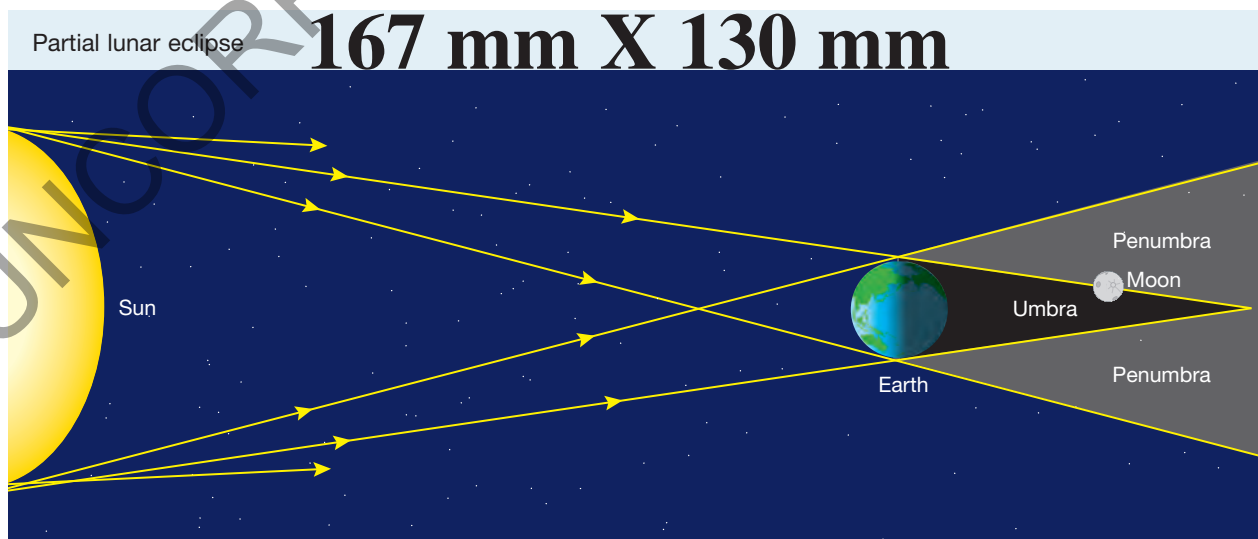
The shadow cast by the moon during an eclipse is not sharp. Most of the shadow is only partially dark. Only the centre of the shadow is in total darkness. Even though the moon passes between the sun and the

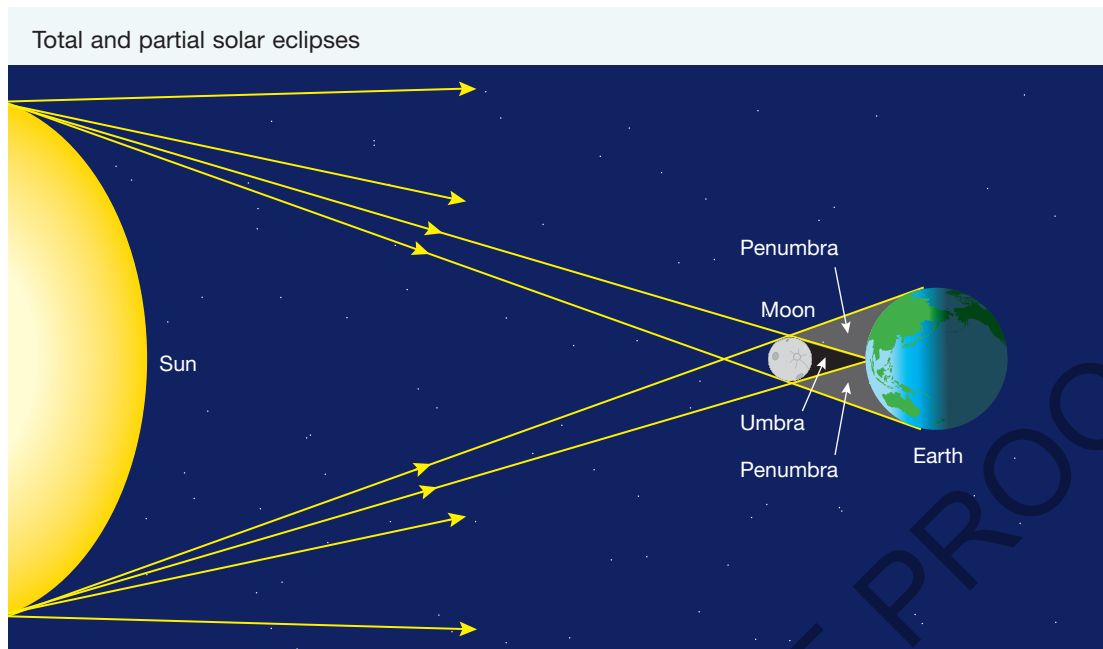
Earth every 29½ days, eclipses do not occur very often. Usually the whole shadow passes above or below the Earth. If the dark centre of the shadow falls on the Earth, a **total solar eclipse** is experienced.

During a total solar eclipse, the area in the dark centre of the shadow becomes completely dark, as if it were night-time. The sun is completely blocked out. The last total solar eclipse to affect Australia passed across a narrow band of tropical northern Australia in November 2012. It plunged the Cairns area into complete darkness for about two minutes. The next total solar eclipse to affect Australia will touch the coast at Exmouth in Western Australia in April 2023. A further total solar eclipse in July 2028 will cross a narrow band from the Kimberley in Western Australia all the way to Sydney.

**Partial solar eclipses** and **annular solar eclipses** are much more common than total solar eclipses. A partial solar eclipse is experienced by areas in the partially dark part of the shadow. Not enough of the sun is blocked out to cause darkness. An annular eclipse occurs when the moon blocks out the central part of the sun, leaving a ring (called an annulus) of light from the outer part of the sun, which is visible from Earth.

Solar eclipses are extremely useful to astronomers because the outer part of the sun, known as the corona, can be seen. The corona is normally not visible because of the brightness of the rest of the sun. However, during a total solar eclipse the rest of the sun's light is blocked out by the moon. The corona can then be successfully photographed and studied.





### CAUTION

You must NEVER look directly at an eclipse of the sun — even a partial eclipse. You could permanently damage your eyes. Sunglasses will not protect you.

The Earth's shadow makes the moon appear to change phases during a total lunar eclipse. Note the red tinge of the moon at the height of the eclipse.

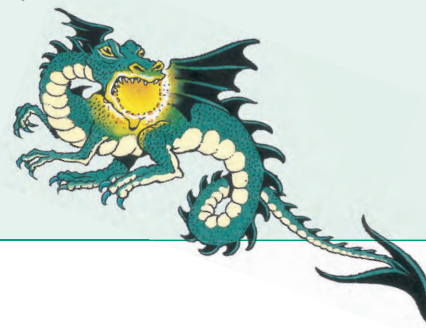


A total solar eclipse — the sun's light is blocked as the moon passes in front of it.



### HOW ABOUT THAT!

The ancient Chinese believed that solar eclipses occurred when a giant dragon ate the sun. They thought that if they made enough noise they could frighten the dragon. The frightened dragon would then spit the sun out, bringing daylight back.



### INVESTIGATION 6.6

#### Modelling solar and lunar eclipses

**AIM:** To model solar and lunar eclipses

**Materials:**

projector

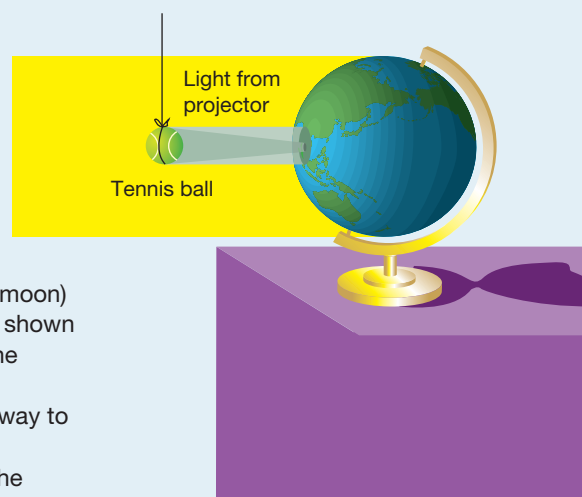
globe

tennis ball attached to string

**Method and results**

- Darken the room and aim a beam of light at the globe.
- To simulate a solar eclipse, suspend the tennis ball (moon) between the projector (sun) and the globe (Earth) as shown below. Ensure that you keep your own shadow off the globe.
- Rotate the globe a little (think carefully about which way to turn it) and note what happens to the shadow.
- To simulate a lunar eclipse, move the tennis ball to the opposite side of the globe from the projector. Suspend it so that it is partly in the shadow of the globe.

#### Modelling a solar eclipse



1. Draw a diagram to show the initial positions of Earth, moon and sun in your model of a solar eclipse.
2. During which phase of the moon does a solar eclipse occur?
3. When you rotate the globe, does the shadow move from east to west or from west to east?
4. Draw a diagram showing the positions of the Earth, moon and sun in your lunar eclipse model.
5. During which phase of the moon does a lunar eclipse occur?

## INVESTIGATION 6.7

### Fuzzy shadows

**AIM:** To investigate the creation of sharp and fuzzy shadows

**Materials:**

torch

white card or a bare wall to act as a screen

coin

**Method and results**

- Use a torch to cast light on a white card or bare wall. Observe the shadow of a coin as you move it between the light source and screen.
  - Create sharp shadows and fuzzy shadows.
  - Create a shadow that is dark in the centre and partially dark on the outside. This is the type of shadow cast on the Earth by the moon.
1. Where does the coin need to be to create a sharp shadow?
  2. Where does the coin need to be to create a fuzzy shadow?
  3. Draw a diagram of this fuzzy shadow.

## 6.6 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### Remember

1. Outline the difference between a solar eclipse and a lunar eclipse.
2. Explain why you must never look directly at a solar eclipse.

### Think

3. Explain why total solar eclipses are much less frequent than partial solar eclipses.
4. Explain why a total lunar eclipse occurs only when there is a full moon, and why a solar eclipse occurs only when there is a new moon.

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RESOURCES — ONLINE ONLY



**Try out this interactivity:** Eclipses

Searchlight ID: int-0207



**Complete this digital doc:** Worksheet 6.3: Eclipses

Searchlight ID: doc-19837



## 6.7 Explaining the night sky

Science as a human endeavour

### 6.7.1 The earliest astronomers

Astronomers have been recording observations of the night sky for at least 4000 years. For just as long they have been trying to explain their observations. The quest for knowledge and understanding of the universe is not over. Astronomers are still making new discoveries, often leading to more questions than answers.

Almost all ancient cultures had stories about how the universe was created, what it was like and how the Earth, sun, moon, planets and stars got here. Thousands of years ago, Indigenous Australians told stories that explained the stars, the sun and the moon. They identified the shapes of groups of stars in the night sky and told stories about them that were passed on from generation to generation. The shapes described and the stories about them varied from tribe to tribe.

#### The emu in the sky

Rock engravings carved by the Guringai people of the northern outskirts of Sydney show an emu in the sky that stretches from its head in a dark patch of the Southern Cross through the cloud-like band of stars that we call the Milky Way. Their story explains that when the real emu in the sky is directly above the engravings, it is the emu egg-laying season. It signals that it is time to gather the eggs. Another explanation from Papunya in the Northern Territory tells the story of an old blind man who speared the emu and sent it to the Milky Way after it killed his wife while protecting its eggs.

The emu in the sky. The head is the dark Coal Sack nebula in the Southern Cross.



#### Chopped to bits

The Yolngu people of Arnhem Land explain the phases of the moon with the story of Ngalindi and his wives. At the time of the full moon, Ngalindi is a fat, lazy man. His wives punish him by attacking him with an axe, and he is seen as a waning moon as parts of him are chopped off. Unable to escape his wives, Ngalindi dies of his wounds, and this is the time of the new moon. He rises from the dead after three days and is seen as the waxing moon as he again grows round and fat. Two weeks later, his wives punish him again, and the cycle repeats.

### 6.7.2 The lunar chariot of Rome

The ancient Romans thought that the moon was a goddess. Named Luna, she drove across the sky at night in a chariot. When the moon did not appear, Luna had driven her chariot down to Earth to visit her mortal lover, a shepherd named Endymion.

### 6.7.3 Ancient Greek astronomy

The ancient Greeks provided many of the early ideas from which modern astronomy was developed. Their ideas were widely accepted throughout Europe for hundreds of years.

The Greeks discovered that the Earth was spherical; the Greek philosopher Eratosthenes calculated the circumference of the Earth to within about 300 kilometres of the true value. In the fourth century BC, Aristotle was one of the most influential philosophers in Greece. He believed that the sun and moon revolved around the Earth, which was the centre of the universe. Aristotle's model was easily accepted at the time because people who studied the night sky saw celestial bodies passing over the Earth.

#### Ahead of his time

In the following century, Aristarchus developed a model of the universe in which the sun was fixed and all the planets, including Earth, orbited it along circular paths. He also noted that, once a day, the moon revolved around the Earth and the Earth rotated on its axis. Aristarchus's model did not gain wide acceptance. This sun-centred theory would have defied common sense at the time because we do not feel the Earth spinning or moving through space.

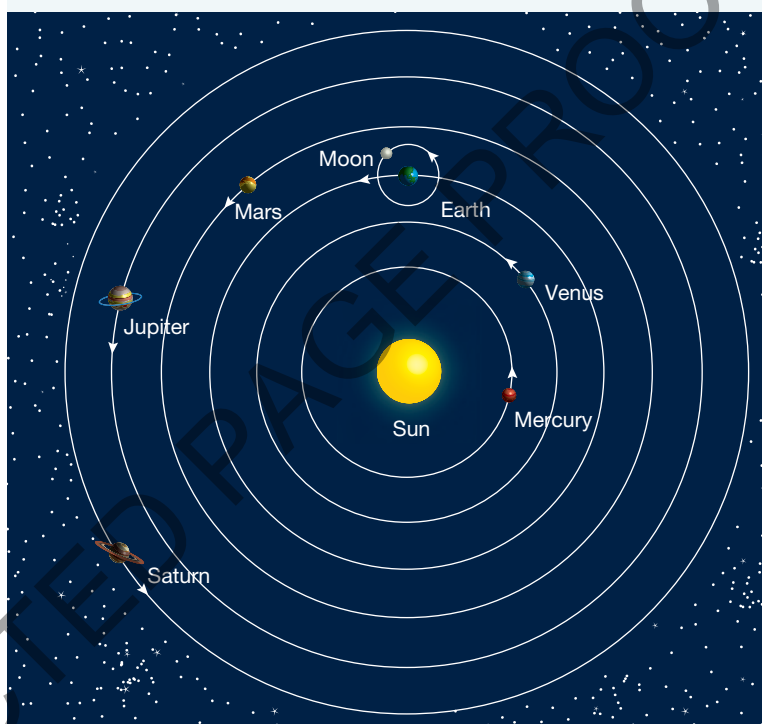
### 6.7.4 The Incas of Peru

For about 300 years, from the 1200s until the Spanish conquistadors invaded in the 1500s, much of South America around Peru was ruled by the Incan empire.

The Incas had a deep knowledge of the stars and constellations, which they observed and named. They named the Milky Way *mayu*, meaning 'river'. This celestial river was said to join up with the Urubamba River in the waters of a great cosmic sea that encircled the Earth. The Incans believed that the celestial river, the Milky Way, was the source of rain on Earth as it passed through the night sky.

At Cusco, the astronomical centre of their empire, the Incas constructed a series of stone towers to mark the points of sunrise and sunset on important days. These included the

Aristarchus's heliocentric model



Most historians agree that the Incans had a calendar based on observations of the sun and the moon and their relationship to the stars. Names of 12 lunar months are recorded.



summer solstice (the longest day of the year) and the winter solstice (the shortest day of the year). The Incas created an accurate annual calendar based on the positions at which the moon rose and set on the horizon, as well as observations of the phases of the moon.

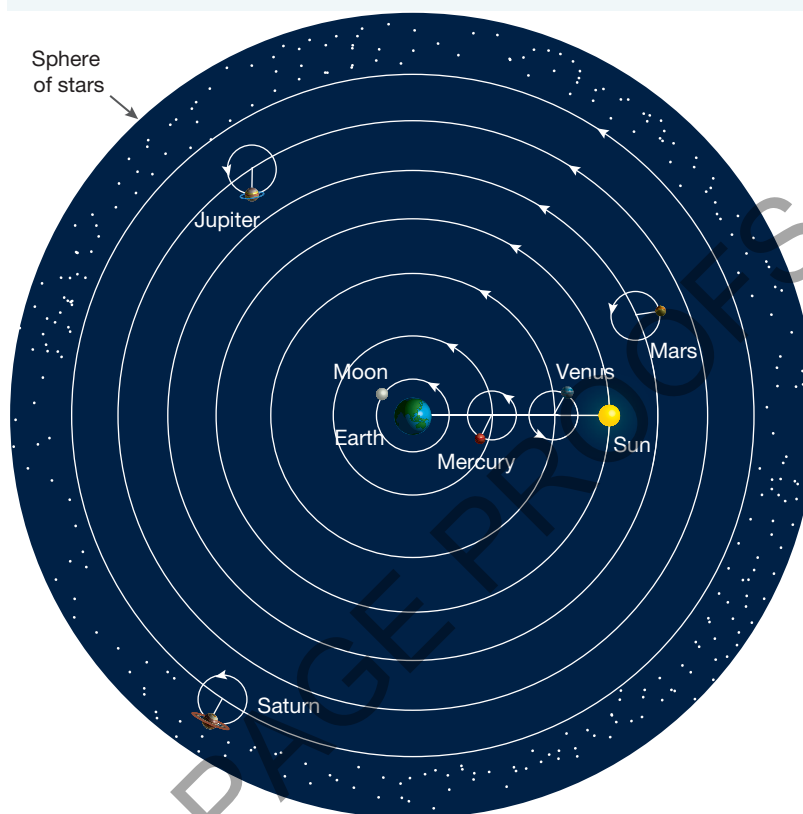
### 6.7.5 The Earth-centred model returns

The early Greek astronomer Ptolemy, in about AD 150, used his own observations and the ideas of other Greek astronomers to develop a model of the **universe**. The universe is the whole of space and everything in it. In Ptolemy's model, the Earth was the centre of the universe. The universe was surrounded by a sphere called the celestial sphere to which all of the stars were attached. The moon, sun and planets orbited the Earth, which did not move at all. Ptolemy's model was generally accepted as correct for almost 1500 years.

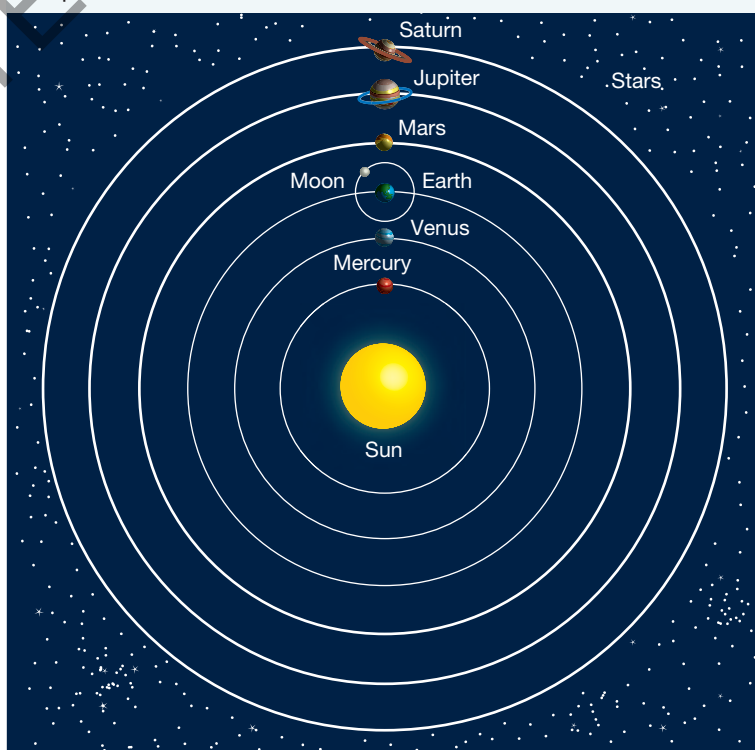
### 6.7.6 The sun at the centre?

Nicolaus Copernicus, born in Poland in 1473, was a mathematician with a keen interest in astronomy. He was unhappy with Ptolemy's model. Although it explained the circular movement of the stars, it did not fully explain the movement of the planets across the sky. Copernicus was convinced that the planets revolved around the sun. The movement of the stars could be explained if the Earth spun on its own axis once a day. Copernicus wrote a book in which he used

Ptolemy's model of planetary motion



Copernicus's heliocentric model





mathematics to explain his ideas. He died in 1543 on the day that his book, *On the Revolutions of Heavenly Spheres*, was published. The book was then banned because it disputed the teachings of the Church and was considered to be morally wrong. According to the Church at that time, the Earth had to be at the centre of the universe.

### 6.7.7 He was right after all!

Galileo Galilei (1564–1642) was the first astronomer to use a telescope to observe the night sky. His discovery in 1610 of four moons orbiting the planet Jupiter showed that not all heavenly bodies revolve around the Earth. Galileo, despite strong opposition from the Church, actively supported the ideas of Copernicus. In 1616 he was ordered by the Roman Catholic Church not to defend the Copernican model. However, he defied the order and in 1632 published a book in which he showed that the ideas of Copernicus were far more sensible than the Earth-centred model of Ptolemy. The following year Galileo was forced, under threat of torture, to deny his beliefs in public. His book was banned and he was sentenced to life imprisonment. Old, sick and losing his sight, Galileo was allowed to serve his sentence locked in his own home. He was totally blind during the last four years of his life.

It was not long after Galileo's death that the observations of other astronomers, and the theories of English scientist Sir Isaac Newton, confirmed that the sun was at the centre of the solar system. Newton died in 1727 knowing that he had finally convinced most astronomers that the Earth was not the centre of the solar system or the universe.

### 6.7.8 The quest continues

Astronomers continue to observe the night sky using telescopes. New technology has allowed observations to be made during the day. Observations can be made even from space — above the gases in the Earth's atmosphere that blur the detail. Sometimes, new observations help astronomers answer questions. The discovery of a new star might, for example, provide some clues about how big the universe is.

One advance in exploring and explaining the universe is the Hubble Space Telescope. It orbits the Earth at a distance of about 600 kilometres above the surface. The images are much clearer than could be obtained by similar telescopes on the Earth's surface. The Hubble Space Telescope was lifted into orbit in 1990 by a space shuttle.

Since the accidental discovery in 1931 that stars emit radio waves as well as light, a new generation of telescopes has emerged. Radio telescopes are huge dishes that collect radio waves from distant stars and galaxies. CSIRO's Australia Telescope Compact Array near Narrabri, NSW, built in 1988, consists of radio telescopes that can be moved along railway tracks to make a more complete picture of the sky. (Photograph courtesy of CSIRO)



## 6.7 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### Remember

1. How does the position of the emu in the sky influence the Guringai people of New South Wales?
2. Besides Dreamtime stories that still survive today, what other evidence is there that Aboriginal peoples studied the night sky?
3. The Incan calendar, like our own, is based on astronomy. Outline the information used to help create such a calendar.
4. Explain why an Earth-centred model of the solar system made much more sense to early astronomers than a sun-centred one.
5. Why were the ideas of Copernicus rejected for so long?
6. Which new technology enabled Galileo to make observations that supported the idea of a sun-centred solar system?

### Think

7. Describe the limitations that ancient cultures had on their study of the night sky.
8. How did Copernicus explain the circular motion of the stars, if the Earth was not at the centre of the universe?
9. What evidence would you use if you had to argue that the Earth was at the centre of the universe?
10. During the lifetimes of Copernicus and Galileo, new theories about our solar system developed rapidly and previous ones were rejected. In science, why are existing theories replaced by new ones?


### Create

11. Use resources from the library or home to find out more about how explanations of the night sky have changed since ancient times. Include in your timeline the technology, such as telescopes and space probes, that has made new explanations possible. You might need to use separate timelines to show some of the detail from AD 1400 to AD 1700 and from AD 1950 to the present time.

### Investigate

12. Research and write a report of approximately 200 words about the life and times of Omar Khayyam and the contributions he made to astronomy.

**learnON** RESOURCES — ONLINE ONLY

 **Complete this digital doc:** Worksheet 6.4: Astronomical history  
Searchlight ID: doc-19838



## 6.8 Mind maps and tree maps

### 6.8.1 Mind maps and tree maps

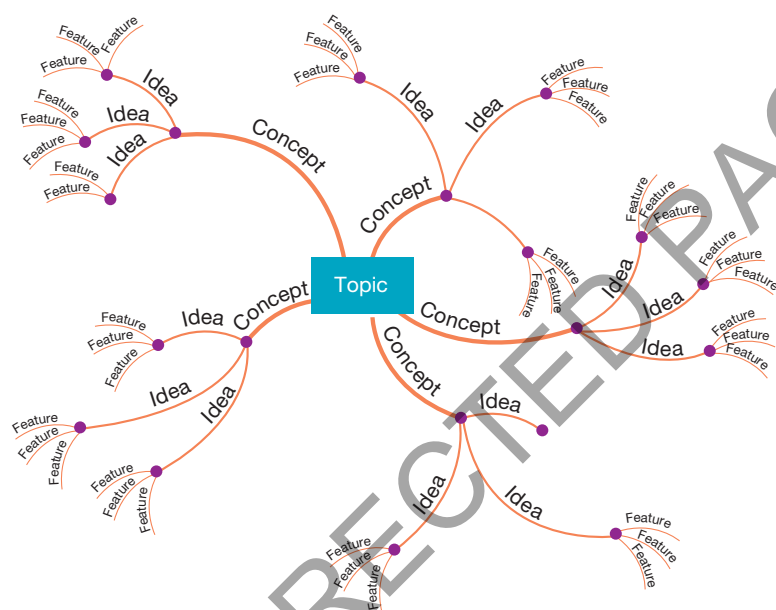
1. Write your topic in the middle of a sheet of paper and draw a number of lines branching out from it.
2. Think of some main ideas related to the topic and write one on each branch.
3. Draw a number of lines branching from each of your main ideas.
4. Think of words or terms related to one of your main ideas and write one on each branch.
5. Continue adding branches until you run out of ideas.
6. Decorate your map with colour, clip art, drawings, photos etc. to make the ideas and links clearer.

To show the hierarchy of ideas within a topic

how to ...?

why use?

**Mind map**



question

How can I summarise this?

comparison

**Similarity**

Main concepts are identified and broken down into sections or groups.

Tree map

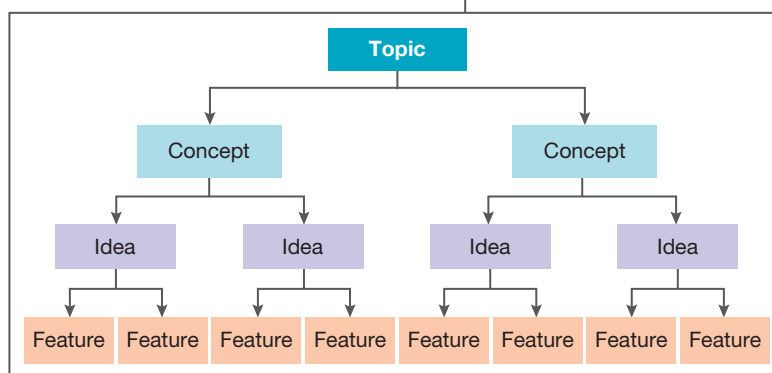
**Difference**

Mind maps radiate from the centre. Ideas in tree maps are organised horizontally.

example

also called

Model map;  
memory map;  
brain map;  
learning map



**RESIZED 168 mm X 204 mm**

## 6.8 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). *Note:* Question numbers may vary slightly.

### Think and create

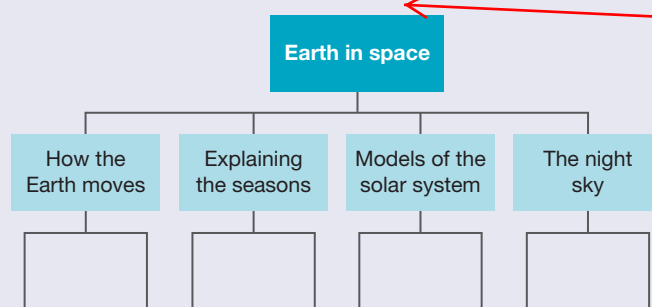
1. Draw a mind map to summarise what you have learned about the Earth in space. Your mind map should consist of branches of words and pictures flowing from a picture of the Earth in the centre. You can use the mind map below to help you get started. Just add more branches.

Use this mind map as a starting point.



2. (a) Convert your mind map of Earth in space into a tree diagram using only the following four main ideas.
  - How the Earth moves
  - Explaining the seasons
  - Models of the solar system
  - The night sky

Use this to start your own tree map showing what you have learned about the Earth in space.



<This space is correct.>

- (b) Use your tree map to explain how each of these pairs of 'main ideas' are closely related to each other:
- (i) the seasons and the tilt of the Earth
  - (ii) the apparent movement of the stars during the night and the Earth in orbit
  - (iii) the change of the positions of stars in the night sky from month to month and the seasons.
- (c) Add another branch or layer to your tree map to identify technology that has been used to make observations of the moon, other objects visible in the night sky and the Earth. The technology should include a range of examples such as telescopes, satellites and space probes.
3. (a) Research the seasonal calendars of an Aboriginal or Torres Strait Islander people. Identify the regularly occurring features of the local environment and weather.
- (b) Compare your Indigenous seasonal calendar with the western model of seasons (that is, spring, summer, autumn and winter).

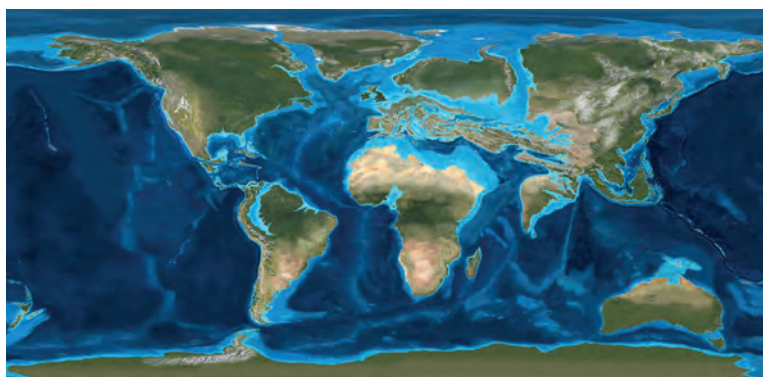
## learn on

# 6.9 Project: Australia 50 million years BC

## 6.9.1 Scenario

For much of its 4.5 billion year history, the Earth's surface has undergone enormous changes. Based on scientific evidence, our present theories about how and why these changes occur indicate that the Earth of 100, or even 50, million years ago would be vastly different from the one we know today. At various times, according to the theories, the oceans have risen and fallen, Antarctica has been green and forested, continents have collided and separated, the climate has altered and volcanoes have been born and died.

Now, with the development of a time machine by Australian research company Chronoscience P/L, scientists have a unique opportunity to see for themselves just how well their theories match up with reality. After years of testing on watermelons, white rats and labradors, the company is finally ready to start human trials. Their intention is to send a team of four explorers (or 'chrononauts', as the company likes to call them) back to Australia as it was 50 million years ago to make scientific observations that they will bring back with them when they are retrieved to the present era a week later.



The company needs to know a lot more about what our continent was like at that time so that they can prepare their expeditionary team properly — particularly because they aren't exactly sure where on the continent the team will end up.

### 6.9.2 Your task

As key team members of Chronoscience's Time Taskforce, you are required to prepare a report that will be used to brief, train and equip the expeditionary team. The report will need to describe:

- where the Australian continent was located 50 million years ago relative to its current position
- the seasons that the team will experience, and how they differ from the seasons of today
- the geography of the continent — for example, the shape of the coastline, the main mountain ranges, locations of large lakes or inland seas if present
- what many of Australia's famous natural features, such as Uluru, Wave Rock and the Twelve Apostles, would have looked like at that time
- the conditions of climate and terrain that the team are likely to encounter
- the most likely dangers (including possible predators) that the team may encounter and where on the continent they would be most likely to find them.

*Note:* In each case, the team will need to describe what scientific evidence exists to justify their findings.

The report will also include

- a map of Australia at that time, with key features such as lakes, seas, volcanic regions, deserts, mountain ranges, jungle, glaciers and forests noted if appropriate
- a bibliography.

### 6.9.3 Process

Watch the introductory video lesson and in your group complete your report to brief, train and equip the expeditionary team.





## 6.10 Review

### 6.10.1 The seasons, day and night

- explain the seasons in terms of the tilt of the Earth's axis and the orbit of the Earth around the sun
- state the time taken for a complete orbit of the Earth around the sun
- explain day and night in terms of the rotation of the Earth about its axis
- state the time taken for a complete rotation of the Earth about its axis
- explain why the amount of daylight varies from season to season and distance from the equator
- use a model to demonstrate how the movement of the sun and Earth causes day and night and the seasons

### 6.10.2 The moon

- describe the surface of the moon
- state the time taken for a complete orbit of the moon around the Earth
- identify the different phases of the moon

### 6.10.3 Earth, moon and sun

- explain the phases of the moon in terms of the orbit of the moon around the Earth and the Earth around the sun
- use a model to demonstrate how the phases of the moon occur
- explain how the gravitational pull of the sun and the moon, together with relative movements of the Earth, moon and sun, causes tides
- explain solar and lunar eclipses in terms of shadows and the relative movement of the Earth, moon and sun
- use a model to demonstrate how solar and lunar eclipses occur

### 6.10.4 Science as a human endeavour

- describe the way in which different cultures have explained night and day, the seasons, phases of the moon and eclipses
- describe the developments of models of the universe and solar system put forward by astronomers including Ptolemy, Copernicus and Galileo
- explain how telescopes, space probes and other advances in technology have affected space exploration

#### Individual pathways

##### ACTIVITY 6.1

Investigating Earth science  
doc-6090

##### ACTIVITY 6.2

Earth science analysis  
doc-6091

##### ACTIVITY 6.3

Investigating Earth science further  
doc-6092

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### 6.10 Review 1: Looking back

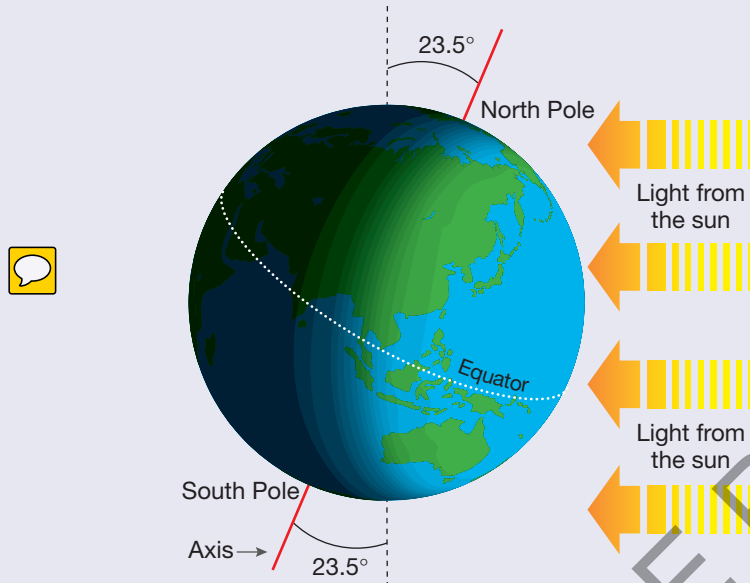
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#### Remember

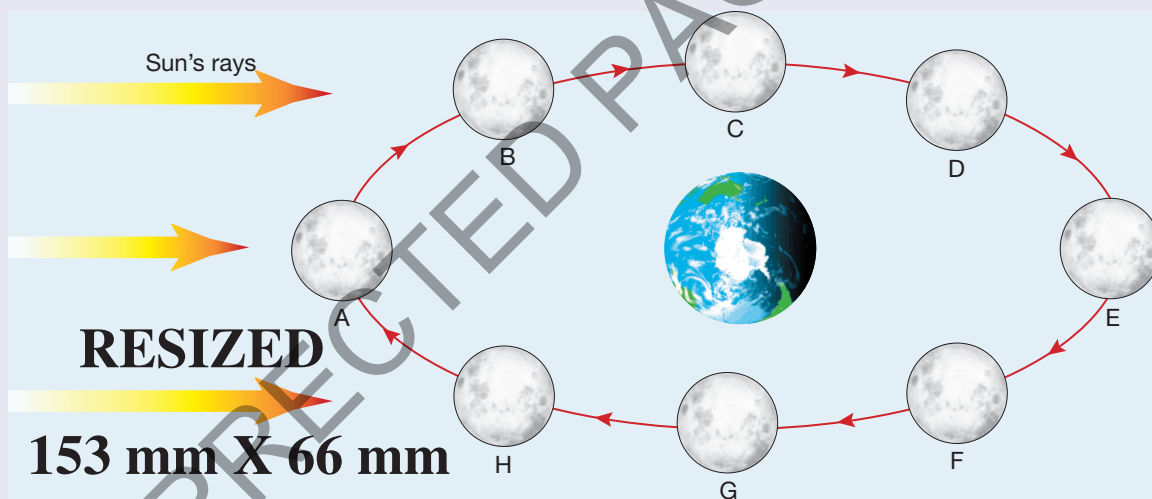
1. Imagine that you are given the task of describing your planet to an alien from a distant galaxy. You are, however, limited to a maximum of 200 words. Write your description. You are not able to use diagrams and must write more than 100 words.



2. The diagram below shows half the Earth in sunlight while the other half is in darkness. Which Australian season is represented in this diagram? Explain how you know.



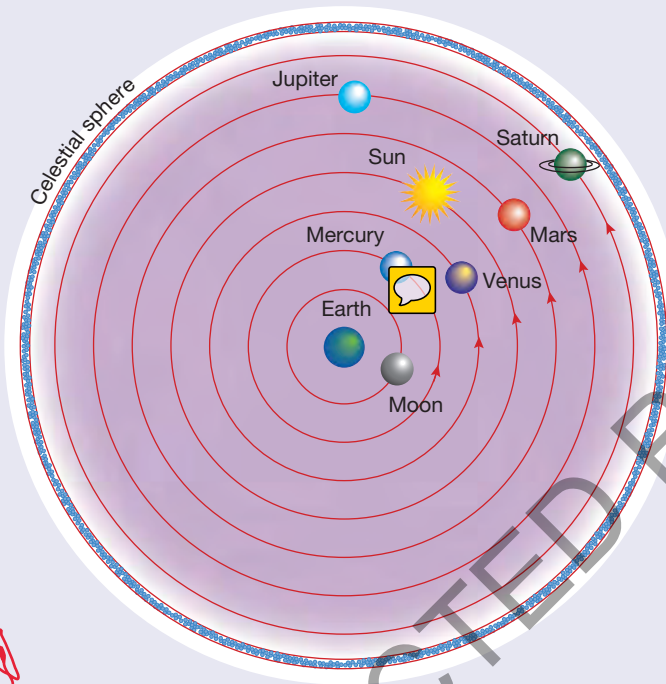
3. Explain why the position of the sun in the sky at midday changes from day to day.  
4. The diagram below shows the moon in eight different positions during an orbit around the Earth.



- (a) Copy the diagram and shade the parts of the Earth and moon that are in darkness.  
(b) How long does it take the moon to complete a single orbit?  
(c) Why is it not possible to see a new moon during the day?  
(d) Which one or more positions of the moon would result in a quarter moon? Why?  
(e) Which one or more positions of the moon would result in a gibbous moon?  
(f) Which one or more positions of the moon would result in a full moon?  
(g) How many times does the moon rotate about its own axis while completing a single orbit of the Earth?
5. The length of a day on the planet Venus is 243 Earth days. The length of a year on Venus is only 225 Earth days. Explain how it is possible for a day to be longer than a year.
6. The photograph below shows the Earth as it is seen from the moon.
- (a) Why is the Earth visible even though it does not emit its own light?  
(b) Would you expect the Earth to always be visible from the part of the moon that faces it? Explain your answer.  
(c) Does the Earth have the same phases as the moon? Draw some diagrams showing the positions of the sun, Earth and moon to explain your answer.  
(d) If you were on the moon, how long would you expect to have to wait between Earthrise and Earthset?
7. Astronauts have already visited the moon and may soon land on Mars. Is it likely that astronauts will one day visit a planet outside our solar system? Explain your answer.

8. Which type of tide is experienced when a full moon is overhead? Explain your answer.
9. What causes a partial solar eclipse? How is it different from a total solar eclipse?
10. (a) Which astronomer developed the model of the universe shown in the diagram below?  
 (b) Where are the stars on this model?  
 (c) Why do you think that this model of the universe was so well accepted for almost 1500 years?  
 (d) Name three well-known scientists or mathematicians who put an end to the popularity of this model.

11. The diagram below shows the view of the Earth from above the South Pole. While the moon is in the position shown, which type of tide is being experienced on the east coast of Australia — high tide, low tide or neap tide?



Photographs like this composite image of the Earth were taken from the *Apollo 8* spacecraft in 1968 as it orbited the moon.



The moon's orbit around the Earth as seen from above Antarctica



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