●●●○○ Level 3 · Science S3.12

The solar system and seasons

The Earth is one of eight planets going round the Sun, and its tilt gives us seasons.

Name the eight planets, make a scale model along a long string, see how gravity keeps planets in orbit, explain seasons with a tilted ball and a lamp, compare seasons and rain around the world, graph day length and track the Sun with a stick, meet moons, asteroids and comets, and learn how telescopes, satellites and probes help us.

YOU ARE READY FOR THIS BOOK IF

You can show day and night with a lamp and a ball.

One step up	S4.14 Atmosphere and climate
This book	**S3.12 The solar system and seasons**
One step down	S2.9 Earth, Sun and Moon

Contents

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S3.12.6 Day length and the Sun's height

S3.12.7 Moons, asteroids and comets

S3.12.8 Exploring space

Key words, A to Z

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S3.12.1 CHAPTER 1

The planets

> **Some bright dots in the night sky are planets, not stars. What is a planet?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Four are small and rocky, two are giant balls of gas, and two are giant and icy.
- ☐ **B** All eight planets are rocky balls, like the Earth.
- ☐ **C** The eight planets are all the same size. Only their distance is different.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Earth, Sun and Moon, S2.9.1. You met the Sun, the Earth and the Moon there.

BY THE END YOU CAN

- Name the eight planets in order from the Sun
- Compare planets by size, distance and what they are made of

The Sun is a star. A **planet** is a big ball of rock or gas that goes round a star. Eight planets go round our Sun.

The Sun and everything that goes round it is called the **solar system**. The Earth is a planet, so you live in the solar system.

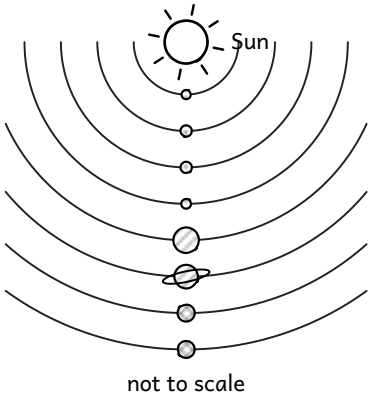
Be safe. Never look at the Sun. Not for a moment. Not through glass, binoculars, a telescope or a phone. It can blind you.

DRAW IT FIRST

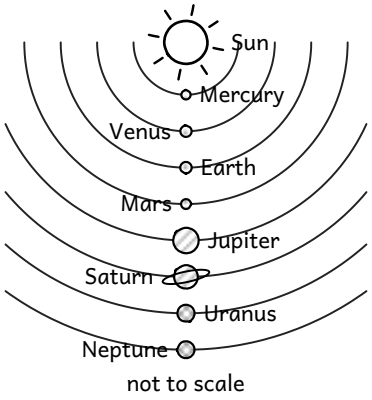
Draw the planets in order



1 Draw the Sun. It is the star in the middle.



2 Draw eight rings round the Sun. Put one planet on each ring.



3 Write the names in order. Start with the planet nearest the Sun.

In order from the Sun, the planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

A sentence helps you remember the order. Use the first letters: M, V, E, M, J, S, U, N. Make your own sentence. Your own silly sentence will stay in your head best.

The picture is not to scale. The rings are spaced evenly so that all eight fit. In space the outer planets are far, far apart.

The four planets nearest the Sun are small and made of rock. They are **rocky planets**. The Earth is one of them. You can stand on a rocky planet.

Jupiter and Saturn are huge balls of gas. They are **gas giants**. They have no ground to stand on.

Uranus and Neptune are **ice giants**. They hold a lot of water and other icy stuff, under thick gas. They are not solid balls of ice.

SEE IT THREE WAYS

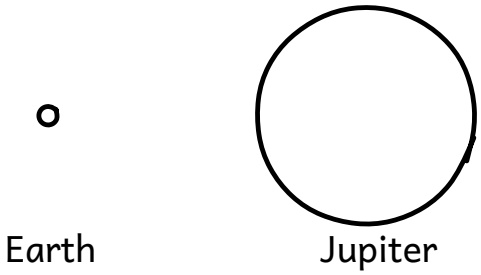
As a picture

planet	type	million km
Mercury	rocky	58
Venus	rocky	108
Earth	rocky	150
Mars	rocky	228
Jupiter	gas	778
Saturn	gas	1430
Uranus	ice	2870
Neptune	ice	4500

In words

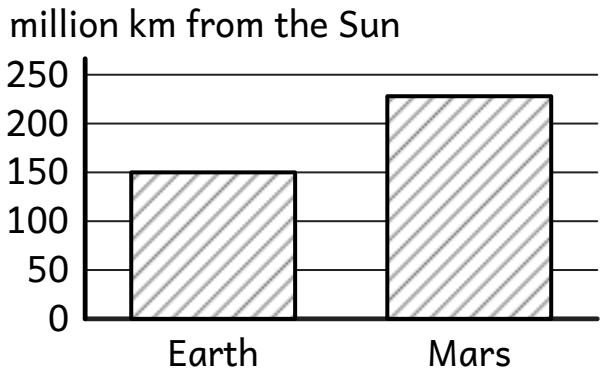
The table lists the planets in order from the Sun. The four nearest are rocky. Then come two gas giants and two ice giants. The distances grow bigger and bigger, and the gaps between the outer planets are huge.

The planets are very different in size. Jupiter is the biggest. It is about 11 times as wide as the Earth. Mercury is the smallest.



Earth and Jupiter at one scale. Jupiter is drawn 11 times as wide as the Earth.

Distances in space are so large that we count them in millions of kilometres. The Earth is about 150 million km from the Sun. Neptune is about 4 500 million km away.



How far Earth and Mars are from the Sun. Read the two numbers for the next example.

WORKED EXAMPLE

How much farther from the Sun is Mars than the Earth?

1. Earth is about 150 million km from the Sun.
2. Mars is about 228 million km from the Sun.
3. Take away the smaller from the bigger: 228 − 150 = 78.
4. Mars is about 78 million km farther from the Sun.

Answer: 78 million km

TRY IT

Draw Earth and Jupiter at one scale

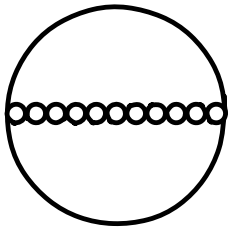
You need: a big sheet of paper, a pencil, a string about 10 cm long, a ruler or a paper strip marked in cm.

Be safe: Keep the pencil point away from your face and eyes.

1. Let 1 cm stand for 10 000 km. The Earth is about 12 700 km wide, so it is about 1.3 cm wide.
2. Draw the Earth as a dot or a tiny circle, 1.3 cm wide.
3. Jupiter is about 140 000 km wide, so it is about 14 cm wide. Tie the pencil to one end of the string. Mark the string 7 cm from the pencil point.
4. Hold the mark on the paper with a finger. Pull the string tight and draw a full circle round your finger.
5. Lay your Earth beside Jupiter. How many Earths would fit across it?

What you will see: About 11 Earths fit across Jupiter. The planet that looks like a tiny dot beside Jupiter is the world you live on.

If you cannot try it, this is what happens.



Jupiter 14 cm wide
about 11 Earths fit across

A WRONG IDEA MANY PEOPLE HAVE

~~All the planets are rocky balls, like the Earth.~~

Why it feels right: We live on rock, and pictures show every planet as a round ball with a surface.

The test that breaks it: Look at the table. Only four planets are rocky. Jupiter is a gas giant. A ship that tried to land would sink through thick gas. It would find no ground.

What is true: Only Mercury, Venus, Earth and Mars are rocky. The other four are giants, made mostly of gas or of water and icy stuff.

KEY WORDS

planet
a big ball of rock or gas that goes round a star.

solar system
the Sun and everything that goes round it.

rocky planets
small planets made of rock. There are four.

gas giants
huge planets made of gas. Jupiter and Saturn.

ice giants
huge planets with a lot of water and icy stuff. Uranus and Neptune.

BACK TO YOUR GUESS

The answer is A: Four are small and rocky, two are giant balls of gas, and two are giant and icy.

The four planets nearest the Sun are small and rocky. Jupiter and Saturn are giant balls of gas. Uranus and Neptune are giants with a lot of water and icy stuff. The planets are very different in size.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Going away from the Sun, which planet comes right after Mars?

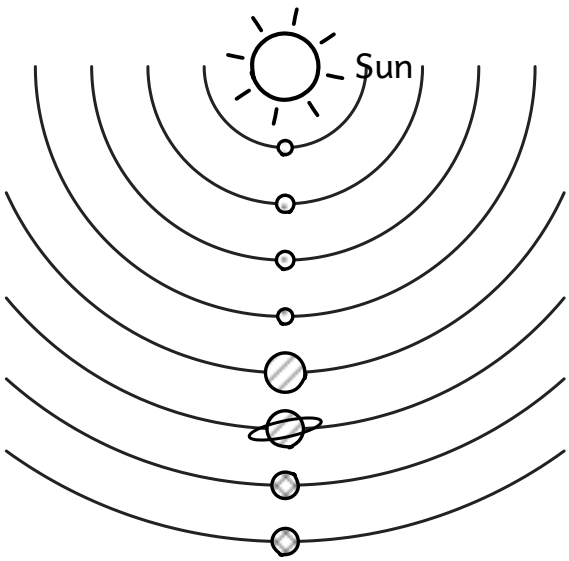
   A Venus

   B Jupiter

   C Saturn

   Answer at the back of the book.

2. The picture shows the Sun and the eight planets, with the names left out. Which planet is third from the Sun?



not to scale

   A Venus

   B Mars

   C Earth

   Answer at the back of the book.

3. Which of these is a gas giant?

   A Mars

   B Neptune

   C Venus

   D Jupiter

   Answer at the back of the book.

4. The Earth is about 12 742 km wide. Neptune is about 49 244 km wide. Which is wider, and about how many times?

   A Neptune, about 4 times as wide

   B Earth, about 4 times as wide

   C Neptune, about 40 times as wide

   D They are the same width.

   Answer at the back of the book.

5. The Earth is about 150 million km from the Sun. Neptune is about 4 500 million km from the Sun. About how many times as far is Neptune?

   A 3 times

   B 30 times

   C 300 times

   D 4 350 times

   Answer at the back of the book.

6. Ravi reads that Mercury is 58 million km from the Sun and Mars is 228 million km. How much farther from the Sun is Mars?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Eight planets go round the Sun. Rocky: Mercury, Venus, Earth, Mars. Gas giants: Jupiter, Saturn. Ice giants: Uranus, Neptune. Jupiter is biggest.

Draw: The Sun, and eight rings round it with the planets named in order.

S3.12.2 CHAPTER 2

How big and how far

How far apart are the planets? Could I make a model of them with a string?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The planets are close together, like peas on a plate.
- ☐ **B** The planets are far apart, but a model fits on a table.
- ☐ **C** The planets are very far apart. A model needs a string as long as a playground.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Measuring, M2.6.3. You read lengths such as 1.08 m and divide by 100.

BY THE END YOU CAN

- Use a scale to turn real distances into model distances
- Make a scale model of the planets along a long string

Space is far too big to draw as it is. So we make a model. A model is smaller than the real thing, but every part is in the right place.

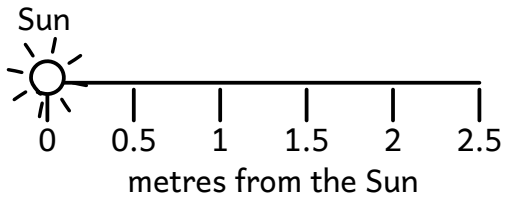
To make a model, we choose a **scale**. A scale says how much real distance one piece of the model stands for.

Here is our scale. One metre of string stands for 100 million km. We write it as 1 m = 100 million km.

DRAW IT FIRST

Put the planets on *a* string

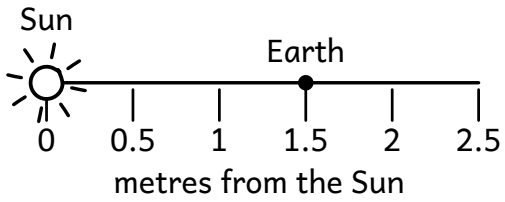
scale: 1 m = 100 million km



1 Write the scale. 1 m of string stands for 100 million km. Put *a* stone for the Sun *a*t one end.

scale: 1 m = 100 million km

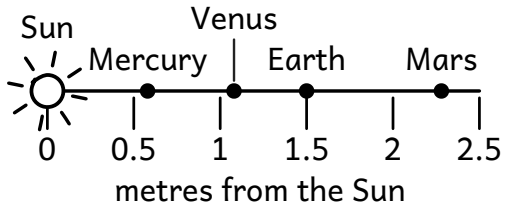
150 ÷ 100 = 1.5 m



2 Divide the real distance by 100. The Earth is 150 million km *a*way, so 150 ÷ 100 = 1.5 m.

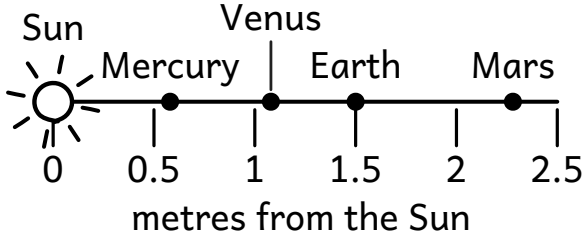
scale: 1 m = 100 million km

150 ÷ 100 = 1.5 m



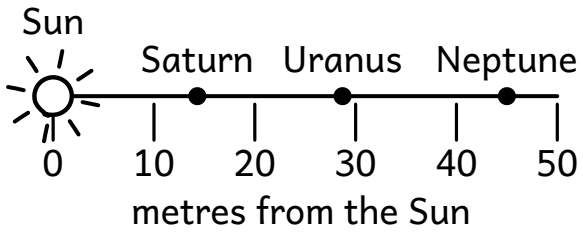
3 Do the same for every planet. Mark *e*ach one on the string.

The rule is short. The **<u>model distance</u>** is the **<u>real distance</u>** divided by the scale. Real distance ÷ scale = model distance.



The four rocky planets *a*ll fit on the first 2.5 m of string.

Now go out to Saturn, Uranus and Neptune. They are much farther out, so the string must be 50 m long. The scale and the rule stay the same.



Saturn, Uranus and Neptune on a string 50 m long. Jupiter would sit at 7.78 m, and the four rocky planets in the first 2.3 m.

SEE IT THREE WAYS

As a picture

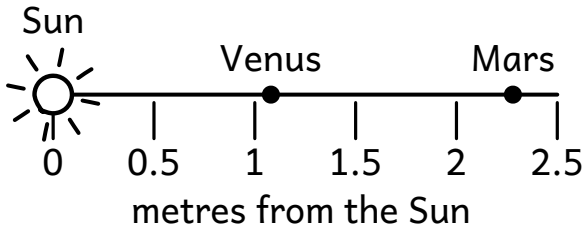
planet	million km	metres
Mercury	58	0.58
Venus	108	1.08
Earth	150	1.5
Mars	228	2.28
Jupiter	778	7.78
Saturn	1430	14.3
Uranus	2870	28.7
Neptune	4500	45

In words

Each row gives the real distance from the Sun and the model distance on the string. The metres are the million km divided by 100. Neptune goes 45 m out. Mercury goes 0.58 m, just over half a metre.

In symbols

Model distance = real distance ÷ 100. For Neptune: 4 500 ÷ 100 = 45 m.



Venus and Mars on the string. The next example finds the gap between them.

WORKED EXAMPLE

On the model, 1 m stands for 100 million km. How far apart are Venus and Mars on the string?

1. Venus is about 108 million km from the Sun. Mars is about 228 million km.
2. Venus on the string: 108 ÷ 100 = 1.08 m.
3. Mars on the string: 228 ÷ 100 = 2.28 m.
4. Take away the smaller from the bigger: 2.28 − 1.08 = 1.2 m.

Answer: 1.2 m

Now think about the sizes of the planets. Use the same scale, 1 m = 100 million km. How wide are the Sun and the planets on the model?

body	km wide	model
Sun	1 400 000	1.4 cm
Jupiter	139 820	1.4 mm
Earth	12 742	0.13 mm

The Sun would be a bead 1.4 cm wide. The Earth would be a speck of dust.

At this scale the Earth is only 0.13 mm wide. That is a speck you could hardly see. So a model of sizes and a model of distances need different scales. If you made the planets big enough to see, they would not fit on the string. If you used one scale for both, you could not see the planets.

TRY IT

Walk the solar system

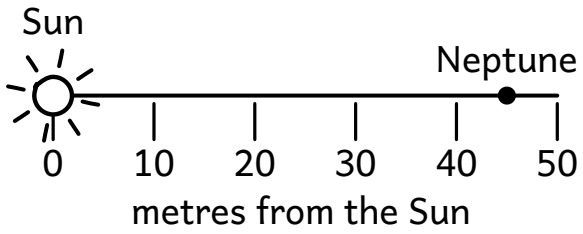
You need: a long string or rope, or many strings tied together, 45 m long, a stick or a rope marked at 1 m, ten small stones, an open flat place, such as a playground or a field.

Be safe: Choose a flat place away from roads, holes and crowds. Do not leave string across a path where people walk.

1. Put a stone on the ground. It is the Sun.
2. Walk away from it, pulling the string tight. Measure each distance in the table with your 1 m stick.
3. Put a stone at 0.58 m for Mercury and 1.08 m for Venus. Put one at 1.5 m for Earth and 2.28 m for Mars. They are very close.
4. Walk on. Put stones at 7.78 m for Jupiter and 14.3 m for Saturn. Then 28.7 m for Uranus and 45 m for Neptune.
5. Stand at Neptune. Look back at the Sun stone. If 45 m is too long, use 1 m = 200 million km and halve every number.

What you will see: The four rocky planets bunch up near the Sun, in about 2 m of string. Then there is a long, long gap before Jupiter. Neptune stands 45 m from the Sun. Most of the solar system is empty space.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~A good model of the solar system shows the planets as big balls close together.~~

Why it feels right: Pictures in books squeeze everything onto one page, so the planets look like neighbours on a shelf.

The test that breaks it: Put the planets on the string. Mars is at 2.28 m and Jupiter is at 7.78 m. The gap is more than 5 m. At the same scale the Earth is a speck of dust.

What is true: The planets are tiny compared with the gaps between them. A picture in a book shows them big and close so you can see them. It is not to scale.

KEY WORDS

scale
how much real distance one piece of the model stands for.

model distance
the distance on the model, in metres.

real distance
the true distance in space, in million km.

BACK TO YOUR GUESS

The answer is C: The planets are very far apart. A model needs a string as long as a playground.

The planets are very far apart. If 1 m of string stands for 100 million km, Neptune is 45 m from the Sun. That is a long walk.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. On a model, 1 m of string stands for 100 million km. Uranus is about 2 870 million km from the Sun. How far along the string does Uranus go?

   A 287 m

   B 2.87 m

   C 287 000 m

   D 28.7 m

   Answer at the back of the book.

2. A string model says 1 m = 100 million km. What does this scale tell you?

   A Each metre of string stands for the same long real distance.

   B The string is that many million km long.

   C Each planet is one metre wide on the model.

   Answer at the back of the book.

3. Why can the planets not be drawn on the string at the same scale as their distances?

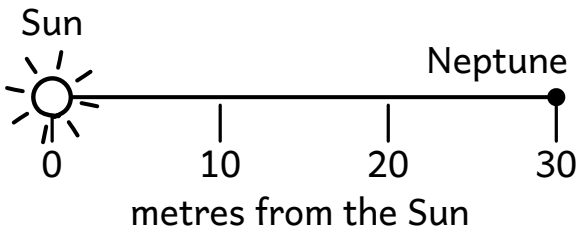
   A The planets are all the same size, so nobody needs a scale.

   B At that scale the Earth would be a speck of dust, too small to see.

   C The Sun is too big to fit on the string.

   Answer at the back of the book.

4. On this model, Neptune is 30 m from the Sun. In real space it is 4 500 million km away. How many million km does 1 m of string stand for?



A 135 000 million km

B 15 million km

C 150 million km

D 4 470 million km

Answer at the back of the book.

5. Mei makes a ball for the Earth, 2 cm wide. Jupiter is about 11 times as wide as the Earth. How wide should her Jupiter ball be?

A 13 cm

B 5.5 cm

C 220 cm

D 22 cm

Answer at the back of the book.

6. **From an earlier chapter**

Which planet would stand at the far end of the string, farthest from the Sun?

A Neptune

B Saturn

C Pluto

Answer at the back of the book.

7. Lucía's string model uses 1 m for every 100 million km. Mars is on the string at 2.28 m. Jupiter is at 7.78 m. How far apart are they on the string?

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A scale says how much real distance a piece of the model stands for. Model distance = real distance ÷ scale. 1 m = 100 million km puts Neptune 45 m out.

Draw: A string with a Sun at 0, the Earth at 1.5 m and Neptune at 45 m. Write 1 m = 100 million km.

S3.12.3 CHAPTER 3

Gravity and orbits

Why does the Earth not fall into the Sun, or fly off into space?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Nothing holds the Earth. It just floats there.
- ☐ **B** The Sun pulls the Earth, and the Earth is moving sideways, so it keeps curving round the Sun.
- ☐ **C** A hard, invisible wall keeps the Earth on its path.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Forces: friction, falling and floating, S2.5.5. Gravity pulls things down.
- Level 3, Speed, forces and pressure, S3.7.4. The pull of gravity grows with the mass of a body.
- Level 2, Earth, Sun and Moon, S2.9.4. A year is one trip of the Earth round the Sun.

BY THE END YOU CAN

- Explain that gravity keeps planets and moons in orbit
- Explain why planets far from the Sun take longer to go round

The Earth goes round the Sun. The Moon goes round the Earth. What keeps them on their paths?

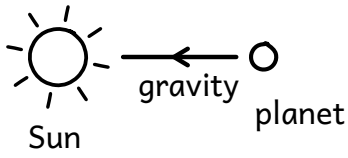
Gravity is the pull that every body has on every other body. The more mass a body has, the stronger its pull. The Sun is huge. It holds nearly all the mass of the solar system.

So the Sun pulls on every planet. The pull is strong enough to hold the Earth, even from 150 million km away.

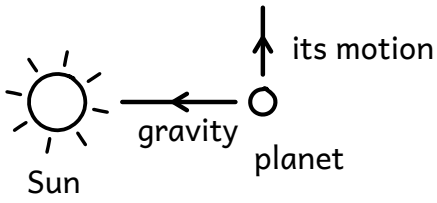
If the pull were all, the planets would fall straight into the Sun. But each planet is also moving sideways, very fast. The Earth moves about 30 km every second.

DRAW IT FIRST

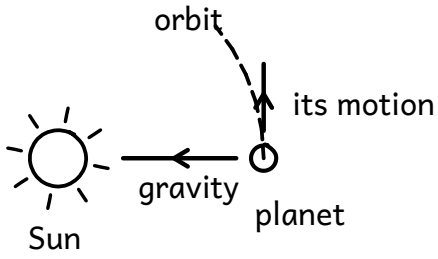
Draw why a planet curves



1 Draw the Sun and a planet. Draw an arrow from the planet to the Sun. It is the pull of gravity.



2 Draw a second arrow from the planet, at right angles to the first. It shows the planet moving sideways.



3 The pull keeps bending the path. The planet follows a curve round the Sun. Draw the curve and call it the orbit.

The curved path round a bigger body is an **orbit**. The pull never lets the planet go, and the sideways motion never lets it fall in. So it goes round and round.

Without the pull, a planet would not go round. It would fly off in a straight line. You can see this with a ball on a string.

TRY IT

Swing a ball on a string

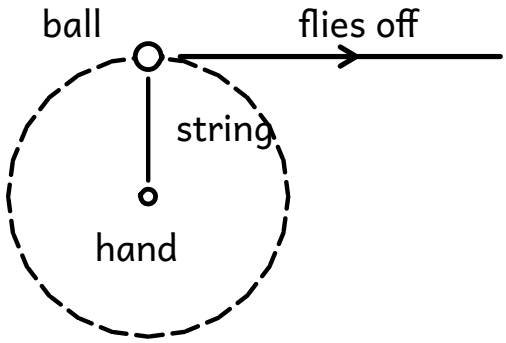
You need: a light, soft ball made of rolled cloth or a knotted sock, a string about 1 m long, a wide, open, flat place with nobody near.

Be safe: Use only a light, soft ball. Never use a stone. Swing and let go well away from people, animals and windows.

1. Tie the string firmly to the soft ball. Check that nobody is within 4 m.
2. Hold the end of the string. Swing the ball round in a flat circle at about waist height.
3. Feel the string pull your hand inwards. The pull is like gravity.
4. Slow down and stop. Then swing again and let go on purpose, with nobody in the way. Watch where the ball goes.

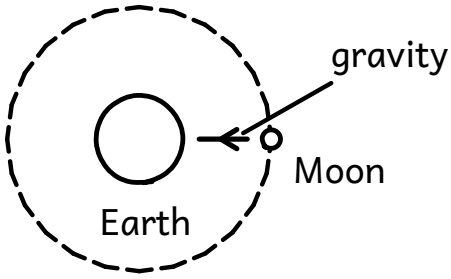
What you will see: While you hold the string, the ball goes round in a circle. The string pulls it inwards all the time. When you let go, the pull stops. The ball flies off in a straight line, not round and round.

If you cannot try it, this is what happens.



The Sun is like your hand, and gravity is like the pull of the string. Let the pull go, and a planet leaves its orbit in a straight line.

Gravity also holds moons. The Earth pulls on the Moon, and the Moon moves sideways, so the Moon goes round the Earth.



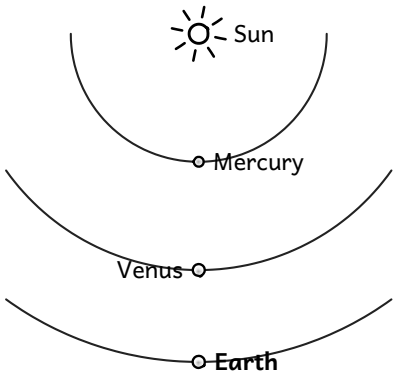
The Earth pulls the Moon inwards. The Moon moves sideways. So it goes round the Earth.

Now think about time. One trip round the Sun is a **year**. The Earth takes about 365 days, so our year has 365 days.

A planet that is nearer the Sun has a shorter way round, and it moves faster. A planet that is farther out has a longer way round, and it moves slower.

SEE IT THREE WAYS

As a picture



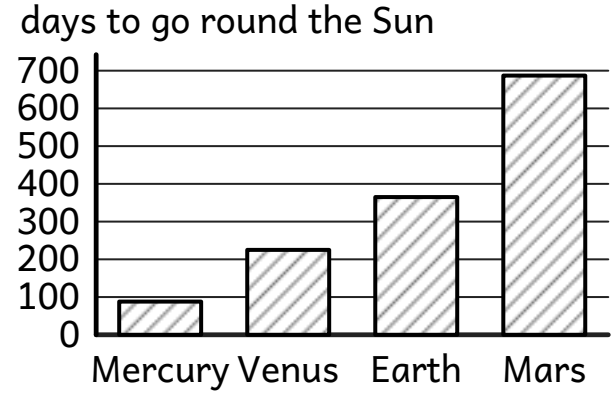
sizes not to scale

In words

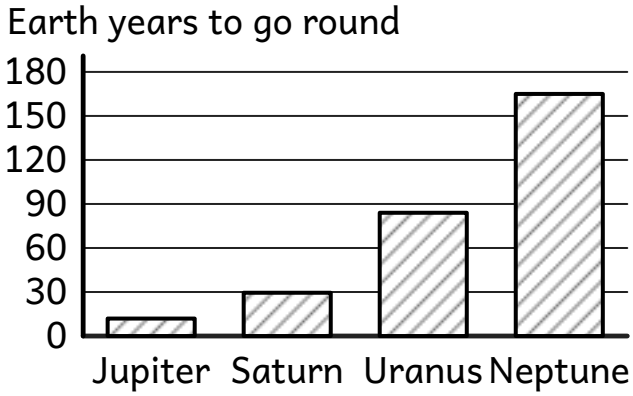
The nearer a planet is to the Sun, the shorter its orbit and the faster it moves. So Mercury takes the shortest time to go round. It takes only 88 days. The Earth takes 365 days.

In symbols

Mercury: 88 days.
Venus: 225 days.
Earth: 365 days.



The year of each rocky planet, in Earth days. The farther the planet, the longer the year.



The year of each giant, in Earth years. Neptune takes 165 Earth years to go round once.

There are two reasons. A far planet has a longer way round. It also moves more slowly, because the Sun pulls less far out. The Earth moves about 30 km a second. Neptune moves only about 5 km a second.

WORKED EXAMPLE

Venus takes 225 days to go round the Sun. How many times does it go round in 900 Earth days?

1. One trip takes 225 days.
2. Two trips take 2 × 225 = 450 days.
3. Four trips take 4 × 225 = 900 days.
4. So 900 ÷ 225 = 4. Venus goes round 4 times.

Answer: 4 times

A WRONG IDEA MANY PEOPLE HAVE

~~**There is nothing to hold a planet, so it just floats where it is.**~~

Why it feels right: Space looks empty, and there are no ropes or walls to see.

The test that breaks it: Swing the ball on its string. The ball goes round only while the string pulls. Let go, and it flies away. A planet stays on its path because something pulls it all the time.

What is true: Gravity is the invisible pull. It bends the path of each planet into an orbit round the Sun.

KEY WORDS

gravity
the pull that every body has on every other body.

orbit
the curved path of one body going round another.

year
the time a planet takes to go round the Sun once.

BACK TO YOUR GUESS

The answer is B: The Sun pulls the Earth, and the Earth is moving sideways, so it keeps curving round the Sun.

The Sun pulls the Earth with gravity. The Earth is also moving sideways. The pull bends its path into a curve, so the Earth keeps going round the Sun.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What keeps the Earth going round the Sun?

   A Air that pushes the Earth along

   B The Earth spinning on its axis

   C The pull of the Sun's gravity

   D Nothing. It floats where it is.

   Answer at the back of the book.

2. Suppose the Sun's pull on the Earth stopped suddenly. What would the Earth do?

   A Fly off in a straight line

   B Stop and hang still in space

   C Fall straight into the Sun

   Answer at the back of the book.

3. Which planet takes the longest time to go round the Sun?

   A Mercury

   B Neptune

   C Jupiter

   Answer at the back of the book.

4. Why does Neptune take so long to go round the Sun?

   A It is very cold, so it moves slowly.

   B It is bigger than the Earth, so it is heavy to move.

   C It is far away, so it has a long way to go and moves slowly.

   Answer at the back of the book.

5. Mercury goes round the Sun once in 88 days. How many times does it go round in 264 Earth days?

   A 176 times

   B 352 times

   C 23 232 times

   D 3 times

   Answer at the back of the book.

6. **From an earlier chapter**

   Mei makes a string model where 1 m stands for 200 million km. The Earth is about 150 million km from the Sun. How far along the string is the Earth?

   A 0.75 m

   B 7.5 m

   C 0.075 m

   D 30 000 m

   Answer at the back of the book.

7. What keeps the Moon going round the Earth?

   A The Sun pushes it round.

   B The Earth's gravity pulls on it.

   C The Moon is lighter than air, so it floats.

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Gravity pulls planets towards the Sun. A planet also moves sideways, so its path curves into an orbit. Planets far out go slower and have a longer year.

Draw: The Sun and a planet. Add an arrow of pull to the Sun, an arrow sideways, and a curved orbit.

S3.12.4 CHAPTER 4

Tilt and the seasons

Why is it hot for part of the year and cold for another part? Is the Earth nearer the Sun in summer?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The Earth is nearer the Sun in summer and farther away in winter.
- ☐ **B** The Sun itself gets hotter and colder through the year.
- ☐ **C** The Earth's axis is tilted, so each half takes turns leaning towards the Sun.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Earth, Sun and Moon, S2.9.4. The Earth goes round the Sun once in a year.
- Level 2, Earth, Sun and Moon, S2.9.2. The Earth spins, so each place has day and night.

BY THE END YOU CAN

- Explain seasons using the tilt of the Earth's axis
- Model seasons with a tilted ball going round a lamp

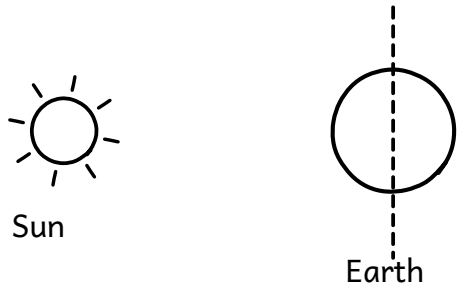
Through the year the weather changes. So does the length of the day. A **season** is a part of the year with its own kind of weather.

The Earth spins round a line through its middle, from the North Pole to the South Pole. This line is the ***axis***.

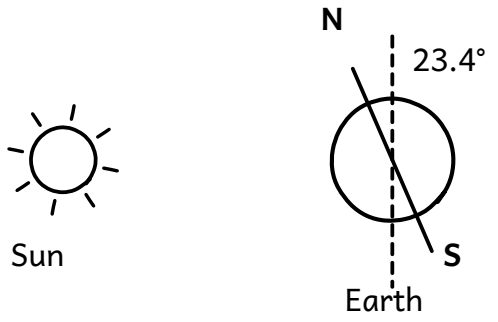
The axis does not stand upright. It leans over by about 23.4 degrees. We say the Earth is **tilted**.

DRAW IT FIRST

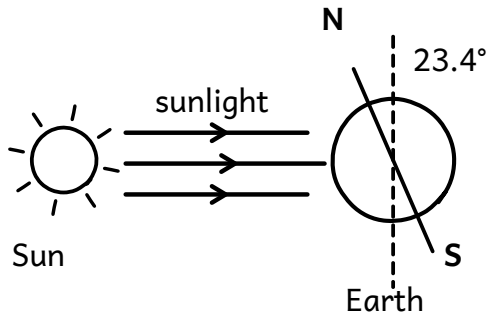
Draw the tilted Earth



1 Draw the Sun and the Earth. Draw an upright dotted line through the Earth, to show what upright means.

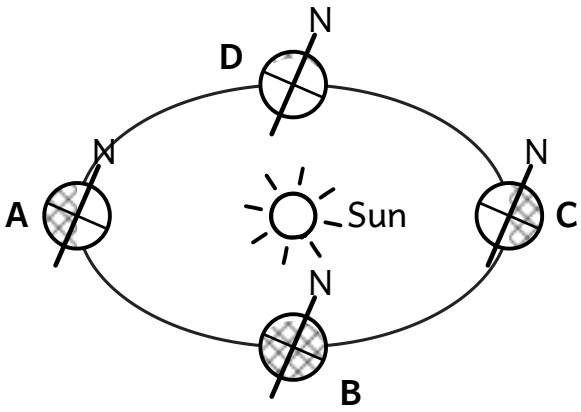


2 Draw the axis leaning by 23.4°. Write N at the north end and S at the south end.



3 Draw the sunlight going from the Sun to the Earth. The north end of the axis leans towards the Sun.

The axis points the same way in space all year. It always points to the same far-off spot in the sky. The Earth goes round the Sun, but the axis does not turn.



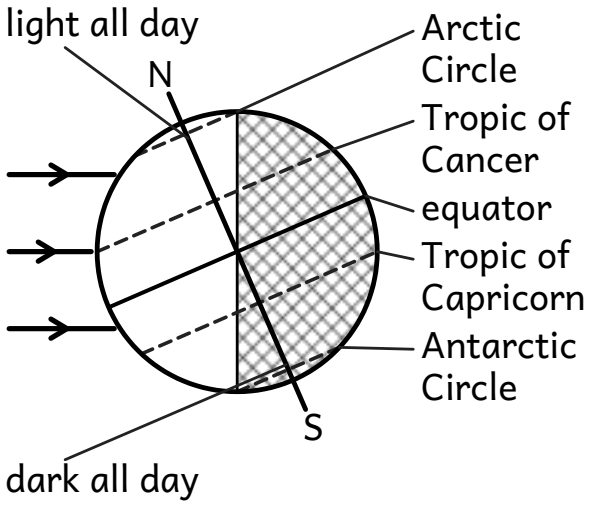
A north tipped towards the Sun
B north and south lit equally
C south tipped towards the Sun
D north and south lit equally

The Earth at four places on its path. The axis leans the same way each time. N shows the north end.

The Earth has two halves. The half north of the equator is the northern **hemisphere**. The half south of it is the southern hemisphere.

At A, the northern hemisphere leans towards the Sun. It has **summer**. The southern hemisphere leans away. It has **winter**.

Half a year later the Earth is at C. Now the south leans towards the Sun and has summer. The north leans away and has winter.



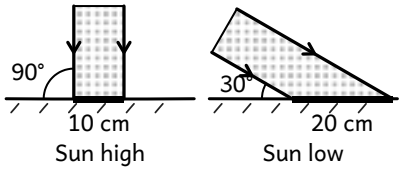
The north is tipped towards the Sun. The north has summer. The rings across the Earth are lines of latitude. The middle one is the equator.

Why does the tip make the difference? There are two reasons. The Sun climbs higher in the sky at midday. And the day is longer.

A high Sun is better at warming. Look at one beam of light, 10 cm wide, from a high Sun and from a low one.

SEE IT THREE WAYS

As a picture



In words

The same beam of light covers more ground when the Sun is low. So each square centimetre gets less light and less warmth. A high Sun gives a stronger warming.

In symbols

At 30° the patch is 10 × 2 = 20 cm long. The light is spread twice as thin.

Away from the equator, in summer the Sun is high at midday, and the days are long. So the ground has more time to warm, and it warms faster. In winter the Sun is low and the days are short.

The Earth does not change in distance very much. The table shows how far it is from the Sun at its nearest and its farthest.

place	million km
nearest	147
farthest	152

The Earth is nearest the Sun in early January. It is farthest in early July.

The difference is only about 5 million km out of 150 million km. That is tiny. And in early January it is winter in the north and summer in the south.

TRY IT

Make seasons with a ball and a lamp

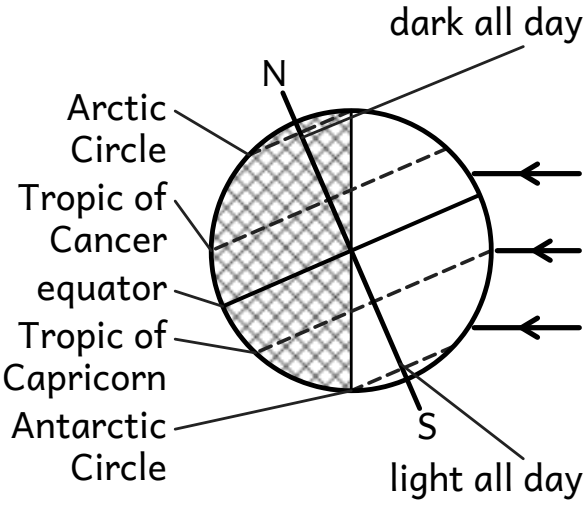
You need: a torch or battery lamp, a ball or an orange, a stick or pencil to push through the ball, a pen, a table in a room you can make dark, a sticky note for the wall.

Be safe: A lamp can get hot. Keep it away from paper and do not touch the bulb. Never use a lamp plugged into a wall socket. Never shine a torch into anyone's eyes.

1. Push the stick through the ball from top to bottom. The ends are the poles. Lean the stick over, about a quarter of the way to flat.
2. Draw a dot on the upper half of the ball for the north. Draw another on the lower half for the south.
3. Put the lamp in the middle of the table. Stick the note on one wall of the room.
4. Carry the ball in a big circle round the lamp. Keep the top of the stick leaning towards the note all the way. Never turn it.
5. Stop at four places, a quarter of the way apart. At each place, see which dot gets more light.

What you will see: In one place the top of the stick leans towards the lamp. The north dot gets more light. Half way round it leans away, and the south dot gets more light. In the two places between, both dots are lit about the same.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~It is summer when the Earth is nearer the Sun.~~

Why it feels right: A fire feels hotter when you are nearer. So the Sun seems to work the same way.

The test that breaks it: The Earth is nearest the Sun in early January. But it is winter in the north then. When the north has summer, the south has winter, yet both are the same distance from the Sun.

What is true: The tilt causes the seasons. The half of the Earth tipped towards the Sun has summer. The distance changes very little.

KEY WORDS

season
a part of the year with its own kind of weather.

axis
the line through the Earth from pole to pole, which it spins round.

tilted
leaning over. The Earth's axis leans by about 23.4 degrees.

hemisphere
one half of the Earth: north or south of the equator.

summer
the season when your hemisphere is tipped towards the Sun.

winter
the season when your hemisphere is tipped away from the Sun.

BACK TO YOUR GUESS

The answer is C: The Earth's axis is tilted, so each half takes turns leaning towards the Sun.

The Earth's axis is tilted. The half that leans towards the Sun has summer. The half that leans away has winter. The distance to the Sun hardly changes.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What causes the seasons?

   A The tilt of the Earth's axis

   B The Earth getting nearer to and farther from the Sun

   C The Sun getting hotter and colder

   Answer at the back of the book.

2. The northern hemisphere is having summer. What season is the southern hemisphere having?

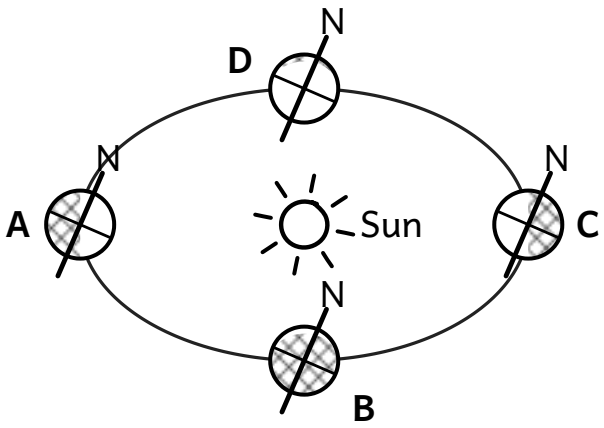
   A Summer too, because both halves get the same light

   B Winter

   C Summer, because it is the same distance from the Sun

   Answer at the back of the book.

3. You carry a tilted ball round a lamp, as in the try it. The stick leans the same way all the time. The ball is at four stops, A, B, C and D. The Sun stands for the lamp. At which stop is the south half tipped towards the lamp?



   A Stop A

   B Stop B

   C Stop D

   D Stop C

   Answer at the back of the book.

4. Why is the Sun's light weaker on the ground in winter?

   A The Earth is farther from the Sun, so the light is dimmer.

   B The Sun is smaller in winter.

   C The Sun is lower, so the same light is spread over more ground.

   Answer at the back of the book.

5. The Earth is 147 million km from the Sun at its nearest. It is 152 million km at its farthest. What does this tell us about the seasons?

   A The distance changes by only 5 million km, so it cannot cause the seasons.

   B The Earth is nearest in summer, so summer is hot.

   C The Earth is farthest in winter, so winter is cold.

   Answer at the back of the book.

6. **From an earlier chapter**

   What do we call the curved path of the Earth round the Sun?

   A Its axis

   B Its orbit

   C Its year

   Answer at the back of the book.

7. A beam of sunlight 8 cm wide falls on flat ground. The Sun is low, at 30 degrees. The patch is 2 times as long as the beam is wide. How long is the patch?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

The Earth's axis is tilted about 23.4° and points the same way all year. The half tipped towards the Sun has summer. The other half has winter.

Draw: The Sun, and the Earth at two opposite places with the axis tilted the same way. Mark summer and winter in each half.

S3.12.5 CHAPTER 5

Seasons around the world

> **Why is it summer in one place while it is winter in another? Why is it warm all year at the equator?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Every place on Earth has the same season at the same time.
- ☐ **B** The south is always farther from the Sun than the north.
- ☐ **C** When the north leans towards the Sun, the south leans away. So the two halves have opposite seasons.

IF THIS FEELS HARD, READ THIS FIRST

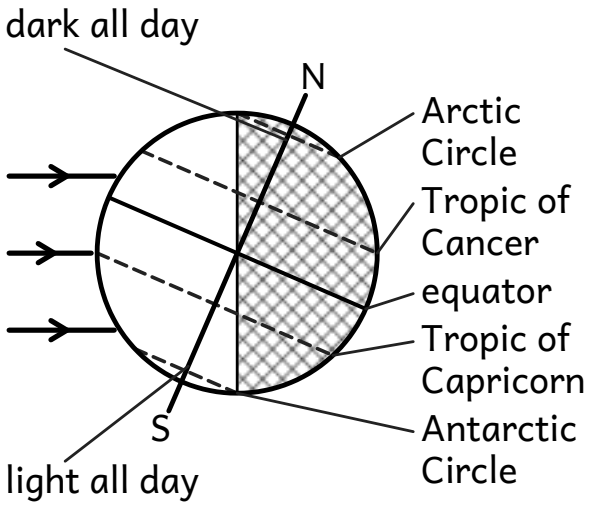
- Level 3, The solar system and seasons, S3.12.4. The seasons come from the tilt of the Earth's axis.
- Level 2, Earth, Sun and Moon, S2.9.3. The Sun climbs high in the sky and goes down again.

BY THE END YOU CAN

- Explain why the two hemispheres have opposite seasons
- Explain why places near the equator stay warm all year
- Explain how the rain belt follows the overhead Sun to make wet seasons

In some places the year goes from hot to cold and back again. Near the equator it stays warm. There the seasons are wet and dry. Why is the Earth so different from place to place?

First, the two halves of the Earth. In the last chapter you saw that the north and the south take turns leaning towards the Sun. When one half leans in, the other leans out.

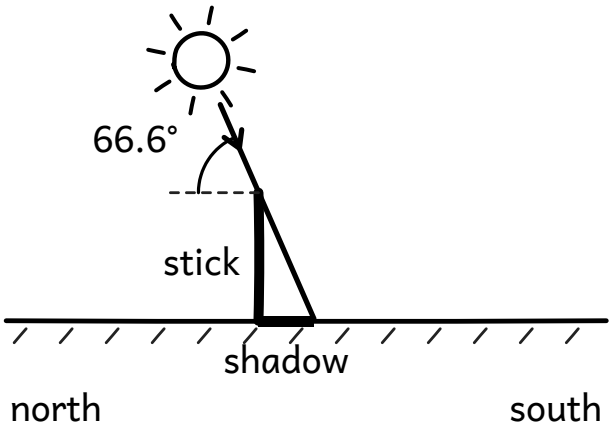


The south is tipped towards the Sun. The south has summer and the north has winter.

When the south leans towards the Sun, it has summer. At the same time the north leans away and has winter. When the north has its longest day, the south has its shortest. The two halves have opposite seasons.

Now look at the middle of the Earth. The **equator** is the line round the middle, halfway between the poles. Places near it are warm all year.

At the equator the Sun is always high at midday. Even on its lowest day it is more than 66 degrees above the horizon. That is not far from straight above you.



The lowest the midday Sun gets at the equator. It is still very high, so the shadow is short.

The days near the equator are about the same length all year. The table gives the hours of day at the equator. It is about 12 hours of day and 12 hours of night, in every month.

SEE IT THREE WAYS

As a picture

month	hours of day
Jan	12
Apr	12
Jul	12
Oct	12

In words

Near the equator the Sun is high at midday. The day is about 12 hours long all year. The ground gets strong sunlight for a long time every day, so it stays warm.

In symbols

At the equator: 12 hours of day + 12 hours of night = 24 hours.

There is more. Between two special lines the midday Sun can stand straight overhead. **Overhead** means straight above you. One is the Tropic of Cancer, 23.4 degrees north of the equator. The other is the Tropic of Capricorn, 23.4 degrees south of it.

The band between the two lines is called the **tropics**. Outside the tropics the midday Sun is never overhead.

The place where the midday Sun is overhead moves. It goes north to the Tropic of Cancer and back south. It crosses the equator on the way. Then it goes to the Tropic of Capricorn and back. This takes one year.

date	overhead at
21 March	equator
21 June	23.4° north
22 September	equator
21 December	23.4° south

The overhead Sun on four days of the year. It goes north, then south, then north again.

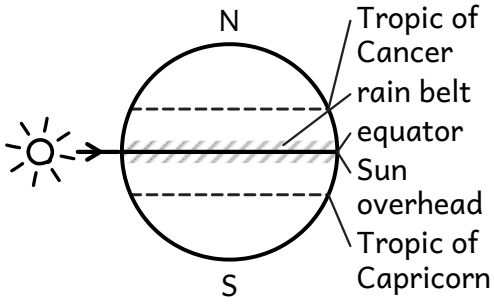
Now rain. Where the Sun is high, the ground gets very hot. The hot ground warms the air above it. Warm, moist air rises. As it rises it cools, and clouds and heavy rain form.

So rain falls most under the overhead Sun. There is a belt of cloud and rain round the Earth near the equator. It is the **rain belt**. It follows the overhead Sun north

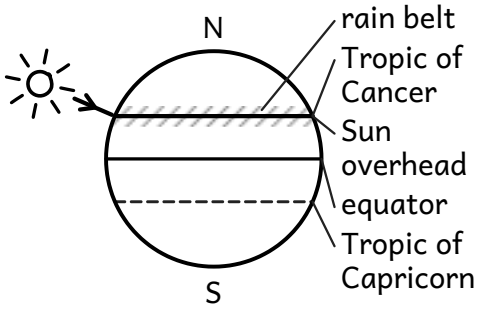
and south, a little behind it.

DRAW IT FIRST

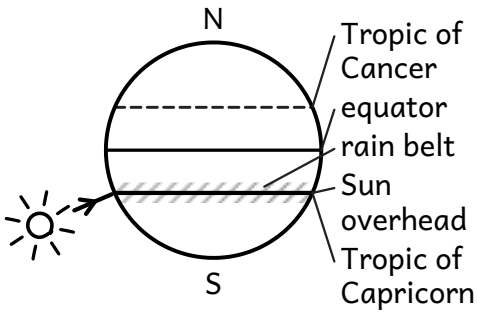
Draw the rain belt following the Sun



1 Draw the Earth with the equator and the two tropics. When the Sun is overhead at the equator, draw the rain belt along the equator.



2 Move the overhead line to the Tropic of Cancer. The belt moves north with it.



3 Move the overhead line to the Tropic of Capricorn. The belt moves south.

These pictures show the idea. The real belt is not a neat band. Land, sea and mountains push it about. We say it moves roughly with the overhead Sun.

When the rain belt is over a place, it is the **wet season**. When the belt has moved away, it is the **dry season**. The belt passes over a place near the equator twice a year. That place has two wet seasons. A place farther from the equator gets it once

a year, so it has one wet season. Some places near the tropics are past where the belt reaches. They stay dry, and many are deserts.

TRY IT

Move the overhead Sun with a torch

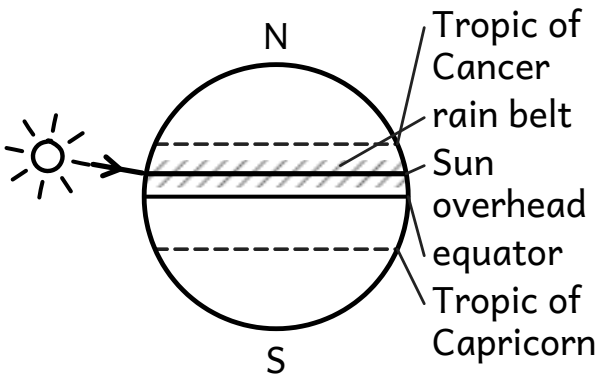
You need: a torch or battery lamp, a ball or an orange, a stick or pencil to push through the ball, a pen, a room you can make dark.

Be safe: A lamp can get hot. Keep it away from paper and do not touch the bulb. Never use a lamp plugged into a wall socket. Never shine a torch into anyone's eyes.

1. Push the stick through the ball from top to bottom. Draw the equator round the middle with the pen.
2. Draw one line about a quarter of the way up from the equator, for the Tropic of Cancer. Draw one the same distance down, for the Tropic of Capricorn.
3. In the dark, hold the torch a hand's width from the ball. Shine it at the equator. The brightest spot is where the Sun is overhead.
4. Lean the top of the stick towards the torch, about a quarter of the way to flat. Keep the torch still, shining at the middle of the ball. Watch the bright spot.
5. Lean the stick the other way, so the bottom leans towards the torch. Watch the spot again.

What you will see: The bright spot is on the equator when the stick is upright. It moves north when you lean the top towards the torch. It moves south when you lean the other way. It never goes beyond the two tropic lines.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~The equator is warm because it is nearer the Sun.~~

Why it feels right: A map or a ball shows the equator sticking out towards the Sun. Nearer things feel hotter.

The test that breaks it: The side of the Earth that faces the Sun is at most about 6 400 km nearer. The Sun is 150 million km away. Such a tiny difference cannot matter.

What is true: The equator is warm because the midday Sun is always high there. The days are about 12 hours long all year. The sunlight is strong and it lasts.

KEY WORDS

equator
the line round the middle of the Earth, halfway between the poles.

overhead
straight above you.

tropics
the band between the Tropic of Cancer and the Tropic of Capricorn.

rain belt
the belt of cloud and heavy rain that follows the overhead Sun.

wet season
the time when the rain belt is over a place.

dry season
the time when the rain belt has moved away.

BACK TO YOUR GUESS

The answer is C: When the north leans towards the Sun, the south leans away. So the two halves have opposite seasons.

The axis leans one way. When the north is tipped towards the Sun, the south is tipped away. So the two halves have opposite seasons, at the same time.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. The southern half of the Earth is having winter. What season is the northern half having?

   A Summer

   B Winter too, because the Earth has one season at a time

   C The northern half has no seasons.

   Answer at the back of the book.

2. Why is it warm all year near the equator?

   A The equator is nearer the Sun than anywhere else.

   B The midday Sun is always high, and the days are about 12 hours long all year.

   C The equator is not tilted, so it has summer all year.

   Answer at the back of the book.

3. Where on the Earth can the midday Sun be straight overhead?

   A Anywhere, at midday in summer

   B Only at the equator

   C At the poles

   D Only between the Tropic of Cancer and the Tropic of Capricorn

   Answer at the back of the book.

4. What makes a wet season?

   A The Earth is farthest from the Sun, so the air is cold and wet.

   B It is winter in the place, so it must rain.

   C The rain belt moves over the place, following the overhead Sun.

   Answer at the back of the book.

5. The midday Sun is overhead at about 20° north. A town lies at 20° north and another at 20° south. Which town is more likely to have the rain belt over it now?

   A The town at 20° north

   B The town at 20° south

   C Both towns have the same rain.

   Answer at the back of the book.

6. **From an earlier chapter**

   A friend says it is summer when the Earth is nearer the Sun. What do you say?

   A That is true. A nearer Sun is hotter.

   B That is not true. The tilt of the axis causes the seasons.

   C That is true for the south but not for the north.

   Answer at the back of the book.

7. Tariq notes that the overhead Sun is at 10° south. Some weeks later it is overhead at 20° north. How many degrees has it moved?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

North and south have opposite seasons. Near the equator the Sun is always high, so it stays warm. The rain belt follows the overhead Sun and makes the wet seasons.

Draw: The Earth with the equator and two tropics. Draw the overhead line and the rain belt on it.

S3.12.6 CHAPTER 6

Day length and the Sun's height

> **Why are some days longer than others? Can I track the Sun with a stick?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Every day has the same length everywhere, all year.
- ☐ **B** The days change because the Earth spins faster in summer.
- ☐ **C** In most places the day length changes through the year. Near the equator it hardly changes.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Tables and charts, M2.7.6. You plot points and join them in a line graph.
- Level 2, Light and shadows, S2.6.6. A stick's shadow shows where the Sun is.

BY THE END YOU CAN

- Graph day length through a year from a table
- Track the Sun's midday height by measuring a stick's shadow

The **day length** is the time from **sunrise** to **sunset**. It is the hours of daylight. In most places it is not the same all year.

Near the equator, day and night are about 12 hours each, all year. Farther from the equator the day length changes a lot.

Here are the day lengths for two places. One is 40 degrees north of the equator. The other is 40 degrees south of it. The table gives the hours of day in the middle of each month.

SEE IT THREE WAYS

As a picture

month	40° N	40° S
Jan	9.5	14.5
Feb	10.5	13.5
Mar	11.7	12.3
Apr	13.1	10.9
May	14.2	9.8
Jun	14.8	9.2
Jul	14.6	9.4
Aug	13.6	10.4
Sep	12.2	11.8
Oct	10.9	13.1
Nov	9.7	14.3
Dec	9.2	14.8

In words

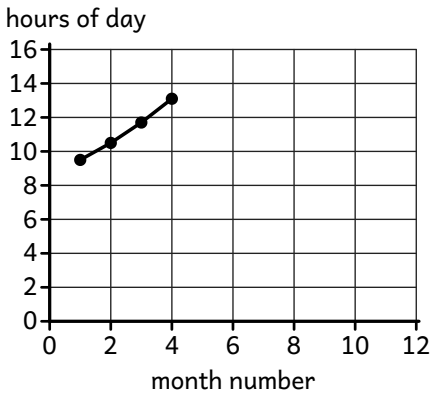
At 40° north the day is longest in June and shortest in December. At 40° south it is the other way round. The two places have the same pattern, six months apart.

In symbols

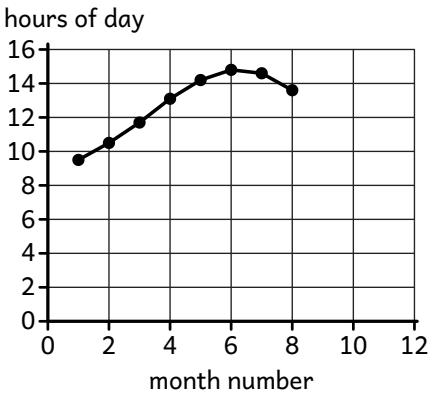
40° N: longest 14.8 hours, shortest 9.2 hours.

DRAW IT FIRST

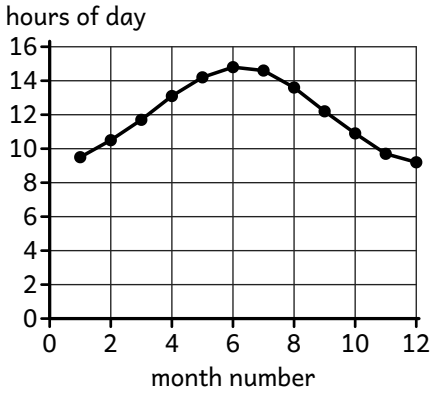
Graph the day length



1 Draw the two axes. Put the month number along the bottom and the hours of day up the side. Plot the first four months.

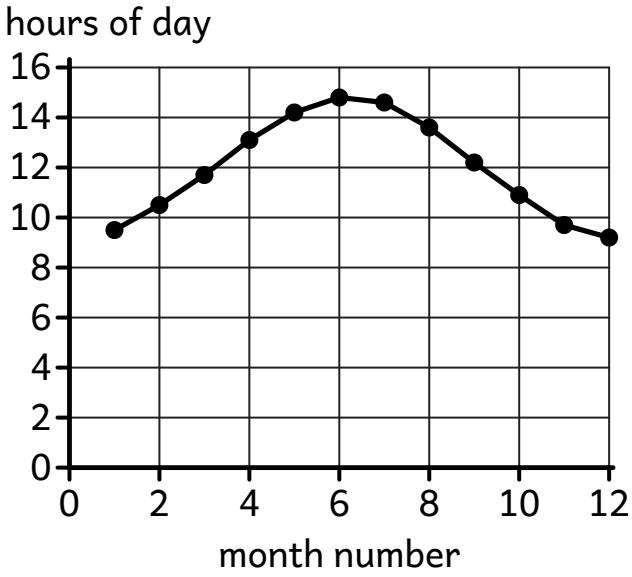


2 Plot the next four months. Put each point exactly at its month and its hours.

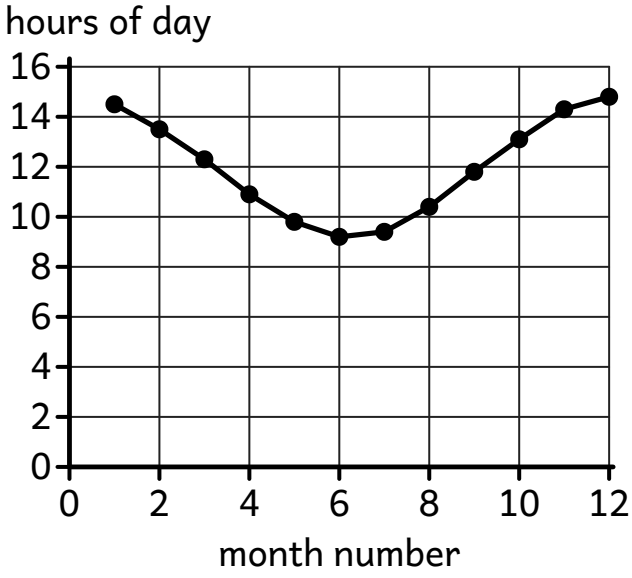


3 Plot the last four months. Join the points with a line.

The line rises to a peak, then falls to a low point, then rises again. At 40° north the peak is in the middle of the year.



Day length at 40° north. The peak is the longest day. The low point is the shortest.



Day length at 40° south. The peak is at the end of the year, six months from the north.

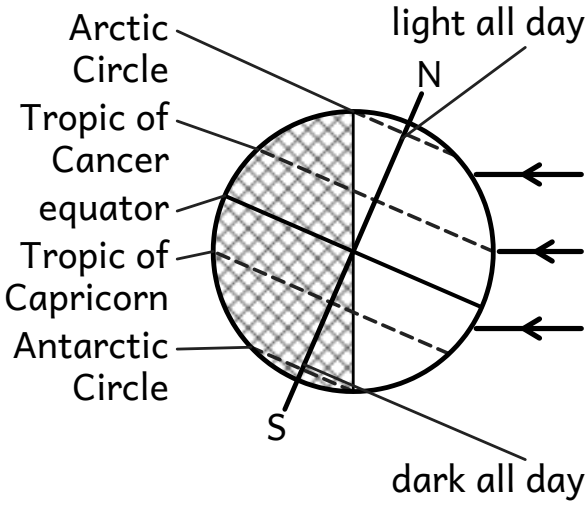
WORKED EXAMPLE

Use the graph for 40° north. How much longer is the longest day than the shortest day?

1. The graph for 40° north has one peak and one low point in the year.
2. The peak is at month 6, June.
3. At month 6 the graph is at 14.8 hours. That is the longest day.
4. The lowest point, at month 12, is 9.2 hours. That is the shortest day.
5. Take away the smaller from the bigger: 14.8 − 9.2 = 5.6 hours.

Answer: 5.6 hours

Near the poles the changes are huge. Inside the polar circles some days have 24 hours of light. Others have 24 hours of dark. At the poles themselves the Sun stays up for about six months. Then it stays down for about six months.



The ring round the north pole is in the light all day. The ring round the south pole is in the dark all day.

Now the Sun's height. At midday the Sun is at its highest point in the sky. The higher it is, the shorter the shadow of a stick. A low Sun makes a long shadow.

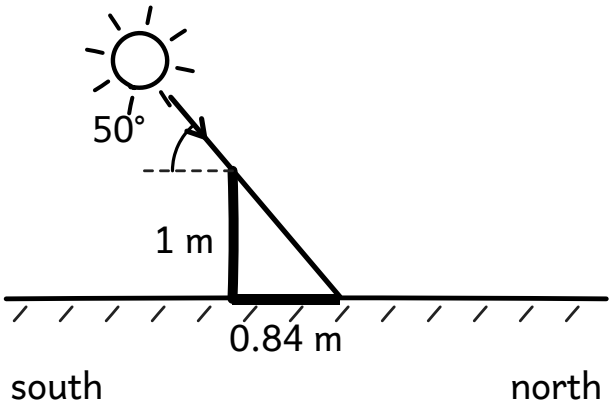
Be safe. Look only at the ground and at the shadow. Never look at the Sun.

Sun height	shadow (cm)
30°	173
45°	100
60°	58
75°	27
90°	0

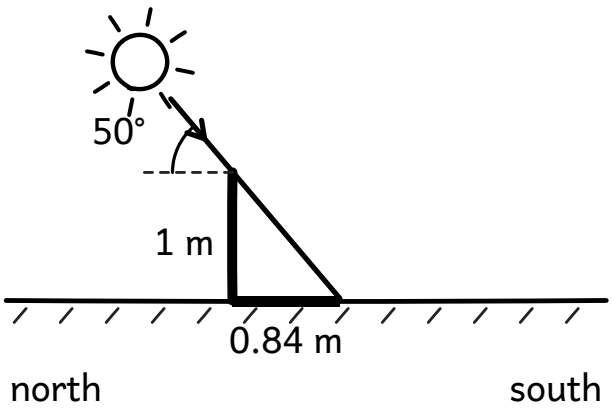
A stick 100 cm tall. A higher Sun gives a shorter shadow. A stick half as tall gives half the shadow.

A stick that is twice as tall has a shadow twice as long. Later in mathematics you will meet a rule for this, using a button called tan. You do not need it now. The table gives the numbers.

The shadow points away from the Sun. So which way it points at midday depends on where you live.



At 40° north the midday Sun is in the south, so the shadow points north. This is on a day when the midday Sun is overhead at the equator.



At 40° south the midday Sun is in the north, so the shadow points south. This is on a day when the midday Sun is overhead at the equator.

North of the Tropic of Cancer the midday shadow always points north. South of the Tropic of Capricorn it always points south. Between the two tropics it can point either way. On two days a year the Sun is overhead, and there is no shadow at all.

TRY IT

Track the midday Sun with a stick

You need: a straight stick about 1 m tall, a flat patch of ground, in the Sun all day, small stones, a ruler or a string marked in cm, a clock or a watch, paper and a pencil.

Be safe: Look only at the ground and at the shadow. Never look at the Sun, not even for a moment, and not through anything.

1. Push the stick into the ground, so that it stands straight up. Press the earth round it. Measure its height above the ground.
2. Start at about 11 by the clock and go on until about 2. Every 15 minutes, put a stone on the tip of the shadow.
3. The shortest shadow is the midday one. Measure it from the foot of the stick to the stone, in cm.
4. Do it once a week for four weeks. Write down each midday shadow.
5. Look at the numbers. Is the shadow getting longer, or shorter?

What you will see: Our shadows were 70, 76, 82 and 90 cm long. They grew longer, so the Sun was getting lower at midday. Your shadows may get shorter, if the Sun is getting higher where you live.

If you cannot try it, this is what happens.

week	shadow (cm)
1	70
2	76
3	82
4	90

A WRONG IDEA MANY PEOPLE HAVE

~~The shortest shadow comes when the clock says 12.~~

Why it feels right: The word midday sounds like 12 o'clock, so the Sun should be highest then.

The test that breaks it: Mark the tip of the shadow every 15 minutes. The shortest shadow may come before or after 12 on the clock, sometimes by an hour or more. Clocks are set for a whole region, not for your exact place.

What is true: The Sun is highest at midday, and then the shadow is shortest. That is true midday, whatever the clock says.

KEY WORDS

day length
the time from sunrise to sunset, in hours.

sunrise
the moment the Sun first shows over the horizon.

sunset
the moment the Sun disappears below the horizon.

BACK TO YOUR GUESS

The answer is C: In most places the day length changes through the year. Near the equator it hardly changes.

The tilt makes day length change through the year. The change grows as you go away from the equator. At the equator it is close to 12 hours all year. The Earth spins at the same speed all year.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which place has almost the same day length all year?

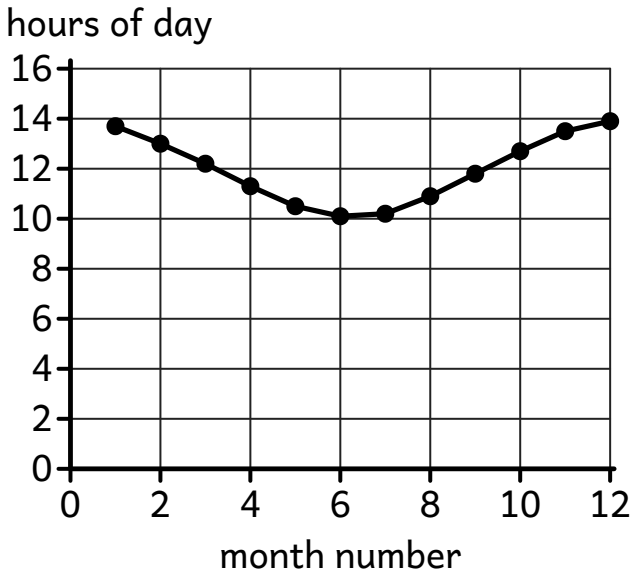
   A A place on the equator

   B A place far from the equator

   C A place near a pole

   Answer at the back of the book.

2. The graph is for a place 30° south of the equator. Month 1 is January. In which month is the day longest?



   A June

   B December

   C March

   Answer at the back of the book.

3. At 30° north the longest day is 13.9 hours. The shortest day is 10.1 hours. How many hours longer is the longest day?

   A 24 hours

   B 12 hours

   C 3.8 hours

   Answer at the back of the book.

4. Mei measures the midday shadow of a stick each week. This week it is shorter than last week. What does that tell her?

   A The midday Sun is higher than last week.

   B The midday Sun is lower than last week.

   C The Sun is nearer the Earth this week.

   Answer at the back of the book.

5. Ana lives 40° south of the equator. At midday, which way does a stick's shadow point?

   A North

   B South

   C Straight down, with no shadow

   Answer at the back of the book.

6. **From an earlier chapter**

   In which of these places can the midday Sun ever be straight overhead?

   A A place 40° north of the equator

   B A place 40° south of the equator

   C A place 10° north of the equator

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Day length changes through the year, except near the equator. North and south have opposite patterns. A high midday Sun gives a short shadow, pointing away from the Sun.

Draw: A graph of day length against month, rising and falling once. Add a stick with a short shadow.

S3.12.7 CHAPTER 7

Moons, asteroids and comets

A shooting star flashes across the sky. Is it a star that is falling?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** It is a small bit of rock or dust burning up high in the air.
- ☐ **B** It is a star that has fallen out of the sky.
- ☐ **C** It is a planet that has lost its way.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Earth, Sun and Moon, S2.9.5. The Moon goes round the Earth.

BY THE END YOU CAN

- Describe moons, dwarf planets, asteroids and comets
- Explain what a shooting star really is

The solar system holds more than the Sun and the eight planets. It holds moons, dwarf planets, asteroids and comets. Each is a different kind of body.

A **moon** is a body that goes round a planet or a dwarf planet. The Earth has one Moon. Mercury and Venus have none. Mars has two.

The giant planets have many moons. New ones are still being found, so we say about.

planet	moons
Mercury	0
Venus	0
Earth	1
Mars	2
Jupiter	about 95
Saturn	about 270
Uranus	about 28
Neptune	about 16

Moons of each planet. Saturn has the most, about 270.

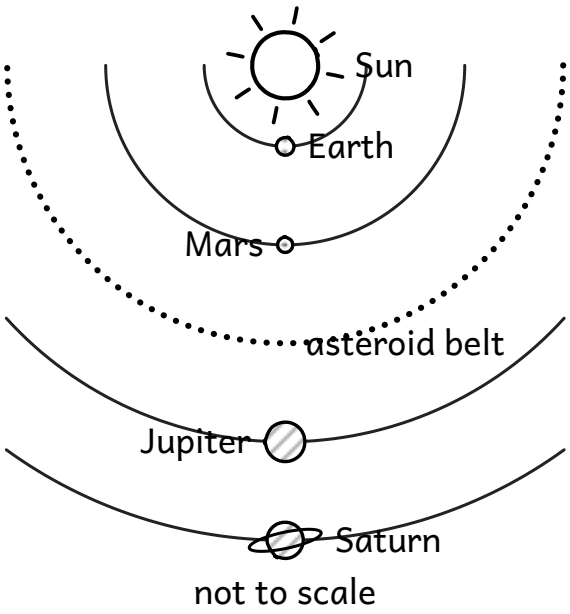
A **dwarf planet** is round, like a planet. But it shares its path round the Sun with many other bodies. Pluto and Ceres are dwarf planets.

Dwarf planets are small. Pluto is smaller than our Moon. The table gives the width of some bodies.

body	km wide
Earth	12 742
Moon	3 474
Pluto	2 377
Ceres	940

Pluto and Ceres are dwarf planets. Both are smaller than the Moon.

An ***asteroid*** is a lump of rock that goes round the Sun. Most asteroids lie in a belt between Mars and Jupiter. There are millions of them, and most are small.



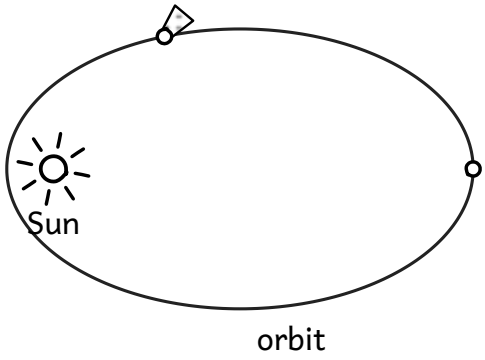
The asteroid belt lies between Mars and Jupiter. Not to scale.

A **comet** is a ball of ice and dust on a long, thin orbit round the Sun. Far from the Sun it is a frozen lump with no tail.

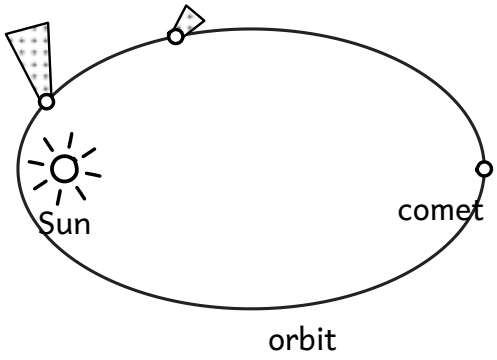
Near the Sun the comet warms. Gas and dust stream off it. The Sun's light and wind push them away from the Sun, so the comet gets a tail. The tail always points away from the Sun.

DRAW IT FIRST

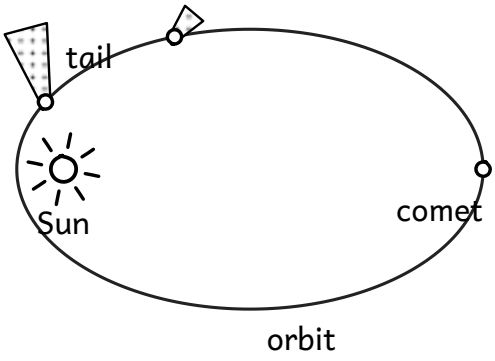
Draw *a* comet on its long orbit



1 Draw the Sun and *a* long, thin orbit. Draw the comet far away with no tail, and *a* little nearer with *a* short tail.



2 Draw the comet near the Sun, too. Near the Sun its tail is longest.



3 Draw each tail pointing straight away from the Sun. Name the parts.

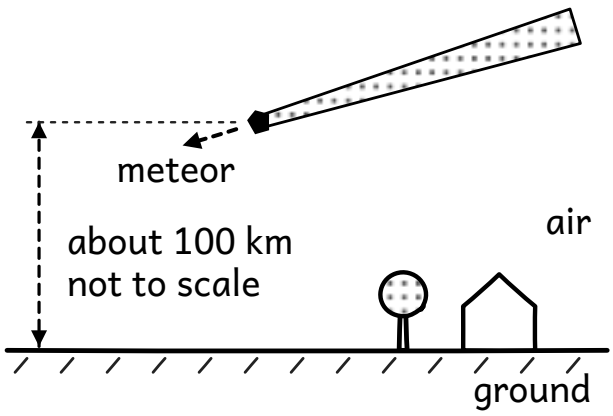
A comet's tail points away from the Sun even when the comet is moving away. The tail is not smoke blown out behind it. It is pushed by the Sun.

Now, the shooting star. Tiny bits of rock and dust fly through space. Many are smaller than *a* pea. Sometimes one meets the Earth and flies into our air.

The bit moves at tens of kilometres every second. It squeezes the air in front of it. The air gets very hot. The bit glows and burns up, high above the ground, about 100 km up.

SEE IT THREE WAYS

As a picture



In words

A small bit of rock or dust burns up in the air. The glowing streak is called a meteor. People call it a shooting star, but it is not a star. A real star is a far-off sun.

We call the streak of light a **meteor**. Most bits burn up completely, so nothing reaches the ground. If a piece does reach the ground, it is a **meteorite**.

TRY IT

Watch for shooting stars

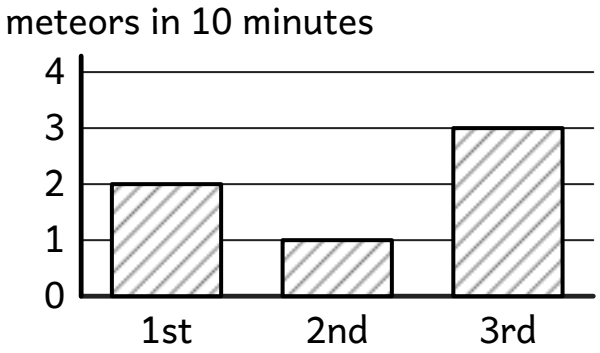
You need: an adult to come with you, a warm blanket or mat to lie on, a safe, open place with a clear dark sky, paper and a pencil.

Be safe: Go with an adult, to a safe place away from roads. Never go alone at night. Stay on the mat and do not wander in the dark.

1. Go out at night with an adult. Choose a safe place, away from roads, water and steep edges.
2. Lie on the mat and look at the sky. Wait for ten minutes, so your eyes get used to the dark.
3. Watch for 30 minutes. Every time you see a bright streak, make a mark on your paper.
4. After each 10 minutes, count the marks and write the number down.

What you will see: You may see a few streaks, or none. Some nights are better than others. Each streak is a bit of rock or dust burning up, high in the air.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~**A shooting star is a star that falls to the Earth.**~~

Why it feels right: The streak looks like a star that has come loose and dropped across the sky.

The test that breaks it: The stars are still in their places after a streak has gone. A real star is a sun, very far away. It does not drop across the sky.

What is true: A shooting star is a meteor. It is a small bit of rock or dust that burns up high in the air.

KEY WORDS

moon
a body that goes round a planet or a dwarf planet.

dwarf planet
a small, round body that shares its path with many others.

asteroid
a lump of rock that goes round the Sun, mostly in a belt between Mars and Jupiter.

comet
a ball of ice and dust on a long orbit, with a tail near the Sun.

meteor
the streak of light when a bit of rock or dust burns up in the air.

meteorite
a piece of space rock that reaches the ground.

BACK TO YOUR GUESS

The answer is A: It is a small bit of rock or dust burning up high in the air.

A shooting star is a small bit of rock or dust from space. It burns up in the air high above us. A real star is a huge, far-off sun, and it does not fall.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What is a shooting star?

   A A star that falls out of the sky

   B A small bit of rock or dust burning up high in the air

   C A planet that has lost its way

   Answer at the back of the book.

2. A comet is close to the Sun. Which way does its tail point?

   A Behind the comet, along the way it has come

   B Towards the Sun

   C Away from the Sun

   Answer at the back of the book.

3. Where is the main belt of asteroids?

   A Between Mars and Jupiter

   B Between Earth and Mars

   C Beyond Neptune

   Answer at the back of the book.

4. Why is Pluto called a dwarf planet?

   A It is not round.

   B It is round, but it shares its path with many other bodies.

   C It has no moon.

   Answer at the back of the book.

5. Which planet has the most moons?

   A Earth

   B Jupiter

   C Saturn

   Answer at the back of the book.

6. **From an earlier chapter**

   What keeps a moon going round its planet?

   A The planet's gravity pulls on it.

   B The Sun pushes it in a circle.

   C It floats where it is, with nothing holding it.

   Answer at the back of the book.

7. Kofi reads that the Moon is 3 474 km wide and Pluto is 2 377 km wide. How much wider is the Moon than Pluto?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Moons orbit planets. Asteroids are rocks, mostly between Mars and Jupiter. Comets are icy and their tails point away from the Sun. A shooting star is a meteor, burning up.

Draw: The Sun and a long thin orbit. Draw a comet near the Sun, its tail pointing away.

S3.12.8 CHAPTER 8

Exploring space

Nobody has been to Jupiter. How do we know what it looks like?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** People have visited every planet and taken photographs.
- ☐ **B** Telescopes, satellites and space probes collect light and send us pictures and measurements.
- ☐ **C** We only guess, from old stories.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, The solar system and seasons, S3.12.3. Satellites are held in orbit by gravity.
- Level 2, Light and shadows, S2.6.3. We see when light reaches our eyes.

BY THE END YOU CAN

- Explain how telescopes, satellites and space probes help us learn
- Name ways satellites help people, such as weather and phone signals

People have walked on only one other body, the Moon. No person has been to another planet. Yet we know what Jupiter's clouds look like. Three kinds of tool do the visiting for us.

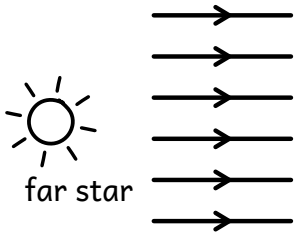
The first tool is the **telescope**. A telescope collects more light than your eye can. So it shows things that are faint or far away.

Be safe. Never look at the Sun, not even through a telescope. It can blind

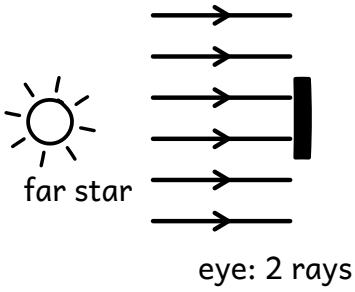
you in a moment.

DRAW IT FIRST

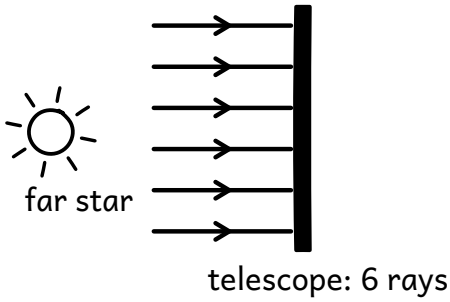
Draw how a telescope collects light



1 Draw a far star and six arrows of light coming from it. The star is so far away that the arrows run side by side.



2 Draw your eye as a small opening. It catches only two of the six arrows.



3 Draw a telescope as a wide opening. It catches all six arrows. A round opening 3 times as wide catches 9 times as much light.

A telescope has a big lens or mirror to catch the light. The wider it is, the more light it catches. More light means a brighter picture, so fainter and farther things can be seen.

TRY IT

Catch rice like a telescope catches light

You need: a small cup about 5 cm wide, a wide bowl about 15 cm wide, a tray or a cloth to work on, a handful of dry rice or small beans, paper and a pencil.

Be safe: Do not eat the rice. Sweep up any that falls on the floor, so that nobody slips.

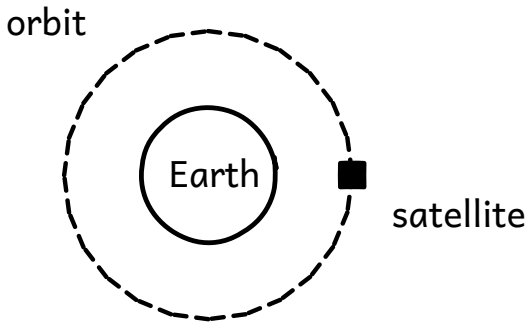
1. Put the cup and the bowl side by side on the tray.
2. Hold a pinch of rice high above them. Let it fall like rain, evenly over both.
3. Do this until the cup has caught a few grains. Stop.
4. Count the grains in the cup and the grains in the bowl. Write both numbers down.
5. Divide the bowl's number by the cup's number. How many times as much did the bowl catch?

What you will see: The bowl is 3 times as wide as the cup. But it catches about 9 times as much rice. A wide mirror catches far more light, in the same way.

If you cannot try it, this is what happens.

container	width	grains
cup	5 cm	12
bowl	15 cm	108

The second tool is the **satellite**. A satellite is a body that goes round a planet. The Moon is a natural satellite of the Earth. People have also built satellites and sent them up. They orbit the Earth, held by gravity.



A satellite goes round the Earth on its orbit, held by gravity.

Satellites help us in many ways. They send down pictures of clouds, so we get weather forecasts. They carry phone and television signals across the world. They help a phone find where you are. They look at forests, farms, ice and the sea.

job	example
weather	cloud pictures
signals	calls and TV
position	where you are
land and sea	forests, ice

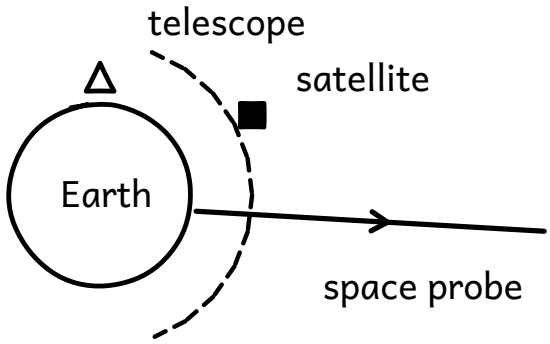
Four jobs for satellites that orbit the Earth.

The third tool is the **space probe**. A space probe is a machine sent to travel to another planet or moon. It has cameras and other instruments. It sends pictures and measurements back to the Earth by radio.

Some probes fly past a planet. Some go into orbit round it. Some land on it. No person has to go.

SEE IT THREE WAYS

As a picture



In words

A telescope stays on the ground, or in orbit, and collects light. A satellite goes round the Earth. A space probe leaves the Earth and goes to another planet.

The probe's messages travel as radio waves. Radio waves go about 300 000 km every second. That is very fast, but space is very big. A signal needs time to cross it.

place	km	seconds
Moon	384 000	1.3
Sun	150 000 000	500

Radio and light go 300 000 km every second. Sunlight takes about 8 minutes to reach us.

Time = distance ÷ 300 000 km each second. A message from the Moon takes about 1.3 seconds. A message from a probe far out in the solar system can take hours.

A WRONG IDEA MANY PEOPLE HAVE

~~We know about the planets because people have visited them.~~

Why it feels right: Pictures of planets look like photographs taken by a traveller.

The test that breaks it: Ask who took the picture. It was taken by a camera on a probe or on a satellite. Or it came from a telescope. No person was there.

What is true: We learn about the planets from light collected by telescopes. We also learn from probes and satellites that go there for us.

KEY WORDS

telescope
a tool that collects more light than your eye, to show faint and far things.

satellite
a body that goes round a planet, such as a built one that orbits the Earth.

space probe
a machine sent to travel to another planet or moon.

BACK TO YOUR GUESS

The answer is B: Telescopes, satellites and space probes collect light and send us pictures and measurements.

Telescopes collect light from far away. Satellites orbit the Earth and look down. Space probes travel to other planets and send pictures and measurements home.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What does a telescope do?

   A It brings far-off things nearer to us.

   B It makes the Sun safe to look at.

   C It collects more light, so faint and far things can be seen.

   Answer at the back of the book.

2. What is a satellite?

   A A body that goes round a planet, such as a machine that orbits the Earth

   B A machine that travels to other planets

   C A small star near the Earth

   Answer at the back of the book.

3. Which machine travels to another planet and sends pictures home?

   A A weather satellite

   B A space probe

   C A telescope on a hill

   Answer at the back of the book.

4. Where do the cloud pictures in a weather report come from?

   A Telescopes on the ground

   B Space probes that visit other planets

   C Satellites that orbit high above the Earth

   Answer at the back of the book.

5. A radio signal travels 300 000 km every second. A probe is 2 700 000 km away. How long does a signal take to reach it?

   A 9 seconds

   B 90 seconds

   C 0.11 seconds

   Answer at the back of the book.

6. Which of these is a way that satellites help people?

   A They make the rain fall.

   B They carry phone and television signals across the world.

   C They give light at night, like a small moon.

   Answer at the back of the book.

7. **From an earlier chapter**

   A comet is near the Sun. Which way does its tail point?

   A Towards the Sun

   B Behind the comet, along the path it has taken

   C Away from the Sun

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Telescopes collect light to show far things. Satellites orbit the Earth for weather, signals and positions. Space probes travel to other planets and send messages by radio.

Draw: The Earth with a telescope, a satellite on a ring and a probe on an arrow.

Key words, A to Z

Every key word in this book, what it means, and the chapter that teaches it.

asteroid
a lump of rock that goes round the Sun, mostly in a belt between Mars and Jupiter. S3.12.7

axis
the line through the Earth from pole to pole, which it spins round. S3.12.4

comet
a ball of ice and dust on a long orbit, with a tail near the Sun. S3.12.7

day length
the time from sunrise to sunset, in hours. S3.12.6

dry season
the time when the rain belt has moved away. S3.12.5

dwarf planet
a small, round body that shares its path with many others. S3.12.7

equator
the line round the middle of the Earth, halfway between the poles. S3.12.5

gas giants
huge planets made of gas. Jupiter and Saturn. S3.12.1

gravity
the pull that every body has on every other body. S3.12.3

hemisphere
one half of the Earth: north or south of the equator. S3.12.4

ice giants
huge planets with a lot of water and icy stuff. Uranus and Neptune. S3.12.1

meteor
the streak of light when a bit of rock or dust burns up in the air. S3.12.7

meteorite
a piece of space rock that reaches the ground. S3.12.7

model distance
the distance on the model, in metres. S3.12.2

moon

a body that goes round a planet or a dwarf planet. S3.12.7

orbit
the curved path of one body going round another. S3.12.3

overhead
straight above you. S3.12.5

planet
a big ball of rock or gas that goes round a star. S3.12.1

rain belt
the belt of cloud and heavy rain that follows the overhead Sun. S3.12.5

real distance
the true distance in space, in million km. S3.12.2

rocky planets
small planets made of rock. There are four. S3.12.1

satellite
a body that goes round a planet, such as a built one that orbits the Earth. S3.12.8

scale
how much real distance one piece of the model stands for. S3.12.2

season
a part of the year with its own kind of weather. S3.12.4

solar system
the Sun and everything that goes round it. S3.12.1

space probe
a machine sent to travel to another planet or moon. S3.12.8

summer
the season when your hemisphere is tipped towards the Sun. S3.12.4

sunrise
the moment the Sun first shows over the horizon. S3.12.6

sunset
the moment the Sun disappears below the horizon. S3.12.6

telescope
a tool that collects more light than your eye, to show faint and far things. S3.12.8

tilted
leaning over. The Earth's axis leans by about 23.4 degrees. S3.12.4

tropics

the band between the Tropic of Cancer and the Tropic of Capricorn. S3.12.5

wet season
the time when the rain belt is over a place. S3.12.5

winter
the season when your hemisphere is tipped away from the Sun. S3.12.4

year
the time a planet takes to go round the Sun once. S3.12.3

Answers

S3.12.1. The planets

1. **Jupiter**

   The order is Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. Jupiter follows Mars.

   - **If you chose A:** Venus is closer to the Sun than Mars. You went towards the Sun, not away from it. Go to S3.12.1.
   - **If you chose C:** Saturn is the planet after Jupiter. You skipped one planet. Go to S3.12.1.

2. **Earth**

   Mercury is first, Venus is second and the Earth is third.

   - **If you chose A:** Venus is second. If you counted the Sun as number one, every planet comes one place too early. Go to S3.12.1.
   - **If you chose B:** Mars is fourth. Count again: Mercury is first, Venus second. Go to S3.12.1.

3. **Jupiter**

   The two gas giants are Jupiter and Saturn. Neptune and Uranus are ice giants.

   - **If you chose A:** Mars is small and rocky. A gas giant is a huge planet with no ground. Go to S3.12.1.
   - **If you chose B:** Neptune is a giant, but it is an ice giant, not a gas giant. It has a lot of water and icy stuff. Go to S3.12.1.
   - **If you chose C:** Venus is a rocky planet, about the size of the Earth. Go to S3.12.1.

4. **Neptune, about 4 times as wide**

   49 244 ÷ 12 742 is about 4. Round to 49 000 and 12 000 and you get 4 with a little left over.

   - **If you chose B:** You may think a far planet must be small. Neptune is far away, but it is wider than the Earth. Compare the two numbers. Go to S3.12.1.
   - **If you chose C:** Check the sum. 49 244 is about 4 times 12 742, not 40 times. Go to S3.12.1.
   - **If you chose D:** The two numbers are different. 49 244 is much bigger than 12 742. Go to S3.12.1.

5. **30 times**

   4 500 ÷ 150 = 30. Neptune is 30 times as far from the Sun as the Earth.

   - **If you chose A:** You dropped a zero. 150 × 3 is only 450. Try 150 × 30. Go to S3.12.1.
   - **If you chose C:** You added a zero. 150 × 300 is 45 000, far more than 4 500. Go to S3.12.1.
   - **If you chose D:** You took one number away from the other. That gives how much farther, not how many times as far. Go to S3.12.1.

6. **170 million km**

   228 − 58 = 170. Mars is 170 million km farther.

S3.12.2. How big and how far

1. **28.7 m**

   Model distance = real distance ÷ scale = 2 870 ÷ 100 = 28.7 m.

   - **If you chose A:** You divided by 10, not by 100. Moving the point two places left divides by 100. Go to S3.12.2.
   - **If you chose B:** You divided by 1 000. The scale is 1 m for 100 million km, so divide by 100. Go to S3.12.2.
   - **If you chose C:** You multiplied. A model is smaller than the real thing, so divide the real distance by the scale. Go to S3.12.2.

2. **Each metre of string stands for the same long real distance.**

   A scale says how much real distance one piece of the model stands for. Every metre of string stands for the same real distance.

   - **If you chose B:** The string is only a few metres long. The scale says how much real distance each metre stands for. Go to S3.12.2.
   - **If you chose C:** The scale is for distances, not for sizes. At this scale the Earth would be a speck. Go to S3.12.2.

3. **At that scale the Earth would be a speck of dust, too small to see.**

   The distances are huge compared with the planets. On the string, the Earth would be only 0.13 mm wide. So sizes and distances need different scales.

   - **If you chose A:** The planets are very different in size. Jupiter is about 11 times as wide as the Earth. Go to S3.12.1.
   - **If you chose C:** At this scale the Sun is a bead only 1.4 cm wide. It is the planets that become too small to see. Go to S3.12.2.

4. **150 million km**

   Scale = real distance ÷ model distance. 4 500 ÷ 30 = 150 million km for every metre.

   - **If you chose A:** You multiplied 4 500 by 30. To find the scale, divide the real distance by the model distance. Go to S3.12.2.
   - **If you chose B:** Check the sum. 15 × 30 is only 450, not 4 500. Go to S3.12.2.
   - **If you chose D:** You took 30 away from 4 500. A scale is found by dividing, not by taking away. Go to S3.12.2.

5. **22 cm**

   11 × 2 = 22 cm. This is a model of sizes, so it needs its own scale. It is not the string scale.

   - **If you chose A:** You added 11 and 2. "11 times as wide" means multiply the width by 11. Go to S3.12.2.
   - **If you chose B:** You divided 11 by 2. Jupiter is wider than the Earth, so multiply. Go to S3.12.2.
   - **If you chose C:** You multiplied by 110, one zero too many. 11 × 2 = 22. Go to S3.12.2.

6. **Neptune**

   The eight planets in order are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Neptune is last, so it goes at the end of the string.

   - **If you chose B:** Saturn is the sixth planet. Two planets are farther out: Uranus and Neptune. Go to S3.12.1.
   - **If you chose C:** Pluto is a dwarf planet, not one of the eight planets. The farthest of the eight is Neptune. Go to S3.12.7.

7. **5.5 m**

   7.78 − 2.28 = 5.5 m.

S3.12.3. Gravity and orbits

1. **The pull of the Sun's gravity**

   The Sun's gravity pulls the Earth all the time. The Earth moves sideways, so its path curves into an orbit.

   - **If you chose A:** There is almost no air in space, so nothing pushes the Earth along. The pull of gravity bends its path. Go to S3.12.3.
   - **If you chose B:** The spin gives day and night. It is not what holds the Earth in its orbit. Go to S2.9.2.
   - **If you chose D:** If nothing pulled on it, the Earth would fly off in a straight line. Go to S3.12.3.

2. **Fly off in a straight line**

   The Earth is moving sideways. Without the pull, nothing bends its path, so it goes straight, like the ball you let go.

   - **If you chose B:** A thing that is moving keeps moving. It would not stop. The ball on the string did not stop when you let go. Go to S3.12.3.
   - **If you chose C:** Falling in needs a pull. With no pull, nothing draws the Earth towards the Sun. Go to S3.12.3.

3. **Neptune**

   Neptune is the farthest planet. It has the longest way round and moves slowly, so its year is the longest, 165 Earth years.

   - **If you chose A:** Mercury is nearest the Sun, so it has the shortest way round. Its year is only 88 days. Go to S3.12.3.
   - **If you chose C:** Jupiter is the biggest planet, but size does not decide the year. Its year is 11.9 Earth years. Neptune is farther, so its year is longer. Go to S3.12.3.

4. **It is far away, so it has a long way to go and moves slowly.**

   Far from the Sun, the path is longer. The Sun's pull is weaker, so the planet moves slowly. Both make the year longer.

   - **If you chose A:** Cold does not slow a planet. Its speed depends on the pull of the Sun, which is weaker far out. Go to S3.12.3.
   - **If you chose B:** Size does not decide the year. Jupiter is much bigger than Neptune, yet its year is shorter. Go to S3.12.3.

5. **3 times**

   264 ÷ 88 = 3. Mercury goes round 3 times.

   - **If you chose A:** You took 88 away from 264. To find how many trips, divide the days by the days in one trip. Go to S3.12.3.
   - **If you chose B:** You added 88 and 264. To find how many trips fit, divide. Go to S3.12.3.
   - **If you chose C:** You multiplied the two numbers. That makes a huge number. Divide the days by the days in one trip. Go to S3.12.3.

6. **0.75 m**

   Model distance = real distance ÷ scale = 150 ÷ 200 = 0.75 m.

   - **If you chose B:** You divided by 20, not by 200. Check how many zeros the scale has. Go to S3.12.2.
   - **If you chose C:** You divided by 2 000. The scale is 200, so divide 150 by 200. Go to S3.12.2.
   - **If you chose D:** You multiplied. A model is smaller than the real thing, so divide the real distance by the scale. Go to S3.12.2.

7. **The Earth's gravity pulls on it.**

   The Earth pulls on the Moon all the time. The Moon moves sideways, so its path curves into an orbit round the Earth.

   - **If you chose A:** The Sun does pull on the Moon. But the Earth's gravity is what holds the Moon in orbit round the Earth. Go to S3.12.3.
   - **If you chose C:** There is no air out there. The Moon stays on its path because of the Earth's pull. Go to S3.12.3.

S3.12.4. Tilt and the seasons

1. **The tilt of the Earth's axis**

   The axis points the same way all year. The half tipped towards the Sun has summer, and the half tipped away has winter.

   - **If you chose B:** The distance changes by only about 5 million km out of 150 million km. That is far too small, and the north has winter when the Earth is nearest. Go to S3.12.4.
   - **If you chose C:** The Sun shines about as strongly all year. The seasons come from how the Earth leans. Go to S3.12.4.

2. **Winter**

   When the north is tipped towards the Sun, the south is tipped away. So the south has winter.

   - **If you chose A:** The two halves do not get the same light. When the north tips towards the Sun, the south tips away. Go to S3.12.4.
   - **If you chose C:** The distance is almost the same, but distance does not decide the season. The tilt does. Go to S3.12.4.

3. **Stop C**

   The stick leans the same way at every stop, to the right. At stop C the lamp is on the left. So the south end of the stick leans towards it.

   - **If you chose A:** At stop A the north end of the stick leans towards the lamp. Look at which way the stick leans, compared with the lamp. Go to S3.12.4.
   - **If you chose B:** At stop B the stick leans sideways, neither towards nor away from the lamp. Go to S3.12.4.
   - **If you chose C:** At stop D the stick leans sideways, neither towards nor away from the lamp. Go to S3.12.4.

4. **The Sun is lower, so the same light is spread over more ground.**

   A low Sun makes a long patch of light on the ground. The same light is spread thinner, so each square centimetre is warmed less.

   - **If you chose A:** The distance hardly changes. The Earth is nearest the Sun in early January, which is winter in the north. Go to S3.12.4.
   - **If you chose B:** The Sun is the same size all year. A low Sun spreads its light over more ground. Go to S3.12.4.

5. **The distance changes by only 5 million km, so it cannot cause the seasons.**

   152 − 147 = 5 million km. That is a tiny change next to 150 million km. And the two halves have opposite seasons at the same distance.

   - **If you chose B:** The Earth is nearest in early January. That is winter in the north. So nearness cannot be the cause. Go to S3.12.4.
   - **If you chose C:** The Earth is farthest in early July. That is winter in the south, but it is summer in the north at the same time. Go to S3.12.4.

6. **Its orbit**

   The orbit is the curved path of one body going round another. The Earth's orbit round the Sun takes one year.

   - **If you chose A:** The axis is the line the Earth spins on. The path round the Sun is the orbit. Go to S3.12.4.
   - **If you chose C:** A year is how long one trip takes. The path itself is the orbit. Go to S3.12.3.

7. **16 cm**

   8 × 2 = 16 cm. A low Sun stretches the same beam over a longer patch.

S3.12.5. Seasons around the world

1. **Summer**

   When the south is tipped away from the Sun, the north is tipped towards it. So the north has summer.

   - **If you chose B:** The Earth does not have one season at a time. The two halves lean opposite ways. Go to S3.12.5.
   - **If you chose C:** Both halves have seasons. They are opposite: when one leans towards the Sun, the other leans away. Go to S3.12.4.

2. **The midday Sun is always high, and the days are about 12 hours long all year.**

   At the equator the midday Sun is never lower than 66 degrees. Day and night are both about 12 hours. So the ground always gets strong sunlight for a long time.

   - **If you chose A:** The side facing the Sun is at most about 6 400 km nearer. The Sun is 150 million km away. That is far too small to cause the heat. Go to S3.12.5.
   - **If you chose C:** A place does not have a tilt of its own. The whole Earth is tilted, and the equator stays in strong sunlight. Go to S3.12.4.

3. **Only between the Tropic of Cancer and the Tropic of Capricorn**

   The overhead Sun moves between 23.4 degrees north and 23.4 degrees south of the equator. Outside that band it is never straight above.

   - **If you chose A:** Outside the tropics the midday Sun is never straight overhead, even in summer. It stays south or north of you. Go to S3.12.5.
   - **If you chose B:** The Sun is overhead at the equator on two days a year. But it is also overhead at other places in the tropics, as the spot moves. Go to S3.12.5.
   - **If you chose C:** At the poles the Sun is low in the sky and never gets overhead. Go to S3.12.5.

4. **The rain belt moves over the place, following the overhead Sun.**

   Where the Sun is high, hot ground warms moist air. It rises, cools and makes clouds and heavy rain. The belt follows the overhead Sun, so the rain comes to different places at different times.

   - **If you chose A:** The Earth's distance from the Sun does not decide the rain. The rain belt follows the overhead Sun. Go to S3.12.5.
   - **If you chose B:** Winter does not always bring rain. Rain comes where the Sun is high, the air is warm and moist air rises. Go to S3.12.5.

5. **The town at 20° north**

   The rain belt follows the overhead Sun, a little behind it. The Sun is overhead near 20° north, so the belt is near there. The northern town is more likely to be wet.

   - **If you chose B:** The belt follows the overhead Sun, roughly. The Sun is overhead in the north now, so the belt is in the north too. Go to S3.12.5.
   - **If you chose C:** The belt is a band near the overhead Sun. It cannot be over both places at once. Go to S3.12.5.

6. **That is not true. The tilt of the axis causes the seasons.**

   The distance changes by only about 5 million km out of 150 million km. The tilt makes one half lean towards the Sun, and that half has summer.

   - **If you chose A:** The Earth is nearest the Sun in early January, when it is winter in the north. Nearness does not cause the seasons. Go to S3.12.4.
   - **If you chose C:** The Earth is the same distance from the Sun for both halves. The tilt gives each half its own season. Go to S3.12.4.

7. **30 degrees**

   From 10° south to the equator is 10 degrees. From the equator to 20° north is 20 degrees. 10 + 20 = 30.

S3.12.6. Day length and the Sun's height

1. **A place on the equator**

   At the equator day and night are both about 12 hours in every month. The tilt hardly changes the day length there.

   - **If you chose B:** Far from the equator the day length changes a lot, as the two graphs showed. Go to S3.12.6.
   - **If you chose C:** Inside the polar circles the day length changes the most. There are days of 24 hours of light and of dark. Go to S3.12.6.

2. **December**

   The highest point of the graph is at month 12, December. In the south the longest day comes at the end of the year.

   - **If you chose A:** June has the longest day in the north. In the south the pattern is the other way round. Go to S3.12.6.
   - **If you chose C:** In March the day is about 12 hours. It is on the way down, not at the peak. Go to S3.12.6.

3. **3.8 hours**

   13.9 − 10.1 = 3.8 hours.

   - **If you chose A:** You added the two numbers. To find how much longer, take the smaller from the bigger. Go to S3.12.6.
   - **If you chose B:** That is the average of the two, 12 hours. It is not the difference. Go to S3.12.6.

4. **The midday Sun is higher than last week.**

   A high Sun makes a short shadow. So a shorter shadow means the Sun climbed higher at midday.

   - **If you chose B:** A low Sun gives a long shadow. A shorter shadow means a higher Sun. Go to S3.12.6.
   - **If you chose C:** The distance to the Sun hardly changes. A shorter midday shadow means the Sun is higher in the sky. Go to S3.12.4.

5. **South**

   The shadow points away from the Sun. At 40° south the midday Sun is in the north, so the shadow points south.

   - **If you chose A:** North is where the midday shadow points north of the Tropic of Cancer. At 40° south the midday Sun is in the north. So the shadow points south, away from it. Go to S3.12.6.
   - **If you chose C:** Only in the tropics, on the days the Sun is overhead, is there no midday shadow. At 40° south the Sun is never overhead. Go to S3.12.5.

6. **A place 10° north of the equator**

   The midday Sun is overhead only between 23.4° north and 23.4° south. Only the place 10° north is inside that band.

   - **If you chose A:** The overhead Sun stays between the two tropics, 23.4° each side of the equator. 40° is beyond. Go to S3.12.5.
   - **If you chose B:** The overhead Sun never gets as far as 40° south. It stays within 23.4° of the equator. Go to S3.12.5.

S3.12.7. Moons, asteroids and comets

1. **A small bit of rock or dust burning up high in the air**

   The bit flies into the air at great speed. The air heats it and it glows. We see the streak and call it a meteor.

   - **If you chose A:** Stars are huge, far-off suns. They do not fall. The streak is a tiny bit of rock or dust close to the Earth. Go to S3.12.7.
   - **If you chose C:** A planet is a big ball that goes round a star. A shooting star is a tiny bit of rock or dust that burns up. Go to S3.12.7.

2. **Away from the Sun**

   The Sun's light and wind push the comet's gas and dust away. So the tail always points away from the Sun.

   - **If you chose A:** It is not smoke trailing behind. The Sun's light and wind push the tail away from the Sun, even as the comet goes away. Go to S3.12.7.
   - **If you chose B:** The Sun pushes the gas and dust away. So the tail points away from the Sun, not towards it. Go to S3.12.7.

3. **Between Mars and Jupiter**

   Most asteroids go round the Sun in a belt between the orbits of Mars and Jupiter.

   - **If you chose B:** Mars is the next planet after the Earth, and there is no belt between them. The belt is farther out. Go to S3.12.7.
   - **If you chose C:** Beyond Neptune lie icy bodies and dwarf planets such as Pluto. The main belt of asteroids is nearer the Sun. Go to S3.12.7.

4. **It is round, but it shares its path with many other bodies.**

   A planet clears its path of other bodies. A dwarf planet is round but shares its path with many others. Pluto is small, too: smaller than our Moon.

   - **If you chose A:** Pluto is round. A dwarf planet is round, like a planet. It is the shared path that makes it a dwarf. Go to S3.12.7.
   - **If you chose C:** Pluto does have moons. Having a moon does not decide whether a body is a planet. Go to S3.12.7.

5. **Saturn**

   The table shows about 270 moons for Saturn, more than any other planet. New moons are still being found, so we say about.

   - **If you chose A:** The Earth has only one Moon. The giants have far more. Go to S3.12.7.
   - **If you chose B:** Jupiter has about 95 moons, but Saturn has about 270. Look at the table of moons. Go to S3.12.7.

6. **The planet's gravity pulls on it.**

   The planet pulls on its moon all the time. The moon moves sideways, so its path curves into an orbit.

   - **If you chose B:** The Sun does pull on a moon. But the planet's gravity bends the moon's path into an orbit round the planet. Go to S3.12.3.
   - **If you chose C:** With no pull, a moon would fly off in a straight line, like your ball. Go to S3.12.3.

7. **1 097 km**

   3 474 − 2 377 = 1 097 km.

S3.12.8. Exploring space

1. **It collects more light, so faint and far things can be seen.**

   A telescope has a wide lens or mirror that catches more light than an eye. So it shows things that are faint or far.

   - **If you chose A:** Nothing moves. A telescope only collects more light and makes the picture bigger and brighter. Go to S3.12.8.
   - **If you chose B:** Never look at the Sun, not even through a telescope. It can blind you in a moment. Go to S3.12.8.

2. **A body that goes round a planet, such as a machine that orbits the Earth**

   A satellite goes round a bigger body. The Moon is a natural satellite. Built satellites orbit the Earth.

   - **If you chose B:** That is a space probe. A satellite stays in orbit round a planet or a moon. Go to S3.12.8.
   - **If you chose C:** Stars are far-off suns. A satellite is a body that goes round a planet, held by its gravity. Go to S3.12.8.

3. **A space probe**

   A space probe is sent to travel to another planet or moon. It sends its pictures back by radio.

   - **If you chose A:** A weather satellite stays in orbit round the Earth. It does not go to another planet. Go to S3.12.8.
   - **If you chose C:** A telescope on the ground stays on the Earth. It collects light but does not travel. Go to S3.12.8.

4. **Satellites that orbit high above the Earth**

   Weather satellites orbit the Earth. They look down on the clouds and send pictures to the forecasters.

   - **If you chose A:** A telescope on the ground looks up at space. Cloud pictures come from machines that look down from above. Go to S3.12.8.
   - **If you chose B:** A space probe goes far away. Weather pictures come from satellites that stay in orbit close to the Earth. Go to S3.12.8.

5. **9 seconds**

   Time = distance ÷ speed = 2 700 000 ÷ 300 000 = 9 s.

   - **If you chose B:** You counted one zero too many. 300 000 × 90 is far more than 2 700 000. Go to S3.12.8.
   - **If you chose C:** You divided the speed by the distance, upside down. Time = distance ÷ speed. Go to S3.12.8.

6. **They carry phone and television signals across the world.**

   Satellites pass signals over long distances, so a call or a television picture can cross the world. They also send weather pictures and help a phone find its position.

   - **If you chose A:** Satellites only watch the weather from above. They do not make it. Go to S3.12.8.
   - **If you chose C:** A satellite is far too small to light the ground. You may see one as a moving dot of reflected sunlight. Go to S3.12.8.

7. **Away from the Sun**

   The Sun's light and wind push the comet's gas and dust away from the Sun. So the tail points away from it.

   - **If you chose A:** The Sun's light and wind push the tail away from the Sun, not towards it. Go to S3.12.7.
   - **If you chose B:** The tail is not smoke left behind. It always points away from the Sun, even as the comet goes away. Go to S3.12.7.

About this book

For learners who can read a page alone and do sums with the four operations. In many schools this fits children of about 11 to 13, and older learners can use it too. Activities use string, stones, sticks, paper, a ball or an orange, rice and a torch or battery lamp. Every chapter repeats one rule: never look at the Sun, not even through glass, binoculars or a telescope. The shadow stick looks only at the ground. A lamp can get hot, so keep it away from paper and do not touch the bulb. A shooting star watch is done with an adult, in a safe place away from roads. A learner can work alone: every exercise has its answer and the reason for it.

Written and drawn by attnom. Edition 1.0, 2026-11-12.

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