UNIT 5

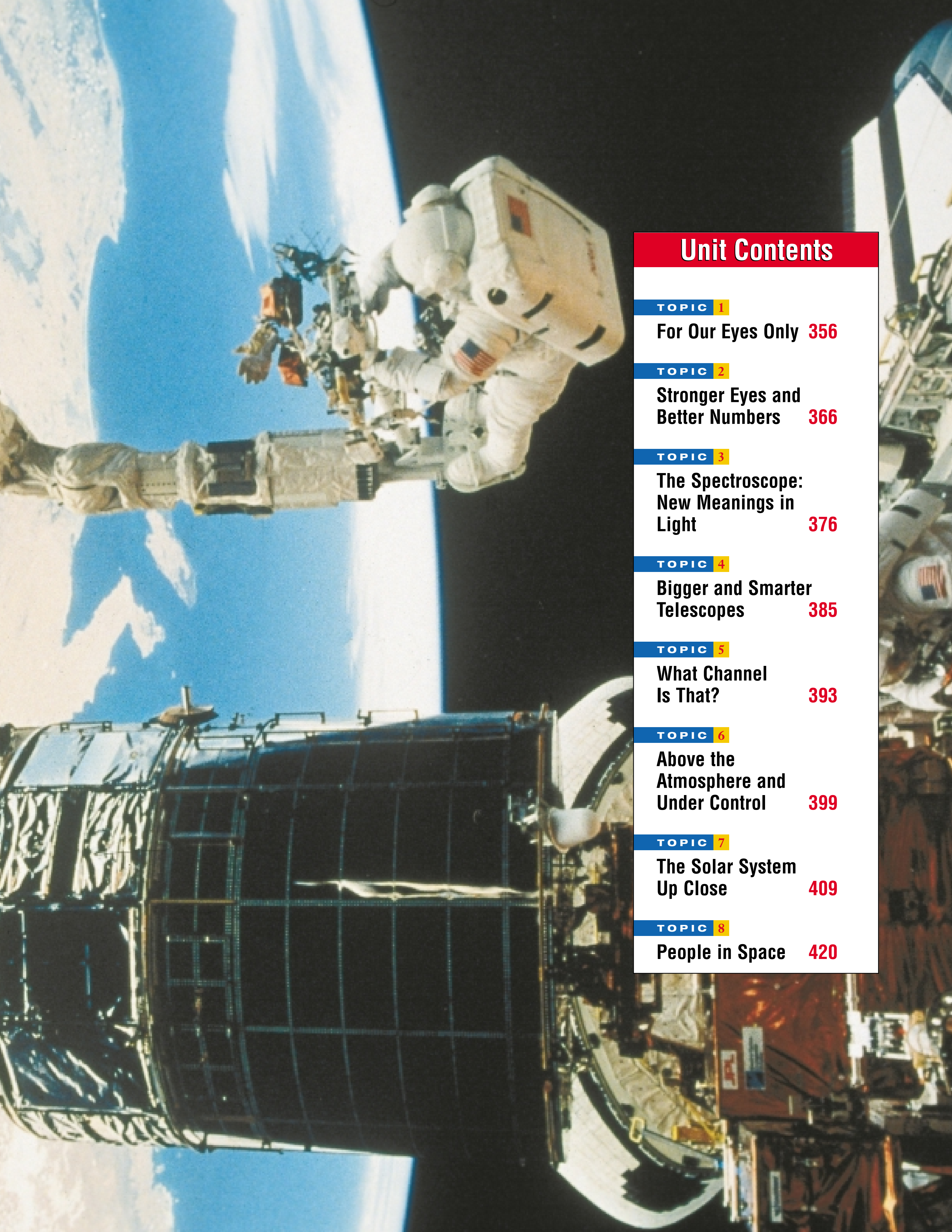
Space Exploration

The Hubble space telescope is a human-made satellite that was launched into Earth's orbit in 1990. The large picture shows the first repair mission for the Hubble space telescope in 1993. NASA astronaut Story Musgrave rides on the Canadian-built shuttle arm (the Canadarm) moving toward the telescope. The telescope is held in space shuttle *Endeavor's* cargo bay during repairs.

While orbiting above Earth's atmosphere, the repaired telescope gives us unsurpassed images of the universe. Astronomers have seen everything from the Moon and planets to quasars and galaxies at the far reaches of the universe. The inset picture is one of the many Hubble images available to scientists and the world via the Internet. This image shows a huge cloud of gas and dust called the Lagoon nebula. Astronomers have evidence that millions of stars are forming in this cloud.

How can astronomers make the claims that they make about the universe? What technological advances led to the construction of a space telescope and a space vehicle that can make a service call to it?

In this unit, you will learn how advances in technology enabled astronomers to view the far reaches of the universe with telescopes. You will also learn how technology has enabled people to work in Earth's orbit, land on the Moon, and send space probes throughout the solar system.



Unit Contents

UNIT 5

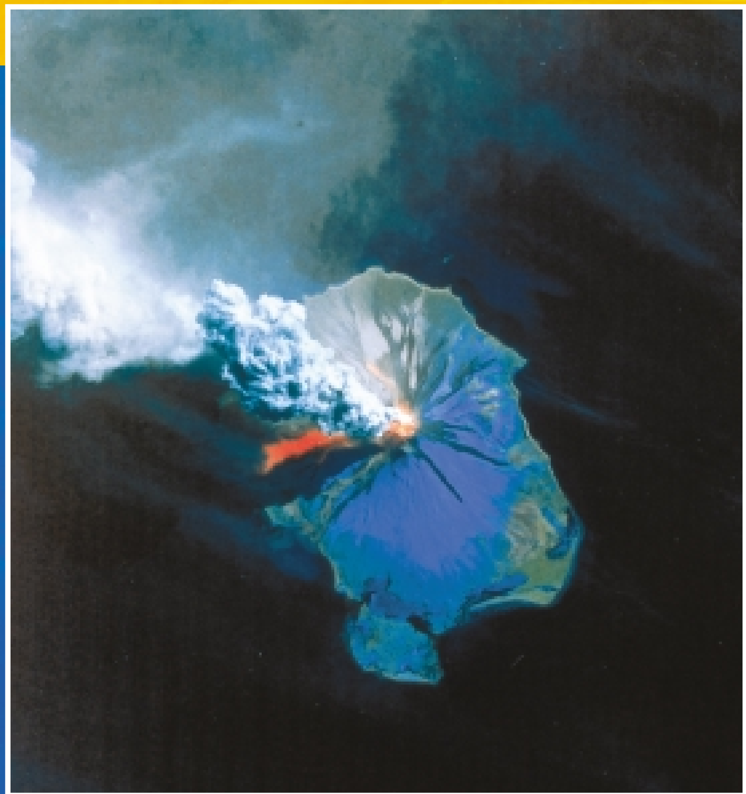
Preview

Focussing Questions

- What technologies have been developed to observe objects in the sky, and what discoveries were made with them?
- How has the development of these technologies contributed to the exploration, use, and understanding of space?
- How have technologies designed for space science been applied to produce benefits on Earth?

How old is the technology that was used to learn about the stars? What was learned with this technology? In Topics 1–2 you will learn what ancient astronomers observed using their eyes and instruments such as the astrolabe shown here.

How have astronomers improved telescopes over the years? What is a radio telescope? What information has been gathered using them? In Topics 3–5 you will follow the improvements in telescope design, including radio telescopes, and see how light itself is analyzed to learn about objects in the universe.

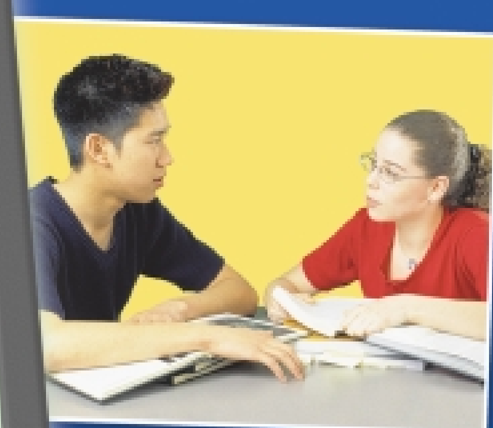


How much of Earth's surface can satellite cameras see? How did we put the satellites in orbit? Where else have we sent spacecraft? In Topics 6–8 you will learn how rockets send spacecraft into orbit and how computers help to keep them there. You will see the planets up close and follow the astronauts into space.

Looking Ahead

Read the Unit 5 Project, An Arm of Your Own, on pages 432–433. Here is your chance to design and build a "remote manipulator." You will conduct this project after you have completed Topics 1–8.

- Carefully read the Challenge posed on page 84. Share design ideas with your classmates. Save them in a Project Planning file.
- Try to solve design problems on paper with diagrams. For example, how will you grasp an object with your remote manipulator?
- Decide on what materials you will use for your device. Consider the strength, weight, and flexibility needed for the materials.



TOPIC 1

For Our Eyes Only

Figure 5.1 This is a photo looking at Earth from the Moon. Whether you are on Earth or on the Moon, you feel that the ground you are standing on is at rest and the sky is turning around it. They are two different frames of reference.

Frames of Reference

Look up into the sky. You'll see the Sun move through the sky in the daytime and the Moon, stars, and planets move through the sky at night. Notice that these objects in the sky rise in the east and set in the west. People have seen this motion in the sky for thousands of years. This motion is caused by Earth's rotation. The objects do not revolve around Earth.

However, when we look up at the sky, our common sense tells us that Earth doesn't move. It seems as if everything in the sky travels around our planet. When we make these observations, we use Earth as a fixed frame of reference from which to view the sky. A **frame of reference** is a set of axes of any kind that is used to describe the positions or motions of things. For example, the equator and the prime meridian are the axes for the frame of reference used to locate positions on Earth (latitude and longitude).

As another example, suppose that you are riding in a bus travelling at 100 km/h. You feel stationary inside the bus because you do not move relative to the bus. This makes it seem as though the road is moving toward you at 100 km/h, not the other way around. If you think this way, you are using the bus as your frame of reference. A person standing beside the road would use Earth as a frame of reference. They would say that you and the bus were moving at 100 km/h relative to the ground. Each frame of reference is neither correct nor incorrect. They are simply two different reference frames — two different points of view.

Science Log

Think about your frame of reference when you look at the stars. Suppose you were standing on the Moon. Would the stars appear to move around Earth or around the Moon? Take a few minutes to write your ideas in your Science Log.

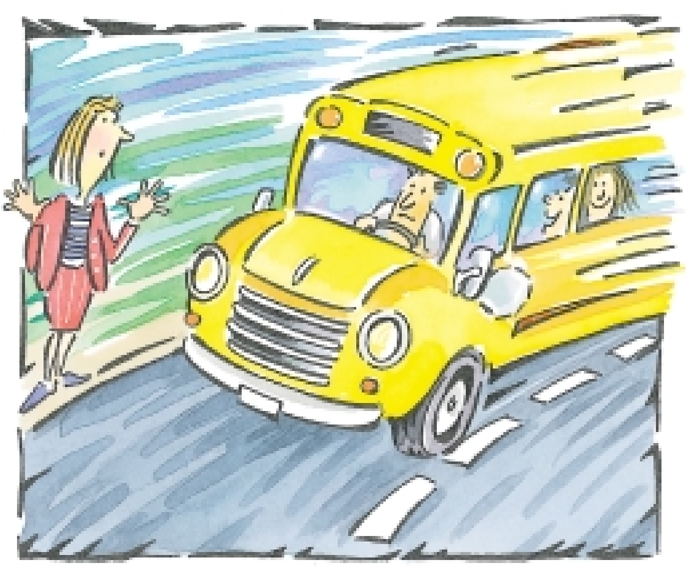


Figure 5.2 The person in the bus feels at rest relative to the bus. The ground seems to be moving toward him. The person on the ground feels at rest relative to the ground and perceives the bus to be moving toward her.

What Our Ancestors Saw

With the view that the stars revolve around Earth, ancient peoples watched the motions of **celestial bodies** (the Sun, Moon, stars, and planets). Many ancient civilizations, such as the ancient Greeks, Babylonians, Hindus, and Egyptians built up a body of knowledge about the stars. These are some things they learned:

- The stars make unchanging patterns in the sky. These patterns looked like objects, which people grouped and named. These groupings are called **constellations**. Orion, the hunter, and Ursa Major, the Great Bear, are examples of constellations.
- On each successive day, a given star rises and sets four minutes earlier than the day before. This means that over a period of months, different stars are in the night sky. Since each month has its own set of stars in the night sky, people developed the ability to predict the changing of the seasons. This helped lead to the creation of calendars.
- The Sun rises and sets at a rate different from the stars.
- The Moon also rises and sets at a rate different from the stars. As well, the Moon shows phases.
- Five other bodies — Mercury, Venus, Mars, Jupiter, and Saturn — rise and set at rates different from the stars. The ancient Greeks considered these to be special stars, which they called **planets**, from the Greek word "wanderer."

Figure 5.3 The stars appear to revolve around one point in the sky. This point is directly above Earth's North Pole. The star Polaris (the North Star) is very close to this point in the sky and never rises or sets. Early people recognized this star because it appeared to stay fixed and could be used to find direction at night.

In the southern hemisphere, there is no bright star over the South Pole. The constellation Crux (called the Southern Cross because it is shaped like a cross) is an easily identified pattern of stars whose long axis points toward the South Celestial Pole.

Word **CONNECT**

Much of early astronomy was influenced by astrology. Research and record the definitions for "astronomy" and "astrology." How are they different in meaning?

DidYouKnow?

Ancient peoples developed stone circle technology to observe the rising and setting of the Sun and Moon. Observations using this technology helped people mark important dates like the summer solstice, the longest day of the year. This more precise knowledge of the arrival of particular days of the year helped agricultural communities know when to plant and harvest their crops. Some stone circles were also used to predict solar and lunar eclipses.

To use this technology, someone would stand at the centre of the circle. On particular days of the year, the Sun would rise right above piles of rocks around the perimeter. In the case of Stonehenge, pictured here, the Sun rises in the spaces under the stone "arches." Stonehenge was constructed in stages between 3000 B.C.E. and 1100 B.C.E.

Ancient Legends

Figure 5.4 The ancient Egyptians believed that the god Ra was pulled across the sky in a sacred boat.

Many ancient societies created stories to explain the origin and movements of the celestial bodies. To the ancient Romans, Jupiter was the king of the gods. To the ancient Egyptians, the Sun god, Ra, was carried daily through the sky in a sacred boat.

Aboriginal people of North America had their own stories. The Algonquin, Iroquois, and Narragansett saw the constellation Ursa Major as a bear running from hunters. According to some stories, because the bear is low enough to brush the maple trees in early autumn evenings, blood from its wounds turns the leaves red. Another group, the Snohomish, have a legend that tells how three hunters chasing four elk became the seven stars of the Big Dipper. One of the hunters is accompanied by a "dog," which you can see if you look carefully at the middle star in the handle.

Find Out ACTIVITY

Pleiades Legends

The Pleiades (pronounced plee-a-deez), shown below, is a cluster of bright white stars. Without a telescope, it looks like a small dipper in the sky. Many ancient civilizations told different stories about the Pleiades star cluster: the ancient Greeks, Hindus, Polynesians, Egyptians, and the Mayans, among others. Many North American Aboriginal people also told stories about the Pleiades: the Blackfoot, the Onondaga, the Monache, and the Wyandot, among others.

Procedure ✷ Performing and Recording

1. Use the Internet or library to research any two legends about the Pleiades star cluster.
2. In your own words, write out the two legends that you have researched.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Describe any similarities or differences in the two legends you researched.
2 Think about the two legends you researched. Why do you think ancient peoples created these particular stories?
3. In general, suggest one or two reasons why people create legends.

Extension

4. Write a short story of your own to explain some aspect of one celestial object.

Sky Co-ordinates

Besides telling stories about the celestial bodies, some ancient peoples wanted to accurately measure the celestial bodies' locations in the sky. To do this, they would give a celestial body two co-ordinates measured in degrees. The first angle is measured clockwise from north. This is called the **azimuth**. Next, measure the celestial body's angle above the horizon in degrees. This is called the **altitude**. Angles used to specify the co-ordinates of a celestial body are called **altitude-azimuth co-ordinates.** The beginnings of this technique go back at least as far as ancient Egypt.

Altitude-azimuth co-ordinates locate a celestial body relative to a fixed Earth (as though the celestial bodies are circling Earth). The altitude-azimuth co-ordinates for each celestial body change depending on the time of the reading. For example, suppose you want to measure the altitude-azimuth co-ordinates of the Moon. You take your first reading of the Moon at 10 P.M. on a particular night of the year. You find that the Moon is located at an azimuth of 180° (south) and at an altitude of 44°. You take another reading at midnight. You find that the Moon has moved to new co-ordinates. These co-ordinates will continue to change with the Moon's movement throughout the night.

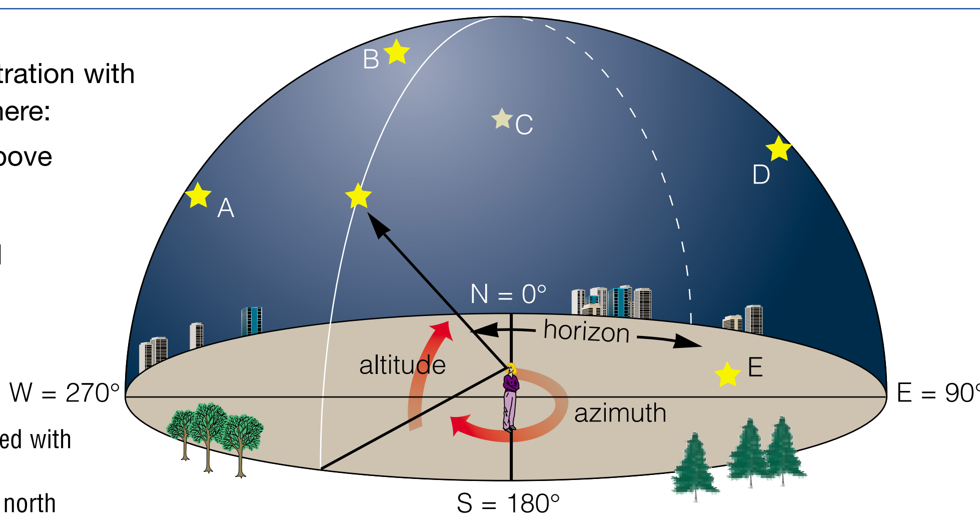
Using these altitude-azimuth co-ordinates, surveyors of the past and present located celestial and terrestrial objects. Our ability to measure the positions of bodies in the sky has always depended upon technological devices. An **astrolabe** is a device used to measure the altitude of an object. (Look at the photograph on page 354 to see what an astrolabe looks like.) A **compass** is used to measure an object's azimuth.

The ancient Greeks invented the astrolabe. This was a device held vertically from a ring with a pointer on it. The pointer was used to sight a star and measure the angle to it. The ancient Romans used angles to survey practical things such as their aqueducts. Later, the compass was imported from the Arabic world about 1200 C.E. With these tools, navigation was improved and the great sea explorations of the world began.

Practice Problems

Identify the stars in the illustration with the co-ordinates indicated here:

1. It's due west and 40° above the horizon.
2. It's in the southeast and 10° above the horizon.
3. It's due north and 53° above the horizon.



Celestial positions can be measured with altitude-azimuth co-ordinates:
Azimuth — angle clockwise from north
Altitude — angle above the horizon

INQUIRY

INVESTIGATION 5-A

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Where in the Sky?

In this investigation you will make a device that is part astrolabe and part compass. This device will enable you to measure the altitude-azimuth co-ordinates of objects around you. You will also use the device to plot the Sun's path in the sky.

Question

What path does the Sun travel in the sky?

Hypothesis

Based on your experience, form an hypothesis to describe the path you think the Sun will make in one day.

Safety Precaution

Never look directly at the Sun.

Part 1

Construct and Test Your Device

Apparatus

compass (for drawing circles)
protractor
small mirror (a few cm^2)
scissors

Materials

wide drinking straw
heavy paper or cardboard
tape
round-headed paper fasteners
paper clip

Procedure

1. Draw a circle on the cardboard (piece A) about 20 cm in diameter, and use a protractor to divide it into 360° similar to diagram A. (Alternatively, cut out and clue a measured circle given to you by your teacher.)
2. Cut a quarter circle of cardboard (piece B) and fold it as shown in diagram A. Use the protractor to draw a scale from 0–90° on it. (Or use a photocopied protractor.) Piece B should be 12 cm high.
3. Fold a rectangular piece of cardboard (piece C) as shown in diagram A. Make this 15 cm long.
4. Use the paper fasteners to attach the pieces, as shown in diagram A. Tape a straw to piece C, as shown in diagram B.
5. Place your device flat on a table or other level surface. Take all your readings from the same spot in the room.
6. Pick an object in the room (the clock, for example), and swing the quarter circle around so it is facing the clock. Slide the straw holder up so that the straw is pointing right at the clock. Use your mirror to **observe** the clock through the straw. Use a paper clip to fix the straw's position.
7. Read and **record** the azimuth of the clock on the compass scale and the altitude on the quarter circle scale.
8. Practise steps 6 and 7 with several other objects in the room. **Predict** their co-ordinates before you measure them. Check with your teacher to see if your readings are accurate.

diagram A

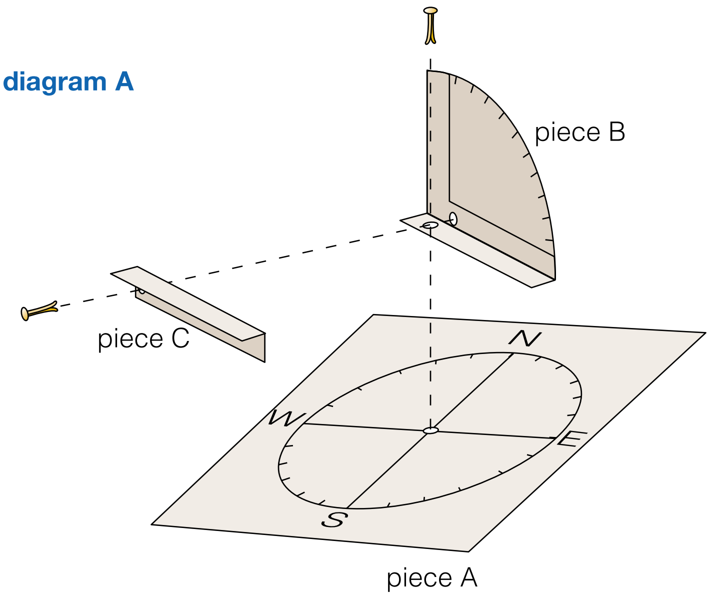
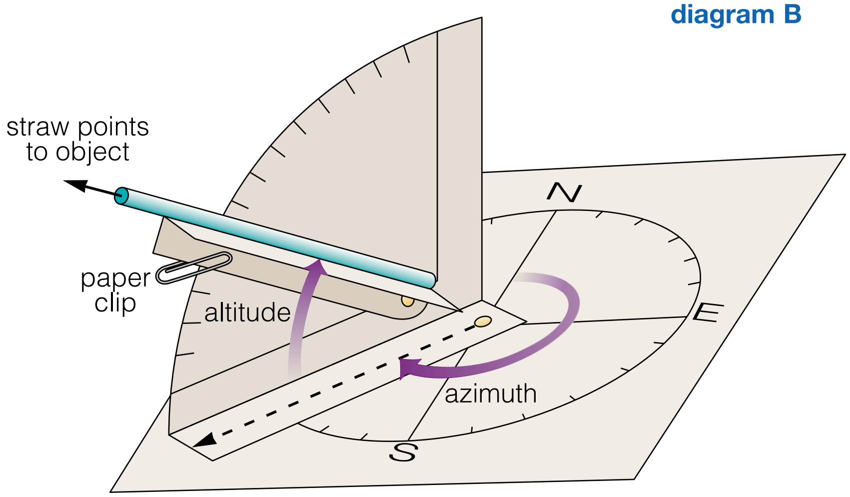


diagram B



Analyze

1. The azimuth and altitude are divided into how many degrees?
2. If you know the co-ordinates of some object in the room, does it matter which co-ordinate you set first when aiming your apparatus at it? Explain your answer.

Conclude and Apply

3. Suppose that you were pointing out the location of an airplane in the sky. Explain how your actions would be similar to using this apparatus you made.

CONTINUED ▶

Part 2

Measure the Sun's Co-ordinates

Safety Precaution:

- **Never look directly at the Sun.**
- Do not use the mirror for this part of the investigation.

Procedure

1. At various times in one day, place your device flat on the ground and swing it around until the straw points directly at the Sun. You know you have done this successfully if the straw's shadow is a circle with the Sun shining through it.
2. **Record** the Sun's co-ordinates and the time of day in a data table like the one below. Give your table a title.

Analyze

1. Make a line graph showing the Sun's position through one day. Place the Sun's altitude on the vertical axis and its azimuth on the horizontal axis. When completed, the graph will show the path of the Sun in the sky. Since the Sun rises in the eastern sky and sets in the western sky, your horizontal axis could be scaled from 90° (east) to 270° (west).
2. What is the highest altitude the Sun reached that day?
3. At what time did the Sun reach its highest point?
4. What part of your device functions as an astrolabe?

Conclude and Apply

5. How would the Sun's path differ if you did this experiment during a different season? Would you use a different azimuth scale in the different seasons?
6. If someone in the southern United States tracked the Sun the same day that you did, what differences should they see in the Sun's motion through the sky?

Time of day	Azimuth	Altitude

Skill FOCUS

For tips on graphing, turn to Skill Focus 10.

DidYouKnow?

In most modern cities, streets are planned and built using co-ordinate measurements. This ensures that the streets line up north/south, and east/west. The ancient Egyptian surveyors aligned their pyramids in the same way.

The Stars as a Frame of Reference

Because of Earth's rotation, the stars and planets appear to circle above us. With Earth as the frame of reference, all celestial bodies move through the sky at about the same rate. However, this does not show their actual movements.

To track the actual motion of each celestial body (such as the Sun, Moon, and planets), you need to use the stars as the frame of reference instead of Earth. This is because we are looking for motions in the sky that are different from the big motion caused by Earth's rotation.

Using the stars as a frame of reference is simple to do. Suppose you want to see the actual movements of the planet Mars. One night you would find Mars in the sky. Then you would find a few very bright stars near Mars. You would mark down Mars's position relative to those few bright stars. The next night you would find Mars and the few bright stars in the sky again. Again, you would mark down Mars's position relative to those few bright stars. If you made similar observations over several weeks, you could see in which direction Mars is really moving.

Many ancient peoples, such as the Greeks, observed the celestial bodies using the stars as a frame of reference. For example, to watch the movement of the planets, they would use stars as a frame of reference.

Word CONNECT

Look up the words "heliocentric" and "geocentric". What do the prefixes *helio-* and *geo-* mean?

The Earth-Centred Model

Even with their advanced knowledge of how to track the motion of the celestial bodies, ancient peoples still believed that the stars circle around Earth. This led to an **Earth-centred** or **geocentric** model of the universe. This model, based on ideas of the Greek philosopher Aristotle, dominated thinking about celestial motions for almost 2000 years.

Aristotle based his model on the mathematics and geometry of Pythagoras and Euclid. He then used his idea of circles and spheres as perfect forms to complete his model. Aristotle also saw that the stars' patterns in the sky were unchanging. So he placed the stars on the surface of an outer sphere that he termed the "firmament of fixed stars" or celestial sphere. Inside this sphere, he arranged more concentric spheres on which were attached the Sun, Moon, and the five known planets.

The Earth-centred model provided a means of predicting the dates and times when celestial bodies rose and set. Ultimately, though, it required up to 55 different inner spheres to account for the observed motions. It was particularly difficult to explain why three of the planets — Mars, Jupiter, and Saturn — sometimes reversed their direction (called retrograde motion).

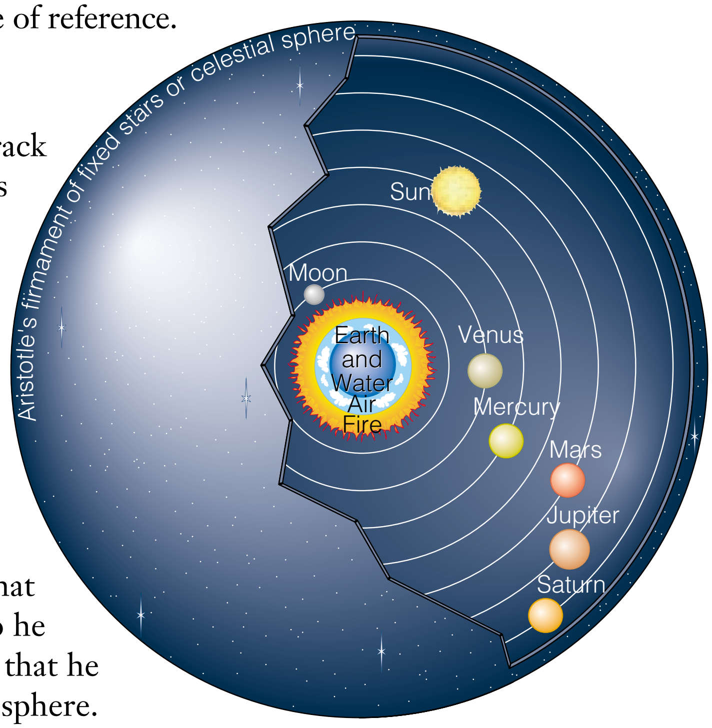


Figure 5.5 Aristotle's Earth-centred model, with its outer celestial sphere and many inner spheres (Earth and water, air, and fire). Since the stars on the celestial sphere were visible from Earth, it was reasoned that the inner spheres had to be "crystalline" or transparent.

Pause& Reflect

Look carefully at Ptolemy's model. Describe in your Science Log how it accounts for:

- day and night
- the fast motion of the Moon through the stars

To account for this, other scientists such as Ptolemy changed Aristotle's Earth-centred model. Ptolemy's model gave these planets another level of circular motion called "epicycles." The result was an even more complex Earth-centred model, although, it did seem to make sense.

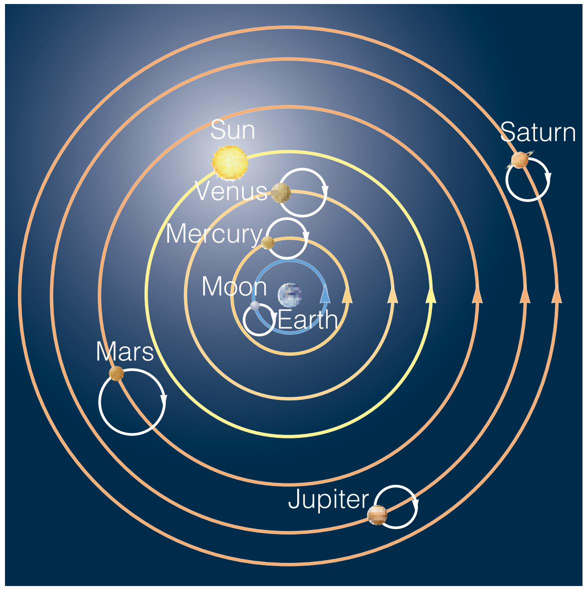


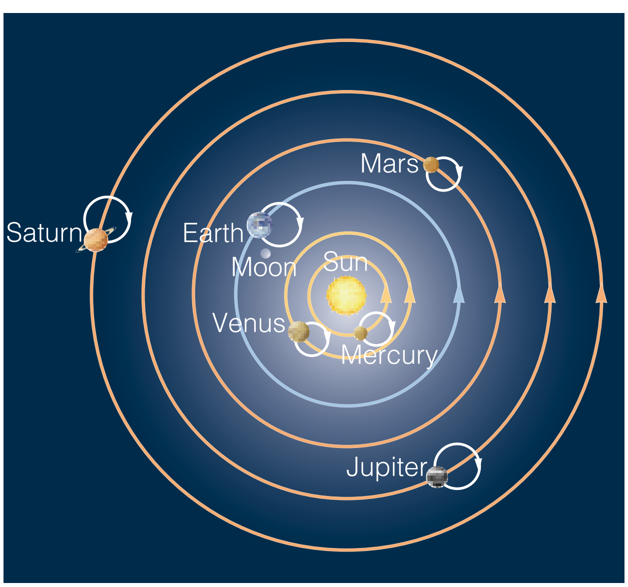
Figure 5.6 In Ptolemy's model, the planets were attached to smaller spheres (epicycles), which were attached to the main spheres.

The Sun-Centred Model

In the early 1500s, Polish astronomer Nicholas Copernicus proposed a different model to explain the view from Earth. In the model he proposed, the Sun was fixed, and a rotating Earth revolved around it rather than Earth being fixed and the Sun travelling eastward through the stars. This is known as the **Sun-centred** or **heliocentric** model of the universe.

In the next Topic, you will learn how the astronomer, Galileo, favoured the Sun-centred model, which is accepted as true today.

Figure 5.7 Copernicus's model uses perfect circular motions and the planets have epicycles. It was about as good as Ptolemy's model in predicting celestial motions. Notice the crucial difference. In Copernicus's model, the planets orbit the Sun, not Earth.



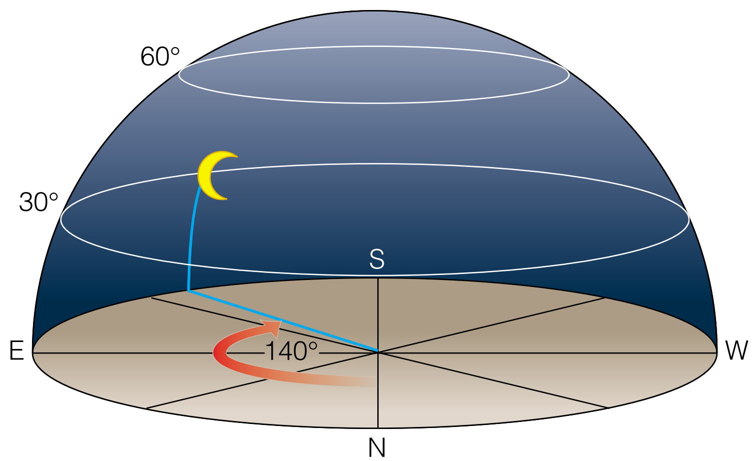
DidYouKnow?

People had many objections to the Copernican model of the universe. Some people thought:

- If day and night results from Earth rotating, people would be thrown off the planet.
- We would experience an extremely fast easterly wind all the time as Earth rotated under the atmosphere.
- It was unacceptable to move Earth from the centre of the universe. People were not ready to believe that they weren't the most important things in the universe. (Many of us today still have trouble believing this!)

TOPIC 1 Review

1. What is a frame of reference?
2. Why did ancient peoples think that Earth was at the centre of the universe?
3. What is an astrolabe and what function does it perform?
4. You want to measure the co-ordinates of a celestial object. The first angle you measure is clockwise from north. What is the name for this angle? Next you measure the celestial object's angle above the horizon. What is this called?
5. **Apply** Write the co-ordinates of the Moon using the diagram to the right.
6. **Thinking Critically** How does the heliocentric model differ from the geocentric model?



Pause & Reflect

Imagine watching a bus moving quickly past you to your right. There is only one passenger sitting on this bus. You see the single passenger walking to the back of the bus. Write answers to the following questions in your Science Log.

1. What motions do the bus and passenger have relative to you?
2. What motion does the passenger have relative to the bus? Does the passenger have a slightly different motion than the bus?
3. Suppose that the bus is like all the stars moving through the sky. The passenger walking to the back is a planet. Does the planet have a slightly different motion than the stars?
4. Now suppose that you want to measure the precise movement of the passenger in the bus. Is it easier to measure these movements standing at the side of the road or inside the bus?
5. Explain whether you think it is easier to measure the apparent movement of the planets in relation to Earth or in relation to the stars.

Looking Ahead

Ancient peoples needed remote manipulators just as we do today. For example, ceramic makers needed remote manipulaton tools to remove hot ceramics from kilns and furnaces. Try your hand at designing a remote manipulator. Turn to the Unit 5 Project, An Arm of Your Own, on page 432.