3 You have learned about the solar system, and stars and constellations. Are there other objects in space? What do you think the image here shows? How far away is it? How was it taken? What can you predict about the motion of what is shown in the image?

Reflecting

Think about the questions in **1**, **2**, **3**. What ideas do you already have? What other questions do you have about the nature of the universe? Think about your answers and questions as you read the chapter.

Try This: Using Angles to Estimate Distances

An important concept you will explore in this chapter is how vast the distances are in the universe. You will discover how astronomers measure those distances by comparing the apparent position of an object viewed from two different places. In this activity you can model how they measure large distances.

- Choose a partner and obtain a metre stick. Stand as far as you can from one of the walls in your classroom. Cover one eye with one hand, then stretch out the other arm and hold your index finger up so it hides an object on a distant wall (**Figure 1**). Use the metre stick to carefully measure the distance from your finger to your eye.
- Holding your finger still, cover your other eye. Notice what object your finger now hides. Determine the angle between the first and second objects hidden. (Use the hand method from Activity 13.5.)
- How does the angle between the two objects depend on the distance between your finger and your eye? Plan steps to answer the question. Will you need to make any other measurements? Then carry out the steps, record your observations, and communicate your discoveries using a diagram, table, graph, and/or spreadsheet.

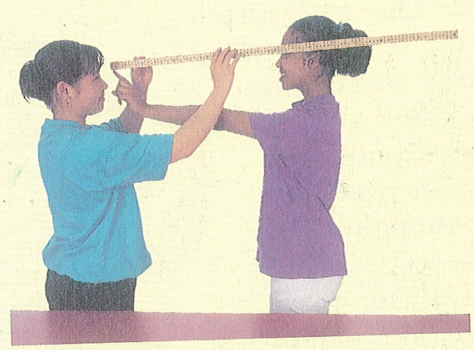


Figure 1
When your hand covers one eye and then the other, the position of the index finger shifts against the background.

Changing Ideas About the Universe

Movies about aliens from space or wars in far-away galaxies are more popular than ever. It seems that many people like to fantasize about what exists in the rest of the universe. Hollywood movies are an expression of our fascination with what is "out there."

People in ancient times didn't make science fiction movies, but they were still fascinated by the universe. Their beliefs and religious ceremonies reflected their ideas of what they thought the universe was like. These people left behind traditions, structures, and writings that give us clues about how they perceived the night sky.

In this section, you will learn how and why ideas about the universe have changed.

Ancient Ideas

Imagine that you are on a spinning merry-go-round. Your friends standing on the ground look as if they are moving in the opposite direction. Now imagine slowing the rate of spinning so that one rotation takes 24 h. At that speed, it would be difficult for you to judge whether it was the ride or the ground moving. Earth certainly seems to be stationary so, in ancient times, people thought everything else moved around it.

Everything in the sky appeared to be in motion. The Sun, Moon, stars, and planets all seemed to rise in the east and set in the west. One early idea about the stars was that they were attached to a large ball that revolved around Earth once every day. People thought that the stars were only slightly farther away than the Sun, Moon, and the planets they could see. In **Figure 1**, you can see one possible arrangement of the universe. This idea is called the **Earth-centred universe**.

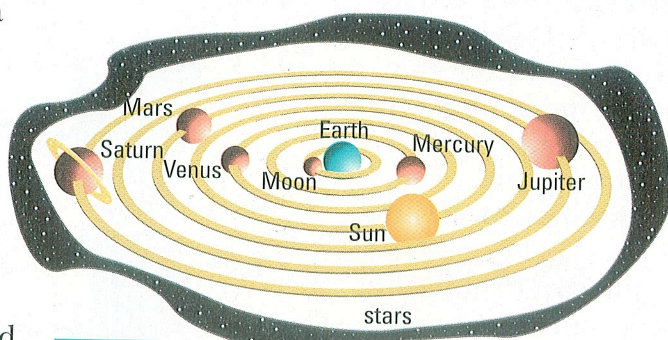


Figure 1
Many people in ancient times thought that Earth was the centre of the universe and that all the other objects revolved around it.

Improvements in Making Observations

The Earth-centred idea of the universe was popular for thousands of years. Then, around 500 years ago, some scientists began to question this idea. Scientific ideas were starting to change for two major reasons: the invention of the telescope and the fact that scientists began experimenting to learn more about nature, Earth, and the universe.

The telescope was invented in Europe in the early 1600s. The great Italian scientist Galileo Galilei improved upon the invention and was the first person to use it to view the night sky. His first telescopes made distant objects look seven to thirty times larger than normal. He saw that the planets were not merely points of light: they were circular, like the Moon. The stars, however, still appeared as points of light. From these observations, Galileo inferred that the stars must be much farther from Earth than the planets. The universe was clearly much bigger than was previously thought.

Before Galileo had discovered how different the sky looked through a telescope, other scientists had begun to question the Earth-centred view of the universe. For example, in the mid-1500s, Copernicus had presented mathematical evidence that the planets all orbit the Sun. Galileo's discoveries, especially his observation that Venus has phases like the Moon, supported the new theories. Galileo became convinced that Earth and other planets travel around the Sun. Persuading other people to accept his theory was difficult and sometimes dangerous work. The predominant view in Europe at the time was that Earth, made by God, was the centre of the universe. Anyone who challenged this idea was considered "heretical" (against the Christian Church) and was even threatened with torture. These threats forced Galileo to deny his findings that Earth travels around the Sun. Eventually, however, despite religious persecution, the idea of the **Sun-centred solar system** replaced the Earth-centred view (**Figure 2**).

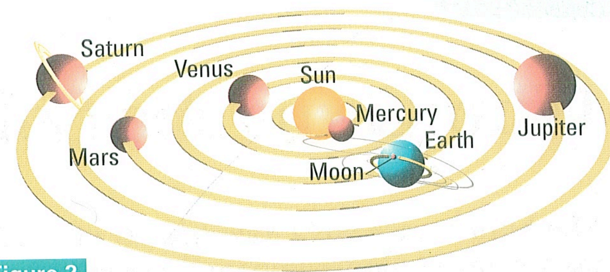


Figure 2

This is the Sun-centred view of the solar system of about 400 years ago. Compare this model with Figure 1. Which planets are not shown? Why not?

Today's Ideas

Nearly 400 years have passed since the invention of the telescope. In that time other inventions have led to many new discoveries about the universe. We now know that the planets orbit the Sun and that the Sun is just one of countless stars. Astronomers have observed that the Sun and other stars are also moving. Stars are gathered in large groups, surrounded by gas and dust. The group of stars that our Sun belongs to is called the Milky Way Galaxy. A **galaxy** is a huge collection of gas, dust, and hundreds of billions of stars and planets.

Modern telescopes show us that there is a vast region beyond the Milky Way Galaxy that appears to be almost empty. Far off in the distance there are countless more galaxies and other fascinating objects (**Figure 3**).

Our knowledge of the universe is always increasing as scientists develop new tools that let astronomers see farther into the distance. For instance, by detecting radiation that may have taken millions of years to reach Earth, they are able to learn about the early history of the universe.

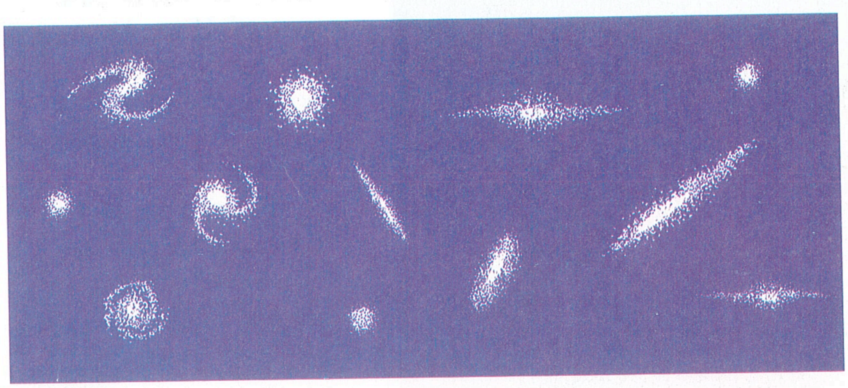


Figure 3

The universe contains huge groups of stars, called galaxies, separated by vast distances. The galaxies and everything in them are constantly in motion.

Understanding Concepts

1. (a) What does the expression "Earth-centred universe" mean?
   (b) What evidence helped scientists change their ideas about an Earth-centred universe?
2. How and why has our estimate of the size of the universe changed in the past few centuries?
3. (a) What is a galaxy?
   (b) What is our galaxy called?

Making Connections

4. Describe how "new" technology in Galileo's time helped to change an established idea. What societal effects were related to the change?

Exploring

5. (3A) Research how one of the following scientists contributed to the development of ideas about the universe: Nicholas Copernicus; Tycho Brahe; Johannes Kepler; Isaac Newton. Create a written report or an audio-visual presentation.

Reflecting

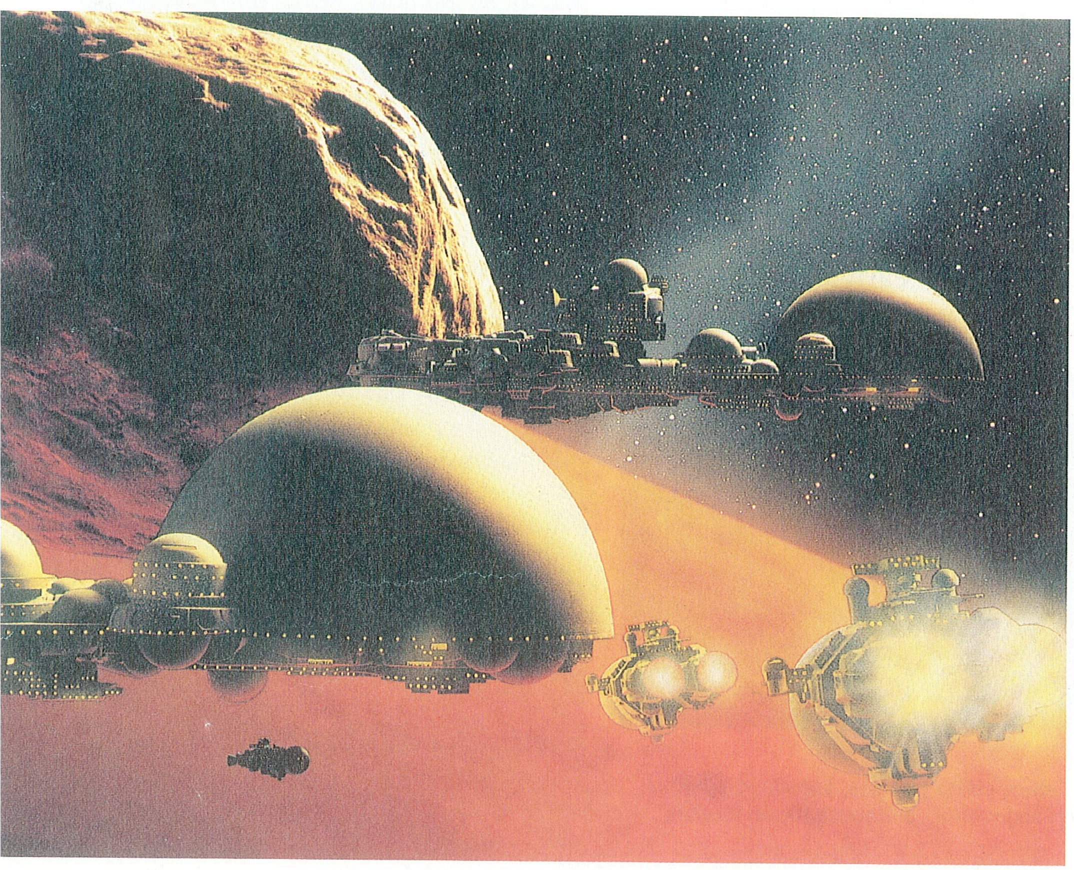
6. The Earth-centred view was replaced by the Sun-centred view of the solar system. How does this illustrate the process of science?

SKILLS HANDBOOK: (3A) Research Skills

Who Owns the Solar System?

The human race has a long history of exploration, colonization, and exploitation. From Stone Age migrations across the Bering Strait to 20th-century forays into the jungles of South America, we have set out to see what we can find and what we can make use of. Most of Earth's surface has now been explored, charted, and investigated with a view to extracting valuable resources. More recently, humans have visited Earth's Moon and sent space probes to explore outer space objects such as comets, asteroids, and other planets and their moons. These explorations have shown scientists that there may be many valuable resources on several of these objects. Mars is rich in iron oxide, which could yield both iron and oxygen, and Jupiter's moon Ganymede appears to contain hydrogen peroxide. Other outer space objects are quite likely to contain other useful substances. An additional advantage of mining a low-gravity object is that it would be easier to lift extracted resources up, into outer space, than it would be from Earth. This has potential implications for the construction of future space stations.

Some people suggest that colonies and mines could indeed be built on such bodies as Mars, our Moon, or a few other moons or large asteroids. But who owns outer space objects? Should ownership rights be awarded on a "first-come, first-served" basis? If colonies are set up, who should live in them? Who would benefit from the existence of the colonies? Who owns any resources that are mined on other bodies? Would it be a case of the rich countries getting richer, and the poorer countries having no chance of participating? What about the environmental aspect? In many instances we have not shown that we can responsibly manage Earth's resources. Do we have any right to export our mismanagement? It has been suggested that this is a way to ease the pressure of a rapidly increasing population here on Earth. Is this a valid reason? If we were to find any form of extraterrestrial life, would our decisions be altered? These questions should be discussed before such expensive projects begin.



Issue A Moratorium on Extraterrestrial Mining (8B)

"We should learn to manage Earth's resources better, before exploiting extraterrestrial resources."

Imagine that you have been asked to participate in a panel discussion, either supporting or opposing the statement above. You might be a mining engineer, an investor, an unemployed miner, an astronomer, a lawyer, an environmentalist, a social worker, a space engineer, or anyone else who might have an opinion in the discussion. Choose your position and support it by developing a three- to five-minute presentation. Refer to the ideas below and add some more of your own. (8C)

Point

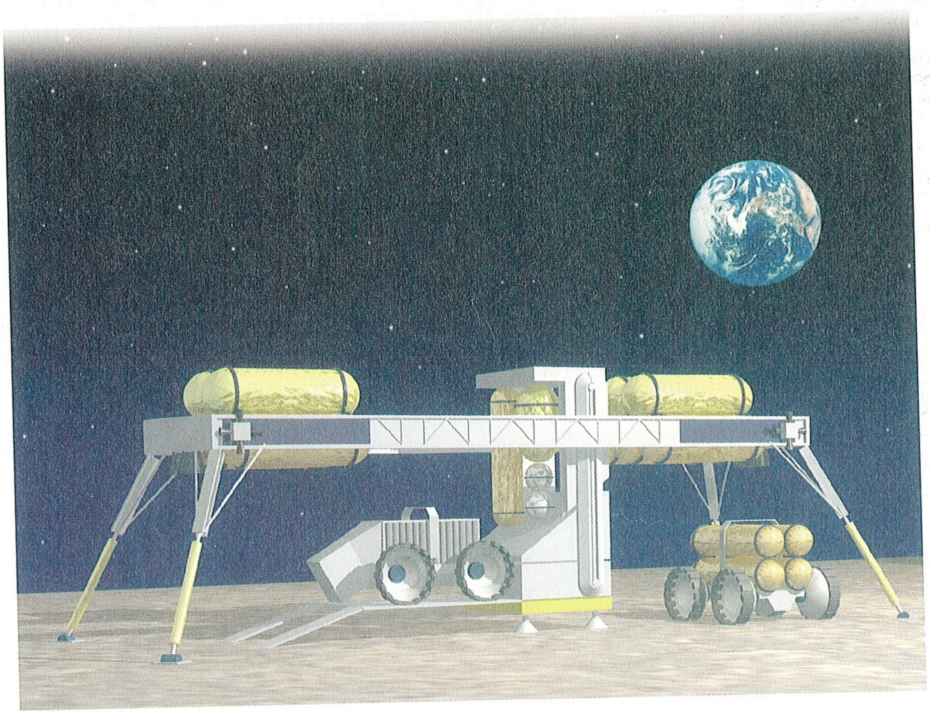
- There are many untapped resources here on Earth. If we were to use and recycle them more efficiently, we would have no need of space mining.
- The cost of the technology to exploit space resources is far too high. The money would be better spent improving efficiencies on Earth.
- We have no right to take resources from outer space objects. They do not belong to us.

Counterpoint

- Using resources from outer space objects would reduce our dependence on Earth resources.
- By having resource extraction facilities set up in space, we would have bases for refuelling and manufacturing, which would make further space exploration much more economical.

Challenge

What issues presented in the panel discussion do you need to consider when participating in any endeavour involving space exploration?



SKILLS HANDBOOK: (8B) Exploring an Issue (8C) Science Projects

Using Triangles to Measure Distances

We know that the Moon is closer to us than the Sun, and that the planets are closer than the stars. How do we know this? Because of their movements relative to each other: the stars form an almost unchanging backdrop for the wandering planets. But just how far away are these objects? How can we measure such vast distances? Try using only one eye to judge how far away something is. It is not as easy as using two eyes to judge distances. The reason is that the lines of sight from your eyes form an angle where they meet an object, and the size of the angle helps you judge distances. You may have noticed this when you did the Getting Started activity on page 437.

In this activity you will measure distances using an indirect method. You will measure angles between a baseline and the object, and draw a scale diagram to calculate the distance to the object. This indirect method of measuring the distance to an object using geometry is called **triangulation**. The more carefully you draw the triangles, the more accurate your answers will be.

Materials

- astrolabe designed in Activity 13.5 (with the string attached but the rubber stopper removed)
- metre stick
- paper
- small protractor
- centimetre ruler

Procedure

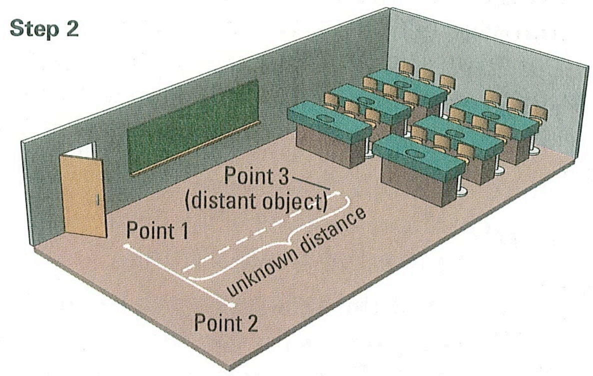
1 Your teacher will suggest an unknown distance that you will measure in the classroom. (For example, the distance could be from one wall to a door hinge on the opposite wall.) Use your eyes (and experience) to estimate the distance.

(a) Record your estimate.

2 (6B) Mark off two points, Point 1 and Point 2, that are at least 5 m apart, and use the metre stick to measure the distance. This distance is called the triangle baseline.

(a) Record the length of the baseline.

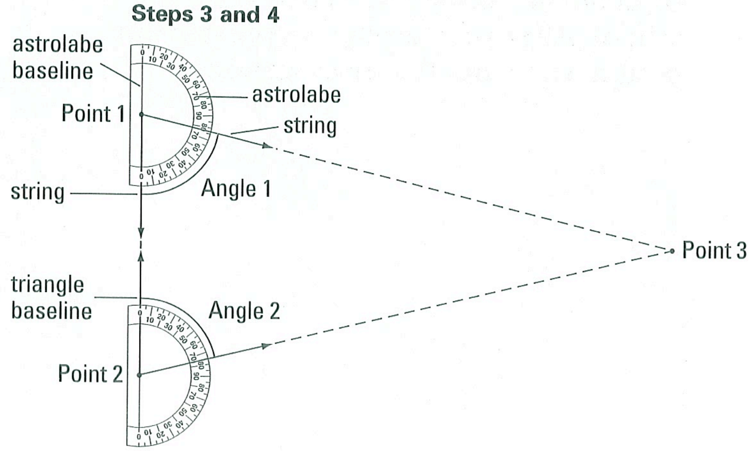
Step 2



3 Have one student stand at Point 1 holding the astrolabe horizontally, so that its baseline lines up with the triangle baseline. Another student should use the string to be sure this is as straight as possible. While one student holds the astrolabe still, another student should move the string around until it lines up with the distant object, Point 3. Measure the angle formed, Angle 1.

(a) Record the value of Angle 1.

Steps 3 and 4



SKILLS HANDBOOK: (6B) Obtaining Quantitative Data

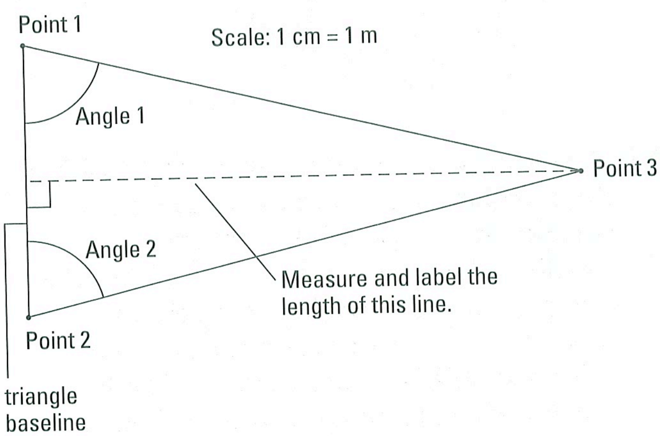
4 Repeat step 3 from Point 2.

(a) Record the value of Angle 2.

5 On a piece of paper, use the centimetre ruler to draw a diagram of your experiment. Choose an appropriate scale so that the triangle baseline will be at least 5 cm long. Label Points 1 and 2. Use a small protractor to draw Angles 1 and 2.

6 From Points 1 and 2, draw straight lines that meet at Point 3. Finally, draw a straight line from Point 3 back to the triangle baseline. (Try to make this line meet the baseline at a 90° angle.) Measure the distance from the baseline to Point 3. Label all the points and distances on your diagram.

Steps 5 and 6



7 (2A) Design your own investigation to measure large distances indirectly, either outdoors or in an appropriate area inside the school. After your teacher approves your design, carry out the investigation.

Understanding Concepts

1. Why is the method of finding distances in this investigation called an indirect method?
2. Do you think that measurements in this investigation would be more accurate with large baselines or smaller ones? Why?
3. Draw two diagrams to show the lines of sight from your eyes to an object that is near, then to one that is farther away. (Your two eyes form a baseline.) How do the angles in your diagrams relate to your ability to judge distances?
4. How could triangulation be used to find out the distance from Earth to a neighbouring star?

Exploring

5. The widely spaced eyes of hawks, eagles, and other birds of prey enable them to judge distances very well. Explain, with the aid of a diagram, why this is so.
6. Astronomers call their way of using triangulation to measure distances "parallax." Look up parallax in an astronomy reference book or other source and describe how it relates to the method you learned in this activity.
7. Use direct measurements to find out the true value of your group's measurements. Use the following equation to determine the percent error of each of your indirect measurements.

$$\%\ \text{error} = \frac{\left|\text{indirect measurement} - \text{direct measurement}\right|}{\text{direct measurement}} \times 100\%$$

Reflecting

8. In Chapter 13 you learned how to use fists and fingers to measure angles. Could fists and fingers be used to measure distances indirectly as you did in this activity? Explain your answer.
9. How does the method of triangulation relate to what you discovered in the Getting Started activity on page 437?

(2A) Controlled Experiments

Distances in Space

Using Scientific Notation

Distances in space are very large, so measurements written out in kilometres can become long. Scientific notation is a mathematical abbreviation for writing very large or small numbers. Using this notation, a number is written with a digit between 1 and 9 before the decimal, followed by a power of 10. That is why Canada's population of 32 million could be written as 3.2×10^7 instead of 32 000 000. The exponent, in this case 7, indicates the number of places you have to move the decimal point.

Using Long Baseline Measurements

A surveyor trying to measure the distance across a raging river can use the indirect method of triangulation. Astronomers can apply the same method to measure distances to objects in the solar system and beyond. To measure large distances with as much accuracy as possible, they use the largest baselines available.

How can scientists obtain long baselines to measure the huge distances to stars? One way to obtain a large baseline is to use the diameter of Earth, about 1.3×10^4 km (**Figure 1**). This method could be used to determine the distance to the Moon or a nearby planet.

What is the largest possible baseline available to observers on Earth? It is the diameter of Earth's orbit, a distance of about 3.0×10^8 km (**Figure 2**). This baseline has been used to calculate the distances to some of the stars nearest to our solar system.

Distances to the Stars

The distance from our Sun to the next nearest star that you can see without using a telescope or binoculars is about 4.1×10^{13} km. This star is called Alpha Centauri. Most other distances in space are much greater than this. To avoid using such huge numbers, scientists have developed units of distance other than kilometres or metres.

One common unit used to measure large distances is the light-year. One **light-year** is the distance that light travels in one year. Light

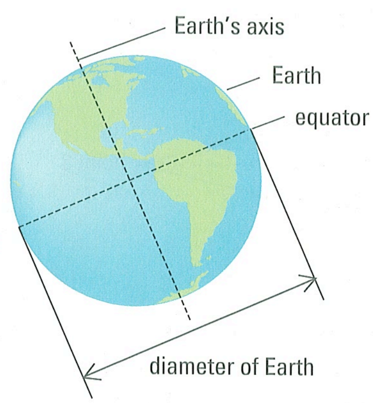


Figure 1
One example of a long baseline is the diameter of Earth at the equator. Because Earth rotates on its axis, it takes 12 h for an observer to move from one side of Earth to the other.

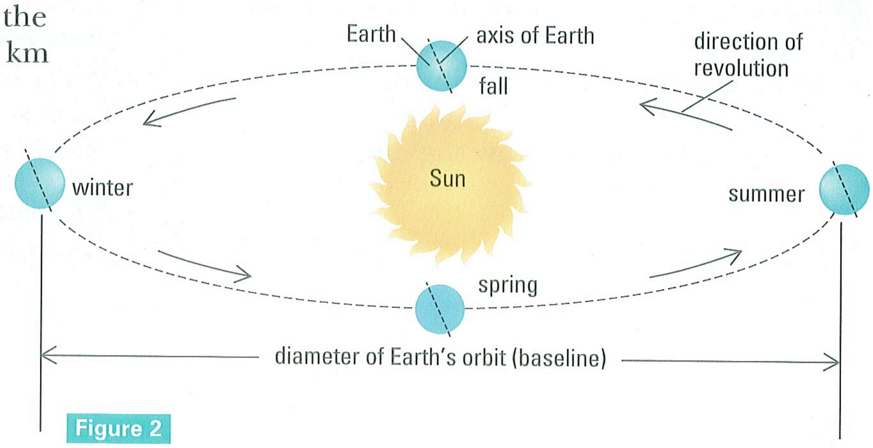


Figure 2
The largest baseline available to observers on Earth is the diameter of Earth's orbit. As it takes a year for one complete orbit, angles to the stars are measured six months apart.

travels at an enormous speed in space, about 300 000 km/s. So in one year it can travel about 9.46×10^{12} km*. Thus, the distance to Alpha Centauri, given above, is equal to 4.3 light-years. (You can prove this by dividing the distance to Alpha Centauri by the distance light travels per year.) **Table 1** lists examples of distances measured in light-years. Notice that all the stars named are different distances from Earth. This is true even for stars in the same constellation. For example, Betelgeuse and Rigel are both in the constellation Orion, but their distances from Earth are quite different.

One interesting fact about light-years is that they tell us how far back we are looking in time: the light from Alpha Centauri that we might see tonight actually left Alpha Centauri 4.3 years ago. Whatever we view on Alpha Centauri *now* has already happened! By looking at stars thousands or even billions of light-years away, astronomers can look back in time and see what the universe was like when it was much younger. Measurements in light-years tell us not only how far away an object is, but also how much time has passed since the light we see left that object.

Table 1 Some Distances of Objects from Earth

Star or object	Approximate distance (light-years)
Alpha Centauri	4.3
Sirius (brightest star in the sky)	8.8
Vega	26
Arcturus	36
Betelgeuse	700
Rigel	900
Deneb	1400
Most-distant known galaxy in the universe	15 000 000 000

Understanding Concepts

1. Why is the length of the baseline important when you use triangulation to measure distances?
2. A surveyor (**Figure 3**) measures off a baseline of 120 m along the shore of a river. He then measures the angle from each end of the baseline to a rock on the opposite shore. The two angles that he measures from the baseline to the rock are 65° and 50°. Draw a scale diagram to determine the width of the river.

Figure 3
A surveyor measures angles with an instrument called a transit theodolite. Why do surveyors need to measure exact angles and distances?

3. (a) Describe the longest baseline possible on Earth.
   (b) How much time passes between the measurement of angles using the baseline you suggested in (a)?
4. What is the difference between a year and a light-year?
5. Determine the distances listed in **Table 1** in kilometres and write the final answers using scientific notation. (7C)

Exploring

6. Design a way to use a triangle method to measure the height of a wall or tree indirectly. Try your method and draw a scale diagram to show your calculations.

*distance = speed × time
= (300 000 km/s) (1 year × 365 d/year × 24 h/d × 3600 s/h)
= 9 460 000 000 000 km or 9.46×10^{12} km

SKILLS HANDBOOK: (7C) Using Math in Science

Scaling the Universe

About how much time do you think it would take to
- drive a car across Canada?
- fly around the world in an airplane?
- travel from Earth to the Moon in a spacecraft?
- travel from Earth to the Andromeda Galaxy in a spacecraft?

Although many people may think of travelling far away in space, they first must find out how long the distances are. This activity will give you an idea of how tiny our Earth is compared with the entire universe.

The distances between different objects in the universe are given different names. Distances between planets in the solar system are called interplanetary distances (*inter* is the Latin word meaning "between"). Distances between the stars are called interstellar distances (*stellar* refers to stars). And distances that separate the galaxies are intergalactic distances (*galactic* refers to galaxies).

As you have learned, large distances in space are often measured in light-years. (Recall that a light-year is the distance light travels in one year, at a speed of 300 000 km/s. Thus, a light-year is a distance of about 9.46×10^{12} km.) In this activity, you will use a model of the light-year to help you understand the vastness of the universe. To make your calculations easier, always round off your answers to easy numbers, such as 10, 100, 1000, and so on.

Materials

- this textbook
- ruler or metre stick with millimetre and centimetre divisions
- calculator

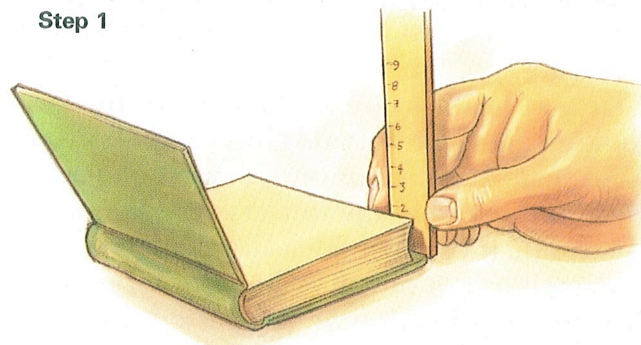
Did You Know?

If the space shuttle could travel in a straight line for a year at its average cruising speed, it would travel 2.5×10^8 km. Light travels 9.46×10^{12} km in a year: more than 30 000 times farther!

Procedure

1 Count out 50 sheets of paper in your textbook. Measure the thickness of those 50 sheets together in millimetres. Use your measurement to calculate the approximate number of sheets of paper per millimetre (sheets/mm). You will need this number in the next two steps, so before going on, check with your teacher to be sure that your calculation is reasonable.

Step 1



(a) Record your measurement and calculation.

2 Repeat this two more times.

(a) Record your measurements.

(b) Calculate a mean value of your results. Remember to include the units.

3 Assuming that the thickness of one sheet of paper represents a distance of one light-year, determine the number of light-years in: 1 mm; 1 cm; 1 m; 1 km; 1000 km; 2000 km (the approximate distance from Montreal to Winnipeg as shown in **Figure 1**).

(a) Record your answers.

4 Copy the first three columns of **Table 1** into your notebook and complete the required information.

(a) Write the actual distance in kilometres (7C) using scientific notation.

SKILLS HANDBOOK: (7C) Using Math in Science