

LESSON 3

How Does Light Travel?



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JOHNSON SPACE CENTER

The Sun provides the light that illuminates our planet. Why does the space between Earth and the Sun look so dark?

INTRODUCTION

In the previous lesson, you discussed light as being a type of energy. You discovered that light is made as a result of energy transformations. For example, in the lightbulb of the flashlight, electrical energy was transformed into light energy. Once light energy is produced, where does it go and how does it get there? In this lesson, you will observe light as it travels through and strikes different substances. You also will discuss how fast light travels.

OBJECTIVES FOR THIS LESSON

Try to detect light as it travels through air and water.

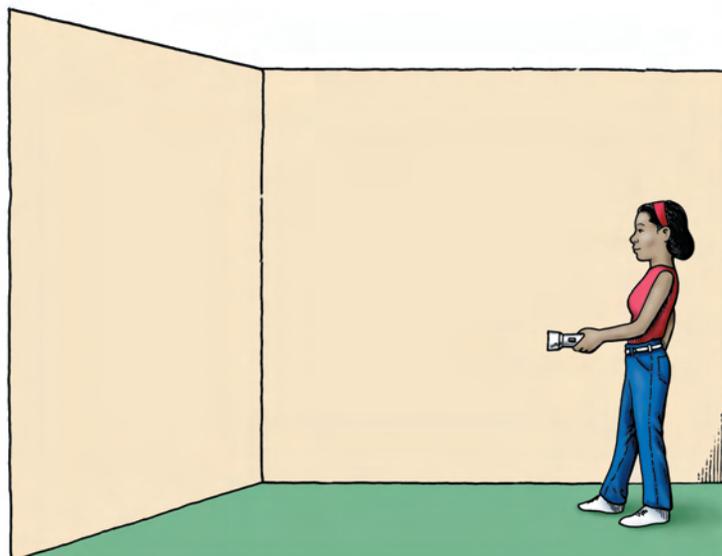
Determine how light behaves as it travels.

Discuss how to determine the speed of light.

Getting Started

1. One member of your group should collect the plastic box of materials. Remove a flashlight from the plastic box of materials.
2. Shine the flashlight toward the wall. Answer the following questions on Student Sheet 3.1: Looking at How Light Travels:
 - A. Does light from the flashlight reach the wall?
 - B. How do you know?
 - C. Look at Figure 3.1. Where is light from the flashlight? Draw on the picture on the student sheet to show where you could find light from the flashlight.
 - D. Could you see light from the flashlight between the flashlight and the wall?
 - E. If not, how do you know it is there? (How could you detect it?)

Figure 3.1 This flashlight is switched on. Where can you find the light it is producing?



MATERIALS FOR LESSON 3

For you

- 1 copy of Student Sheet 3.1: Looking at How Light Travels

For you and your lab partner

- 1 flashlight
- 2 D-cell batteries
- 1 plastic soda bottle
- 1 length of rubber tubing
- 1 dropping bottle

Inquiry 3.1

Looking at How Light Travels

PROCEDURE

1. Divide the remaining materials between the pairs in your group. Use the plastic bottle and water to determine whether light travels through water. Answer the following questions on the student sheet:
 - A. How did you detect light on the side of the bottle opposite the flashlight?
 - B. Could you see light from the flashlight as it traveled through the water?
 - C. If you think light was passing through the water, but was invisible, how could you make it visible?
2. Test one of the suggestions from the class discussion.
 - D. Draw a labeled picture on the student sheet showing what you observed. Accurately describe the shape and the edges of the beam.
3. From what you have seen, do you think light travels in straight lines? Devise an experiment to test your hypothesis using the apparatus in your plastic box. Conduct your experiment.
 - E. Use the outline in Table 1 on the student sheet to help you describe in words and diagrams the experiment you designed and what you discovered.

REFLECTING ON WHAT YOU'VE DONE

1. You have shown that light travels through air in straight lines. How fast does it go? Discuss with your group how you could determine the speed of light. Here are some questions to think about—

What would you need to measure?

How would you make these measurements?

How accurate would your measurements need to be?

2. Participate in a class discussion on this topic.
3. Think about the points listed below. Discuss them with other students.

Does light travel through air and water?

What do you need to do to detect light?

What evidence did you gather that suggests that light travels in straight lines?

How fast does light travel?

- A. Use these points to help you write a paragraph on the student sheet summarizing what you have discovered and discussed during this lesson.

Racing To Find the SPEED of Light

Light travels so fast that our eyes can't detect its movement. In the past, some people thought light traveled instantly from one place to another. Others thought light had a very fast, but finite speed—a specific speed that could somehow be measured. How do you measure such a fast speed? Think about it.

Galileo's Glimmer

Galileo, the famous 17th-century scientist, asked just that question. And he had a plan to answer it. Galileo's plan involved two lanterns, a timing device, and a willing assistant. The assistant had to be willing—his job was to walk many kilometers and hike up a steep hill carrying one of the lanterns and the timing device.

Once on top of the hill, the assistant waited until dark. He covered the lantern so no light could be seen from it, and carefully lit it. Meanwhile, a nicely rested Galileo looked toward the hill and waited. He too had a lit, covered lantern. The assistant started the timer and uncovered his lantern. As soon as Galileo saw the light, he pulled the cover off his lantern. The assistant saw the distant glimmer. He tried to measure the time it had taken for the light to travel to Galileo and back to him. Unfortunately, the light had traveled too quickly for the timer to make an accurate measurement.

Galileo's method for determining the speed of light seemed like a good idea—but it was a failure. However, Galileo did learn something. He discovered that the speed of light was very fast. So fast that it could not be measured over such a short distance using such a simple timing device.



Who is this stranger with the hidden lantern? What was his role in trying to determine the speed of light?

Roemer and the Orbit of Io

If you can't make a better timer, why not increase the distance? That's a good idea, but a huge distance would be needed—a distance on an astronomical scale. Astronomer Oleas Roemer took up this challenge.

Roemer was studying Io, a moon that orbits Jupiter once every 1.76 days. He thought that he could use Io to calculate the speed of light. He knew that moons orbit planets at about the same speed regardless of the time of year. Why, he asked himself, did Io sometimes appear to be in the wrong position? At times, Io appeared to be ahead or behind its predicted position in orbit by up to 10 minutes. Roemer noticed that Io was ahead of schedule when Jupiter (with its orbiting moon Io) was near Earth and behind schedule when Jupiter was farther away.

Could the speed of the light reflected from Io to Earth have something to do with this

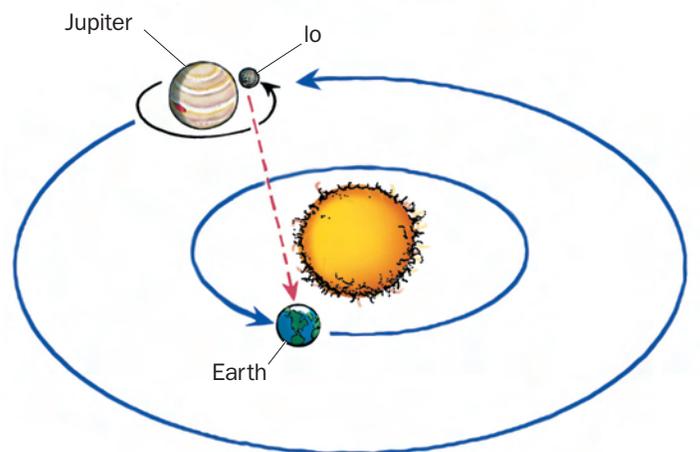
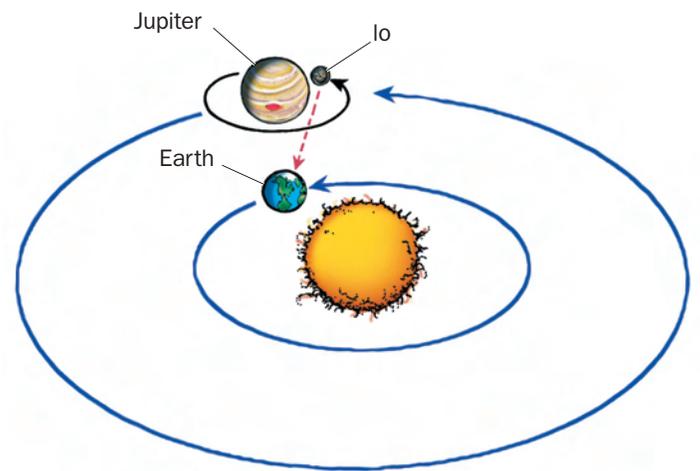
mystery? Roemer realized that the difference in schedule could be explained if light traveled at a specific, rather than at an infinite, speed. If light traveled at a specific speed, the farther the light had to travel, the longer it would take it to reach a destination. He calculated the change in distance when Io was farthest away from Earth and divided it by the change in time from Io's predicted position. Presto! Roemer had calculated the speed of light as 220,000,000 meters per second.

The Final Figure

Roemer's calculation was pretty close, but scientists were determined to get a more accurate measurement. Many more attempts to determine the speed of light were made. The honor for the first truly accurate measurement went to the American physicist Albert Michelson. Like Galileo and Roemer, Michelson realized that to accurately measure the speed of light he needed to precisely measure the time it took light to travel a long distance. He used a specially designed apparatus with two mirrors that

were 35 kilometers apart. Using a very accurate clock, he measured the speed of light at 299,799,600 meters per second. Close, but not close enough for some scientists.

The most recent speed for light is 299,792,458 meters per second. This measurement was made using very precise atomic clocks to calculate the time it takes for light to travel over very accurately measured distances. Science has come a long way since Galileo's experiment with lanterns and a timer! □



Note: Bodies and orbits are not to scale.

The farther away Jupiter and its moons are from Earth, the longer it takes light reflected from them to reach us. Roemer realized that apparent variations in the orbit time of one of Jupiter's moons and the difference in distance between it and Earth could be used to calculate the speed of light.

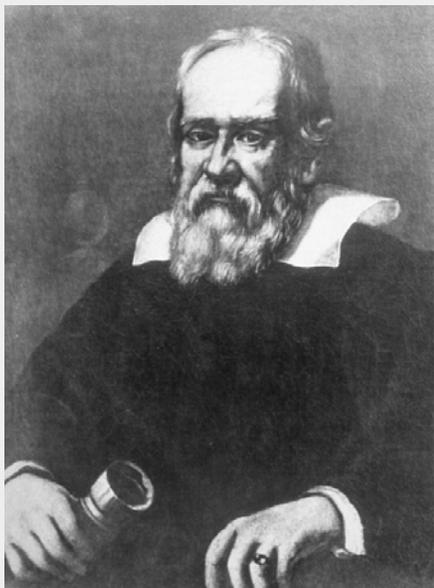
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How did Io, a moon orbiting Jupiter, contribute to our knowledge of the speed of light?

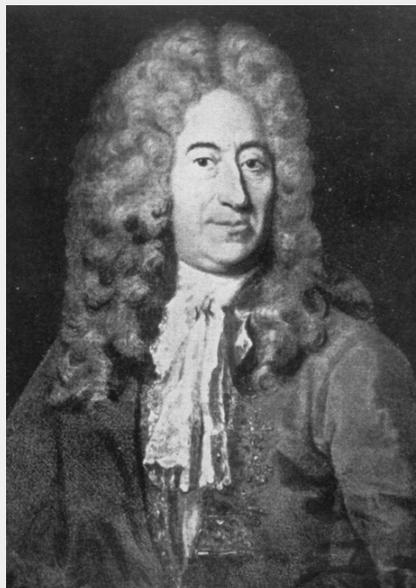
Light Speedsters

All these scientists attempted to find the speed of light. The accuracy of their results for the speed of light depended on their ability to design experiments and build apparatus that would accurately measure time and distance.



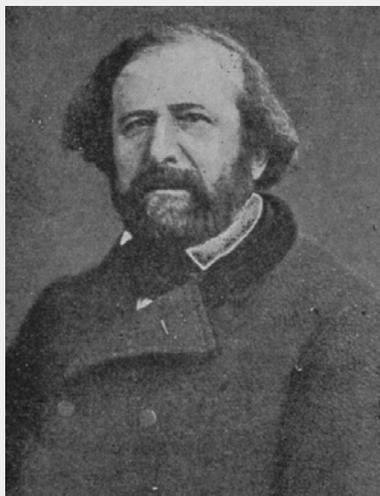
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Galileo (1564–1642) tried unsuccessfully to measure the speed of light with lanterns and a timing device.



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Olas Roemer (1644–1710) used astronomical distances to calculate the speed of light.



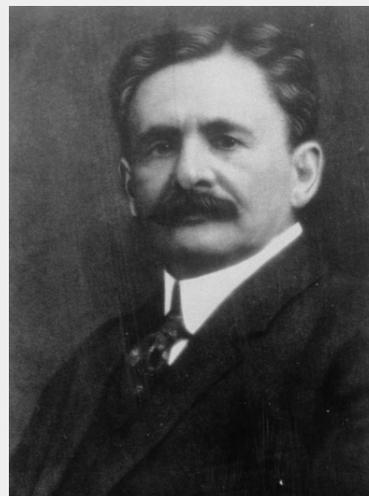
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Arnard Fizeau (1819–1896) designed an apparatus that used rotating mirrors and a distance of 9 kilometers to make a more accurate measurement for the speed of light.



COURTESY OF THE ARCHIVES, CALIFORNIA INSTITUTE OF TECHNOLOGY

Jean Foucault (1819–1868), Fizeau's former assistant, improved on Fizeau's apparatus and measurements.



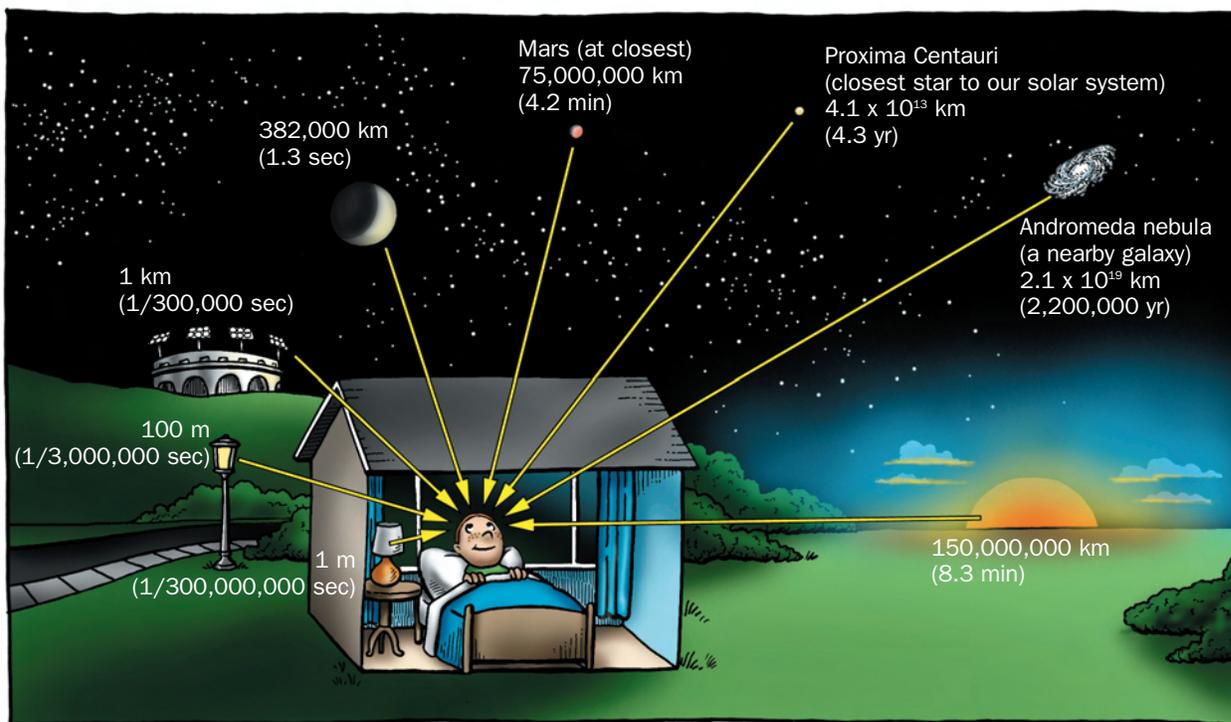
NATIONAL ACADEMY OF SCIENCES

Albert Michelson (1852–1931), a U.S. physicist and Nobel Prize winner, obtained what is considered to be the first really accurate measurement for the speed of light.

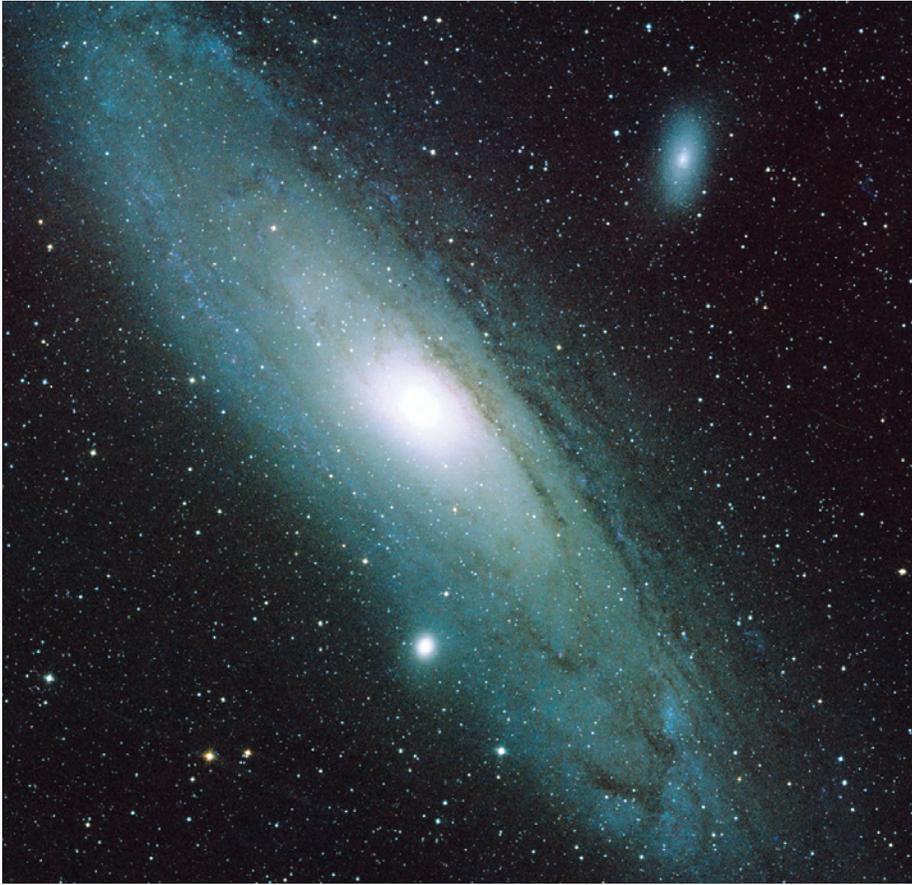
LIGHT TIME

Light travels very fast. So fast, in fact, that to us it appears to travel instantly from one place to another. However, light does have a finite speed. Light travels at 299,792,458 meters (about 186,282 miles) per second in a vacuum. Light is slower when passing through transparent materials, such as air, water, or glass. Even so, it is difficult to imagine this kind of speed. To get an idea of how fast light travels, compare the time it takes for light to travel from different objects to the boy pictured in bed.

Because light is so fast, the distance it travels over a period of 1 year is sometimes used as a measure of astronomical distances. This unit of measure is called a light-year. The light-year unit is sometimes used by astronomers to measure the vast distances between stars and even between galaxies. A light-year is therefore a measure of distance, not time! One light-year is equal to about 9,500,000,000,000 kilometers (9.5×10^{12} km). □



When you look at the Moon, you are actually seeing it as it was 1.3 seconds ago. If you glance up at the Sun, you are seeing it as it was about 8.3 minutes ago. That's how long it took the light the boy sees to travel to the boy's eyes. If you used a telescope to view distant galaxies, you would see them as they were millions of years ago! The finite speed of light allows astronomers to see into the past and unravel the history of our universe.



Compared with other galaxies, the Andromeda galaxy is close to Earth. Light from the Andromeda galaxy takes 2.2 million years to reach Earth. Estimates are that light from the most distant objects in the universe takes over 13 billion years to reach Earth.



A high-speed train, traveling at about 240 kilometers (150 miles) per hour, would take about 75 years—an entire lifetime—to travel to the Sun. Yet, it takes light only 8.3 minutes to cover the same distance.