LESSON 25

Communicating With Light

Light is the fastest way of sending information from one place to another. This lighthouse warns sailors that they are near dangerous waters. The flashing light provides information about the identity of the lighthouse.

INTRODUCTION

Your ability to detect light allows you to gather a lot of information about the surrounding environment. Think about all the kinds of information you receive by detecting light. Light also can be used to send specific information from one place to another. Because nothing travels faster than the speed of light, light provides the fastest means of communication. In this lesson, you will investigate some ways in which light can be used to send information.

OBJECTIVES FOR THIS LESSON

Explore how light can be used for communication.

Observe how light can be directed through transparent materials.

Investigate optical fibers and how they can be used in communication.

Observe and discuss total internal reflection.

Getting Started

1. We use our voices to speak to each other and transfer information. Voice communication uses sound waves. Discuss this question with your group:

How do we use light to transfer information?

2. Make a list of all the ways that light can be used to transfer information. Be prepared to discuss your examples with the class.

MATERIALS FOR LESSON 25

For you

- 1 copy of Student Sheet 25.3: Assessment Review—Part 3
- 1 copy of Student Sheet 25.4: Sample Assessment Questions for Part 3

For you and your lab partner

- 1 flashlight
- 2 D-cell batteries
- 1 length of black optical fiber
- 1 hand lens
- 1 red filter
- 1 green filter
- 1 blue filter

For your group

- 1 wooden block
- Masking tape

Inquiry 25.1
Investigating an Optical Fiber

PROCEDURE

1. One member of your group should collect the plastic box of materials. Divide the materials between the pairs in your group. Record your responses for this inquiry in your science notebook.

2. Examine the black optical fiber. Discuss with your partner how it is constructed.

   A. Draw a simple diagram of the fiber construction.

3. Can this fiber transmit light? Devise and conduct an investigation to answer this question.

   B. Write a short paragraph describing what you did and what you discovered.

   C. What evidence do you have that the optical fiber transmits a wide range of different wavelengths of light?

   D. What do you notice about light where it comes out of the bare end of the optical fiber? Suggest an explanation for your observations.

4. Working with another pair, determine whether you can connect two pieces of fiber together so that the double-length piece transmits light.

   E. If the joined lengths of optical fiber can transmit light, what measures did you have to take to ensure light transmission?

   F. Is there any difference in the brightness of the beam when using the double-length fiber as compared to the single length of fiber? Can you suggest a reason for your result?

5. Your teacher will use a light pipe and a small laser to model how light can travel along a fiber.

   G. Draw a diagram illustrating what you observe.

   H. Where have you observed this type of reflection before?

Inquiry 25.2
Sending a Message Along an Optical Fiber

PROCEDURE

1. Work with your group. Discuss ways you can use the materials in the box to use light to transfer a simple message along a length of optical fiber. Think about the following question:

   What would both the transmitter and receiver of the message need to know in order to successfully transfer information?

2. Devise a code that you can transmit along the optical fiber that could be used to instruct a member of your group to move the wooden block to an exact spot on a table somewhere in the room.

   What sort of instructions will you have to give to your team members?

   How will you represent these instructions?

3. Develop and test your ideas. Be prepared to describe and demonstrate them to the class.

4. What problems would your system of light communication have communicating over large distances? How could this problem be overcome? Think about the following questions. Be prepared to outline your ideas to the class.

   Does your communication system have any other limitations?

   How could these limitations be overcome?

REFLECTING ON WHAT YOU'VE DONE

Respond to the following questions in your notebook:

A. In Inquiry 25.2, you used a code to communicate with light. How could many different wavelengths of light be used to increase the amount of information that could be carried by a light communication device at any one time?

B. On-off signals—that is, binary (digital) code—are used to transmit information. Why is this type of code ideal for transmitting information along optical fibers?

COURTESY OF THE CHINA NATIONAL TOURIST OFFICE, NEW YORK

The Great Wall of China was first built around 200 B.C. and has been altered many times since to protect the borders of the Chinese Empire. Its sentries used light to send urgent messages. Fires lit on guardhouses signaled an attack.

Sentry duty on the Great Wall of China was a lonely job. During that winter night in 210 B.C. bitter winds from the heart of Asia whipped across the top of the wall. Most of the sentries hid in the guardhouses. Huddled around fires, they exchanged tales of glorious battles fought long ago.

It was Xu Zhihong's turn to be out guarding this section of the wall. Above the whistling wind, he heard a clink of metal on stone. Peering over the parapet, he could just make out the glint of a sword in the moonlight. The wall and the Chinese Empire were being attacked. The whoosh of arrows joined the howl of the wind as he ran back to the guardhouse.

"The Huns are attacking!" he shouted. Xu could hear their footsteps behind him as he ran. Bursting through the door of the guardhouse, he knew he had only a few seconds left to live. "Light the Signal Fire," he cried.

Grabbing a lit torch, one of the guards scrambled up the steps to the roof of the guardhouse. Arrows fell around him as he plunged the torch into the heart of a stack of wood on the roof. As the attackers burst through the guardhouse door, the wood burst into flame. Within minutes, signal fires on guardhouses glowed along many kilometers of the Great Wall. Light from the fires signaled to the local garrison that the Chinese Empire was under attack. Another surprise attack by the Huns had been foiled.

An Inventive Flare

The Chinese also had great expertise in making fireworks. Martha Coston, an inventor from Philadelphia, adapted their ideas to make a light-signaling device. In 1871, she patented the “Pyrotechnic Night Signal.” When fired in the air, this device produced a bright light visible from many kilometers away. These light-signaling devices became known as signal flares. They were widely used in the Civil War. They were later adopted worldwide, mainly as a device for ships to signal that they are in distress.

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Martha Coston—Inventor of a light-signaling device that has saved the lives of many seafarers

NAVAL HISTORICAL CENTER

Martha Coston's signal flares were widely used in the Civil War. Here the USS Rhode Island *signals to another vessel for help with efforts to rescue the crew of the sinking USS* Monitor.

In the days before telegraphs, telephones, and radios, light was widely used as a means of communication. At night, signal fires could be lit to signal an enemy attack; lamps of different colors could be used to communicate more complex messages. Messages could even be flashed using code. In daylight, flags and other signs could be used to communicate between watchtowers and ships. If these signals were made from high places, they could travel over many kilometers.

Signal towers were widely used before the days of telegraph. Various codes were used to transmit complex messages. Semaphore was one such code. It uses two flags to represent numbers and letters. Semaphore is still used today. By using several signal stations within sight of each other, messages could travel across an entire country or along the entire 5000-kilometer length of the Great Wall of China.

Morse code is one way in which flashes of light can be used to transmit complex messages. This code uses series of short and long flashes to represent letters and numbers. Powerful lamps with special shutters can be used to flash messages. Sometimes light from the Sun is harnessed for the same purpose and mirrors are used to flash sunlight over long distances. Special devices called heliographs were made for this purpose.

Even telephone messages could be carried by light. In 1880, Alexander Graham Bell invented the photophone, which used sunlight and a vibrating mirror to send voice messages along a beam of light.

But sending messages by light has its problems. What happens if it's a foggy or rainy day with poor visibility? How do you transmit the signal over very long distances? Building all those intermediate signal stations is expensive. What happens in very mountainous terrain or in big cities where the view may be blocked by hills or buildings? Eventually sending electrical signals along metal cables—as telegraph or telephone messages—or transmitting them using radio waves replaced messages using visible light.

Ships at sea still use flags to send signals. By using a telescope from the top of a mast, a sailor can read a flag message sent from many miles away. What message is this ship's captain sending?

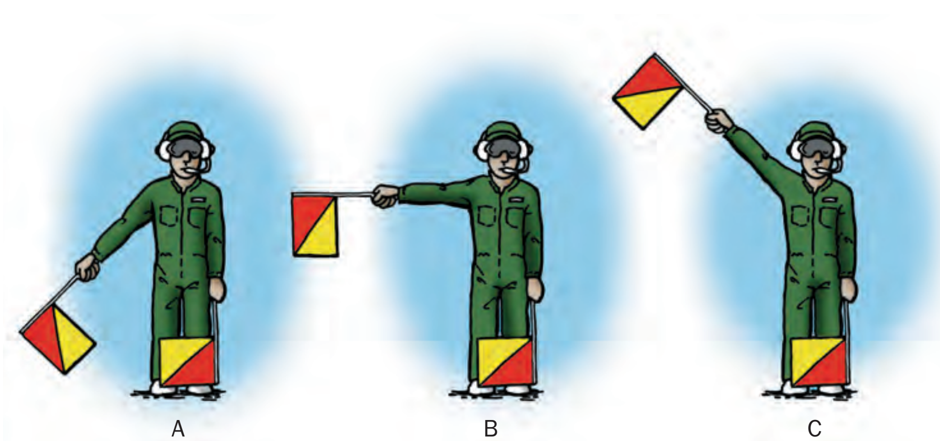
The Fiber-Optic Revolution

Today, light plays a new role in communication. Light is used to send huge amounts of information long distances along cables. But these cables are not made from metal. They are made of glass.

Look through a window and you see the world outside. The view is bright and clear because the glass of the window transmits light. But what if the window were 500 meters thick? Would the view still be as clear? Would you be able to see anything through glass this thick? No, glass in a pane may look clear but if light had to pass through large amounts of window glass it would be absorbed.

So how do you get light to travel along kilometers of glass fiber-optic cable? There are two solutions. Design a super-transparent glass and use very intense light sources.

NAVY VISUAL NEWS SERVICE



A sailor uses semaphore to signal another ship. Semaphore uses flags as a code to represent letters and numbers. Learn your ABCs in semaphore.

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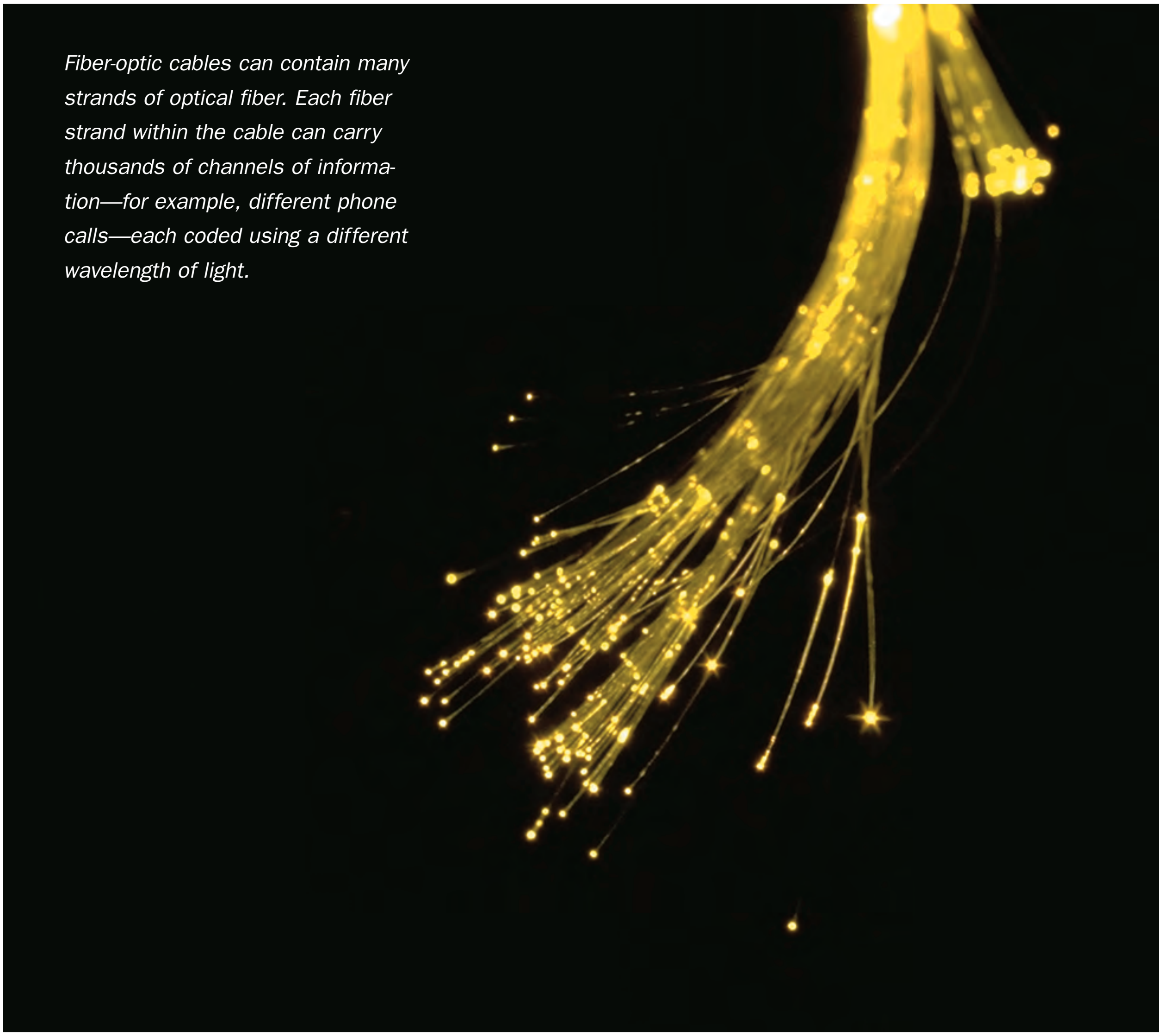
This heliograph used mirrors to reflect light from the Sun to signal messages over long distances. The user tapped out a message using a key check attached to the mirror. His partner looked for the return message.

In the search for a super-transparent glass, the trick was to make the glass as pure as possible. Beginning in the 1970s, really pure glass fibers were made. These super-transparent fibers of glass were improved over the next 10 years and can now carry a wide range of light wavelengths for long distances. The intense light source took the form of miniature lasers that work like the one in your CD player. Combining these two technologies allows fiber-optic cables to transmit signals over 60 kilometers. If the signals are automatically boosted at intervals, they can be transmitted any distance.

Fiber-optic cables carry messages all over the world. Each time you use a telephone you are probably using a fiber-optic cable. The electrical signal generated when you speak into the telephone is converted somewhere along the line into flashes of light. Fiber-optic cables even carry messages under the ocean to other continents. These large fiber-optic cables can contain hundreds of separate strands of optical fibers. They carry huge amounts of data—especially in digital form. This is why they form most of the network of cables that connect the computers that make up the Internet. When telephone conversations are converted into digital form, each strand can carry tens of thousands of phone messages at one time! Fiber-optic cables are more robust, cheaper, and more secure than old metal wire systems. Today, a different Xu Zhihong can sit at his desk in China and use light to communicate almost instantly to the other side of the world. □



Fiber-optic cables can contain many strands of optical fiber. Each fiber strand within the cable can carry thousands of channels of information—for example, different phone calls—each coded using a different wavelength of light.