OCEAN EXPLORATION & RESEARCH

Section 2: Telepresence for Volume 2: How Do We Explore?

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Okeanos Explorer's prominent VSAT (Very small aperture terminal) dome enables satellite communications between explorers ashore and at sea and provides multiple high-definition video streams for widespread dissemination. Image credit: NOAA.

A Day in the Life of an Ocean Explorer

Focus

Telepresence and communications for ocean exploration

Grade Level

5-6 (Physical Science)

Focus Question

What strategies are used aboard the NOAA Ship *Okeanos Explorer* to investigate unknown areas in Earth's ocean and how are human communication and telepresence involved with these strategies?

Learning Objectives

- Students identify the basic requirements for human communication, and describe at least three ways in which humans communicate.
- Students discuss the importance of scientific communication.
- Students explain the concept of telepresence, how it is implemented aboard the NOAA Ship *Okeanos Explorer*, and how it is used to increase the pace, efficiency, and scope of ocean exploration.

Materials

- Copies of *Questions About A Day in the Life of an Ocean Explorer Student Worksheet*, and *Hands-On Activity Guide—Wireless Communications: Light Beam Modulation;* one for each student or student group
- 1 - rope, at least 3/8-inch diameter x 8 ft; braided nylon or other flexible material, preferably in a bright color for good visibility)
- Materials for Light Modulation Activity:
  - 2 - Alligator clips (*e.g.*, Radio Shack 270-380)
  - 5 ft - Insulated solid copper wire, 20- or 22-gauge
  - 3 ft - Audio cable with 3.5 mm phone plug on both ends; mono (not stereo)
  - 1 - 470-ohm resistor
  - 1 - Light emitting diode, white, high brightness (*e.g.*, Radio Shack 276-0017)
  - 1 - Solar cell (*e.g.*, Edmund Scientific 3039808; most solar cells will work)
  - 1 - 9-volt battery
  - 1 - 9-volt battery snap connector
  - 1 - Piece of hook-and-loop fastener material, approximately 1-inch square
  - 1 - Amplified speaker (*e.g.*, Radio Shack 277-1008, or battery-powered speaker for computer sound or MP3 player) with 3.5 mm input jack
  - 1 - Small radio or CD player with 3.5 mm headphone jack (be sure this jack is used ONLY for headphones; if it is used for battery charging or other

functions, find another music source!)
2 - Prototyping Boards (Breadboards) approximately 2 x 3 in (*e.g.*, Radio Shack 276-003 or Mouser Electronics 383-A360)
- Tools for Light Modulation Activity:
  1 - Pair needle nose pliers
  1 - Sharp knife or wire strippers
  1 - Screwdriver to fit alligator clip
  1 - Soldering iron

Note: Mention of commercial names does not imply endorsement by NOAA.

Audiovisual Materials
- Optional – Images of exploration technologies (see Learning Procedure, Step 1d)

Teaching Time
Three to six 45-minute class periods (see Learning Procedure, Note)

Seating Arrangement
Groups of two to four students

Maximum Number of Students
30

Key Words and Concepts
Ocean Exploration
Okeanos Explorer
Telepresence
Satellite communication
Wireless communication
Electromagnetic wave
Frequency
Wavelength
Modulation

Background Information
NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as "America's Ship for Ocean Exploration;" the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean. The strategy for accomplishing this mission is to use state-of-the-art technologies to search the ocean for anomalies; things that are unusual and unexpected. When an anomaly is found, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is the distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary investigations that provide enough data to justify follow-up by future expeditions.

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Okeanos Explorer Vital Statistics:
Commissioned: August 13, 2008; Seattle, Washington
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.
Follow voyages of America's ship for ocean exploration with the *Okeanos Explorer* Atlas at *http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*

The *Okeanos Explorer* strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four types of technology:

- Telepresence;
- Multibeam sonar mapping;
- CTD (an instrument that measures conductivity, temperature, and depth) and other electronic sensors to measure chemical and physical seawater properties; and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 6,000 meters.

In many ways, telepresence is the key to the *Okeanos Explorer*'s exploration strategy. This technology allows people to observe and interact with events at a remote location. The *Okeanos Explorer*'s telepresence capability is based on advanced broadband satellite communication through which live images can be transmitted from the seafloor to scientists ashore, classrooms, and newsrooms, and opens new educational opportunities that are a major part of *Okeanos Explorer*'s mission for advancement of knowledge.

In the summer of 2010, years of planning, field trials, and state-of-the-art technology came together for the first time on the the ship's maiden voyage as part of the INDEX-SATAL 2010 Expedition. This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region. This region is located in the 'Coral Triangle', which is the global heart of shallow-water marine biodiversity. A major objective of the expedition was to advance our understanding of undersea ecosystems, particularly those associated with submarine volcanoes and hydrothermal vents. Among the Expedition's many "firsts," this was the first time scientists have been able to use an underwater robot to get a first-hand look at deepwater biodiversity in the waters of the Sangihe Talaud Region. For more information about

Map showing the Coral Triangle region – the most diverse and biologically complex marine ecosystem on the planet. The Coral Triangle covers 5.7 million square km, and matches the species richness and diversity of the Amazon rainforest. Although much of the diversity within the Coral Triangle is known, most still remains unknown and undocumented. Image courtesy of *www.reefbase.org*. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/coral_triangle_hires.jpg*

the INDEX-SATAL 2010 Expedition, see *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*.

Thanks to telepresence, these experiences were not confined to a few scientists aboard the *Okeanos Explorer*. Video from the underwater robot was transmitted to a satellite orbiting in a fixed position above Earth, then was relayed to the University of Rhode Island's Inner Space Center. From there, video and audio from the ship was sent to other Exploration Command Centers (ECCs) in Seattle, New Hampshire, Maryland, Connecticut, and Indonesia. Observers in these ECCs were able to communicate with the *Okeanos Explorer*'s Control Room via the Internet. At first, only computers connected to the advanced academic network called Internet2 were able to view the video,

> "but as the excitement built up around the *Okeanos Explorer* and the INDEX-SATAL Expedition, participants began using increasingly creative solutions for developing ad-hoc viewing stations and in some cases mini-ECCs utilizing the standard Internet. These solutions extended telepresence capabilities to smaller academic institutions, public venues, hotel rooms, the cafeteria at the U.S. Embassy in Jakarta, and even at one scientist's private residence."

This quotation is from "Implementing Telepresence: Technology Knows No Bounds," INDEX-SATAL 2010 daily log for July 9, 2010 by Webb Pinner and Kelley Elliott; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/july09.html*.

This lesson guides an introduction to ocean exploration aboard the *Okeanos Explorer*, and how the concept of telepresence is implemented as part of the overall exploration strategy.

Learning Procedure

NOTES:

a. This lesson is intended to provide an introduction to some of the fundamental concepts that provide the foundation for wireless communication technology, as well as opportunities to integrate technology and engineering content with core science and mathematics curricula. Depending upon curriculum mandates and the availability of time and resources, this introduction may be extended to include additional content and activities described in the American Radio Relay League's *Education and Technology Curriculum Guide* and *Radio Lab Handbook* available as free downloads from *http://www.arrl.org/curriculum-guide* and *http://www.arrl.org/radio-lab-handbook*, respectively.

b. This lesson includes content on the process of ocean exploration aboard the *Okeanos Explorer*, basic concepts of communication, and the technological basis for telepresence. While these topics are closely related in the context of the *Okeanos Explorer* mission, several class periods will be needed to complete the entire Learning Procedure. Educators are encouraged to adapt these topics to their own curricula, and steps in the Learning Procedure have been identified with the relevant topic to assist this process.

c. In addition to the *Light Beam Modulation* activity included with this lesson, you may also wish to consider using the *Make the Simplest Radio* activity included with the *Please Pass the Remote* lesson.

All communications with the shore are made possible by the *Okeanos Explorer's* powerful satellite dome, which enables the ship to establish high-bandwidth connectivity with Exploration Command Centers throughout the world. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010 *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/okeanos_vsat_hires.jpg*

Satellite Communications Aboard the *Okeanos Explorer*

The most prominent piece of communications equipment aboard *Okeanos Explorer* is the 4.2 m diameter dome that houses the ship's 3.7 meter Very Small Aperture Terminal (VSAT) dish antenna. This antenna is the critical link between the *Okeanos Explorer* and the satellites that relay information between the ship and shore-based Exploration Command Centers, as well as NOAA's Network Operations Center.

Computers and hardware included in the antenna system make constant adjustments that compensate for the ship's heave, roll and pitch to keep the antenna pointed toward the appropriate communications satellite. Radio transmitters and receivers connected to the VSAT antenna operate in the global C-band, using frequencies between 3.7 to 4.2 GHz for downlinks, and frequencies between 5.925 GHz to 6.425 GHz for uplinks (signals received from a satellite are downlinks; signals sent to a satellite are uplinks). These frequencies are in the microwave region of the electromagnetic spectrum.

The satellites used by the *Okeanos Explorer*'s telepresence system are 22,753.2 statute miles ("normal" miles, not nautical miles) above Earth's surface. At this altitude, the satellites' rotational speed matches the speed of Earth's rotation so they appear to remain in a fixed position when viewed from Earth's surface. For this reason, these satellites are called "geo-synchronous" or "geo-stationary".

The impact of telepresence is marvelous: 10-20 scientists and thousands of public onlookers from three countries, five time zones, and distributed across thousands of miles, are able to witness, discuss and document the incredible life and habitats existing at the bottom of Indonesia's deep ocean. Here, participants view images sent from the bottom of the ocean off Indonesia to monitors at the Exploration Command Center in Seattle. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/seattle_command_center_hires.jpg

1. To prepare for this lesson:
   a) Review:
   - Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*);
   - "Executing Telepresence: The Seattle ECC Comes Online!" by Kelley Elliott and David Butterfield (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june29/june29.html*);
   - "Implementing Telepresence: Technology Knows No Bounds" by Webb Pinner and Kelley Elliott (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/july09.html*); and
   - "A Day in the Life of an Explorer" by Colleen Peters (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july29/july29.html*).

   b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.
   c) Make copies of the daily log for July 29, 2010 by Colleen Peters, referenced above.
   d) If desired, download images to accompany discussions in Step 3.
   e) Review procedures for the *Hands-On Activity Guide: Wireless Communications: Light Beam Modulation* referenced in Step 7.

2. **A Day Aboard the *Okeanos Explorer*** – Tell students that they are about to read about a day in the life of modern ocean explorers. Provide each student or student group with copies of the daily log for July 29, 2010 by Colleen Peters, as well as copies of *Questions About A Day in the Life of an Ocean Explorer*. If students have not completed the lesson, *To Explore Strange New Worlds*, proceed with this activity anyway; background about the *Okeanos Explorer* and the INDEX-SATAL 2010 Expedition can be provided in Step 3. You may want to assign this activity as homework before beginning the remaining steps.

   When students have finished reading the log entry, and have answered the questions, lead a discussion, which should include:
   - A "mapping watch" is a group of activities that involves mapping (on ships, "watch" may also refer to the people who are doing the activity).
   - The watch standers are mapping the ocean floor in the vicinity of the ship using multibeam sonar.
   - A watch is four hours long.
   - The ROV was in the water for about 8.5 hours (0830-1700).
   - The Deck Department day workers' workday was 8.5 hours, including lunch and breaks.
   - About 14.5 hours were spent mapping (1730-0815).
   - The Galley Department's workday was 13 hours (0600-1900).

Students should realize that communications of various kinds are involved with many of the activities described in the log entry. These include hourly science updates, recording information in various logs, reviewing reports and data, meetings (safety, mapping products, and daily operations are mentioned specifically), and communication of orders. Methods of communication include face-to-face conversations, intercom, written logs, and satellite radio (including Internet). Crew members regularly use walkie talkies as well, though these are not mentioned in the log entry.

For an additional activity about career opportunities, see *Discovering Careers in Ocean Exploration* in the *Diving Deeper* section of the *To Explore Strange New Worlds* lesson.

3. **Ocean Exploration Aboard the *Okeanos Explorer*** – If you have not already done so, briefly introduce the NOAA Ship *Okeanos Explorer*, the only U.S. ship whose sole assignment is ocean exploration. Say that the log entry students just read was written during the ship's maiden voyage in the summer of 2010. Briefly discuss why this kind of exploration is important (for background information, please see the lesson, *Earth's Ocean is 95% Unexplored: So What?*; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf*). Student should realize that ocean exploration involves many people with many different skills. Some of these people are scientists, but operating a modern ship of exploration requires many other talents as well.

Review the overall exploration strategy used by *Okeanos Explorer*, highlighting the following points:

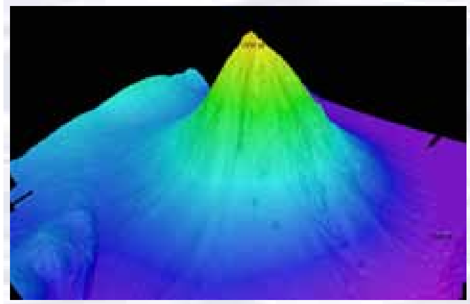
a. The overall strategy is based on finding anomalies.

b. This strategy involves three major activities:
- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Be sure students understand that
- Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater.;
- Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped; and
- Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

c. This strategy relies on four key technologies:
- Multibeam sonar mapping system;
- CTD and other electronic sensors to measure chemical and physical seawater properties;
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters; and
- Telepresence technologies that allow people to observe and interact with events at a remote location.

The ROV Little Hercules descends through deep water to an undersea volcano in the Celebes Sea to search for hydrothermal vents and associated ecosystems. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/1june29_hires.jpg



Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

Scientists in the Exploration Command Center at NOAA's Pacific Marine Environmental Laboratory in Seattle view live video from the *Okeanos Explorer*'s ROV. Image courtesy NOAA
http://www.pmel.noaa.gov/images/headlines/ecc.jpg

Senior Survey Technician Elaine Stuart holds onto the CTD as it comes aboard the *Okeanos Explorer*. Image courtesy NOAA
http://www.moc.noaa.gov/oe/visitor/photos/photospage-b/CAP%20015.jpg

You may want to show some or all of the images in the sidebar on page 6 to accompany this review.

4. **Basic Concepts of Communication** – Tell students that telepresence is basically about improving ways that humans can communicate, and ask students to describe the requirements for human communication. In the simplest analysis, human communication requires someone to send a message, someone to receive the message, and something that can carry the message from the sender to the receiver. Discuss some of the ways that humans send messages. In addition to verbal messages, there are many forms of nonverbal communication based on various signals. Facial expressions, gestures, and body language are well-known examples. Students should realize that signals may be passive (silence can send a powerful message under some circumstances!); and that if the sender and receiver do not attach the same meaning to a given signal, communication has still occurred. Ask students which of our senses are used for communication. With a little thought, students should realize that all five senses can be involved under some circumstances.

   Point out that communication can involve different scales of time and distance. Some signals may be received long after they are sent. Pictographs created thousands of years ago can still convey messages to "receivers" who see them (you may want to ask students if they think this is a legitimate example of communicating with people who are no longer alive).

   Sometimes the meaning of a particular message seems fairly clear (such as hunters shooting arrows at a large animal). In other cases, the message may contain symbols whose meaning is much less obvious. Ask students if they ever use symbols to communicate. If students do not identify "emoticons," show a few of these symbols [such as :-) or :-(]. Ask what these symbols mean, and why they are used. Students should recognize that these symbols provide a way of quickly sending a message that might otherwise require many words to express. Point out that we have inserted two more steps in the basic model of communication: an encoding step in which the sender translates a message into one or more symbols, and a decoding step in which the receiver translates the symbols back into the ideas or words they represent. Students should also recognize that a symbol is only useful if the sender and receiver attach the same meaning to the symbol. This requirement is also useful if the sender wants to conceal a message from some receivers, and is the basis for codes and encryption.

   Discuss the importance of communication to science. Students should realize that science is absolutely dependent upon communication, because the scientific process is based on the idea of testing hypotheses, then reporting the results to others who can verify those results or find additional information that builds on them. For this reason, the pace of scientific discovery and progress is highly dependent upon the rate at which communication can take place. In the case of the *Challenger* Expedition, for example, 19 years were required before all of the scientific results of the expedition were available; and until those results were published, there was no way for other scientists to build on the findings of the expedition. Ask students whether they think it is important for scientists to communicate with the public or if communicating with other scientists is enough. There are a number of reasons that public communication is also essential to science, including:

- Many scientists depend upon public money to support their work, and if people do not understand why this work is important, funding may be difficult to obtain;
- Often, information from scientific investigations may be important to formulating public policies, but people need to understand this information before they can use it; and
- Non-scientists can be important to scientific investigations and discoveries as well as professional scientists (for example, Kathryn Aurora Gray, a ten-year-old Canadian student who discovered a supernova on New Years Eve, 2010).

5. **The Technological Basis for Telepresence** – Ask students how we can communicate over long distances. Point out that this almost always involves some type of technology, ranging from smoke signals to microwaves (for purposes of this discussion, we do not get into ideas about mental telepathy). Students are likely to identify various types of telecommunications (such as television, cell phones, satellites, radio, and wireless Internet) as technologies that support communication over long distances. Say that these technologies are all based on the principles of radio communication, and that we will be exploring some of these principles shortly. Some students may consider radio to be an old-fashioned or even out-dated technology, but the basic principles of radio communication are the foundation of modern wireless communications including remote controls, cell phones, satellite television, and wireless Internet.

   Ask students how they think telepresence benefits ocean exploration. Students should recognize that telepresence not only enables scientists at sea to communicate with scientists ashore, but also with other interested parties as well. This means that many people can be directly involved with exploration activities and discoveries as soon as they happen, which means that ocean exploration can happen faster, more efficiently (more people involved at less cost), and cover more area; in other words, telepresence increases the pace, efficiency, and scope of ocean exploration.

   Remind students of the basic model of human communication (sender, receiver, and something to carry messages between them), and say that they are going to explore how this model applies to the way that telepresence is implemented aboard the *Okeanos Explorer*. Aboard the *Okeanos Explorer*, the "sender" in our basic model is anyone who has a message or information that they wish to send to one or more "receivers" in another location including Exploration Command Centers. Telepresence, by definition, involves communicating with remote locations, and the "something to carry messages" is a modern version of radio technology.

   Ask students to identify the thing that carries their message when they use a cell phone. Students should (possibly with your help) identify radio waves as the "message carrier," and should recognize that these waves are a form of electromagnetic radiation. Other familiar forms of electromagnetic radiation include light and microwaves.

6. **About Waves** – Ask students to name some different kinds of waves. Answers may include sound waves, light waves, radio waves, microwaves, ocean waves, stadium waves, earthquake waves, and slinky waves (students may think of others as well). Ask for two volunteers, and have them hold opposite ends of a piece of rope with enough slack so that a wave will form when one end of the rope is

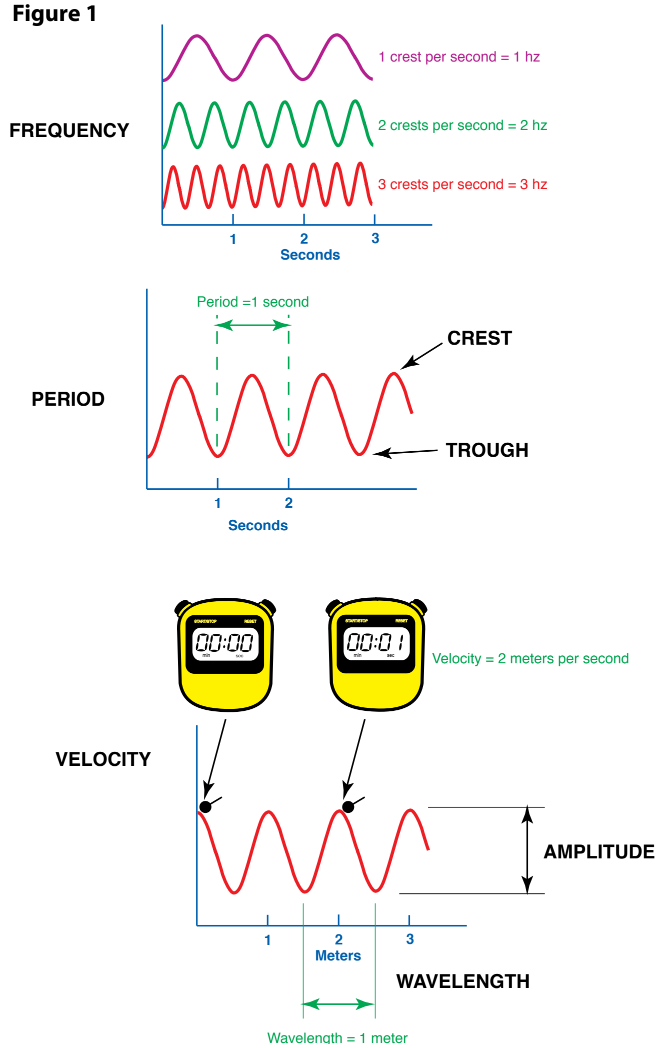
repeatedly raised and lowered. Instruct the two students to form a wave in the rope. Have other students make a sketch of the wave.

Discuss the following questions (you may choose to have students write their answers first, or just discuss each question with the entire class):
- What moved in the rope wave?
- As the wave moved along the rope, was anything moved from one location to another location?

Students should realize that portions of the rope moved in the rope wave, but that nothing ended up in a different location. Students may be puzzled by this point, because in both cases they saw "something" moving from one place to another. Encourage students to think again about exactly what they saw, and provide sufficient hints to lead them to identify a disturbance as the "thing" that moved, and that the disturbance was caused by an input of energy that moved through the system with the wave. The energy caused portions of the rope to temporarily move from their original positions, but they returned to these positions when the energy moved to adjacent portions.

Discuss the following features of waves, and have students label them on their sketches (see Figure 1):

Figure 1



- Wavelength – the distance over which a wave's shape repeats
- Amplitude – the height of a wave
- Velocity – how fast the crest of a wave is moving from a fixed point
- Period – the amount of time it takes for one particle to complete its full range of motion and return to its original position
- Frequency – the number of crests that pass a given point in a certain amount of time
- Crest – the highest point reached by a water particle in a water wave
- Trough – the lowest point reached by a water particle in a water wave

Tell students that all waves have three features in common:

1. They are energy transport phenomena. This means that they are involved in transporting energy, but do not transfer matter.
2. The energy of waves moves in specific patterns.
3. Waves have characteristics that include wavelength, amplitude, velocity, and sometimes frequency.

7. **About Radio Waves** – Ask students how they think the rope wave differs from a radio wave. Students (possibly with some help) should realize that rope waves require a medium (the rope) through which they can transfer energy (this type of wave is called a mechanical wave). Radio waves, on the other hand, do not require a medium. These waves are composed of an electric field and a magnetic field that are oscillating (moving back and forth) together, and are called electromagnetic waves (these waves are sometimes described as the movement of particles called photons, which are massless packets of energy that travel at the speed of light).

Say that now we know something about the radio waves that are used to implement telepresence, and ask students how we send radio waves from one place to another. Students should identify that a device (technically called a transmitter, but students may suggest other names) is used to send radio waves, and may also identify an antenna as a necessary component of the system. Some students may have had experience with walkie-talkies, which should suggest these answers. Students may also identify satellites as a necessary component of the communications system. For telepresence as it is implemented aboard *Okeanos Explorer*, satellites are definitely needed. Radio waves were transmitted without satellites for many years before satellites became available, and often are still transmitted this way; but satellite communications are much more reliable, particularly when the transmitting and receiving stations are thousands of miles apart. Satellites used for this kind of communication are sometimes called repeaters, because they receive signals that are transmitted to them, and then re-send these signals to receivers. So, the elements of our basic communications model have appeared again: transmitters, receivers, and things that allow messages to be exchanged between them.

Point out that we now know that radio waves transport energy, and we know something about how those waves are sent from one place to another. Ask students, "How do we use this process to send a message?" Some students may know that in the early days of radio, messages were sent by basically turning the transmitter on and off in a pattern that formed a code, and this code was used to send messages (in fact, this is also how messages were sent on radio's predecessor: the wire telegraph). Some students also may be familiar with Morse code, which is still used to send messages this way. To send voice, music, or visual messages, though, we need an alternative approach.

This alternative involves changing the radio waves when they are sent so that the changes incorporate the desired message, then having a receiver that can "read" the changes and reproduce the message. The process of changing the radio wave is called modulation, and the process of extracting the message from a modulated radio wave is called demodulation. A device that can modulate and demodulate is called a modulator-demodulator, or modem for short. *The Hands-On Activity Guide: Wireless Communications: Light Beam Modulation* demonstrates this process with light; which, of course, is also an electromagnetic wave like radio waves, only with a different frequency and wavelength. Depending upon available time and resources, this activity may be done by the educator as a demonstration, or by one or two groups of students as a demonstration, or by all students working in small groups with each group performing the activity independently.

Once the activity is completed, discuss why this works, and some of the factors that influence the effectiveness of message transfer between the sender and receiver. Be sure students understand that the output from the radio or media player is an electric current that replicates a sound that originated somewhere else. This current is added to the current from the battery, and causes the LED to flicker as the current varies. The solar cell converts light energy to an electric current. When light from the LED strikes the photocell, a current is produced that varies according to the intensity of the light. The current from the photocell is converted into sound energy by the amplified speaker.

Factors that influence the effectiveness of message transfer include the distance between the sender and receiver, the amount of interference from stray light striking the solar cell, and the strength of the signal from the radio or media player. Signal strength compared to background noise is a factor that influences many other kinds of communication; consider trying to have a conversation in a noisy room, or trying to read words on a page that is cluttered with random pictures or colors. Ask students how the message transfer system might be improved. One possibility is to focus light from the LED so that it is concentrated on the solar cell. This is the idea behind using an antenna, and is why *Okeanos Explorer* needs a large dish to send its wireless signals to the satellite that relays these signals to receivers in Exploration Command Centers.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Human Activities," then click on "Technology" for activities and links about satellite communications and other ocean exploration technologies.

The "Me" Connection

Have students write a short essay describing how telepresence could be of personal benefit.

Connections to Other Subjects

English/Language Arts, Mathematics, Social Studies

Assessment

Class discussions and students' answers to worksheet questions provide opportunities for assessment.

Extensions

1. See *Earth's Ocean is 95% Unexplored: So What?* and *Living Light* (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf* and *http://oceanexplorer.noaa.gov/explorations/09bioluminescence/background/edu/media/ds_09_livinglight.pdf*, respectively) for information about scientific communication using wall magazines and scientific posters.

2. Mathematics - Frequency and wavelength of electromagnetic waves are related by the formula:

$$W = C \div F$$

where W is wavelength in meters, C is the velocity of the wave, and F is frequency in hertz (cycles per second). The velocity of electromagnetic waves is the velocity of light, which is 300,000,000 meters per second. Information about wavelength is used to design antennas for radio communication. From the information given in the sidebar on page 4—Satellite Communications Aboard *Okeanos Explorer*—what wavelengths correspond to the frequencies used for satellite communications on the ship?

3. See the *Please Pass the Remote* and *Wow, That Hertz!* lessons for other hands-on activities involving radio technology.

4. Find out more about wireless communications and amateur radio: The American Radio Relay League (the national association for amateur radio) has extensive resources about wireless technology including curricula, lesson plans, free downloads, kits, and projects; see *http://www.arrl.org/etp-classroom-resources*.

Multimedia Discovery Missions

http://www.oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 5 and 6 for interactive multimedia presentations and Learning Activities on Chemosynthesis and Hydrothermal Vent Life and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Earth's Ocean is 95% Unexplored: So What?

(from the INDEX-SATAL 2010 Expedition)

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf

Focus: Importance of deep-ocean exploration (Grades 5-6; Life Science/Earth Science)

Students describe at least three different deep-ocean ecosystems, explain at least three reasons for exploring Earth's deep ocean, and explain at least three ways that deep-ocean ecosystems may benefit humans, and create a wall magazine to communicate scientific ideas.

Living Light
(from the Bioluminescence 2009: Living Light on the Deep Sea Floor Expedition)
http://oceanexplorer.noaa.gov/explorations/09bioluminescence/background/edu/media/ds_09_livinglight.pdf
Focus: Bioluminescence (Grades 9-12; Chemistry/Life Science)
Students explain the overall process of bioluminescence, including the role of luciferins, luciferases, and co-factors; discuss at least three phyla that include bioluminescent organisms; discuss at least three ways that bioluminescence may benefit deep-sea organisms, and give an example of at least one organism that actually receives each of the benefits discussed; and create a scientific poster to communicate technical information.

Other Resources

Anonymous. 2010. Web site for the INDEX-SATAL 2010 Expedition [Internet]. Office of Ocean Exploration and Research, NOAA [cited January 7, 2011]. Available from *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html* – Includes links to lesson plans, career connections, and other resources

Anonymous. Light Modulation [Internet]. Prof. Bunsen Science [cited January 10, 2011]. Available from: *www.profbunsen.com.au/downloads/Light%20Modulation.pdf*

Anonymous. Ocean Explorer [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*.

DeVito, J. A. 2007. Essentials of Human Communication (6th Edition). Allyn & Bacon. Boston. 388 pp.

Elliott, K. and D. Butterfield 2010. Executing Telepresence: The Seattle ECC Comes Online! [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june29/june29.html*

Peters, C. 2010. A Day in the Life of an Explorer [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july29/july29.html*

Pinner, W. and K. Elliott. 2010. Implementing Telepresence: Technology Knows No Bounds [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/july09.html*

Purwoadi, M. A. 2010. Introducing the Jakarta ECC [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june25/june25.html*

Rathjen, D. and P. Doherty. Modulated LED [Internet]. Exploratorium [cited January 10, 2011]. Available from: *www.exploratorium.edu/square_wheels/modulated_led.pdf* – Part of the "Square Wheels ...and Other Easy-To-Build, Hands-On Science Activities" collection (*http://www.exploratorium.edu/square_wheels/index.html*)

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Transfer of energy

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Science and technology in society

Content Standard G: History and Nature of Science

- Science as a human endeavor
- Nature of science

Ocean Literacy Essential Principles and Fundamental Concepts

Because most Fundamental Concepts are broad in scope, some aspects of some Concepts may not be explicitly addressed in this lesson. Such aspects, however, can be easily included at the discretion of the individual educator.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
Fundamental Concept g. There are deep-ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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Student Worksheet
Questions About "A Day in the Life of an Explorer"

1. What is a "mapping watch?" What were the watch standers mapping? How were they mapping?

2. How long was the "watch" (how many hours were there between watch turnovers)?

3. About how long was the ROV in the water?

4. How long was the Deck Department day workers' workday?

5. About how much time was spent mapping?

6. How long was the Galley Department's workday?

7. How are communications involved with these activities? Based on the log entry, what methods of communication do you think are used aboard *Okeanos Explorer*?

Glossary

XBT – Expendable bathythermograph; an instrument that measures the temperature of the ocean at different depths; this information is used to calculate the speed of sound in seawater, which is used to adjust the multibeam sonar mapping system

MSD book cell – A Marine Sanitation Device (MSD) is designed to keep untreated sewage out of the ocean; a book cell produces chlorine gas from the salt in seawater using electricity; chlorine gas is used to reduce the number of microorganisms in sewage

CO – Commanding Officer; the captain of the ship

VSAT – Very Small Aperture Terminal; refers to the satellite dish antenna in the large dome on the *Okeanos Explorer*'s mast

FTP – File Transfer Protocol; a type of Web site that is used to exchange very large data files (such as video)

ECC – Exploration Command Center; a location that is equipped to exchange video, voice transmissions, and other data with the *Okeanos Explorer* and other ships equipped for telepresence

Secure – On ships, this verb means to stop doing some activity or to put away equipment so that it cannot move with the motion of the ship

ROV – Remotely Operated Vehicle; an underwater robot used to obtain video images or perform other tasks; usually connected with a cable

In August 2008, NOAA Ship *Okeanos Explorer* was commissioned as the only U.S. ship whose sole mission is to systematically explore our largely unknown ocean for the purposes of discovery and the advancement of knowledge. List some ideas for exploration strategies that could be used to fulfill this mission. In particular, consider:

- What kind of measurements or observations should be made?
- What technologies could be used to make these measurements or observations?

Hands-On Activity Guide
Wireless Communications: Light Beam Modulation

Other versions of this activity have been described and are available on the Internet (*e.g.*, *http://www.exploratorium.edu/square_wheels/index.html*; *www.profbunsen.com.au/downloads/Light%20Modulation.pdf*). The procedure described below uses prototyping boards (also called breadboards) that can be re-used for many other activities involving electronic circuits. These boards are available in a variety of sizes, usually can be snapped together with other boards for larger circuits, and allow circuits to be assembled without soldering, making connections with #22 solid hookup wire. Typically, prototyping boards have many small holes that will hold a #22 solid wire. Some of these holes are joined together by connections built into the board. See Figure 1 for an example.

Figure 1. Prototyping Board

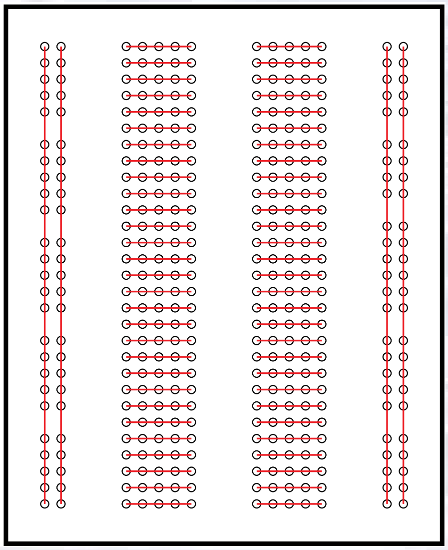


Figure 1. Layout of a typical prototyping board. The red lines show holes that are electrically joined by connections inside the board. On this board, there are two vertically-oriented sets of 25 connected holes on the left and right sides of the board. These holes are often used for connections to a battery, to make it easy to supply power to any spot on the board. In the middle part of the board, there are 58 horizontally-oriented sets of 5 connected holes; 29 on the right side of center, and 29 on the left side of center. These middle sets of holes are used to connect the components of various circuits. Since there are 58 separate sets of holes, this board can hold a lot of components!

A note about soldering: If you have never soldered before, you may want to visit *http://www.instructables.com/id/How-to-solder/*. Be sure to wear safety glasses or goggles when soldering, and work in a well-ventilated space (you can set up a small fan if necessary to blow away soldering fumes).

Materials

2 - Alligator clips (*e.g.*, Radio Shack 270-380)
5 ft - Insulated solid copper wire, 20- or 22-gauge
3 ft - Audio cable with 3.5 mm phone plug on both ends; mono (not stereo)
1 - 470-ohm resistor
1 - Light emitting diode, white, high brightness (*e.g.*, Radio Shack 276-0017)
1 - Solar cell (*e.g.*, Edmund Scientific 3039808; most solar cells will work)
1 - 9-volt battery
1 - 9-volt battery snap connector
1 - Piece of hook-and-loop fastener material, approximately 1-inch square
1 - Amplified speaker (*e.g.*, Radio Shack 277-1008, or battery-powered speaker for computer sound or MP3 player) with 3.5 mm input jack
1 - Small radio or CD player with 3.5 mm headphone jack (be sure this jack is used ONLY for headphones; if it is used for battery charging or other functions, find another music source!)
2 - Prototyping Boards (Breadboards) approximately 2 x 3 in (*e.g.*, Radio Shack 276-003 or Mouser Electronics 383-A360)

Tools

1 - Pair needle nose pliers
1 - Sharp knife or wire strippers
1 - Screwdriver to fit alligator clip
1 - Soldering iron

Note: Mention of commercial names does not imply endorsement by NOAA.

Figure 2.

Procedure

1. Cut two 2-inch lengths of insulated solid copper wire, and remove about 1/2-inch of the insulation from each end. Attach an alligator clip to one end of each wire (Figure 2).

2. Cut the audio cable in half, and remove about 2-inches of the outer plastic jacket from each of the cut ends. Be careful not to cut into the insulation of the wire inside the cable. If you have a mono cable, you should find one insulated wire and one uninsulated wire inside the cable. If there are two insulated wires instead

of one, then you have a stereo cable (see the next paragraph). Remove about 1/2-inch of the insulation from the end of the wire inside the cable. Twist the strands of the wire together, and then twist them around a short length (about 3/4-inch) of bare #22 wire, and solder the connection (the short length of solid wire makes it easier to connect the wire to the prototyping board. Twist the strands of the uninsulated wire together, and solder another short length of bare #22 wire onto this wire as well (Figure 3). Prepare both halves of the audio cable this way.

Note: If you have a stereo cable instead of a mono cable, you will have two insulated wires instead of one. If your radio or media player uses stereo earphones, remove about 1/2-inch of the insulation from both wires, twist them together, and solder a short length of bare #22 wire onto the two wires. If your radio or media player does not use stereo earphones, you will need to identify which of the insulated wires in the stereo cable goes to the very tip of the plug on the other end of the cable (usually it will be the red or white wire; you can use the "ohms" setting on a multimeter or a continuity tester to check). Remove about 1/2-inch of the insulation from the OTHER wire, and twist it together with the uninsulated wire, then solder a short length of bare #22 wire onto the two wires.

3. Remove about 1/2-inch of the insulation from the ends of the two wires attached to the battery snap connector. Twist one of these wires around a short length (about 3/4-inch) of bare #22 wire, and solder the connection. Repeat with the other wire attached to the snap connector (Figure 4).

Figure 4.

4. Examine your prototyping boards, and determine which holes are connected together (if the package containing your prototyping board does not have this information, you can use the "ohms" setting on a multimeter or a continuity tester to find out which holes are connected). Connect the alligator clips to the terminals on the solar cell, then plug the wires from the alligator clips into two sets of holes that are NOT connected. Use one of the other holes in each set to connect the wires from one of the audio cables (Figure 5).

Figure 5.

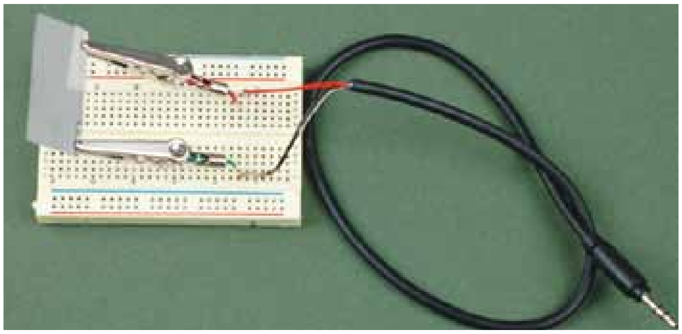


Figure 3.

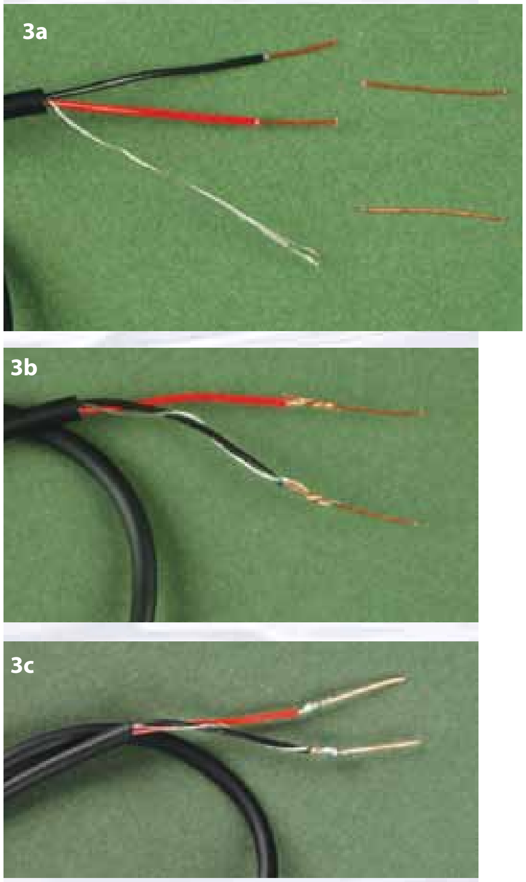


Figure 3. Audio cable ends prepared for connecting to prototype board. Note that this was a stereo cable; the red wire connects to the tip of the plug, the black and uninsulated wires are twisted together. a. Insulation removed from ends of insulated wires; short lengths of bare #22 wire ready to attach; b. Bare ends of wires in audio cable twisted around short lengths of #22 wire; c. Twisted wires soldered.

5. Connect the plug on the audio cable used in Step 4 to the input jack of the amplified speaker, and turn the speaker on. If you shine a light onto the solar cell, you should hear static in the speaker (Figure 6).

Figure 6.

6. Examine the LED, and notice that one side is flattened (Figure 7). This is the cathode (negative side) of the LED. Plug the cathode into one set of holes on the second prototyping board, and plug the anode (positive side) of the LED into another set of holes that is NOT connected to the first set (Figure 8).

Figure 7.

Figure 8.

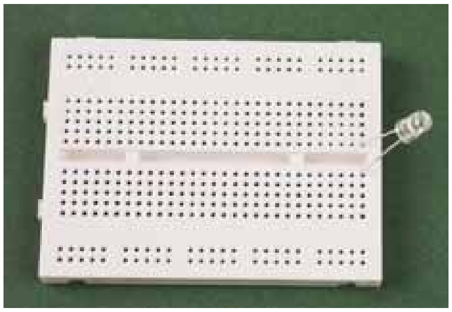
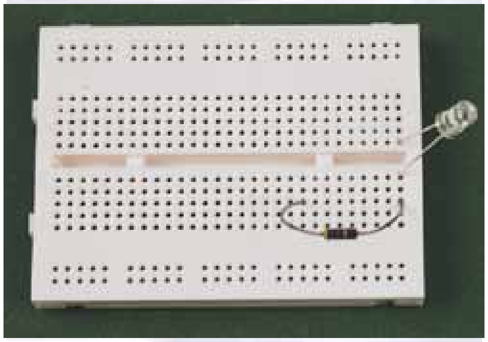


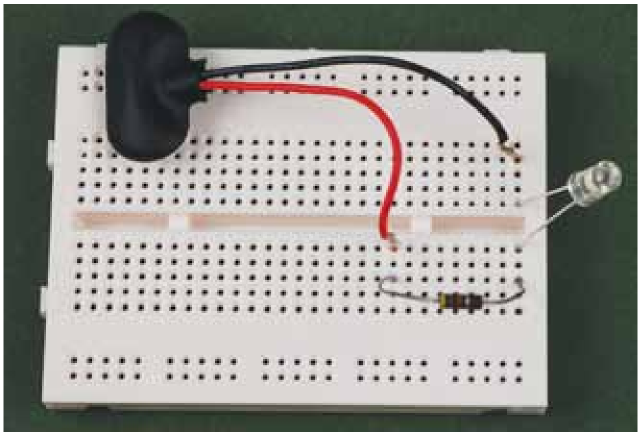
Figure 9.



7. Plug one end of the 470-ohm resistor (it doesn't matter which end) into one of the other holes in the set to which the anode of the LED is connected. Plug the other end of the resistor into a third set of holes that is NOT connected to either of the sets already used (Figure 9).

8. Connect the negative (black) wire attached to the battery snap connector to one of the other holes in the set to which the cathode of the LED is connected. Connect the positive (red) wire from the snap connector to one of the other holes in the set to which the end of the resistor is connected (connect the battery to the end of the resistor that is NOT connected to the LED) (Figure 10).

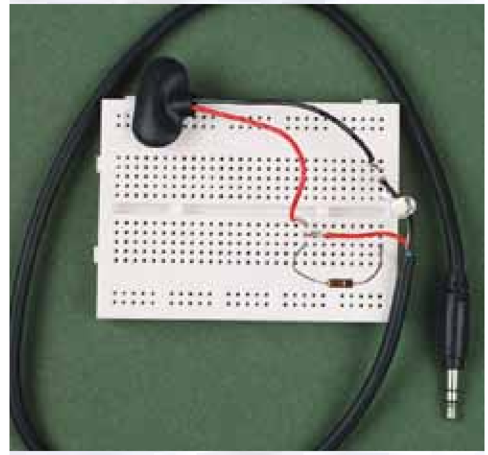
Figure 10.



9. Attach the battery to the battery snap connector. The LED should turn on and glow steadily. Disconnect the battery from the snap connector.

10. Connect one of the wires (it doesn't matter which one) from the remaining audio cable to one of the other holes in the set to which the positive wire from the battery snap connector is connected. Connect the other wire from the same audio cable to one of the other holes in the set to which the negative wire from the battery snap connector is connected (Figure 11).

Figure 11.



11. Turn on the radio or media player, and check to be sure a strong sound is coming from the speaker.

11. Connect the plug on the end of the audio cable used in Step 9 to the headphone jack on the radio or media player. This will disconnect the speaker, so you won't hear anything.

12. Attach the battery to the battery snap connector. The LED should turn on, but it should be dimmer and flickering.

13. Place the LED so that it shines on the solar cell, and turn on the amplified speaker (Figure 12). You should hear sound from the radio or media player coming from the amplified speaker. If you place an opaque object between the LED and the solar cell, the sound should stop.

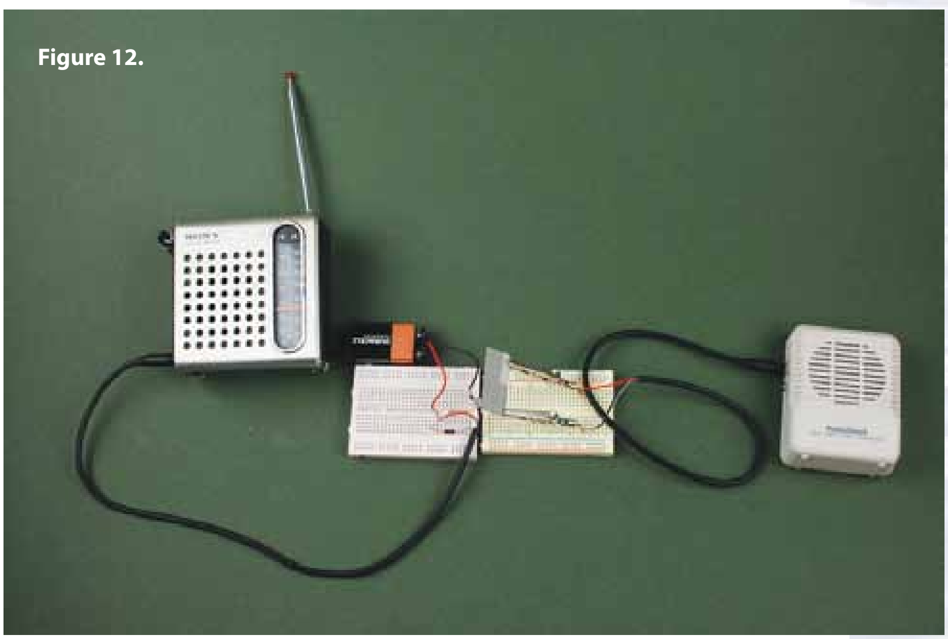


Figure 12.

14. What's Happening Here? – The battery provides a steady current to the LED, and when the radio is disconnected the LED shines steadily. The resistor limits the current to avoid damaging the LED. When the radio or media player is turned on, the audio signal from the radio is added to the current from the battery. This causes the LED to flicker. Light from the flickering LED causes the solar cell to generate an electrical signal that varies in strength corresponding to the audio signal. The varying electrical signal is amplified and fed to the speaker, which produces a sound that replicates the audio signal from the radio or media player.