NAVSEA SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS

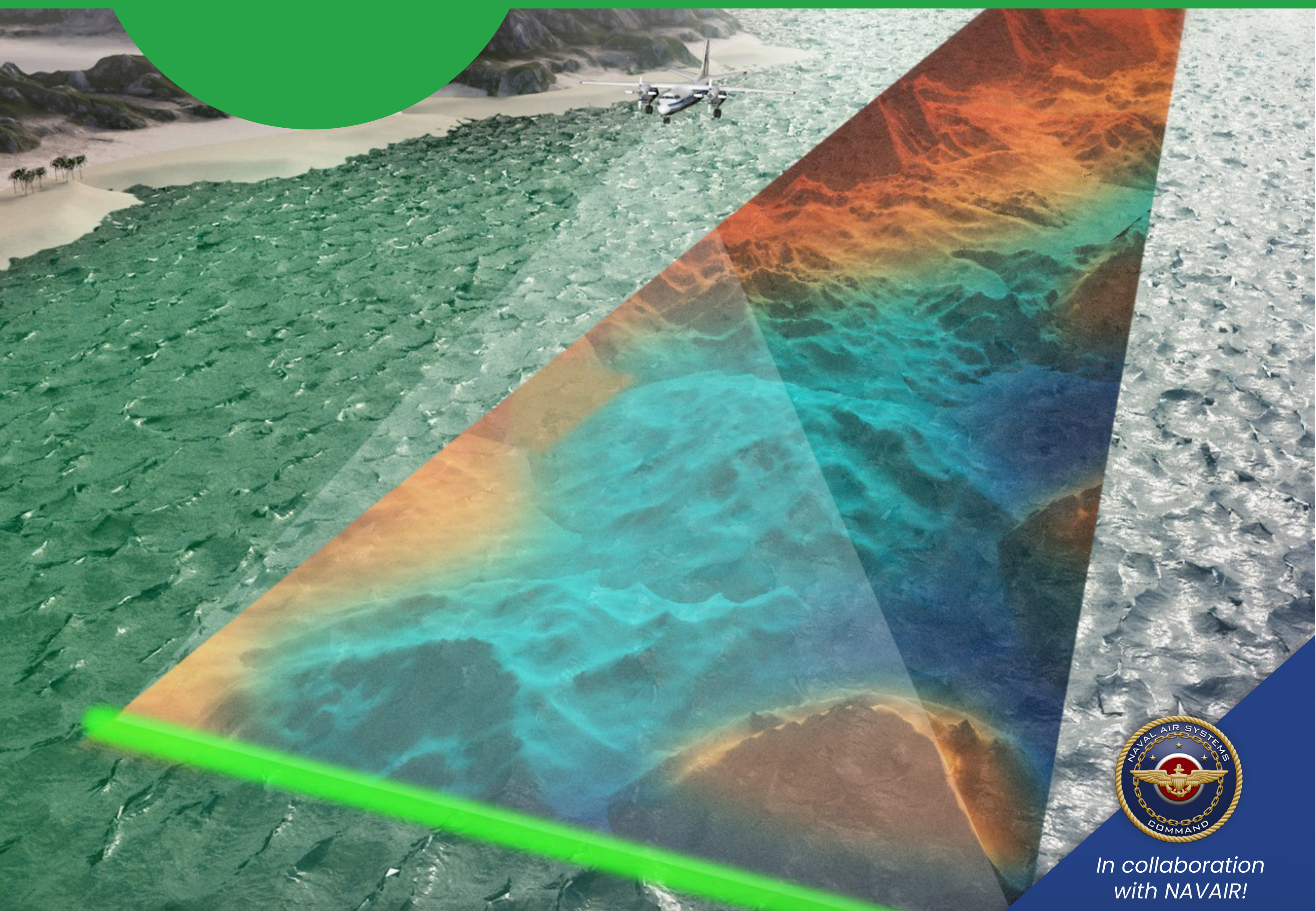
#SeaworthySTEM
#AirworthySTEM

Communication Over Lasers in Ocean Research:

An Exploration of COLOR

Grades 6-8

Teacher Guide



In collaboration with NAVAIR!

Seaworthy STEM™ in a Box Series

Communication Over Lasers in Ocean Research

An Exploration of COLOR

Teacher Guide for 6-8

#SeaworthySTEM®

Seaworthy STEM™ in a Box Educator Kit description:

Seaworthy STEM™ in a Box activities are a Navy initiative to provide enhanced Naval-relevant, standards aligned, hands-on activities to K-12 teachers and students. Components of this program include, curated sets of classroom activities that aim to build deep conceptual understanding in Naval-relevant content areas. The kits also includes comprehensive lesson plans, material lists, scientific background information, STEM related literacy books, and student activity sheets. The Seaworthy STEM™ in a Box program is designed to support teachers as they select content, acquire materials, and implement more hands-on STEM activities in their classrooms. Increasing student access to hands-on STEM activities, also increases awareness of STEM career paths, engage students in STEM, and support development of student's abilities in STEM content.

The Seaworthy STEM™ in a Box kits were designed to guide students through the scientific inquiry-based theory and the engineering design process. The content and Naval-relevant activities are aligned with the Next Generation Science Standards. The topics and content covered within the lessons are connected and scaffolded based on distinct grade bands (K-2nd, 3rd-5th, 6th-8th, and 9th-12th).

Photo on the Cover: Artist's illustration of the Fugro RAMMS hydrographic mapping capability, now being used to inform maritime domain awareness for the US Navy. *Photo from LIDAR Magazine*

NAVSEA

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS

Table of Contents

Lesson Title:

Communication Over Lasers in Ocean Research
An Exploration in COLOR

Time:
Average learning time is 4-5, 50 minute class periods

Student Objectives:

1. Understand the principles of laser technology in underwater communication.
2. Apply the engineering design process to construct a functional and efficient optical communication kit.
3. Test and evaluate their optical communication kit's performance through various colored water samples.
4. Collaborate with peers to solve real-world engineering challenges.

Lesson Overview:

In this high school engineering challenge, students will embark on an adventure to build their own #SeaWorthySTEM communication kits using lasers and a limited set of materials. Students will be building an optical communication kit and performing experiments with it. This demonstration will help students to understand how different educational concepts are relevant to US Navy LIDAR technology. In order to assemble the kit and understand the activity, students will learn background information on the properties of light, basic electronics, and various Navy technologies.

Next Gen Science Standards (NGSS):

NGSS Standard: MS-PS4-2
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

NGSS Standard: MS-PS4-3
Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signal.

Notes

Materials and Equipment List

Section One: Building the Circuit System (Transmitter & Receiver)

Part A: Transmitter

- ☑ 3 slot AA battery holder
- ☑ Mini breadboard
- ☑ 3 AA batteries
- ☑ 6 male-to-male breadboard jumper wires
- ☑ Rubber grommet with ID 1/4”, OD 9/16”
- ☑ 2 alligator clips
- ☑ 3.5mm mono audio plug to alligator clip cable
- ☑ Aluminum laser mount
- ☑ 600:600 Ohm audio transformer
- ☑ 5mW laser diode
- ☑ 10k Ohm potentiometer
- ☑ 2 5.08mm pitch screw terminals
- ☑ 2mm flathead screwdriver

Part B: Receiver

- ☑ 3 slot AA battery holder
- ☑ Mini breadboard
- ☑ Photoresistor
- ☑ 3 AA batteries
- ☑ 5 male-to-male breadboard jumper wires
- ☑ 10k Ohm resistor
- ☑ One pair of earbuds
- ☑ 2mm flat head screwdriver (reused)
- ☑ 3.5mm mono audio jack to alligator clip cable
- ☑ 2 5.08mm pitch screw terminals
- ☑ 2 Alcohol wipes / prep pads
- ☑ Phone dongle (USB-C or Lightning to 3.5mm)

Section Two: COLOR Activity Testing

- 4 Small plastic containers with lids, 5oz
- 2 -12 oz food containers
- 1 oz liquid antacid
- Red, green, and blue food coloring
- Water to fill the 4 small plastic containers

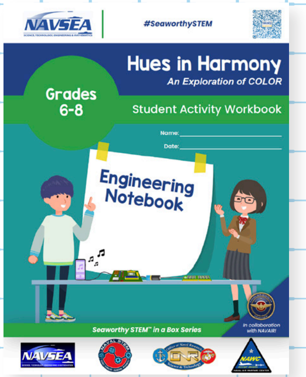
Other Materials

- Stopwatch or timer
- Paper Towels
- Teacher access to the internet (YouTube needs to be available)
- Student access to an internet compatible device
- Computer with attached projector
- Student Worksheets & Writing Utensil

**Teacher can include any other materials available if choosing to do*

Student Activity Sheets/Handouts:

Student Activity Worksheet: Communication Over Lasers In Ocean Research: An Exploration of COLOR



Technology Tools:

Computer

Internet access

Part 1: Background Research

1 Pre-Assessment Activity:

The student journal response can be used as a pre-assessment for this unit. Have the students answer these questions in the "Journal Entry" section of their engineering notebook.

Sample Journal Prompts:

1. What do you know about lasers?
2. What do you know about electrical circuits?
3. What do you know about structure and function?

2 Pre-Activity:

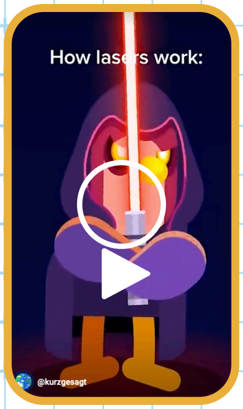
Have the students answer these questions in the "Think about..." section of their engineering notebook. The teacher can post the questions below for the class to reference when answering.

Tell the students to "Think of what they already know about lasers" then answer the following questions:

1. Why would the Navy want to use lasers?
2. Specifically underwater, what factors could affect lasers?

3 Hook:

YouTube:



Show this video of how lasers work: https://www.youtube.com/shorts/RzwaiFvyN6s?si=NbCCITCf-99Ih8Qc

4 Background Research- Information Research Sheets:

Have the students complete the following research sheets:

1. Optical Communications Research Sheet
2. Electronics Research Sheet

5 Student Discussion:

After the students complete their research, use the information within both research sections to review with the students. Class discussions, share outs, partner shares or gallery walks are effective methods of communicating findings.

6 Engineering Design Challenge:

Discuss lasers and share Navy examples and explain the upcoming design engineering challenge.

Some examples are included below:

1. **Communication:** The Navy uses lasers like a flashlight to send messages between ships and planes. It's similar to using a beam of light to talk to each other quickly and without using traditional radio signals.
2. **Targeting:** Think of lasers like a precise pointer. The Navy can use lasers to point at things, like targets in the sky or in the water, to aim their weapons more accurately.
3. **Navigation:** Lighthouses can help ships navigate to locations. Similarly, lasers can help the Navy navigate as well. They create a light path for naval vessels to follow, helping them stay on course.
4. **Defense:** The Navy uses lasers to target adversaries that may present a threat to our military.
5. **Detecting Objects:** The Navy can use lasers to help them locate items. Lasers can be used to locate objects or movement. This can be in the sea or in the air.

Part 2: Engineering Design Challenge

Background Information:

The US Navy operates both above and below the surface of the water. Technologies such as SONAR, RADAR, and LIDAR are used for navigation, detection, and ranging. In the underwater domain, LIDAR has some distinct advantages over SONAR and RADAR.

Advantages (+) and Disadvantages (-) of RADAR
RADAR - RA(dio) D(etection) A(nd) R(anging)

+ Uses electromagnetic waves - does not need medium to propagate like SONAR

+ Good transmission through different weather and lighting conditions

+ Shorter wavelength - high resolution

- High absorption in water - can only detect surface objects

Advantages (+) and Disadvantages (-) of SONAR
SONAR - SO(und) N(avigation) A(nd) R(anging)

+ Sound travels long distances in water due to water being a being a dense medium

+ SONAR can be passive and active

- Broad beam transmission

- Lower resolution

- Can't transmit through air - sea interface

Advantages (+) and Disadvantages (-) of LIDAR
LIDAR - LI(ight) D(etection) A(nd) R(anging)

+ Wide bandwidth

+ Covert

+ Transmits at the speed of light

+ Transmits wirelessly

+ Can penetrate Air-Sea Interface

- Performance limited by absorption and scattering

The Engineering Design Challenge:

You have explored the background of light and optics. The Navy has tasked your design team with creating a circuit system that connects a transmitter to a receiver. You will be using a laser to explore communication, light transmission and potential water properties. The goal of your challenge is to correctly assemble a transmitter-receiver circuit. After this device has been constructed you will be able to test multiple variables about lasers. Your team must be creative in using what you already know, what you learned during the research phase and what you observe during the build phase to draw conclusions about laser technology.

Materials:

2mm flat head screwdriver

Rubber grommet with ID 1/4”, OD 9/16”

Mini breadboard

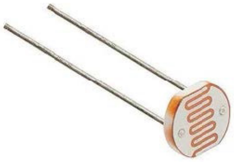
Male-to-male breadboard jumper wires

3 slot AA battery holder

3 AA batteries

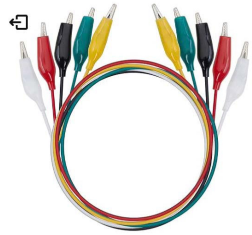
Aluminum laser mount

5mW laser diode



Photoresistor

Phone dongle



Alligator clips

3.5mm audio plug to alligator clip cable

10k Ohm potentiometer

10k Ohm resistor

Alcohol wipes

600:600 Ohm audio transformer

5.08mm pitch screw terminal

Earbuds

3.5mm mono audio jack to alligator clip cable

Section One: Building the Circuit System (Transmitter & Receiver)

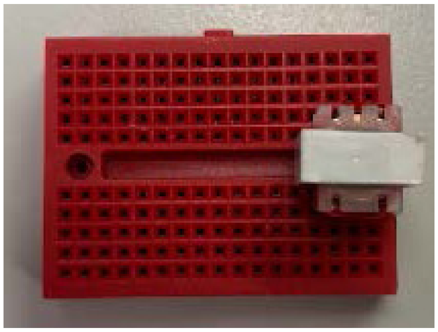
Part A: Transmitter

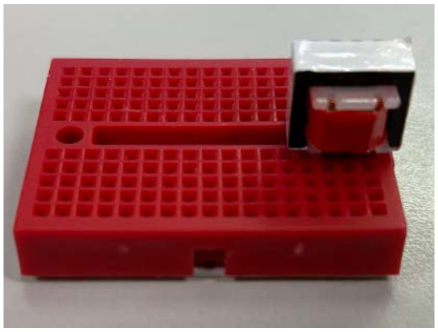
Materials:

- ☑ 3 slot AA battery holder
- ☑ Mini breadboard
- ☑ 3 AA batteries
- ☑ 6 male-to-male breadboard jumper wires
- ☑ Rubber grommet with ID 1/4”, OD 9/16”
- ☑ 2 alligator clips
- ☑ 3.5mm mono audio plug to alligator clip cable
- ☑ Aluminum laser mount
- ☑ 600:600 Ohm audio transformer
- ☑ 5mW laser diode
- ☑ 10k Ohm potentiometer
- ☑ 2 5.08mm pitch screw terminals
- ☑ 2mm flathead screwdriver

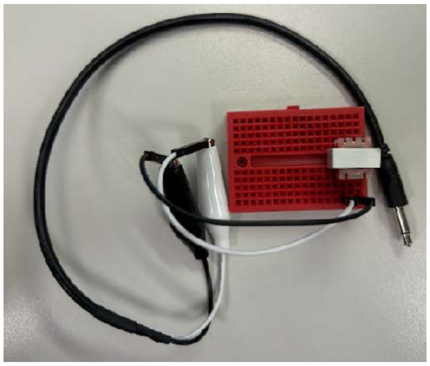
Procedure:

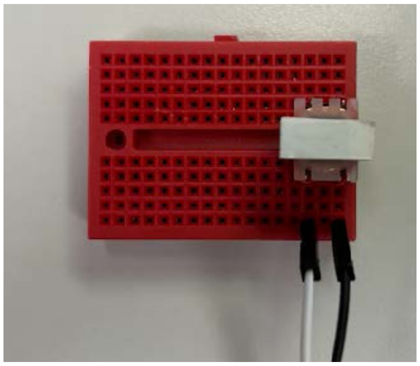
1. Place your transformer (the red, square component) so that it bridges the gap between the top and bottom sections of the breadboard. This means two legs should be on each half of the board. It does not matter which side is facing up or down. Place it on the right side of the board.



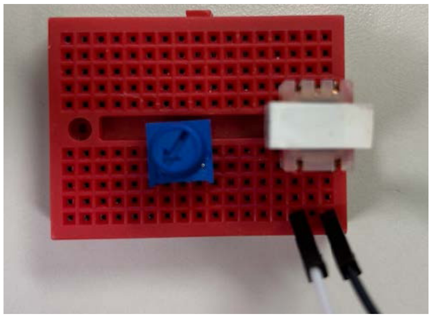


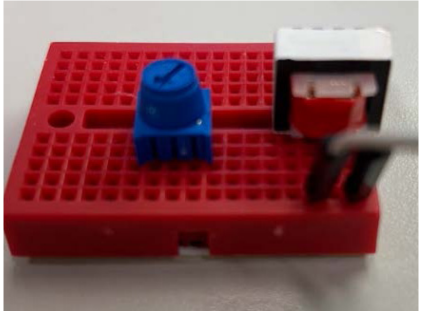
2. Connect your audio jack to the same columns as the bottom pins of the transformer. The positive (usually white) wire should be on the left side and the negative (usually black) wire should be on the right. Remember that any components that are in the same column are electrically connected!



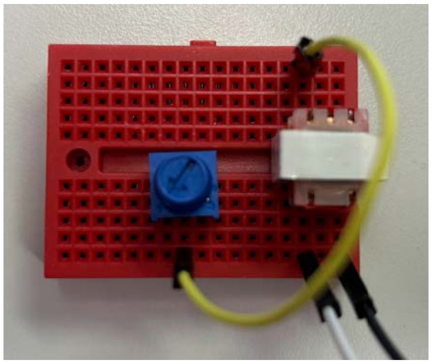


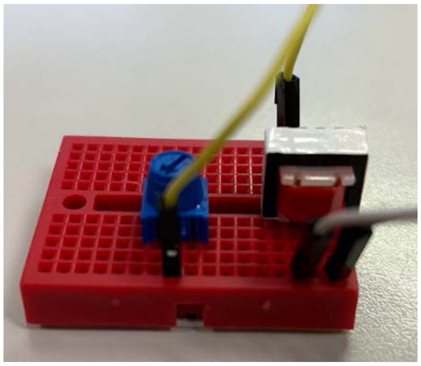
3. Place the potentiometer in the center of the breadboard, so that all three legs are in different columns. The ridges on the potentiometer should be facing you. Turn the potentiometer all the way to the left (counter-clockwise).



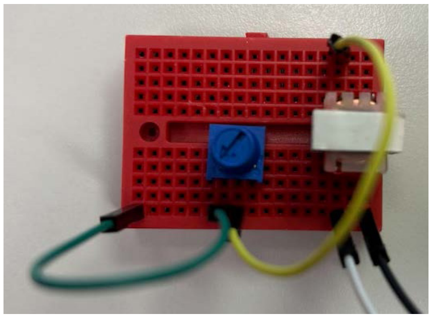


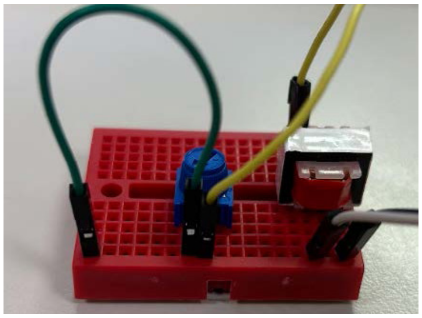
4. Connect the upper left pin of the transformer to the center (wiper) pin of the potentiometer.



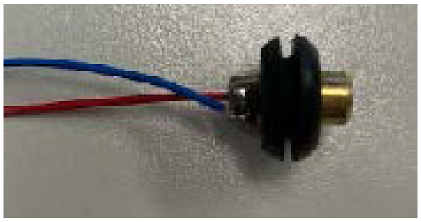


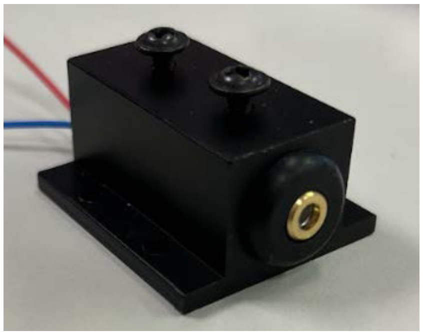
5 Connect a jumper wire from the leftmost pin of the potentiometer to the leftmost column of the breadboard.



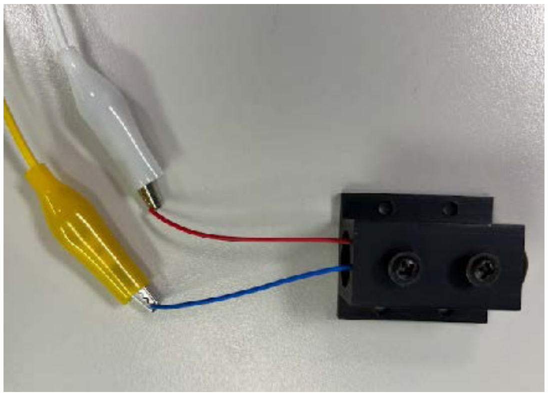


6 Place your laser into the center of the rubber grommet. Then, feed the laser wires backwards through the aluminum laser mount,and squeeze the grommet with the laser into the laser mount. This will keep the laser from moving when you do your experiment.

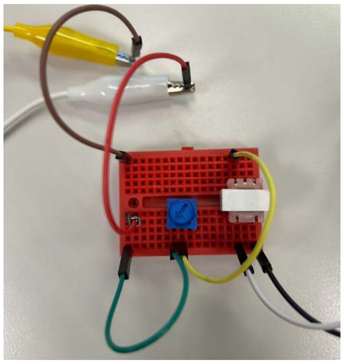


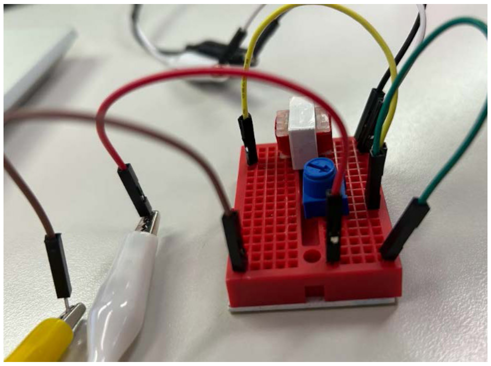


7 Connect your laser to the breadboard. Clip one alligator clip onto each wire of the laser. Clip a wire onto the other end of each alligator clip.

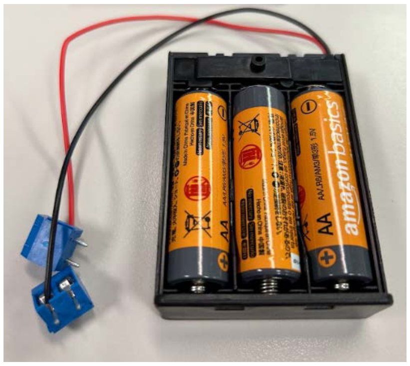


8 The wire connected to the red laser wire (shown here as red) goes in the first bottom column of the breadboard. The wire connected to the blue laser wire (shown here as brown) goes in the first top column of the breadboard.

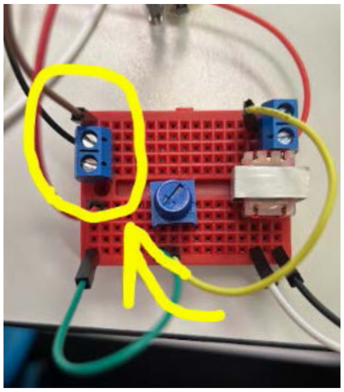




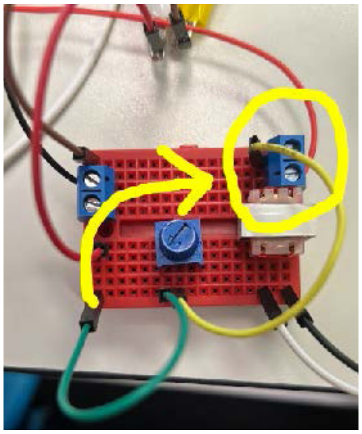
9 Place each battery wire in a blue screw terminal. To do this, unscrew one of the screws on top of the screw terminal. Hold the wire in place in the front slot while you screw the top screw back in. The wire should stay in place in the screw terminal.



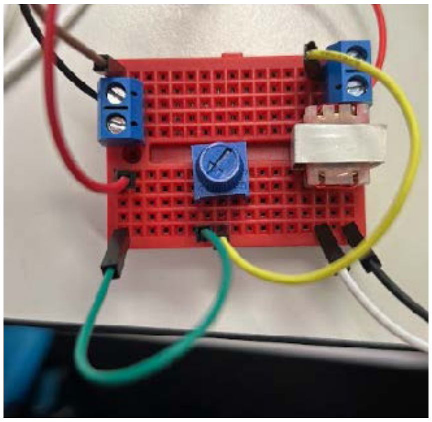
10 Connect the negative (black) battery lead to the first top column of the breadboard. It is in the same column as the wire going to the blue laser wire.

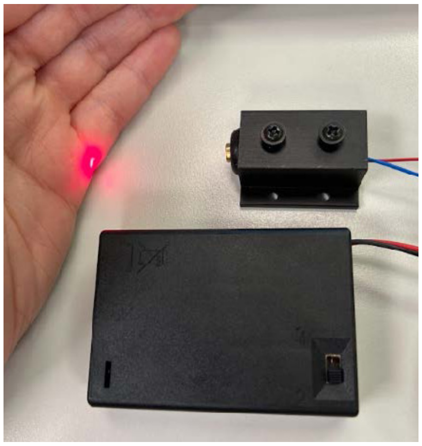


11 Connect the remaining screw terminal to the upper right leg of the transformer.



12 Your laser is now ready to be turned on. Place the batteries in the holder. Make sure that the laser is pointed away from any person, and is preferably pointed at your hand or the kit's container. Flip the switch on the battery holder to turn on your laser. If you point the laser at your or anyone else's eyes, your kit will be taken away.





Troubleshooting: My laser won't turn on!

Ten steps to get it working. Try each step and turn on your battery holder after completing it.

1. Ensure that the battery holder is switched on.
2. Check the wires connected to each transformer or potentiometer leg- make sure each wire is in the same column as the leg it should be connected to. Ask a teacher to make sure it is wired correctly, or ask another student for help.
3. Make sure that the alligator clips are clipped onto the metal of the laser wires and that each component is pressed down into the breadboard.
4. Make sure that your potentiometer is turned all the way to the left, counterclockwise. The arrow should be pointing towards you and slightly to the left. This will make the laser as bright as possible.
5. Now, we will have to start replacing components. The transformer in this kit is the most commonly broken part. Ask a teacher for a new one.
6. The laser and potentiometer are also commonly broken parts. Ask your teacher for new ones, testing them one at a time.
7. Replace the batteries.
8. It is uncommon for the remaining components to be broken. However, you can try swapping out the wires and alligator clips.
9. By this point, you've pretty much rebuilt the circuit. The problem must be the battery holder or the screw terminals. Replace them.
10. If it is still not working, one of the replacement parts must be broken. Go back to step 5.

Section Two: Building the Circuit System (Transmitter & Receiver)

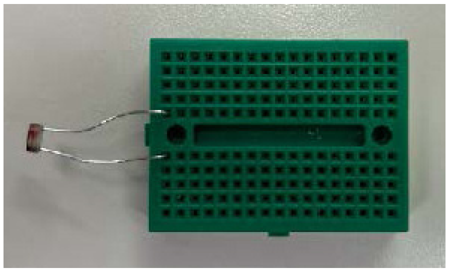
Part B: Receiver

Materials:

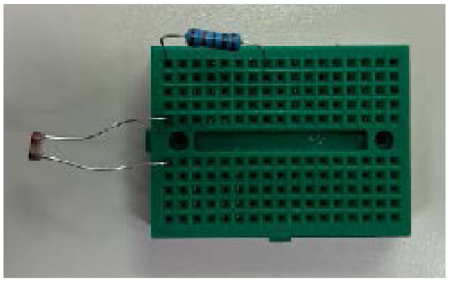
- ☑ 3 slot AA battery holder
- ☑ Mini breadboard
- ☑ Photoresistor
- ☑ 3 AA batteries
- ☑ 5 male-to-male breadboard jumper wires
- ☑ 10k Ohm resistor
- ☑ One pair of earbuds
- ☑ 2mm flat head screwdriver (reused)
- ☑ 3.5mm mono audio jack to alligator clip cable
- ☑ 2 5.08mm pitch screw terminals
- ☑ 2 Alcohol wipes / prep pads
- ☑ Phone dongle (USB-C/Lightning to 3.5mm)

Procedure:

1. Use the photoresistor to bridge the gap between the two sides of the breadboard.

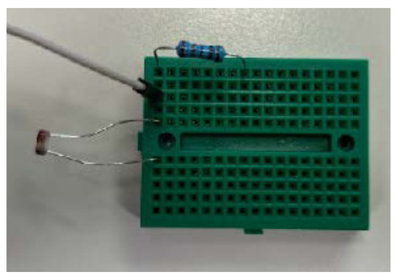


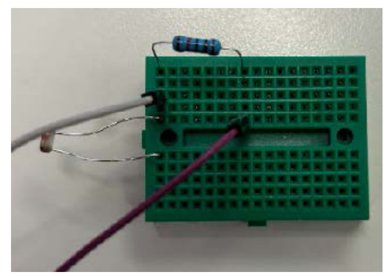
2. Connect a resistor leg to the upper leg of the photoresistor, and the other leg can go in any other column.



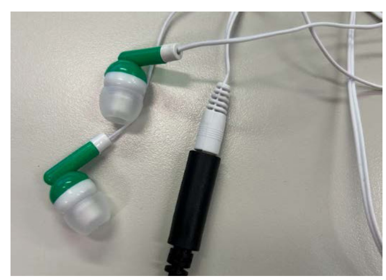
3. Now, we will connect the headphone jack to the circuit. Connect one wire to each alligator clip on the audio jack.

4. One wire (gray, in image) is connected to the white clip. Plug it into the upper leftmost column. The other wire (purple, in image) is connected to the black clip. Plug it into the same column as the far right resistor leg.

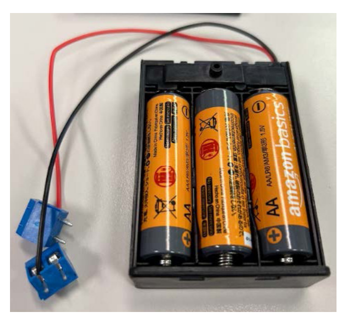




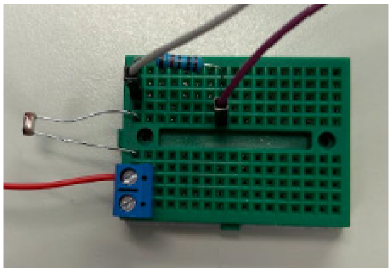
5. Now, we will plug in the earbuds. Use an alcohol wipe to clean off the silicone earbud tips. Plug in your earbuds to the audio jack.

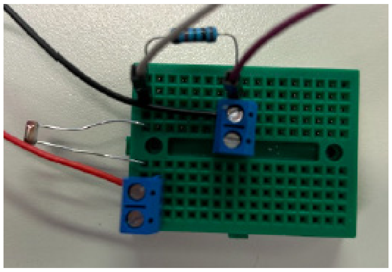


6. To plug in the batteries, first use two screw terminals to house the red and black wires from the batteries. Place the batteries in the holder.

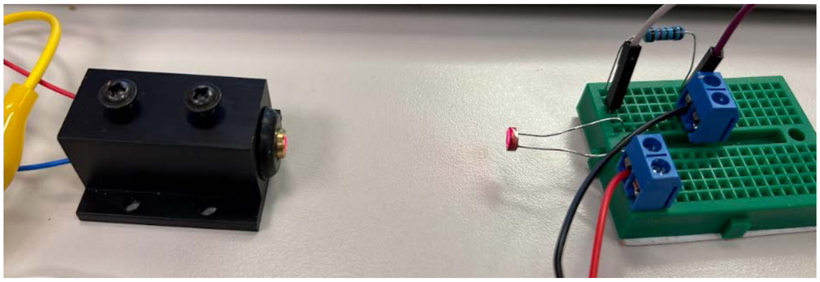


7 Place your battery's red wire in the lower leftmost column on the breadboard. Place the black wire in line with the far right resistor's leg.



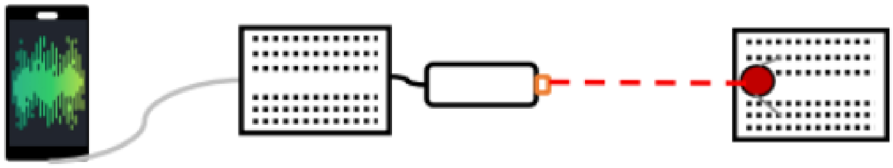


8 Turn on the battery holder. Plug your phone into the transmitter's audio plug, using a dongle, and aim the laser at the photoresistor. Get ready to test your circuit! If your circuits aren't working, go to page 23 for troubleshooting tips.



Section Three: COLOR Activity Testing

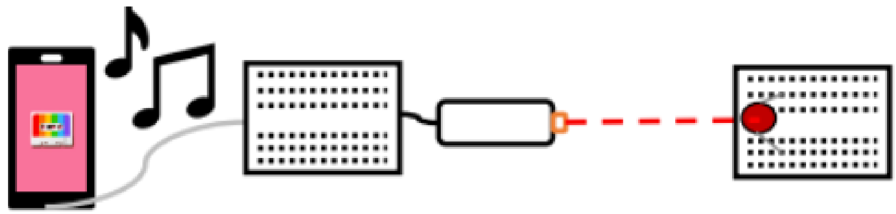
Part A: Testing Transmitter- Laser Power



Directions: Collect the materials from the teacher for the demonstration, perform the procedure and answer the questions as you work.

1. Connect phone to 3.5 mm audio jack.
2. Transmit audio in 10-20Hz range using tone generator app.
3. Adjust potentiometer and verify that laser output power changes. Why does this happen?
4. Illuminate the photoresistor with the laser.
5. Try changing the audio tone frequency.
6. Does the audio coming out of the speaker change when you change the frequency?

Part B: Testing Transmitter- Tone Frequency



Directions: Collect the materials from the teacher for the demonstration, perform the procedure and answer the questions as you work.

1. Send music from the smartphone instead of the audio tone.
2. Illuminate photoresistor with laser.
3. Can you find a volume/laser power setting that optimizes the audio quality of the music from the speaker?

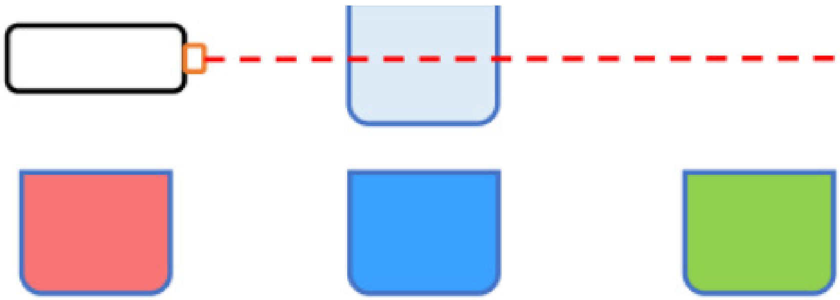
Part C: Testing Water Colors- Laser Power & Scattering Agent

Directions: Collect the materials from the teacher for the demonstration, perform the procedure and answer the questions as you work.

1. Place a clear water cell between the transmitter

and receiver, then align the laser to hit the center of the photoresistor.

2. Which color of water do you think the light will transmit through best? Record the word best under the photo below and explain.



3. Try adding different colored dyes to the water one at a time to test how well they transmit light.

4. Use 4-5 drops of food coloring per ½ cup water.

5. Was your prediction about which color would have the best transmission correct? Record why or why not under the color below and discuss what happened.

6. Your experiment should show that the red laser light transmits best through the red water. When you attempt to transmit the red laser light through the blue or green water, the red light from that laser tends to be absorbed.

7. What color of light would work best for transmitting light through blue or green water? Explain.

8. Add 1-2 drops per ½ cup water of scattering agent (antacid) to clean water.

9. What happens to the laser beam and sound?
10. Why do you think this happens?
11. How could you use lasers if you were an Environmental Engineer knowing what you know now?

Troubleshooting: **My music won't turn on!**

Try each step, listen through your earbuds after completing it.

1. Ensure that the battery holders are switched on and the laser is pointing directly at the photoresistor. Turn the potentiometer on the transmitter counterclockwise as far as it will go to make the laser brighter.
2. Put in both earbuds. The music can only come through one side since we are using mono audio.
3. Have a teacher or another student check your wiring. Make sure everything that needs to be connected is in the same column. Make sure that all wires are secure and are pressed down into the breadboard.
4. Use a Tone Generator app to generate a frequency between 10Hz and 20Hz. Is the laser flashing/blinking? If it is NOT, there is a problem with the transmitter (very rarely, it will not flash but still transmit music). Go to page 14.
5. Now we will need to start replacing components. The earbuds are the most fragile piece. Swap them out for a new pair.
6. Swap out the resistor and photoresistor, one at a time, testing in between.
7. It is less likely that the remaining components are broken, but you can swap out the remaining wires and screw terminals if you need to.

If it is still not working, one of the replacement parts must be broken. Go back to step 5.

Part D: Clean Up!

1. Turn off both of the battery packs.
2. Remove the batteries from the battery holders. This prevents the circuit from powering on while in storage.
3. Use an alcohol wipe to clean off the silicone ear tips of the earbuds.
4. Ask your teacher whether to take the kits apart or put them in the container fully assembled.
5. If you are taking apart the transmitter and/or receiver, make sure that you do not swap parts between the kits. The transmitter container should only have transmitter parts in it. The same goes for the receiver.
6. Carefully place each component into its assigned container. Place the lid on the container.
7. Place the kits in the center of your desk or table.

Congratulations! You have successfully built a laser communication device and completed this assignment.

Conclusion to reiterate to students:

1. Scattering agent (antacid) acts like an obstacle for the light transmitting through the water.

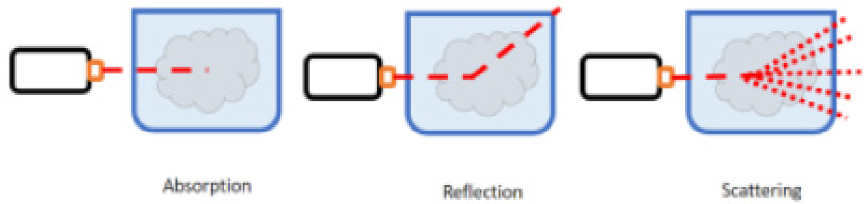
2. When the light collides with the particles of a scattering agent, it can bounce off in various directions.

3. This scattering leads to some of the light not making it to the photoresistor receiver.

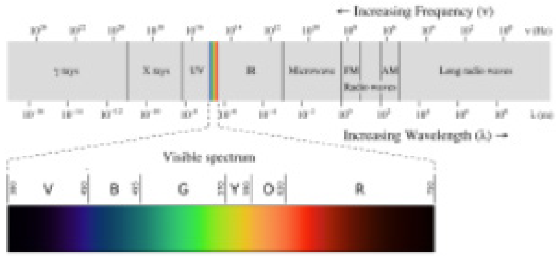
4. The result of this is reduced volume coming out of the speaker at the receiver.

Teacher Background Information / Notes:

When light strikes an object, it can be absorbed, transmitted, or reflected.



Electromagnetic waves have a characteristic wavelength and frequency. Visible light is an electromagnetic wave with a wavelength between 400-700 nm.



Optical communication is:

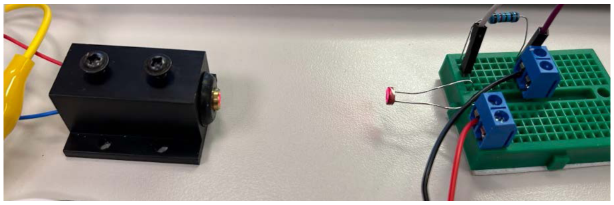
1. One of the many technologies that make use of light.

2. Used by fiber optic cables that serve as the information highways for the internet.

3. Optical communication can also be conducted through air or water without a fiber optic cable.

4. Doing this requires a transmitter such as a laser to send the light. It also requires a receiver to collect and process the light to understand the information it is transmitting.

Overall:
Students will be building the optical communication kit shown here. Before building the kit, they will need to complete the research to discuss the electronic components that are used in the kit and go over some basic electronics concepts.



Vocabulary Terms:

- LIDAR
- SONAR
- RADAR
- Optics
- Electromagnetic
- Transmitter
- Receiver
- Electronics
- Voltage
- Current
- Resistance
- Breadboards
- Resistors
- Photoresistors
- Potentiometers
- Transformers

STEM Related Careers:

- **Electronics Engineer:** Works to create and test electrical and optical systems, including those with lasers.

  Physicist: Does research into the mathematics behind physical phenomena, such as how light and water interact.
- **Mechanical Engineer:** Creates physical systems and studies how materials and objects interact. Works on various mechanical systems, including those in marine applications.
- **Environmental Engineer:** Focuses on water quality and conservation.

Notes

Notes

NAVSEA

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS

The Seaworthy STEM™ in a Box curricula was developed through collaborative efforts of a team of individuals at the Naval Surface Warfare Center Carderock Division and Albert Einstein Distinguished Educator Fellows via an inter-agency agreement with the U.S. Department of Energy for the Albert Einstein Distinguished Educator Fellowship (AEF) Program. We are grateful to the following Content Specialists who contributed their knowledge and expertise by researching and writing on selected topics: Suzanne Otto, Stephanie Klixbull, Thomas Jenkins and Melissa Thompson. We'd also like to acknowledge the contributions of AEF participant Ms. Deborah Reynolds, the inaugural AEF Educator at Carderock that helped inspire the design of Seaworthy STEM™ in a Box content. Special thanks to Albert Einstein Fellow Melissa Thompson, for the creation of a collaborative high school engineering curriculum and supplemental additions to the early grade bands; career portfolios, workforce trading cards, and in-house short story publications. Gratitude to Carderock Outreach Specialist Ashlee Floyd, STEM Program Manager, Charlotte George, and Media Specialist Kristin Behrle for the creation and support of this naval endeavor that showcases the diversity of NAVSEA Sites.

#SeaworthySTEM
#AirworthySTEM

COLOR Teacher Guide

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