

Imaging the Human Body

Module Overview



In this TechXcite: Discover Engineering module youth are introduced to ways in which engineers use science and math to create technology capable of seeing inside the human body. Youth will explore the concept of density and learn how X-rays, CT scans, and ultrasound technologies work.

This curriculum is intended for use with youth in middle grades in informal settings, such as after-school programs and summer camps. However, it has also been successfully implemented in formal school contexts, homeschool content, and with youth in elementary and high school.

Activity 1: Learn how an X-ray machine works by creating images with sunlight.

Activity 2: Test the density of objects relative to water to gain a basic understanding of how X-rays use density to create images.

Activity 3: Learn how computed tomography (CT) scans use math to integrate many different X-ray images into a single, detailed three-dimensional image.

Activity 4: Determine the minimum sampling interval for detecting objects and how it relates to ultrasound and submarines.

Activity 5: Create a device for mapping a surface in a manner analogous to ultrasound.

Table of Contents



Module Overview.....	2
Table of Contents	3
TechXcite: Discover Engineering	4
Using this Guide	5
Activity 1: Solar Imaging	6
Activity 2: Density of Materials	9
Activity 3: What is Computed Tomography?.....	11
Activity 4: Ultrasound and Submarines	15
Activity 5: Imaging with Sound	18
Glossary	21
Acknowledgments.....	22
Image Credits	24

TechXcite: Discover Engineering



TechXcite is an informal engineering program partnering 4-H Youth Development/Family and Consumer Sciences at North Carolina State University, National 4-H Council and the Engineering K-PhD Program at Duke University's Pratt School of Engineering. It was initially funded by a five-year grant from the National Science Foundation.

In 2000, Drs. Ybarra and Klenk created an informal after-school engineering program at Rogers-Herr Middle School in Durham called Techtronics, which spread to additional schools across North Carolina and other states. The TechXcite: Discover Engineering curriculum builds on the Techtronics foundation by implementing hands-on, exploratory, engineering learning modules in 4-H Afterschool programs nationwide. Other after-school programs and even formal in-school and home-school programs have chosen to use the TechXcite curriculum. TechXcite is an engaging, substantive, experiential and inquiry-based curriculum centered on engineering, while using technology, applied science and mathematics learned in school. TechXcite's mission is to encourage youth in both rural and urban settings to pursue careers in engineering and technology.

TechXcite is the product of a collaboration of twelve 4-H leaders at land grant universities, two leaders at National 4-H Council and a team at Duke University.

Online Support

The TechXcite website (techxcite.org) contains additional material to facilitate implementation of this module. There are videos, Facilitator's Guides, Youth Handouts, and kit inventories with vendors and pricing for each item required. Although the curriculum is written with a focus on middle school youth, it has been successfully implemented at both the elementary and high school levels. Anyone can download copies of the Facilitator's Guide and Youth Handouts from our website. There are links to additional resources for information about the module topics and ideas for further activities and exploration.

Training Videos

Each module comes with a set of training videos found on its curriculum page (techxcite.org/curriculum). These videos serve as a companion to the Facilitator's Guide. An introductory video provides an overview of the material and concepts. The corresponding video for each activity then covers basic setup, Facilitating the Activity, and helpful tips for facilitating that activity. It's recommended that instructors watch all of the videos before starting the module.

Using this Guide



The Facilitator's Guide for each activity follows the same format. Below is what you can expect to find in each section. At the beginning, you will be given basic information about the activity. This includes:

- Time Required
- Group Size – Suggested number of students per group.
- Materials List
- Youth Handouts – These will need to be copied.
- Getting Ready – What you need to do before the activity and approximately how much time it will take you.
- Learner Outcomes
- Vocabulary

Introduction and Activity Closure

The Introduction and Activity Closure are scripted. You may read these sections verbatim to students. Instructions that are not to be read to students, as well as answers to questions, are in brackets/italics.

Facilitating the Activity

This section contains step-by-step instructions for facilitating the activity. Students have their own procedure in the Youth Handouts.

Exploration Questions

Provides possible answers to the Exploration Questions found at the end of each activity in the Youth Handouts. After the students have a chance to answer the questions individually, instructors should hold a class discussion. The main purpose of this section is to encourage critical thinking and to promote the exchange of ideas.

Activity 1: Solar Imaging



Time Required: 45 minutes

Group Size: 2-3

Materials List

Each group needs:

- Sunprint® photo paper
- Leaves or flowers (Not included in kit)

Each class needs:

- Sunprint® kit developing supplies
- Small aluminum pan
- Water

Youth Handouts:

- Solar Imaging

Getting Ready (15 minutes)

- Select a sunny, outdoor area where you can place photo paper to develop for 5 to 10 minutes.
- Make sure you have a water source to develop the prints.
- Gather a few leaves or flowers. Choose materials that have varying thickness or composition.

Learner Outcomes

- Explain that X-rays and visible light are both electromagnetic radiation.
- Explain how an X-ray image is made.

Vocabulary

Word	Definition
Cathode ray	A beam of electrons.
Electromagnetic radiation (EM)	EM radiation is light. Some types are visible; others are invisible (see intro).
X-ray	A form of electromagnetic radiation with a wavelength between 0.01 to 10 nanometers.

Activity 1: Solar Imaging



Introduction

Today we are going to learn about **X-ray** images. Have you ever had an X-ray to detect a cavity or broken bone? What did the doctor do to make the image? What did the image look like?

Electromagnetic (EM) radiation is all around us, but most of it we can't see or feel. The only type of radiation that humans can see is called visible light. Visible light bouncing off of objects and into our eyes is actually what allows us to see.

Even though you can't see the other types of radiation, you're probably very familiar with them. The heat that you feel when standing next to a burning fire is an example of infrared radiation. Cell phones use an invisible type of radiation called radio waves to transmit signals and microwave ovens use microwave radiation to cook food. Most radiation passes right through your body without you feeling it.

X-radiation (composed of X-rays) is invisible to the naked eye but can be captured on X-ray-sensitive film. An X-ray machine directs X-rays through the body and onto a piece of film on the opposite side. Hard parts of the body, such as bones and teeth, absorb the radiation and appear as white spots on the image. Since X-rays pass more easily through muscles and organs, the shadowy or dark parts of an the image represent soft tissue or air spaces. Fractures, cracks, and holes show up as dark spots, allowing doctors to detect broken bones or tooth cavities.

Today we are going to produce an image of an object using sunlight, similar to the way a doctor makes an X-ray. Leaves and flowers will be used to represent the human body since they are thin enough to allow some visible light through. We will also be using special light-sensitive paper that acts like the X-ray film.

Facilitating the Activity

1. Before taking the students outside, hand out the Sunprint® paper and objects to each group. Direct sunlight will expose the paper quickly and even ambient light in the shade or from a window will cause slow exposure so keep the paper out of the reach of the sun until the last minute.
2. If the objects to be "x-rayed" have not been gathered yet, have students collect a few leaves or flowers of varying thickness or composition.
3. Instruct students to arrange their objects on top of the paper. If they want hard, sharp edges on their Sunprints, students should flatten the objects as much as possible first.
4. Take the Sunprints outside and lay them in direct sunlight for 5 minutes. The areas exposed to the sun will turn from blue to white. When most the color disappears, the print has been fully exposed. The paper will continue to react until it is rinsed in water.

Note: If it's cloudy, the process may take up to 20 minutes depending on the thickness of the clouds.

5. Rinse the prints in the pan of water. The white will turn blue and the blue will turn white. Leave it in the water for 2-5 minutes to get the deepest blue. If you are going to rinse it inside, block light from the paper while taking it indoors.
6. Give students an opportunity to examine each other's prints and identify some of the objects.

Activity 1: Solar Imaging

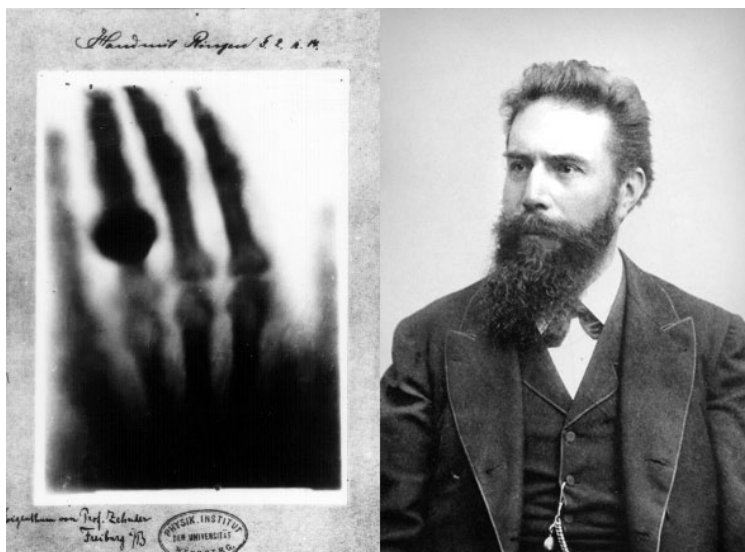


Activity Closure

In this activity, your photosensitive paper captured the light that penetrated your object, just as X-ray film captures X-rays. However, unlike sunlight, X-rays can easily pass through much thicker objects, like skin and organs. Only harder substances, like bones, prevent X-rays from reaching the film.

A German physicist named Wilhelm Röntgen discovered X-rays accidentally while working with **cathode rays** in his laboratory in 1895. He noticed an image cast on a projection screen far beyond what could have been reached by the cathode rays. He then experimented by placing several different objects, including a deck of cards, a book, and a wooden box with metal weights inside, between the cathode ray tube and the screen. Röntgen observed that X-rays passed through some materials more readily than others. When he placed a lead pipe between the rays and screen, he noticed that his finger bones appeared in shadow. He later took an X-ray of his wife's hand that produced a picture of her bones and wedding ring (below) on a photographic plate, which is considered to be the first "medical" X-ray.

Röntgen called the rays "X" radiation because this type of radiation was unknown. The term later became X-rays, for short. Röntgen's groundbreaking discovery led to many advances in the field of medicine.



Exploration Questions

1. Explain what happened when the objects were placed on the photosensitive paper.

[In places where light could easily pass through the object, the paper was darker because it was more exposed. Where part of an object blocked sunlight from reaching the paper, the image remained lighter. Light can shine through some objects more easily than others.]

2. Were some objects reproduced on film more clearly than others? If so, which ones and why?

[The prints with the sharpest edges were pressed firmly down onto the paper before being exposed to sunlight, preventing light from leaking in around the sides. Thicker materials generally produce sharper edges as well.]

Activity 2: Density of Materials



Time Required: 30 minutes

Group Size: 2

Materials List

Each group needs:

- Wood ball (5/8” dia)
- Wood ball (2½” dia)
- Marble (5/8” dia)
- Steel ball (5/8” dia)
- Plastic cup (16 oz)
- Water

Youth Handouts:

- Density of Materials

Getting Ready (5 minutes)

- Fill each group’s cup about half-full with water. Make sure the 2½-inch diameter wooden ball has space to float.

Learner Outcomes

- Explain that some materials have a greater density than others.
- Explain that density is mass divided by volume.

Vocabulary

Word	Definition
Mass	Quantity of matter in an object.
Volume	Amount of space taken up by a three-dimensional shape.
Density	Mass per unit of volume.

Introduction

Today we are going to explore the concept of density. In the previous activity, you learned how we use sunlight or X-rays to take a picture. Sunlight can only penetrate thin objects. X-rays, on the other hand, can penetrate much thicker objects. The **density** of an object determines how much of the X-radiation it absorbs and how much it allows through. In other words, density essentially determines how translucent an object is on X-ray film.

Activity 2: Density of Materials



Facilitating the Activity

1. Place students in pairs.
2. Give each pair 4 different balls: 1 marble, 2 sizes of wooden balls, and 1 steel ball. Do not hand out the cups of water yet.
3. Instruct them to spend a few minutes discussing the differences between the objects. They may notice:
 - a. Superficial differences in texture or other properties
 - b. Three of the objects are the same size but not the same weight
 - c. Wood is lightest of the equal-volume spheres, but the large wooden sphere is heaviest
4. Ask students which objects they think will float or sink when placed in water.
5. Give each group a cup filled with water and ask them to test their predictions by putting the balls and marbles in their cups of water.
6. Once students have had time to experiment, ask them what they think causes an object to float or sink. They will likely have a number of answers. Encourage them to test their ideas.

Activity Closure

What did you discover about the objects that did or did not float?

[Allow students to discuss what they observed during the experiment.]

You probably learned that knowing an object's **mass** or **volume** individually is not enough to predict whether it will sink or float. The small wooden ball was the lightest object and the large wooden ball was the heaviest, yet both of them floated. The small wooden ball had the same volume as the steel ball and the marble, yet it floated and the steel ball and marble sank. To predict whether an object will sink or float, you need to know not only its volume, but also its mass.

Density is the property that determines whether an object will sink or float. The object will float in water if its density is less than the density of water. Who knows how to calculate density? *[Density equals mass divided by volume.]*

One way to think about density is how tightly packed the atoms or molecules are in a substance. Materials, such as styrofoam, may take up a lot of space but they don't weigh very much because most of that space is empty. A large volume with a small mass has a low density. Materials, such as steel, that have tightly packed atoms will usually sink immediately, even at tiny volumes.

Exploration Questions

1. What causes an object to float or sink?
2. Would the same objects float or sink if the liquid was changed from water to syrup? Why?

Activity 3: What is Computed Tomography?



Time Required: 45 minutes

Group Size: 3-4

Materials List

Each group needs:

- Deck of cards
- Markers or colored pencils

Youth Handouts:

- What is Computed Tomography?

Getting Ready (None)

Learner Outcomes

- Explain that CT scans compile information from X-ray images taken from multiple angles to form a three-dimensional image.
- Explain that CT and CAT are two terms for the same medical imaging technology.



Vocabulary

Word	Definition
Back projection	A method of combining data from multiple beams of X-rays to create a picture of the inside of the body.
Computed tomography (CT)	A form of X-ray imaging that produces a three-dimensional image.

Introduction

In the previous activity, we looked at how a standard X-ray image is created. Today we're going to explore another medical technology that uses X-rays to capture a more detailed view of the body called **computed tomography (CT)** or computed axial tomography (CAT). Has anyone ever heard of a CAT scan? What do you think it is? *[Allow students to answer.]* A CAT scan is a form of X-ray imaging, except instead of generating two-dimensional images, CT provides a three-dimensional view.

A CT scanner takes a series of X-ray images from many different angles and creates a three-dimensional image using a process called **back projection**. Like X-ray images, CT depicts the density of something inside the body, but with much greater accuracy. Dense objects have a large mass-to-volume ratio, and as such, X-rays will not pass through them easily. On a CT image, a dense object will appear white. This is important because tumors are often more dense than surrounding tissue. A dense spot on the scan could be a tumor and may need to be examined by a doctor.

In this activity, we're going to use a grid of playing cards to illustrate back projection.

Activity 3: What is Computed Tomography?

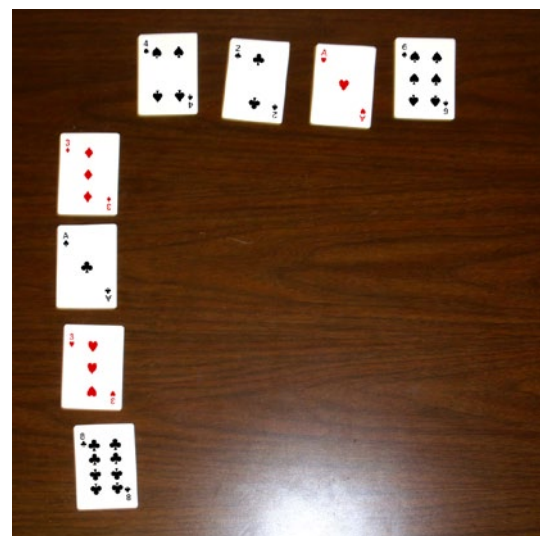


Facilitating the Activity

1. Place students in groups of 3 or 4.
2. Give each group a deck of cards and markers (or colored pencils).
3. While students are completing the activity, circulate to assist.
4. When students lay their cards on the table, they will create a grid that looks like the picture below. Each card represents the X-ray intensity measured at that point. Students will then use the back projection technique of adding the two cards together to determine the density at a given point.
5. Tell them to record the value in the grid on their handouts and color the grid using the color guide (see example grid below).

Number	Color
1-3	Red
4-6	Orange
7-9	Yellow
10-12	Green
13-15	Blue
16-20	Purple

		X-ray data					
		4	2	1	6		
X-ray data	3	7	5	4	9	←	X-ray beams (right)
	1	5	3	2	7	←	
	3	7	5	4	9	←	
	8	12	10	9	14	←	
		↑	↑	↑	↑	X-ray beams (back)	

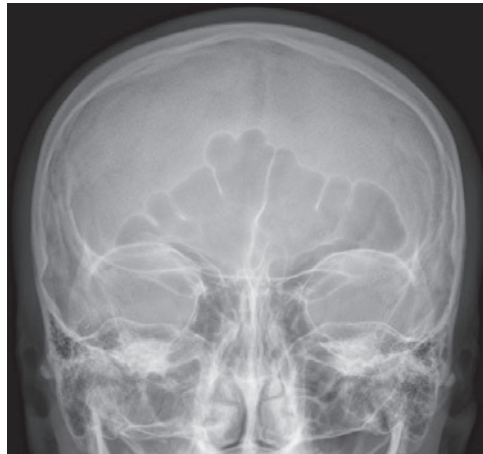


Activity 3: What is Computed Tomography?

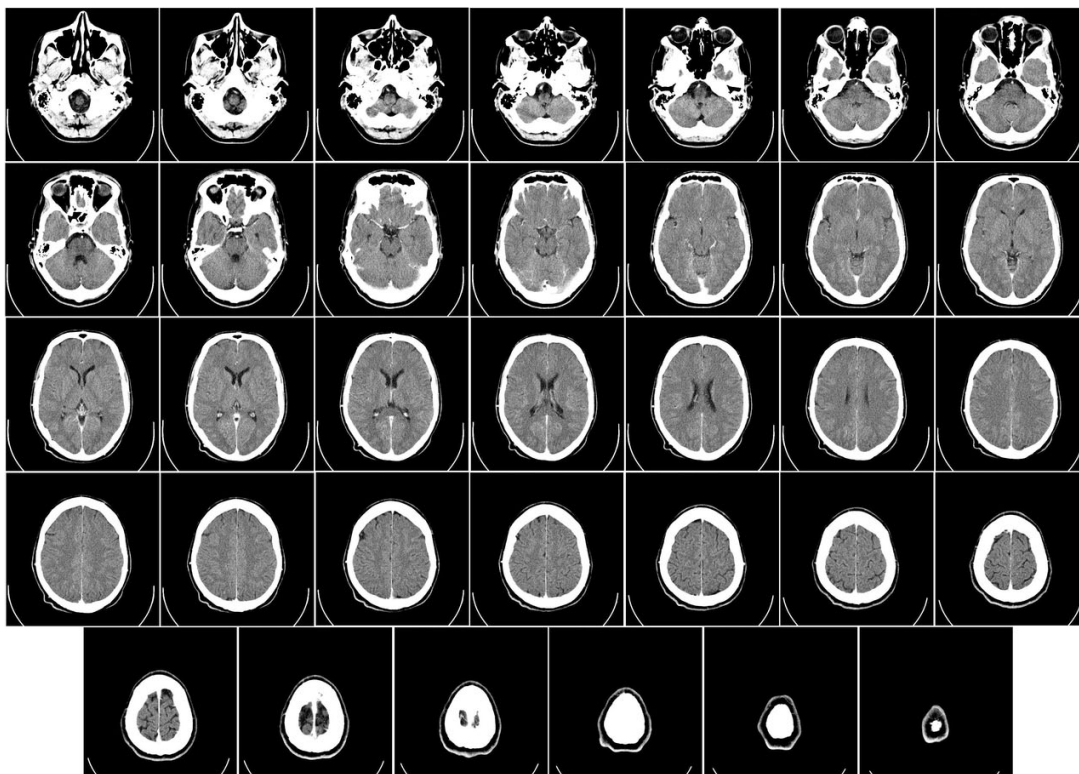


Activity Closure

Below are three images of a human head. [Show the images to the class as you read.] The first image is a standard X-ray. The object (in this case a head) was exposed to X-rays, similar to the sunlight and leaf in the Sunprint® activity. The densities of the areas in the skull are shown, but only from one angle.



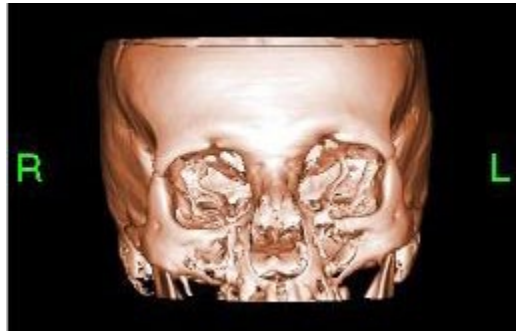
The next image is actually series of images known as CT slices. Each slice was created by compiling information from X-ray scans taken from multiple angles. The activity you just completed models the back projection technique used to create just one of these slices.



Activity 3: What is Computed Tomography?



The final image is complete three-dimensional CT reconstruction. This 3D image was created by combining data from the individual CT slices in the previous image, making it possible for a doctor to easily examine the skull and brain for density differences at any point.



Exploration Questions

1. How does CT differ from a standard X-ray?

[CT combines multiple images to form a three-dimensional picture.]

2. What are some advantages of CT over a normal X-ray?

[Greater detail and nothing blocks the view of things behind it (for example, in a chest X-ray, the bones can obscure the view of the organs inside the rib cage).]

Activity 4: Ultrasound and Submarines



Time Required: 30 minutes

Group Size: 2

Materials List

Youth Handouts:

- Ultrasound and Submarines

Getting Ready (10 minutes)

- Choose an outdoor location with a large wall, such as a gymnasium.
- Obtain two small, thick blocks of wood that you can clap together to make a loud sound. You could also simply clap your hands.
- Stand 75-100 feet from the wall and make the sound. Do you hear the echo? In this way, you can sense the wall. You can use this exercise as an opening demonstration for this activity

Learner Outcomes

- Explain that echolocation is used to determine the distance of objects from an ultrasound sensor.
- Explain that to ensure that all objects are found, the space between samples taken must be the size of the smallest object to be sampled.

Vocabulary

Word	Definition
Echo	A sound produced by the reflection of sound waves.
Echolocation	Determining the distance to an object using sound waves.
Frequency	Number of waves per second.
Resolution	Size of the smallest detectable space between two objects.
Sampling interval	The frequency of data collection.
Sonar	A technique that uses sound propagation to navigate, communicate with, or detect objects on or under the surface of the water.
Ultrasound	High-frequency sound waves that cannot be heard by the human ear.

Activity 4: Ultrasound and Submarines



Introduction

In the last few activities, we examined medical imaging that uses X-radiation. The inside of the body may also be imaged using sound waves that are outside of the range of human hearing, called **ultrasound**.

[Take students outside to the desired location and have everyone stand 75-100 feet from the wall. Clap two blocks of wood together or just clap your hands. You could also have a student yell.]

Do you hear an **echo**? That echo tells us there's a wall in that direction. If we wanted, we could also calculate exactly how far away the wall is. Knowing that the speed of sound in air is 768 mph (343 meters per second), we can measure the amount of time between clapping and hearing the clap's echo and determine the distance to the wall.

Another example is determining the distance to a thunderstorm. To tell how far away lightning is, count the seconds between when you see the lightning bolt and when you hear the thunder. Because light travels about 186,000 miles per second, the light will reach your eyes almost instantaneously. Sound, on the other hand, travels about 0.2 miles per second. Therefore, if it takes 5 seconds for the thunder to reach you, you know the lightning is approximately 1 mile away.

Is anyone familiar with the term **echolocation**? *[Give students a chance to answer and explain what they think it means.]* The word means exactly what it implies: using sound, specifically echoes, to figure out where something is located. Bats and dolphins use echolocation to find and catch prey by emitting a sound and then locating the object based on how long it takes the sound to bounce back to them. Clapping our hands and timing the echo off the wall is a form of echolocation. Ultrasound uses a similar technique on a much smaller scale to create images inside the body.

Submarines also use ultrasound to avoid collisions or locate enemy ships. When ultrasound is used to navigate, communicate with, or detect objects underwater it's called **sonar** (originally an acronym for SOUNd Navigation And Ranging). To find an object, a submarine transmits a sound wave and then listens with a special device to see if the sound wave is reflected back. By calculating how long it takes for the reflected wave to return, the people on the submarine can determine how far away the object is. For example, if the submarine transmits a high **frequency** pulse moving at 1,000 meters per second and receives the echo 1 second later, it knows that the object is 500 meters away.

Facilitating the Activity

1. Place students in pairs and distribute handouts.
2. Have them examine the diagram and give them the following instructions: A submarine needs to survey a distance of 100 meters along the ocean floor. Help the submarine determine the number of objects beneath it that are at least 5 meters long.

Activity 4: Ultrasound and Submarines



Activity Closure

To completely sample a field with objects that are X meters long, you must sample *at least* every X meters, if not more, to make sure nothing is missed. However, sampling too often can be a waste of time and money so a **sampling interval** half the size the smallest object—or $X/2$ meters—is considered ideal. This is a fundamental theory in engineering and is used in everything from cell phones to medical imaging equipment. The smallest distance detectable between objects is called **resolution**. On the submarine worksheet, the resolution was 5 meters when the submarine sampled every 2.5 meters.

Exploration Questions

1. How far apart must your survey lines be to accurately detect all of the submarines in the field?

[2.5 meters.]

2. How does this number relate to the 5 meter minimum object size?

[The sampling interval should be less than the minimum object size, but ideally half.]

Activity 5: Imaging with Sound



Time Required: 60 minutes

Group Size: 3

Materials List

Each group needs:

- Shoe box or other small box with lid
- Pair of wooden chopsticks (or skewers)
- Ruler
- Graph paper
- Corrugated cardboard (Not included in kit)
- Objects for bottom of “sea floor” (Not included in kit)

Each class needs:

- Markers
- Masking tape
- Glue stick
- Pipe cleaners
- Wooden craft sticks
- Scissors

Youth Handouts:

- Imaging with Sound

Getting Ready (10 minutes)

- Gather objects to represent the bottom of the sea floor for the terrain maps. These can be cut-outs from boxes, foam bricks, soda bottles, shells, rocks, sand, wooden blocks, etc. They should fit inside the locator boxes; 2 to 5 inches is a good size estimate, though smaller or larger could work.
- Gather some small, lightweight boxes with lids (shoe boxes, cake boxes, etc.). Students will use these to make their locator boxes. The boxes should all be about the same size because the groups will be switching terrain maps in the second half of the activity.
- Find a few corrugated cardboard boxes or other rigid material. Cut out flat pieces that are the same size as the base of students' locator boxes. Students will create their terrain maps on these pieces of cardboard (see handout).

Learner Outcomes

- Explain that ultrasound uses sound waves to see images inside the body.
- Explain that echolocation is used to determine the distance of objects from an ultrasound sensor.
- Explain that the space between samples taken cannot be larger than the size of the smallest sampled object to ensure that all objects are found.



Activity 5: Imaging with Sound



Vocabulary

Word	Definition
Sonographer	A highly skilled medical imaging professional who operates an ultrasound machine to perform diagnostic medical sonographic examinations.
Ultrasound transducer	A device that transmits, receives, and evaluates ultrasonic sound waves that bounce off body tissues.

Introduction

In the previous activity, we began exploring how ultrasound creates an image. In this activity, we'll build our own model ultrasound devices and use them to create images.

Have you ever seen an ultrasound image of a baby before it's born? It looks like a blurry, black-and-white photo except, instead of light or radiation, high-frequency sound waves are used to "take a picture" of the inside of the body. The ultrasonic waves are reflected at the boundary between different types of tissue. These boundaries are what produce the image.

To take an ultrasound, a trained medical technician, called a **sonographer**, places an **ultrasound transducer** on the outside of the body. Much like the submarine surveying the ocean in the previous activity, the transducer sends out ultrasonic waves and measures how long it takes to "hear" a return signal. Instead of scanning at intervals like a submarine, medical ultrasound devices can actually survey a wide area at once. This is because the distance the sound has to travel is much shorter (a few inches verses thousands of feet) and ultrasound transducers use multiple sensors at once.

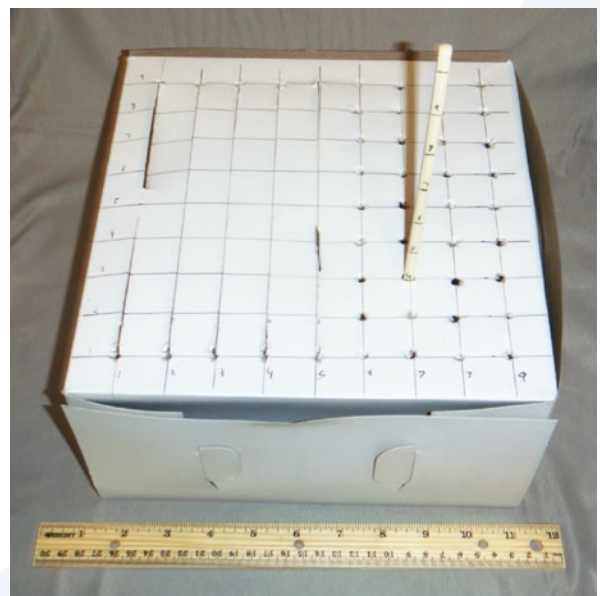
Today you're going to design your own "echolocation" system. You will need to survey a field of objects designed by your classmates and identify of all the objects.

Facilitating the Activity

1. Instruct students to make a locator system that takes depth readings at specified positions. They must be able to tell precisely where the locator is taking readings and how deep it goes.

The example to the right takes depth readings using a locator device (chopstick) with inch measurements marked on it. The locator box use a grid on top to determine depth at multiple locations.

2. Show the students the available supplies. Instruct them to design a map of their terrain on a sheet of paper before handing out the supplies.
3. Distribute supplies and ask students to build their locators and terrain.



Activity 5: Imaging with Sound



4. When everyone's locator is completed, tell the groups to exchange terrain maps with another group. One group is to put its terrain map into another group's locator box, as shown above. *The opposing group's members should not look while this is happening.*
5. Once the lid of the box is closed, they should use their locator device to detect the objects and draw a map of what is in the box on graph paper.
6. Allow about 20 minutes for the groups to locate and identify each other's objects. If time allows, let them switch again with different group.

Activity Closure

Ultrasound determines not only where an object is located, but also its size and shape. Like a CT scan, ultrasound provides a three-dimensional view of the inside of the body.

One benefit of sonograms over CT scans are the instantaneous results. With ultrasound you can actually watch your heart beating. Ultrasound is also relatively inexpensive and portable compared to other imaging techniques such as MRI (magnetic resonance imaging) and CT. Another advantage of ultrasound is that X-radiation, used in CT, can be harmful in large quantities. This would only affect you if you had X-rays every day for a year, but it could hurt newborn babies, who are especially susceptible to radiation. Ultrasound does not use harmful radiation, so there is no limit to the number of images a doctor may safely take, for both adults and newborns.

Exploration Questions

1. What were some problems you encountered while trying to interpret the terrain map provided by the other group? Were the problems related to sampling frequency or something about your designs?
2. How might you improve your locator design if you had more supplies or unlimited resources?
3. What was the smallest feature detectable in the terrain you created?

Glossary

**Back projection**

A method of combining data from multiple beams of X-rays to create a picture of the inside of the body.

Cathode ray

A beam of energetic electrons.

Computed tomography (CT)

A form of X-ray imaging that produces a three-dimensional image.

Density

Mass per unit of volume.

Echo

A sound produced by the reflection of sound waves.

Echolocation

Determining the distance to an object using sound waves.

Electromagnetic radiation (EM)

EM radiation is light. Some types are visible; others are invisible (see intro).

Frequency

Number of waves per second.

Mass

Quantity of matter in an object.

Resolution

Size of the smallest detectable space between two objects.

Sampling interval

The frequency of data collection.

Sonar

A technique that uses sound propagation to navigate, communicate with, or detect objects on or under the surface of the water.

Sonographer

A highly skilled medical imaging professional who operates an ultrasound machine to perform diagnostic medical sonographic examinations.

Ultrasound

High-frequency sound waves that cannot be heard by the human ear.

Ultrasound transducer

A device that transmits, receives, and evaluates ultrasonic sound waves that bounce off body tissues.

Volume

Amount of space taken up by a three-dimensional shape.

X-ray

A form of electromagnetic radiation with a wavelength between 0.01 to 10 nanometers.

Acknowledgements



Authorship Team

Dr. Ed Maxa, Associate Professor (retired 2010), Department of 4-H Youth Development and Family & Consumer Sciences, North Carolina State University.

Kate Guerdat, Former 4-H Extension Associate, Department of 4-H Youth Development and Family & Consumer Sciences, North Carolina State University

Amy Chilcote, 4-H Extension Associate, Department of 4-H Youth Development and Family & Consumer Sciences, North Carolina State University

Dr. Mitzi Downing, Department of 4-H Youth Development Cooperative Extension Service, North Carolina State University.

Kristy Oosterhouse, 4-H Program Coordinator, Children and Youth Institute, Michigan State University Extension

Dr. Jacob DeDecker, Program Leader, Children and Youth Institute, Michigan State University Extension

Steven Worker, 4-H SET Coordinator, University of California Agriculture and Natural Resources, Youth, Family and Communities, 4-H Youth Development Program

Lynn Schmitt-McQuitty, County Director & Science Literacy Youth Development Advisor, University of California Agriculture and Natural Resources

Dr. Matthew T. Portillo, 4-H Youth Development Program Advisor, Academic Assembly Council President, University of California, Butte County

Amanda Meek, 4-H SET Educator, University of Missouri Extension

Dr. Jeff Sallee, Assistant Professor and Extension Specialist 4-H Youth Development, Oklahoma State University

Dr. Gary A. Ybarra, Professor of Electrical and Computer Engineering, Duke University

Rodger Dalton, Research Associate, Duke University and President, Techsplorers

Dr. Paul Klenk, Research Scientist, Duke University

Wendy Candler, Curriculum Development / Graphic Design, Techsplorers

Curriculum Developers

Dr. Paul Klenk, Research Scientist, Duke University

Amy Sharma, Undergraduate and Graduate Student, Pratt, Duke University (BSE '01, Ph.D. '07)

Wendy Candler, Curriculum Development / Graphic Design, Techsplorers

Rebecca Simmons, Research Associate, Duke University

Dr. Gary A. Ybarra, TechXcite Principal Investigator, Duke University

Collaborative Contributors

Donna Patton, Extension Specialist, West Virginia University Extension Service

Sherry Swint, Extension Agent, West Virginia University Extension Service

Lynna Lawson, 4-H Youth Development Specialist, University of Missouri Extension

Robert B. Furr, County Extension Director, North Carolina Cooperative Extension

Carla Burgess, Youth Curriculum Reviewer, Duke University

Acknowledgements



Layout, Graphics, & Design

Jenny McAllister, Adobe InDesign Layout, Techsplorers

Wendy Candler, Illustration / Graphic Design, Techsplorers

Illustration / Graphic Design / Website Design – Cuberis Design + Web Solutions

Leadership Team

Dr. Ed Maxa, Professor Emeritus (retired 2010), Department of 4-H Youth Development and Family & Consumer Sciences, North Carolina State University.

Allen O'Hara, Grant Manager, National 4-H Council

Gregg Tabbachow, Grant Manager, National 4-H Council

Dr. Gary A. Ybarra, Professor of Electrical and Computer Engineering, Duke University

Rodger Dalton, Research Associate, Duke University and President, Techsplorers

Research Team

Dr. Ed Maxa, Professor Emeritus (retired 2010), Department of 4-H Youth Development and Family & Consumer Sciences, North Carolina State University.

Dr. Mitzi Downing, Department of 4-H Youth Development Cooperative Extension Service, North Carolina State University.

Dr. Eddie Locklear, Director of National 4-H Afterschool Program (retired 2012)

Dr. Gary A. Ybarra, TechXcite Principal Investigator, Duke University

Rodger Dalton, Research Associate, Duke University and President, Techsplorers

Dr. Anne D'Agostino, TechXcite Program Evaluator, Compass Evaluation and Research Inc.

Program Management

Rodger Dalton, TechXcite Program Manager (2012-2014), Duke University

Dr. Paul Klenk, TechXcite Program Manager (2007-2012), Duke University

Copyright

© 2014 Duke University all rights reserved.

This Module was created with support from the National Science Foundation grant 0638970.

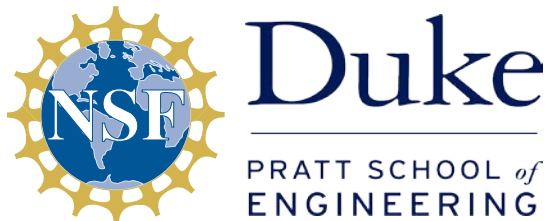


Image Credits



- Page 1: Cover illustration by Jenny McAllister & Wendy Candler
- Page 8: First medical X-ray taken December 22, 1895 by Wilhelm Röntgen. [Public domain], via Wikimedia Commons
 Wilhelm Conrad Röntgen by Unknown [Public domain], via Wikimedia Commons
- Page 11: CT Scan Machine Demonstration by U.S. Navy Chief Warrant Officer 4 Seth Rossman, [Public domain], via Wikimedia Commons
- Page 12: Playing card demonstration by TechXcite
- Page 13: X-ray of human skull by Hellerhoff [CC-BY-SA-3.0], via Wikimedia Commons
 Computer Tomography of the Human Brain (2007) by Radiology, Uppsala University Hospital [Public domain], via Wikimedia Commons
- Page 14: Bone reconstruction by Zgyorfi (January 29, 2006) [GFDL or CC-BY-SA-3.0], via Wikimedia Commons
- Page 18: Ultrasound image of fetus at 12 weeks of pregnancy by Wolfgang Moroder [GFDL or CC-BY-SA-3.0], via Wikimedia Commons
- Page 19: Locator box by TechXcite
- Page 20: Locator terrain by TechXcite