







Materials List for a Real-Time STEM + Families Propelling Our World Program

*You can add any materials that you find useful. This list is not a comprehensive list.

Circuits Challenge Grades 5 - 8 	<ul style="list-style-type: none"> • Scissors • LEDs (10mm) • Coin cell batteries • Copper tape with conductive adhesive • Small binder clip Additional Materials <ul style="list-style-type: none"> • Construction paper • Tape • Markers, colored pencils or crayons
Submarine Science Grades 5 - 7 	<ul style="list-style-type: none"> • Water bottle (empty) • Bendy straws • Thin plastic tubing (or more bendy straws) • Pennies • Duct tape • Drill/sharp object (Get an adult's help with this!)
Capsized Grades 5 - 6 	<ul style="list-style-type: none"> • Corks (varying sizes) • Wooden skewers • Rubber bands • Craft foam or paper milk cartons • Electrical fan • Tub of water • Scissors
Fins! Grades 7 - 8 	<ul style="list-style-type: none"> • 2-liter soda bottle • Water bottle • Knife or scissors (Get an adult's help with this!) • Scissors • Pen or needle • Needle nose pliers • Large paper clips • Chopsticks • Stiff ruler • Rubber bands • Waterproof sealant • Tub of water



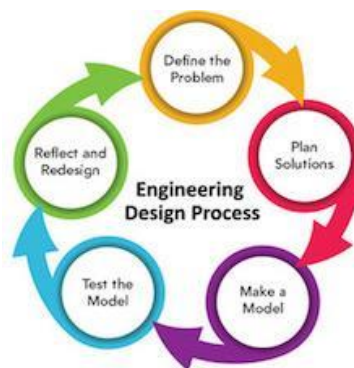
Propelling Our World: Circuits Challenge

Background Knowledge

Aim: Design a simple circuit to illuminate your construction paper designed submarine or aircraft carrier made from household materials.

Problem & Career Focus: A marine electrician is essentially an electrician, meaning these professionals read and interpret technical documents, install wiring and electrical components, maintain and repair electrical systems, and use testing tools and devices to do their job. However, a marine electrician focuses their work primarily on marine vessels and ships. As a marine electrician, you get work that a ship that had been at sea is having issues with their electrical systems providing light to rooms on the ship. Using the engineering design process, your task is to create a new electrical system to fix the broken lighting.

Engineering Design Process: STEM professionals use the engineering design process as steps to help solve real-world problems. With your team: define the problem, discuss solutions, design, build, test and improve a prototype of your solution. One of the most important steps of the engineering design process is to reflect and redesign—if your team notices the circuits aren't working—improve the design. Use the engineering design process steps to guide your exploration during the Circuits Challenge.



Investigating Questions	Materials
<ul style="list-style-type: none"> What safety precautions would a marine electrician need to follow? What everyday items do you interact with that use simple circuits? How is knowledge of engineering, physics, chemistry and mathematics related to simple circuitry? 	<ul style="list-style-type: none"> Scissors LEDs (10mm) Coin cell batteries Copper tape with conductive adhesive Small binder clip <p>Additional Materials</p> <ul style="list-style-type: none"> Construction paper Tape Markers, colored pencils or crayons

Propelling Our World: Circuits Challenge

STEM Career Focus

Marine Electrician

A marine electrician is essentially an electrician, meaning these professionals read and interpret technical documents, install wiring and electrical components, maintain and repair electrical systems, and use testing tools and devices to do their job. Marine electricians may work with all types of marine equipment including yachts, cruise liners, aircraft carriers and more.



Essential STEM Skills



Communication, problem solving, mathematics (measuring and calculating electrical current values), attention to details

Subjects of Study



Mathematics, physics, information technology, electrical technology


Career Pathway



Options include:

- High school diploma/GED
- Apprenticeship or on the job training
- Certifications
- Higher education (bachelor's, master's degrees)



Job Overview 	<p>Average salary: Between \$45K to \$95K a year</p> <p>Project Job Growth by 2025: 14%</p> <p>Number of jobs: 628,800</p>
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Propelling Our World: Circuits Challenge

Background Knowledge

Educational Standards Correlations: Physics, chemistry, mathematics, engineering

Vocabulary:

Electrical energy: Allows us to do work by transferring energy into other forms (e.g., electrical energy converted to light energy)

Cathode: Part of a battery that has a positive (+) charge


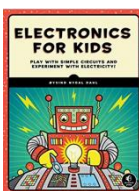
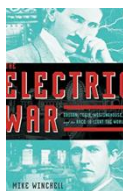
Anode: Part of a battery that has a negative (-) charge

Diode: (LEDs are diodes) A diode only allows current to flow in one direction

Chemical reaction: In this challenge, the chemical reaction happening inside the battery causes electrons to build up on one side of the battery (+ and – electrons) which creates an imbalance, transforming electrical energy running through the circuit.

Real World Applications: You see the effects of electrical and chemical energy in your life everywhere! From devices we use every day including cell phones, light switches, Chromebooks to cars, refrigerators and more we rely on concepts of energy for daily tasks.

Literacy Connections:

<p>The Big Book of Invisible Technology by Chloe Taylor</p> 	<p>Electronics for Kids: Play with Simple Circuits and Experiment with Electricity! by Oyvind Nydal Dahl</p> 	<p>The Electric War: Edison, Tesla, Westinghouse and the Race to Light the World by Mike Winchell</p> 
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Propelling Our World: Circuits Challenge

Background Knowledge

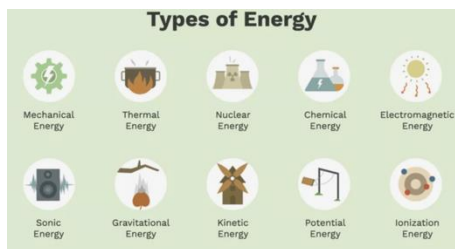
Engineering New Ideas in Everyday Gadgets!

There is a lot of science behind the devices and everyday items you use in your life. Check it out!

Simple Circuits

A basic understanding of circuits is important for many different disciplines including engineering, physics, chemistry and mathematics. It's useful around the house to repair a string of lights for celebrations! Understanding and building simple circuits shows us important concepts learned in school that can be describe useful real-world applications, like devices we use every day such as cell phones, light switches, laptops, cars and more!

The electric charge that flows through your house is called your electric circuits. These carry useful energy through your house that you can transform into other forms of energy to do various tasks. The U.S. standard household circuit has an effective voltage that takes 120-volts. Volts represent the energy per unit charge. There are many different types of energy, shown below (from Thought Co.)

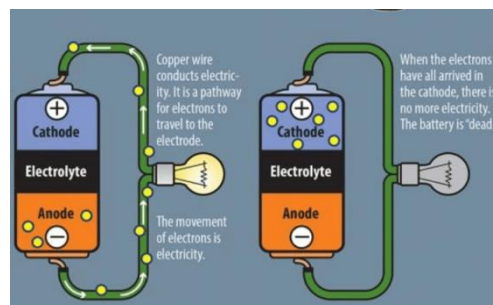


Batteries

Batteries are important to everyday life. They are essential to most electrical devices. A battery is essentially a container full of chemicals that produce electrons. The battery stores chemical energy and converts it to electrical energy.

The chemical reactions in a battery involve the flow of electrons from one material to another. The flow of electrons provides an electric current that can be used to do work.

A battery has three main parts: an anode (negative charge), a cathode (positive charge) and the electrolyte that separates two terminal ends on the battery.



(Image source: <https://kids.wng.org/noode/4218>)

A chemical reaction that happens inside the battery causes electrons (-) to build up on one side of the battery causing one end to be negatively charged (-) and the other end to be positively charged (+)



Propelling Our World: Circuits Challenge

Background Knowledge

The buildup causes an imbalance of electrons that want to travel to the other side of the battery. The electrons can't move freely until a conductive circuit is completely looped for the electrons to travel through. In this activity, your conduit is the copper tape.

When a circuit is complete, or a loop has been created, the electrons will flow through the conductive paths racing to reach the other side of the battery terminal. When electrons flow through the loop, the chemical energy inside the battery is transformed into electrical energy that runs through the circuit. When all electrons (-) make it to the other side, the battery stops working. All of the electric energy was transformed into other forms of energy.

Electrical Energy

Electrical energy allows you to do work by transforming energy into other forms. In this challenge, LEDs are used because it is a simple way to show how electric energy is transformed or converted into light energy.

Marine Electricians

A marine electrician is specifically trained to work with ships and water at the same time. Water and electricity don't mix, so these workers must take special safety precautions when installing electrical components and understand the dynamics of water on the electrical system. This ensures the safety of guests and crew once the vessel is in operation.

Day to Day

Whether fixing a radio, replacing a faulty switch, or locating an electrical short a marine electrician is responsible for keeping the ship's electronics in working order. Every day, a marine electrician installs wires, batteries, engines and equipment like navigation and radio systems. Their work may involve installing components for a new electrical system or replacing bad wiring. When installing a new electrical system, they often handle gauges, outlets, light fixtures and the wires that create the electrical loop that links everything together!

Fun Facts About Electricity

- Electricity was first discovered in 600BC!
- Electric cars date back as far as 1832.
- 54% of all electricity is wasted.
- Electric eels can produce up to a 600-volt shock!
- Lightning is caused by the discharge of electricity in the atmosphere.

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Propelling Our World: Circuits Challenge

Activity Directions

Aim: Design a simple circuit to illuminate your construction paper designed submarine or aircraft carrier made from household materials.

Investigating Questions:

- What safety precautions would a marine electrician need to follow?
- What everyday items do you interact with that use simple circuits?
- How is knowledge of engineering, physics, chemistry and mathematics related to simple circuitry?

Materials:

- Scissors
- LEDs (10mm)
- Coin cell batteries
- Copper tape with conductive adhesive
- Small binder clip

Additional Materials

- Construction paper
- Tape
- Markers, colored pencils or crayons

Criteria & Constraints:

Engineering design challenges (EDCs) are great opportunities for open-ended activities to grow critical thinking and problem-solving skills. EDCs do not use a list of directions to build a specific design, rather suggest a framework of designing a solution based on the problem and goal. How your team chooses to address the problem and goal is entirely up to you.

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Bayer Fund





Challenge Hints:

- Lay out all materials and items available for the challenge. Your first task is to design a 3D boat or submarine with construction paper. Plan to give time researching and looking up designs of boats using paper. (*Define the problem*)
- Discuss with your team the problem relating to your background knowledge. Your challenge is to not only create the construction paper ship or submarine, but also design a simple circuit that will illuminate parts of the ship. The only thing that should be shown on the outside is the LED light. How many LED lights will you use? How many batteries will be needed to make the connections to the copper wire? (*Define the problem and plan solutions*)
- Discuss, sketch and determine what materials your team will use to create the 3D construction paper ship and the simple circuit loop (*Make a model*)
- Using your sketches and discussions, build your 3D ship or submarine from materials provided and add the copper simple circuit directly to the boat. Hint: The copper tape needs to make direct contact with the battery. Adults: Allow teams to explore the materials and help them build problem-solving skills (*Make a model*)
- As you are building your simple circuit, test out your design. Did you use enough copper tape? Test if the LED lights up by connecting the copper wire to the battery. You can use a paper clip or a binder clip to hold the battery in place, so the LED stays lit.
- With your team, continue to discuss and work through design problems. What adjustments can you make in your simple circuitry? If you were to create a new boat, how would you change the shape or design that could better hold more LED lights? (*Reflect and Redesign*)

Ideas to Increase Difficulty:

- Limit the number of materials used.
- Create a more complex circuit loop.



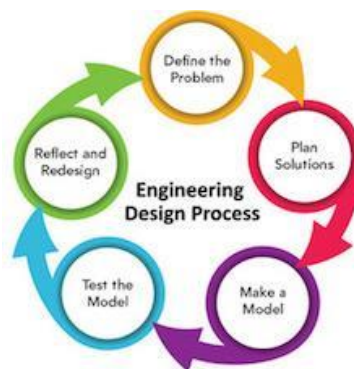
Propelling Our World: Submarine Science

Background Knowledge

Aim: Design a submarine that can move up and down in water using household materials.

Problem & Career Focus: The idea of traveling underneath the ocean waters inside a contained vessel has been around for centuries. Legend says that Alexander the Great ventured below the waters of the Aegean Sea inside a glass barrel around 333 B.C. He is reported to have seen whales and deep-sea life on his underwater journey. The next record of a submarine wasn't acknowledged until 1,900 years later. Submarines are modern marvels. A true feat of centuries of engineering design. Marine engineers design and develop submarines and other maritime vessels. Using the engineering design process, your task as a marine engineer is to explore the innovative mechanics of submarines that help to raise and lower in water.

Engineering Design Process: STEM professionals use the engineering design process as steps to help solve real-world problems. With your team: define the problem, discuss solutions, design, build, test and improve a prototype of your solution. One of the most important steps of the engineering design process is to reflect and redesign. If your team notices the design of your submarine isn't working, improve the design. Use the engineering design process steps to guide your exploration during the Submarine Science activity.



Investigating Questions	Materials
<ul style="list-style-type: none"> How does the design of a submarine help it raise and lower in various water depths? How are submarines built differently than surface ships? How do submarines use forces of gravity and buoyancy? 	<ul style="list-style-type: none"> Water bottle (empty) Bendy straws Thin plastic tubing (or more bendy straws) Pennies (or any other coins you have) Duct tape Drill/sharp object Tub of water







Propelling Our World: Submarine Science

STEM Career Focus

Career: Marine Engineer

Marine engineers design, build and maintain ships ranging from aircraft carriers, submarines, sailboats, tankers and more. Their daily responsibilities could be designing and overseeing the testing, installation, and repair of marine vessels and equipment. They use specialized software for analyzing data, designing prototypes and solutions. Marine engineers use computer-aided drafting programs to conduct simulated tests, gather data and design systems.



Essential STEM Skills 	Problem-solving skills, decision making abilities, understand and apply knowledge of math, physics and chemistry.
Subjects of Study 	Shipbuilding, computer-aided design (CAD), propulsion, fluid and solid mechanics, marine hydrodynamics (study of models to predict behaviors of ships in water systems), varied math courses
Career Pathway 	<p>Typically need a bachelor's degree in marine engineering, marine systems engineering, or marine engineering technology.</p> <p>There are opportunities to achieve a higher degree such as master's or doctorate.</p>
Job Overview 	<p>Average salary: Between \$82K to \$200K a year</p> <p>Project Job Growth by 2030: 4%</p> <p>Number of jobs: 10K+</p>

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Propelling Our World: Submarine Science

Background Knowledge

Educational Standards Correlations: Physics, chemistry, mathematics, engineering

Vocabulary:

Buoyant force: Displacement of water, equal to the weight of water, that creates an upward force. This force is opposite to gravity.

Gravity: Pulls denser air and objects downward, forcing less dense air and water to move upward.

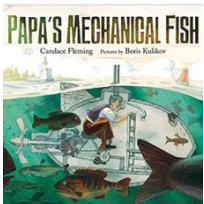
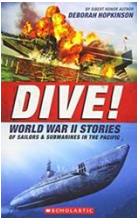
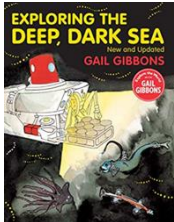
Ballast tanks: A compartment within a boat or submarine that holds water. It reduces or controls buoyancy to provide a more even weight load distribution. A submarine is designed to operate underwater by storing and releasing water through ballast tanks.

Negative buoyancy: Occurs when an object is denser than the fluid it displaces. The object will sink because its weight is greater than the buoyant force.

Positive buoyancy: A condition of weight and mass that will cause the submarine to float

Real World Applications: It's due to buoyancy that fish, human swimmers, icebergs and ships stay afloat. Life vests, helium, fish swimming and other real-life things use properties of buoyancy. Check out the activity background information to learn more!

Literacy Connections:

<p>Papa's Mechanical Fish by Candace Fleming</p> 	<p>Dive! World War II Stories of Sailors & Submarines in the Pacific by Deborah Hopkinson</p> 	<p>Exploring the Deep, Dark Sea by Gail Gibbons</p> 
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Propelling Our World: Submarine Science

Background Knowledge

Engineering New Ideas in Exploration!

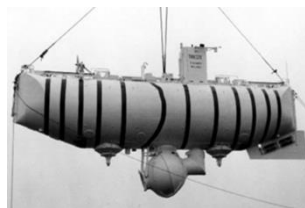
The surface of the moon is more familiar to us here on Earth than the deep sea of our own planet. Many oceanographers, marine engineers and scientists are trying to change this through the development of submarines, submersibles and remotely operated vehicles (ROVs) to learn more about the ocean and ocean floor.

Innovation of Submarines

Legend states that as far back as 333 B.C. Alexander the Great explored the waters of the Aegean Sea in a glass barrel. The next record of ocean journeys came in 1572, by a Dutchman named Cornelius J. Drebbel. He patented his submarine invention in 1598. He was a map maker, engraver, but most importantly an inventor. His submarine was powered by oars allowing it to be rowed underwater. Tubes to the surface provided air. This air system allowed the boat, wrapped in waterproof leather, to travel underwater for several hours! His boat was successfully tested in the Thames River and traveled down depths to 15 feet. Over the years, scientists and engineers explored the designs of submersibles to safely dive humans into ocean depths.

In 1904, the French built the Aigrette the first submarine to use a diesel engine on the surface and an electric engine below. The United States designed the F-class Skipjack.

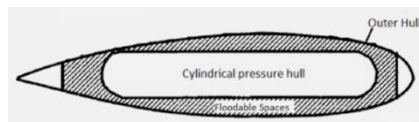
In 1938, Auguste Piccard built his record-setting bathyscaphe Trieste (shown below, courtesy of Marine Bio)



The 50-foot-long submarine still holds the record for the deepest dive: more than 35,000 into Challenger Deep in the south Pacific's Marianas Trench, which is the deepest point known in the ocean.

How Submarines Function

Submarines are built differently than surface ships that float on the surface of water. They are completely enclosed vessels with cylinder shapes, narrowed ends and two hulls: the inner and outer hull. The inner hull protects the human crew from the immense water pressure of the ocean and insulates from freezing temperatures. The inner hull is also called the pressure hull. The outer hull shapes the submarine's body. The ballast tanks, which control the sub's buoyancy, are located between the inner and outer hulls.



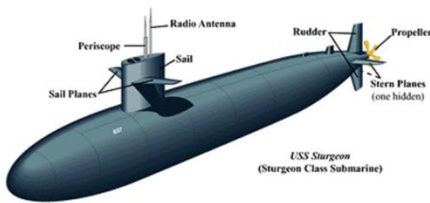
(Submarine Hulls, Marineinsight.com)



Propelling Our World: Submarine Science

Background Knowledge

To stay in control, a submarine underwater must maintain a condition called trim. This means its weight must be perfectly balanced throughout the whole ship. It cannot be too light or too heavy. Marine engineers who design the sub need to know all this information because the submarine's crew must continually work to keep the submarine trim, otherwise they would be burning fuel and supplies.



Once underwater, it has two controls for steering (see image above, courtesy of MarineBio). The rudder controls the side-to-side steering or turning and diving planes control the sub's rising and descent from the water. The first submarines depended on people to help it move, using foot cranks for propulsion. Now submarines use nuclear-powered steam to propel and move.

As advances in technology are made, the look and operation of submarines change. The Virginia-class submarines use Photonics Masts, which mean they don't need periscopes anymore. Now they are build using high-definition color cameras that send images to large screens to the ship's control room via fiber optics.

Submarine Science

Archimedes' principle is the law of buoyancy. This means the weight of any object acts downward and the buoyancy force provided by the displaced fluid acts upward. If these two forces are equal the object will float. Density is defined as weight per volume. If the density of an object is greater than the density of water, the object will sink. Whether a submarine is floating, or submerging depends on its buoyancy. This is controlled by the ballast tanks, found between the submarine's inner and outer hulls.

A submarine resting on the surface has positive buoyancy. The ballast tanks are mainly full of air. To submerge underwater, the submarine must have negative buoyancy. Vents on the top of ballast tanks are opened. Seawater comes through the flood ports which pushes air out the vents. The submarine now begins to sink. To make the submarine rise again, compressed air is blown into the tanks forcing the seawater out.

Check out these video links!

Marine Engineers

https://www.youtube.com/watch?time_continue=

Ocean Engineers

https://youtu.be/Lj_msWdu7VM

Mechanical Engineers

<https://youtu.be/NwwriHfbmB8>

Life at Sea: Navy Submarine

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https://www.youtube.com/watch?v=uKy87o_xaDE

How Submarines Work

<https://www.youtube.com/watch?v=Jo6refffwQLc>



Propelling Our World: Submarine Science Activity Directions

Aim: Design a submarine that can move up and down in water using household materials.

Investigating Questions:

- How does the design of a submarine help it raise and lower in various water depths?
- How are submarines built differently than surface ships?
- How do submarines use forces of gravity and buoyancy?

Materials:

- Water bottle (empty)
- Bendy straws
- Thin plastic tubing (or more bendy straws)
- Pennies (or any other coins you have)
- Duct tape
- Drill/sharp object
- Tub of water

Criteria & Constraints:

Engineering design challenges (EDCs) are great opportunities for open-ended activities to grow critical thinking and problem-solving skills. EDCs do not typically use a list of directions to build a specific design, rather suggest a framework of designing a solution based on the problem and goal. In this activity, your team will be provided a set of steps to create your submarine hulls but will have to determine how you get the submarine to rise and lower. How your team chooses to address the problem and goal is entirely up to you.

Submarine Design:

- Lay out all materials and items available for the challenge. Your first task is to design a submarine with materials provided. Plan to give time researching and looking up designs of submarines using paper. (*Define the problem, Plan Solutions*)
- Cut three small holes into one side of the empty water bottle with scissors, or another sharp object. ***Get an adult's help with this.** The holes must be equally spaced and at least one and a half inches apart. Dot the areas that need to be cut with the black marker. (Photo courtesy of Sciencing.com)

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(Photo courtesy of Sciencing.com)

- Stack the coins that you have into two groups. These stacks will act as weights. Wrap each stack of coins to the sticky part of the tape. Tightly secure the tape around the coins. Make sure each stack is tight and firm.

- Place the rubber bottle, putting one that is closest to the and one beneath the the top of the bottle. stacks under the closest to the bottle's stack of coins under to the bottle's top. be next to the holes. (Photo courtesy of Sciencing.com)



bands around the water just beneath the hole bottoms of the bottle hold that is closest to Position one of the coin rubber band that is bottom and the other the rubber band closest These weights should but NOT cover up the

- Remove the shortest end of the into the opening of play dough around the area is sealed that the straw is bent upwards. Sciencing.com)



bottle's cap and insert the straw (about an inch long) the bottle. Mold clay or the opening, making sure from water entering and secure with its long end (Photo courtesy of

- Now, using the put your tub of water. Work engineers to raise

- Discuss with your to your Your challenge is submarine, but materials lower your sub.



submarine you have built submarine into a small with your team of marine and lower your vessel.

team the problem relating background knowledge. to not only create the also design a way to use provided to raise and Which materials are

- important for helping your submarine raise and lower? Are there any parts of your design your team of marine engineers should change or modify? (*Define the problem and plan solutions*)
- Discuss, sketch and determine the ways your submarine will raise and lower. Adults: Allow teams to explore the materials and help them build problem-solving skills (*Make a model*)
- Test your designs and ideas! (*Test your model*)
- With your team, continue to discuss and work through design problems. What adjustments can you make in your submarine? How can you design your submarine to raise and lower faster? How would you change the design of the submarine for deeper water depths? (*Reflect and Redesign*)

Ideas to Increase Difficulty:

- Provide teams with materials and supplies, with no directions on how to build their submarine. Instead, have them fully research their designs and which materials to use.
- Create designs for propulsion of their submarines. What materials would be needed to help their submarines move around in a tub of water? Allow teams to test their designs.

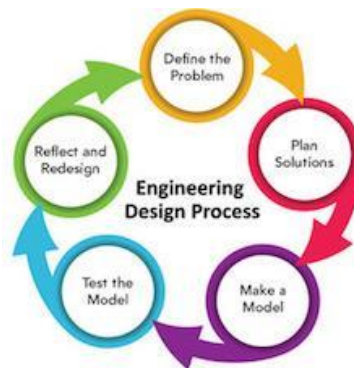


Propelling Our World: Capsized Challenge Background Knowledge

Aim: Design a sailboat from household materials that can move in a range of inclement weather without capsizing.

Problem & Career Focus: Like many inventions, the sailboat probably originated in ancient Egypt. Around 4000 BC, Egyptians assembled a simple rigging system and attached a piece of cloth in the air to pull basic log boats across rivers. These vessels were long and narrow, and their simple rigging was difficult to control. However, the Egyptians discovered they could use the power of wind to do the work instead of oars. By 3000 BC, the sailboat design became more advanced. Naval architects design, build, and maintain many different types of ships, including sailboats. The shape, size, and purpose of different sailboat designs must be able to stay afloat deep waters even in bad weather. Using the engineering design process, your task as a naval architect is to design a sailboat that can withstand different weather conditions.

Engineering Design Process: STEM professionals use the engineering design process as steps to help solve real-world problems. With your team: define the problem, discuss solutions, design, build, test, and improve a prototype of your solution. One of the most important steps of the engineering design process is to reflect and redesign- if your team notices the design of your sailboat isn't working- improve the design. Use the engineering design process steps to guide your exploration during the Capsized Challenge.



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Investigating Questions

- What is capsizing?
- How does the design of a sailboat keep it upright in all types of weather?
- How does the shape of a sailboat hull change its performance in water?

Materials

- Corks (assorted sizes)
- Rubber bands
- Toothpicks
- Craft foam, wax paper, or paper milk carton
- Electrical fan
- Aluminum foil
- Large, empty container
- Tap water

Propelling Our World: Capsized Challenge STEM Career Focus

Career: Naval Architect

Using a combination of art and science, naval architects get to design ship vessels and determine their shapes and sizes. Using advanced engineering tools and a good eye for detail, they conduct research, evaluate vessels' stability and maneuvering characteristics, structures needed to support the forces the ships will experience and the power needed to propel them through waves. Naval architects work closely with marine engineers, who are the experts who design the systems that bring ships to life. Together they design the complete vessel (Images courtesy of Webb Institute).



Essential STEM Skills





Good communication, creative thinking, computer and technological skills, strong in STEM subjects

Subjects of Study



Marine hydrodynamics (study of models to predict behaviors of ships in water systems), engineering courses, science courses, computer science courses and more!







Career Pathway 	<p>Typically need a bachelor's degree in naval architecture. There are opportunities to achieve a higher degree such as master's or doctorate.</p>
Job Overview 	<p>Average salary: Between \$57K to \$150K a year</p> <p>Project Job Growth by 2030: 4%</p> <p>Number of jobs: 10K+</p>

Propelling Our World: Capsized Challenge

Background Knowledge

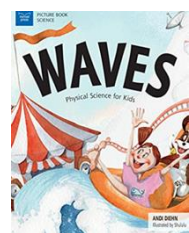

Educational Standards Correlations: Engineering, physics, science

Vocabulary:

<p>Capsizing: A boat overturns in the water, due to poor boat design, bad weather, too much weight on the sailboat, mistake while driving the boat. Ballasts, or added weight, at the bottom of sailboats helps to keep the boat upright.</p>	
<p>Keel: The structural beam that runs in the middle of the boat from bow to stern. This keeps the boat from being blown sideways by the wind and holds the boat right-side up.</p>	
<p>Monohull: A boat with only one hull body.</p>	
<p>Catamaran: A boat with two parallel hull bodies</p>	

Real World Applications: Naval architects have the important job of researching ship hulls to ensure they are safe for humans. Vessels that travel the oceans must withstand dangerous weather. This is an important job!

Literacy Connections:

<p>Waves by Andi Diehn</p> 	<p>The Finest Hours by Michael J. Tougas</p> 	<p>Have You Thanked an Inventor Today? by Patrice McLaurin</p> 
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Propelling Our World: Capsized Challenge

Background Knowledge

Engineering New Ideas in Art and Science!

More than 70% of our planet's surface is covered with water, and our lives are influenced by this fact every day. Whether it's a military vessel patrolling the shores, a large ship carrying goods across an ocean, a smaller ship supporting local industries, or a renewable energy device producing offshore electricity, we rely on water-based industries to support our everyday needs.

Innovation of Sailboats

By early 2000 BC, sailboats had grown in size and usefulness. People learned to move sailboats more reliably using the power of wind and boat designs became more durable and efficient. Historically sailboats, which varied in size, were primarily used for war and for transporting goods for trading. Civilizations from Romans, Vikings and even pirates sailed extensively traveling from one place to another (image below, courtesy of Yachtingworld.com).

In the
and 1600s
ships, or
large
sailboats,



1500s
tall
really

they were becoming the dominant form of merchant and sailing ships. These vessels would continue to increase in size, speed and effectiveness as years progressed. Tall ships of the 17th and 18th centuries were the most modern and capable vessels built, several original examples are still seaworthy to this day!

Sailboat Design

It wasn't until the mid-1600's that sailing small boats became a popular activity beyond work and battles. Documented evidence reveals that sailing up and down the Thames River in England was a popular pastime for royalty (see image below, courtesy of Town & Country). The first yacht club was founded in Ireland around this time.



By the 20th
workboats

century sailing
were not as

common as they were in the past. Sailboats had transitioned their use primarily for recreation and exploration. The sailboat cabin was also popularized, as the need for an open working space and cargo hold largely served no purpose anymore. Modern designs of sailboats use fiberglass instead of wooden planks or plywood. This helped to prolong the life of a sailboat, so the wood wouldn't rot.

Types of Sailboats

Sailboats can be classified into three distinct types based on their primary hull design. These include monohulls, catamarans and multi-hull crafts. Traditionally, monohulls are the most common design for sailboats since they provide storage and overall good vessel stability. However, with the increase in sailing competitions and speed performance, some people prefer the features of catamarans and multi-hull crafts.



Propelling Our World: Capsized Challenge

Background Knowledge

Monohulls are single-hulled structures, that have a large hull beam that provides stability while sailing. The advantage of having a single large hull is the longer beam provides more improved onboard systems (see image below, courtesy of Horizon Yacht.com)



are twin-

that are

specialized compartments to provide strength (see image below, courtesy of Yachting.com). The term originates from the South Indian phrase for “tied pieces of wood” as this was the way traditional boats were built. The advantage of having twin hulls is the increase in stability. If designed properly, the vessel can reach faster speeds than monohull designs.



Multi-craft hulls include vessels with a design between three to five hulls, although the three-hull design is the most common. These are known as trimarans and are considered extremely stable because of their large beam and a lower center of gravity.

Catamarans hulled structures attached by

Three and five hulled vessels are more difficult to manufacture and are rarely used. An example of a three-hull design is shown below (courtesy of Sailing Yachts.com).



Parts

Sailboat and Design

There are multiple parts of a sailboat's design. The central component for any sailboat is the **keel**. The boat keel is important because it must carry the entire weight of the vessel. It is often what the entire craft rests on, needs to have integral strength, and be able to withstand a variety of forces.



the the

While sailing, keel is

lowermost point of the vessel. Sailboats often sit at different heights in the water depending on if the sailboat is designed for competition, leisure, or something else.



Propelling Our World: Capsized Challenge

Background Knowledge

There are many types of keels associated with sailboats: full-length keel, fin keel, centerboard keel, bilge keel, bulb keel and wing keel. Each type of keel is slightly different in size, design and placement on the sailboat.

The other important part of the sailboat design is the sail. Some sailboats have multiple sail designs, each helping the sailboat to move through the water.

The Science of Sailing

The science behind sailing is interesting. Sailboats do not need the wind to push from behind in order to move. The wind can be blowing from the side and the sailboat can still be moving forward. How is this possible?

The answer is the principle of aerodynamic lift. When the wind blows against the sails from the side, this creates a force which has a sideways component and a forward component. However, the sailboat should not move sideways. This would cause it to capsize, and potentially roll over.

To make sure the boat does not capsize, the keel underneath the boat provides the counter force necessary to resist sideways motion of the sailboat. So, the main components that allow the sailboat to move forward are the sail and keel

Sailboat Fun Facts

- Sailing has been a part of the Olympics since 1896
- Sailing around the world westward is more difficult than eastward
- With practice, you could operate a 100-foot sailboat alone
- Sailboats are slow, with a top speed of 10 miles per hour, but multi-hull boats can reach up to 60 miles per hour. The same speed as a car on a highway
- The youngest person to sail across the world was Laura Dekker from the Netherlands. She did it at 16 years old.
- The longest you could sail straight without touching land is 22,229 miles, in theory. Some critics claim it is impossible to navigate a perfect straight line.

Check out these video links!

Naval Architect

<https://www.youtube.com/watch?v=Atm2gxHIO4I>

Ocean Engineer

https://youtu.be/Lj_msWdu7VM

Evolution of Sea Travel

<https://www.youtube.com/watch?v=kupNhlXwGSc>

Sailboat Racing

<https://www.youtube.com/watch?v=zw205QV6Cg0>

Hydrofoil Sailboats Fly Above Water

<https://www.youtube.com/watch?v=L8eq8hoUhBE>

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Propelling Our World: Capsized Challenge

Activity Directions

Aim: Design a sailboat from household materials that can move in a range of inclement weather without capsizing.

Investigating Questions:

- What is capsizing?
- How does the design of a sailboat keep it upright in all types of weather?
- How does the shape of a sailboat hull change its performance in water?

Materials:

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- Corks (assorted sizes)
- Rubber bands
- Toothpicks
- Craft foam, wax paper or paper milk carton
- Electrical fan
- Aluminum foil
- Large, empty container
- Tap water

Criteria & Constraints:

Engineering design challenges (EDCs) are great opportunities for open-ended activities to grow critical thinking and problem-solving skills. EDCs do not typically use a list of directions to build a specific design, rather suggest a framework of designing a solution based on the problem and goal. In this activity your team will be provided materials to create your sailboats using the activity resources. Also, with materials provided create “crew members” that are sitting on your sailboat. Your team of naval architects will have to determine how to design your sailboat to withstand inclement weather and always keep your crew on the ship. This mocked inclement weather will be a fan directed at the tub of water, which can increase wind speeds and create “waves” in the container. How your team chooses to address the problem and goal is entirely up to you.



Sailboat Design:

- Lay out all materials and items available for the challenge. Your first task is to design a sailboat with materials provided. The design needs to be able to survive inclement

weather without capsizing. Plan to give time researching and looking up designs of your sailboat using paper. (*Define the problem, Plan Solutions*)

- Discuss with your team the problem relating to your background knowledge. Your challenge is to not only create the sailboat, but also design a way to use materials provided to keep your sailboat crew members safe. Which materials are important for creating parts of your sailboat to help keep it afloat? Are there any parts of your design your team of naval architects should change or modify? (*Define the problem and plan solutions*)
- Discuss, sketch and determine the ways your sailboat will move in the tub of water. Adults: Allow teams to explore the materials and help them build problem-solving skills (*Make a model*)
- Test your designs and ideas! Turn on the electric fan at varying speeds and observe what happens to your sailboat. (*Test your model*)
- With your team, continue to discuss and work through design problems. What adjustments can you make to your sailboat? How can you design your sailboat to withstand wind and waves? How would you change the design of the sailboat to move faster in the water? (*Reflect and Redesign*)

Ideas to Increase Difficulty:

- Modify the materials provided. Include materials that will not float in water.
- Create a race scenario. Designed boats must compete to reach one side of the tub the fastest. Which design(s) were the most successful? Which performed best in inclement weather? Discuss.



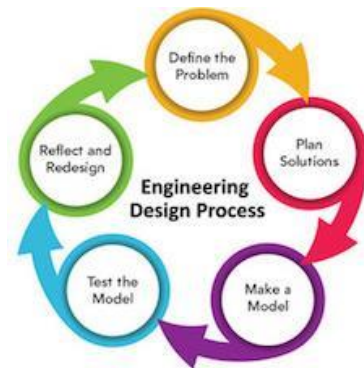
Propelling Our World: Fins! Background Knowledge

Aim: Design a submarine from household materials that can propel itself to move in water.

Problem & Career Focus: When submarines are seen in movie, it appears as if they are moving very slowly but they are actually very fast. The fastest submarines can travel approximately 46 miles per hour. Moving and maneuvering a large submarine underwater is a tricky task because of the forces involved: buoyancy, gravity, pressure and friction. While marine engineers and naval architects design submarines, welders help to build, maintain and repair the parts that help submarines move. They make sure the parts are joined together correctly so the submarine functions properly and safely. Using the engineering design process, your task as a team of welders is to create a submarine by putting its parts together and making it move underwater.

Engineering Design Process:

STEM professionals use the engineering design process as steps to help solve real-world problems. With your team: define the problem, discuss solutions, design, build, test and improve a prototype of your solution. One of the most important steps of the engineering design process is to reflect and redesign- if your team notices the design of your submarine propulsion system isn't working- improve the design. Use the engineering design process steps to guide your exploration during the Fins Challenge.



Investigating Questions	Materials
<ul style="list-style-type: none"> What components make a submarine work? Who helps to create the complete submarine design? How do stabilizing fins help a submarine move? What happens to a submarine's movement without stabilizing fins? 	<ul style="list-style-type: none"> Empty 2-liter soda bottle (1) Empty water bottle (1) Razor blade or knife (Adult needed) Drill (3/32-inch drill bit; should create hole the size of a paper clip) Scissors Pen or needle Needle-nose pliers Large paper clips (2) Chopsticks Ruler Rubber bands Waterproof sealant (such as silicone)



- Tub of water

Propelling Our World: Fins!

STEM Career Focus

Career: Welder

Welders work in all types of environments- working on cars in garages, heavy-duty equipment, and on ships. Shipyard welders either help in the shipbuilding or ship repair processes. They use electrical currents to fuse metals like steel together. They interpret drawings and blueprints to help them understand what they are welding. They use math, material science knowledge and safety precautions while using cutting tools and torches. This job is hot! (Images courtesy of Huntington Ingalls).



Essential STEM Skills



Critical thinking, judgment and good decision making, measurement skills, building and construction, production and processing of materials needed for welding.

Subjects of Study




Advanced mathematics, blueprint reading, hands-on training with welding torches, safety

Career Pathway



Most require training in 3-4 year paid apprenticeships or on-the-job training. A high school GED is typically required.



Job Overview 	Average salary: Between \$45K to \$70K a year Project Job Growth by 2030: 11% Number of jobs: 418,200
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Propelling Our World: Fins!

Background Knowledge

Educational Standards Correlations: Science, physics, mathematics

Vocabulary:

Friction: Fluid friction is the force that resists motion within the fluid itself. It is also known as water resistance

Stabilizing fins: Helps the submarine from spinning around like a tube when the propeller is in motion. The stabilizing fins resist spinning by adding a force of friction, cancelling the spinning motion. This helps the submarine propeller push the submarine forward.

Hydrodynamics: A branch of physics that deals with the motion of fluids and forces acting on solid bodies immersed in fluids. We use hydrodynamics in predicting weather patterns and wave dynamics, measuring flows of water around bridges, gases through pipelines and more!

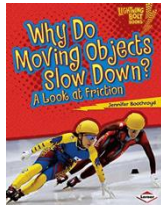
Real World Applications: Friction is not only important in the design and propulsion of submarines, but also in your everyday life. Examples are traction needed to walk without slipping, working an eraser on a piece of paper, holding onto objects, brushing your teeth to remove food and more!

Literacy Connections:



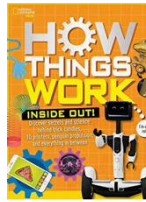
Why Do Moving Objects Slow Down?

by Jennifer Boothroyd



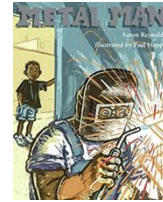
How Things Work: Inside and Out

by T.J. Resler



Metal Man

by Aaron Reynolds





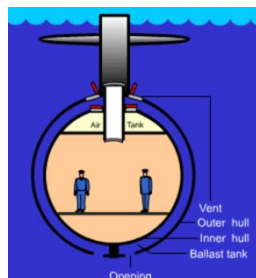
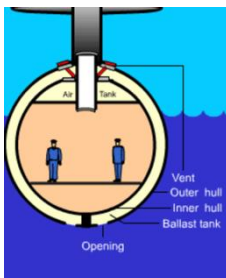
Propelling Our World: Fins! Background Knowledge

Engineering New Ideas in Science

The science of submarines is complex, especially propelling them through the water at or below the surface. Learn more about how submarines use gravity, buoyancy, pressure and friction to explore the ocean depths!

Submarine Science

Submarines are large, heavy vessels that are typically built from types of steel. These ships can float in water or sink to deep depths of the ocean. They are able to float because the ship displaces the weight of water equal to the weight of the ship. It uses buoyant forces, the displacement of water in an upward force through controlling the water in their ballast tanks (see image below, courtesy of How Stuff Works).



This explains how the submarine moves up and down, but not how they move forward in water. One way is to use a propeller, but there is a secret to this movement. When the propeller spins, it can also spin the submarine like a spinning tube.

Stabilizing fins help to keep moving the submarine forward, without spinning like a top in the water. The stabilizing fins resist spinning by adding a force of friction, which cancels the spinning motion and pushes the propeller and submarine forward. This can also help the submarine move in reverse, or backward (Images below courtesy of Wikipedia).



Submarine Fun Facts:

- Submarines have been used since the American Civil War.
- The first periscope was used in 1854 and created by French inventor Edme Hippolyte Marie-Davy.
- Satellites can be used to track some submarines.
- The cheapest submarine will cost you about \$600,000.
- Subs can remain underwater for several months with people aboard, although they can remain underwater for up to 25 years (without a human crew).
- A submarine is driven by at least four people.



Propelling Our World: Fins!

Activity Directions

Aim: Design a submarine from household materials that can propel itself to move in water.

Investigating Questions:

- What components make a submarine work?
- Who helps to create the complete submarine design?
- How do stabilizing fins help a submarine move?
- What happens to a submarine's movement without stabilizing fins?

Materials:

- Empty 2-liter soda bottle (1)
- Empty water bottle (1)
- Razor blade or knife (Adult needed)
- Drill (3/32-inch drill bit; should create hole the size of a paper clip)
- Scissors
- Pen or needle
- Needle-nose pliers
- Large paper clips (2)
- Chopsticks
- Ruler
- Rubber bands
- Waterproof sealant (such as silicone)
- Tub of water

Criteria & Constraints:

Engineering design challenges (EDCs) are great opportunities for open-ended activities to grow critical thinking and problem-solving skills. EDCs do not typically use a list of directions to build a specific design, rather suggest a framework of designing a solution based on the problem and goal. In this activity, your team will be provided a set of steps to create your submarine hulls but will have to determine where your stabilizer fin must be attached. How your team chooses to address the problem and goal is entirely up to you.

- Lay out all materials and items available for the challenge. Your first task is to design a submarine with materials provided. Plan to give time researching and looking up designs of submarines using paper. (*Define the problem, Plan Solutions*)

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Making the Submarine:

- Drill a hole into the bottom of your water bottle. The hole should be the size hole that a paper clip can fit through.
- Using chopsticks, feed an opened paperclip from the top of the water bottle down to the bottom hole created. Hook the paper clip through the bottom hole so it attaches to the water bottle. The paper clip acts like the metal welders would use to attach parts of the submarine.
- Use the chopsticks to hook a rubber band to the paper clip at the bottom of the water bottle.

Making the Propeller

- Your team needs to now make your submarine propeller. To begin making the propeller, cut the bottom half of the 2-L soda bottle. Cut the bottle, as shown by Science Buddies. Make a propeller shape that has five separate curved blades. Be careful! Get an adult's help with this, the plastic is thicker in some places.

- Drill a hole into the bottle two holes into the and another close to the
- Using scissors, cut a small remains of the 2-L bottle. the same size and shape This piece will go in the propeller. This will help and friction which will help a pen or a needle carefully poke a hole so the tip of the paper clip can slide through.



cap of the water bottle. Drill propeller, one in the center center.

circle of plastic out of the The circle should be about as the submarine bottle cap. between the bottle cap and to create a slippery surface the propeller spin. Using a

- Straighten one end of the paper clips and feed it through the hole of the bottle cap, then finally through the center hole of the propeller. The propeller fins need to face down, curved away from the bottom of the bottle cap.
- Using needle-nosed pliers, bend the inside of the paper clip, looping it through the second off-center hole in to secure the two pieces together. The paper clip acts similar to the metal welders would use to attach parts of the submarine.

Putting All the Pieces Together

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- Using chopsticks, grab the rubber-band that's already inside the submarine. Pull the rubber-band and loop it through the paper clip that is attached to the bottle cap (image below courtesy of Science Buddies). Using the waterproof sealant, make sure all holes are fully sealed.



- Discuss with your team your background challenge is to not only but also figure out how water using the are you going to use as will you place the fin on Which materials are propulsion for your any parts of your welders should modify? *(Define the problem and plan solutions)*
- Discuss, sketch and determine the ways your submarine will move in the tub of water. Adults: Allow teams to explore the materials and help them build problem-solving skills *(Make a model)*
- Test your designs and ideas! Observe what happens to your submarine. Is it floating? Is it sinking? How can you use what you've learned about submarines to help it move through water? *(Test your model)*
- With your team, continue to discuss and work through design problems. What adjustments can you make to your submarine? How can you design your submarine to move faster? How would you change the design of the submarine to change directions? *(Reflect and Redesign)*

the problem relating to knowledge. Your create the submarine, to make it move through materials you have. What the stabilizing fin? Where your submarine design? important for creating submarine? Are there design your team of

Ideas to Increase Difficulty:

- Encourage teams to use their own submarine designs (Do not provide step-by-step directions on building their submarines)
- Alter the materials provided (add more, remove materials, etc.)