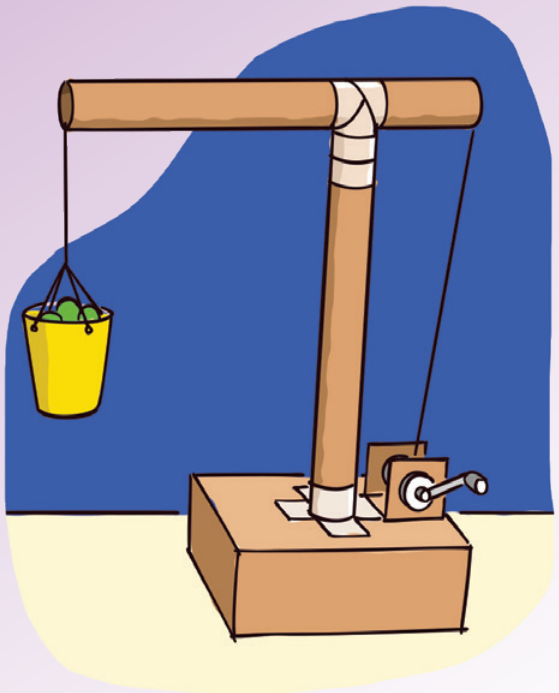
Junior Mechanical Engineering

Develop your mechanical engineering skills by earning these three badges!

Badge 1:
Paddle Boat Design Challenge

Badge 2:
Balloon Car Design Challenge

Badge 3:
Crane Design Challenge



This Mechanical Engineering badge booklet for girls provides the badge requirements, information, and fun facts about engineering for all three (LEVEL) mechanical engineering badges. It does not include all the information needed to complete the badges. Volunteers may access full meeting plans—including detailed activity instructions—on the Volunteer Toolkit (VTK) or by contacting their local council.

Welcome to the world of mechanical engineering!

When you've earned these three badges, you'll know how to use the Design Thinking Process to solve problems like an engineer.

Every day, a mechanical engineer invents another machine to help people or solve a problem—such as nonpolluting cars or a better hearing aid.

Who knows what machines we'll need next! If solving problems excites you, you may want to think about becoming a mechanical engineer so that you can invent these machines yourself!

Badge 1: Paddle Boat Design Challenge

People have been traveling by water for thousands of years. At first, boats, such as canoes, were powered by people. Later, boats were built to use other forms of energy to move, like catching wind in a sail.

While earning this badge, you'll explore how paddle boats work and use the Design Thinking Process to engineer your own paddle boat.

Steps

1. **Explore how paddle boats work**
2. **Design and build a rubber band-powered paddle boat**
3. **Test your rubber band-powered paddle boat**
4. **Analyze and share your results**
5. **Brainstorm ways to improve your design**

Purpose

When I've earned this badge, I will know how to build and test a paddle boat and understand buoyancy, potential energy, and kinetic energy.

Why Do Boats Float?

Buoyancy is the force or pressure that pushes back against an object in the water. Objects in the water push some of the water out of the way. The water pushes back against the object with the same force as the water it displaces. If an object is heavier than the water it displaces, it will sink.

STEP 1

Explore how paddle boats work

If you've ever paddled a canoe or used the oars on a rowboat, you know that making a boat move takes lots of energy. As boats got bigger, people had to find new kinds of energy (besides just rowing). Some ships use sails. Others have engines powered by steam or electricity. There are even some submarines powered by nuclear energy! All these boats move by using potential energy that is released into kinetic energy.

In the 1800s and early 1900s, steam-powered paddle boats became very common.

STEP 2

Design and build a rubber band-powered paddle boat

Engineers solve problems. When an engineer is working on a project, she asks lots of questions and then experiments to find the answers.

When tackling a problem, she follows certain steps which are called the Design Thinking Process. Use the Design Thinking Process to design and build your rubber band-powered paddle boat.

WORDS TO KNOW

- An **axle** is a bar or spindle on which things can rotate, such as a rod passing through the center of each paddle.
- **Ballast** is weight that is used to keep a boat upright.
- **Buoyancy** is the force or pressure that pushes back on an object in the water. When an object is placed in water, it causes the water to push against it with the same force as the weight of the water it displaces. This is called Archimedes' Principle.
- The **Design Thinking Process** is the way engineers solve problems and build solutions. They define the problem, brainstorm and plan, build, test, and improve.
- **Engineers** are people who solve problems. They use their imaginations to invent new things like self-driving cars. They also come up with new and better ways to build things such as bridges, buildings, and planes.
- **Force** is the strength or energy that creates movement. Push and pull are examples of forces.
- **Kinetic energy** is when potential energy is released. Kinetic energy makes bodies and objects move.
- **Potential energy** is the energy stored in your body and everything else in our world.
- A **prototype** is a quick way to show your idea to others or to try it out. It can be as simple as a drawing or it can be made with everyday materials like cardboard, paper, string, and rubber bands.

People Power

People use their arms and legs to power boats every day. Rowboats move by people pushing and pulling on oars. Some people even race in special row boats called sculls or racing shells. Canoes, kayaks, stand-up paddleboards, and gondolas are other examples of boats moved by paddles or oars. Rafts or punts are moved by people pushing a pole into the bottom of the river. And some boats are powered by people pedaling, moving paddles like the ones in a paddle boat.

STEP 3 Test your rubber band-powered paddle boat

So you built a paddle boat, but how do you know if it works? Engineers always test their inventions to learn about what works and what doesn't. They don't expect their products to work perfectly the first (or even second or third) time they test them.

In fact, engineers use what they learn from failures in their tests to change and improve their inventions. Failing is an important part of the design process. Now you have a chance to see your paddle boat in action!

STEP 4 Analyze and share your results

When engineers test their inventions, they usually are surprised by what happens. They take time after the test to think about what happened and what they can learn from it. Thinking about test results carefully is called "analyzing."

Sharing your results with others is an important step, too, because other people may have great ideas about your project. Think carefully about what happened when you tested your paddle boat and talk with others about what happened and what you, and they, think it means.

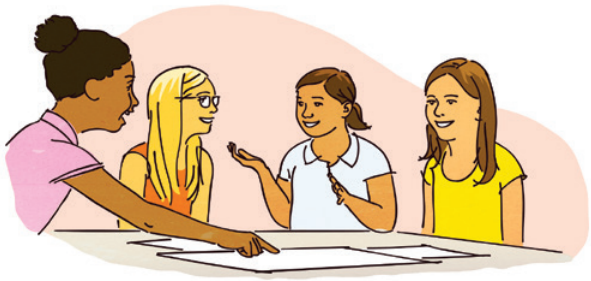
RESULTS

DESIGN THINKING PROCESS

The Design Thinking Process is the way engineers solve problems and build solutions.

DEFINE THE NEED

BRAINSTORM SOLUTIONS



DESIGN

BUILD

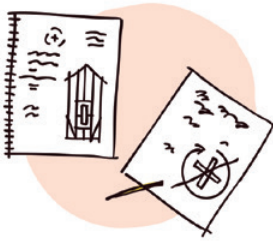
TEST & EVALUATE

GOOD TO GO!

SHARE YOUR WORK

ITERATE & IMPROVE

REDESIGN



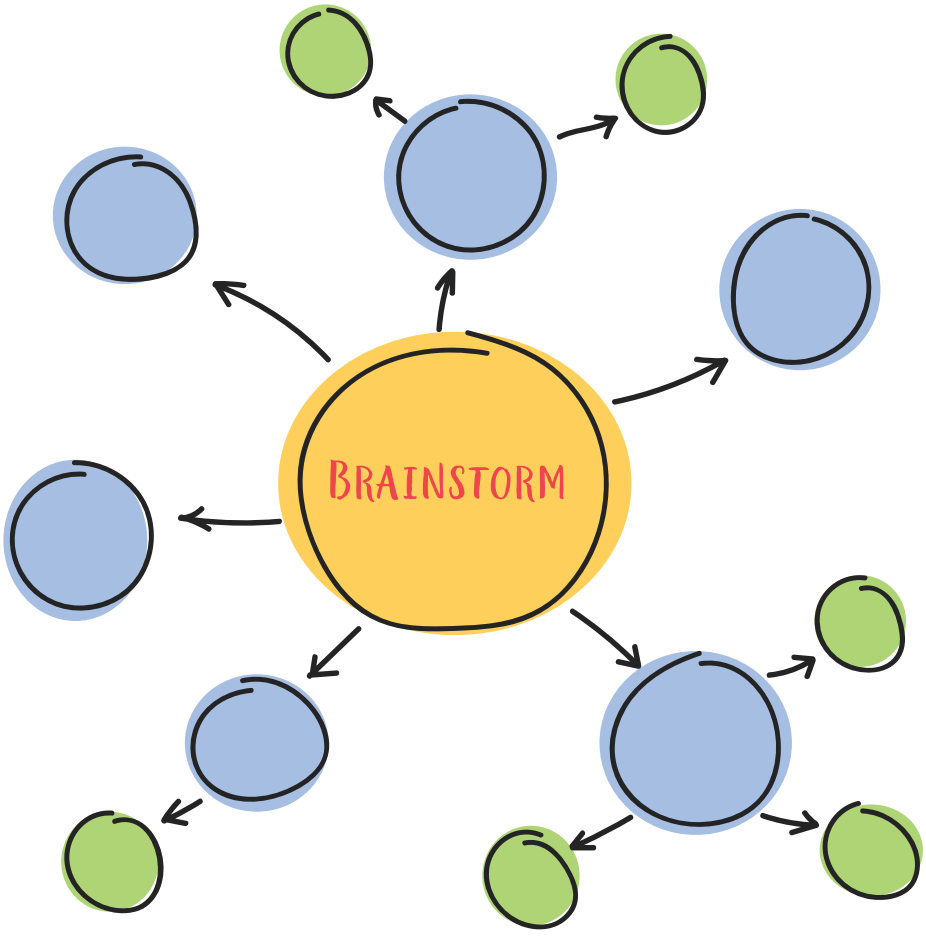
STEP

5 Brainstorm ways to improve your design

Engineering is about making things better. When you invent something, making changes to your original idea is part of the process.

Sometimes your test results will clearly show what kind of changes you should make, but sometimes you have to use your imagination. Brainstorming with fellow engineers is a great way to come up with design improvement ideas and add more ways of thinking about your problem.

Now that you've analyzed your testing results, how could you improve your paddle boat?



IMPROVEMENTS

Now that I've earned this badge, I can give service by:

- Encouraging my friends and Girl Scout sisters to explore science and engineering.
- Using the Design Thinking Process to solve problems for others.
- Teaching others about potential energy, kinetic energy, and buoyancy.

I'm inspired to:

Badge 2: Balloon Car Design Challenge

Can you imagine riding in a horse-drawn carriage to get to school? It wasn't so long ago that most people used animals as their main form of transportation, but over time we've come up with different ways to fuel our rides. Today, the gasoline-powered car is how most people get around, but engineers continue to explore how other kinds of energy can move vehicles. In this badge, you'll learn about air power and create an alternative fuel car.

Steps

1. **Learn about potential and kinetic energy**
2. **Design and build a balloon car**
3. **Test your balloon-powered car**
4. **Analyze and share your results**
5. **Brainstorm ways to improve your design**

Purpose

When I've earned this badge, I will know how to engineer a balloon-powered car and understand potential energy, kinetic energy, and jet propulsion.

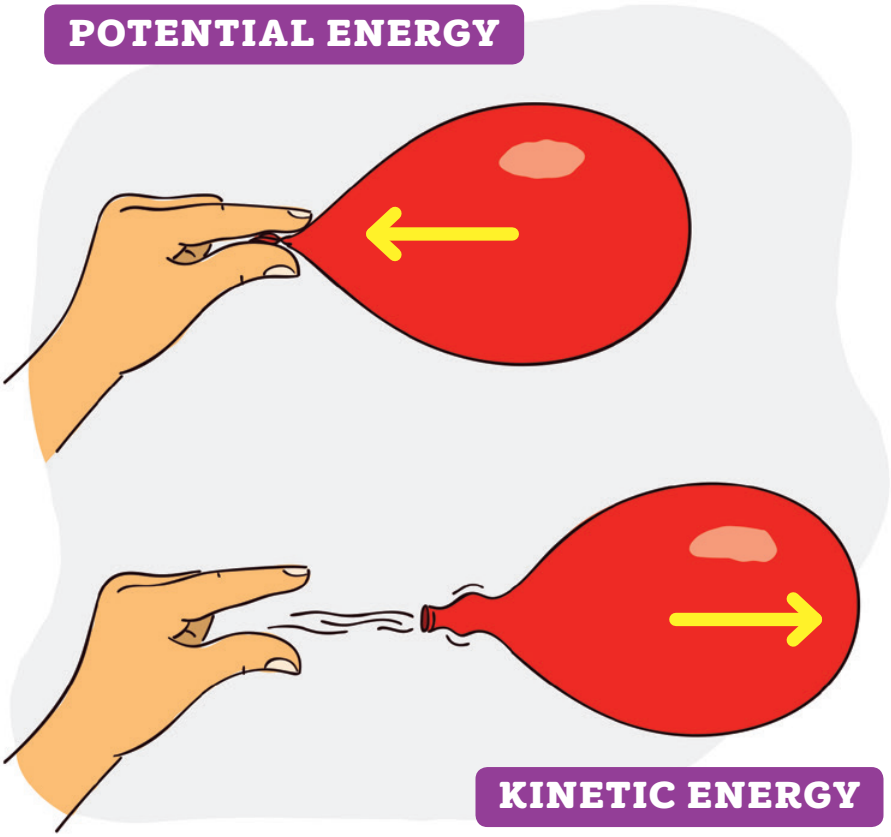
STEP

1 Learn about potential and kinetic energy

Engineers have to understand all aspects of their project. That means knowing about the materials they can use, what those materials can do, and how scientific concepts can affect their project.

If an engineer wants to make an invention that moves, she has to know about potential and kinetic energy. There are lots of ways to store potential energy—in batteries, in springs, and even in your muscles. No matter how it is stored, when potential energy gets converted to kinetic energy, things MOVE! For example, when you bend your knees, they store potential energy that turns into kinetic energy that lets you launch up and jump!

How can you use air as your car's source of energy?



Jet Propulsion

Airplanes use jet engines to fly us quickly from one place to another. Airboats use huge fans to push flat-bottomed boats around shallow water like the Everglades. Astronauts use jet packs to move around outside their spacecraft. And squids, octopuses, and even some jellyfish use jet propulsion to shoot themselves through the water.

The reason they all move is that the air or water shooting away from the object pushes it in the opposite direction. In the late 1600s, Sir Isaac Newton, an English scientist, philosopher, and mathematician, figured out that for every action, there is an equal and opposite reaction (Newton's Third Law), which explains jet propulsion.

WOMEN INVENTORS

What do windshield wipers, disposable diapers, and paper bags have in common? They were all invented by women.

The paper bag with a flat bottom was invented by **Margaret Knight** in 1868. Before she changed the design, paper bags were shaped like envelopes and couldn't stand up on their own.

Mary Anderson invented the first windshield wipers for cars in 1903. Her version had a lever to pull that would clear rain or snow from the windshield. At first, people didn't think it was a good idea, but by the 1920s, cars had automatic windshield wipers.

No more soggy diapers! **Marion Donovan** invented a waterproof cover for cloth diapers out of a shower curtain in 1951 and sold it at Saks Fifth Avenue, a fancy clothing store. A few years later, she invented the first completely disposable paper diaper.

STEP 2 Design and build a balloon car

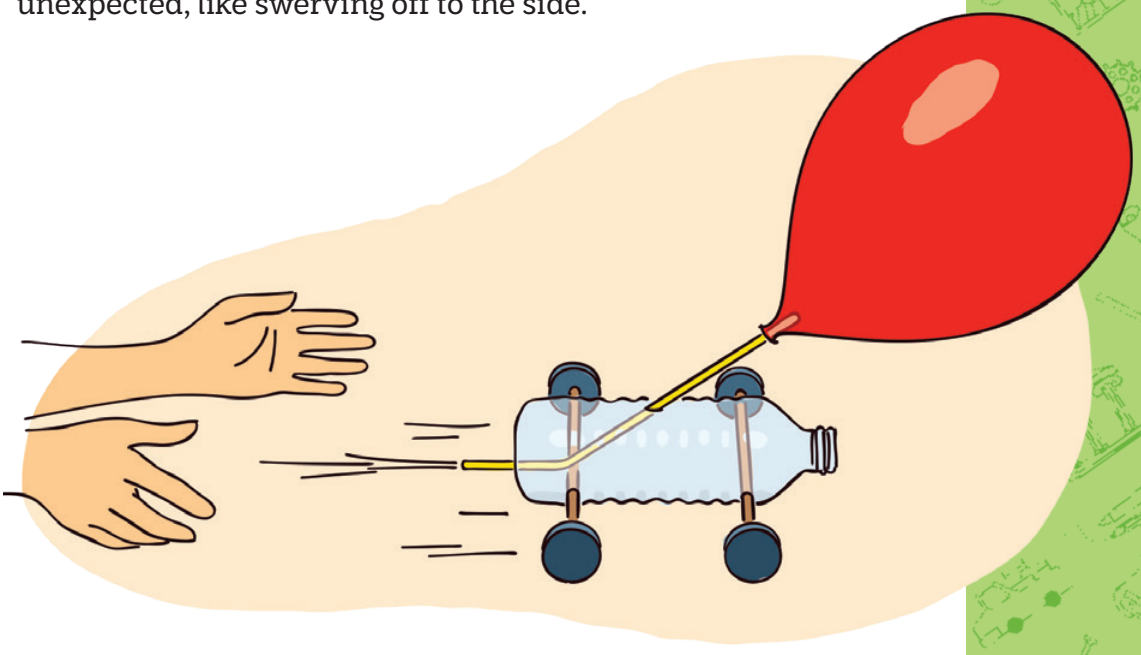
Engineers use ideas like potential and kinetic energy to build things. They also use the Design Thinking Process to guide them as they imagine, design, build, test, and improve their ideas.

Use what you know about energy, thrust, and jet propulsion to design and build your balloon car.

STEP 3 Test your balloon-powered car

In school, you take a test after a number of classes to measure how much you know. Engineers use tests *while* they are developing new products to help them learn about what is working and what isn't.

In many ways, testing an invention isn't the end of the process, but a new beginning. Testing your balloon-powered car will let you see not only how fast it goes, but also if it does anything unexpected, like swerving off to the side.



Jet Cars

Cars powered by jet engines are the fastest around. They use fuel-powered engines to create jet propulsion. Sometimes they are used in drag races, and they've also been used to set land speed records. The fastest jet car went more than 760 miles per hour over one mile!

FEEDBACK

STEP 4 Analyze and share your results

Engineers think about what their results mean after they test their inventions. For example, they might ask themselves questions like, "My car didn't drive straight—why?" or "My invention didn't work—what happened?" When an engineer thinks carefully about what happened during a product test, she analyzes her results. She can learn as much—and maybe even more—from analyzing a failure instead of a success.

By sharing, she invites others to offer their ideas about her project. She could also inspire someone else working on a different, or even similar, problem. Ask "why?" to find out what happened to your car during testing.

STEP 5 Brainstorm ways to improve your design

Engineering is a process—a series of steps to achieve a goal. An engineer's goal is to build the best possible solution to a problem. That means looking for ways to improve on her first (or second or third) design of a product.

Working with other people to imagine improvements is a good idea. If you only work alone, you might miss some good ideas for change. Brainstorm with others how to improve your balloon car design.

ALTERNATIVE POWER FOR CARS

Most of the cars on the road today burn gasoline or diesel to make their engines run. That's a problem because those cars create pollution and our fuel supply is limited. Now, engineers are exploring all kinds of ways to power vehicles to find a solution that is good for people and the environment.

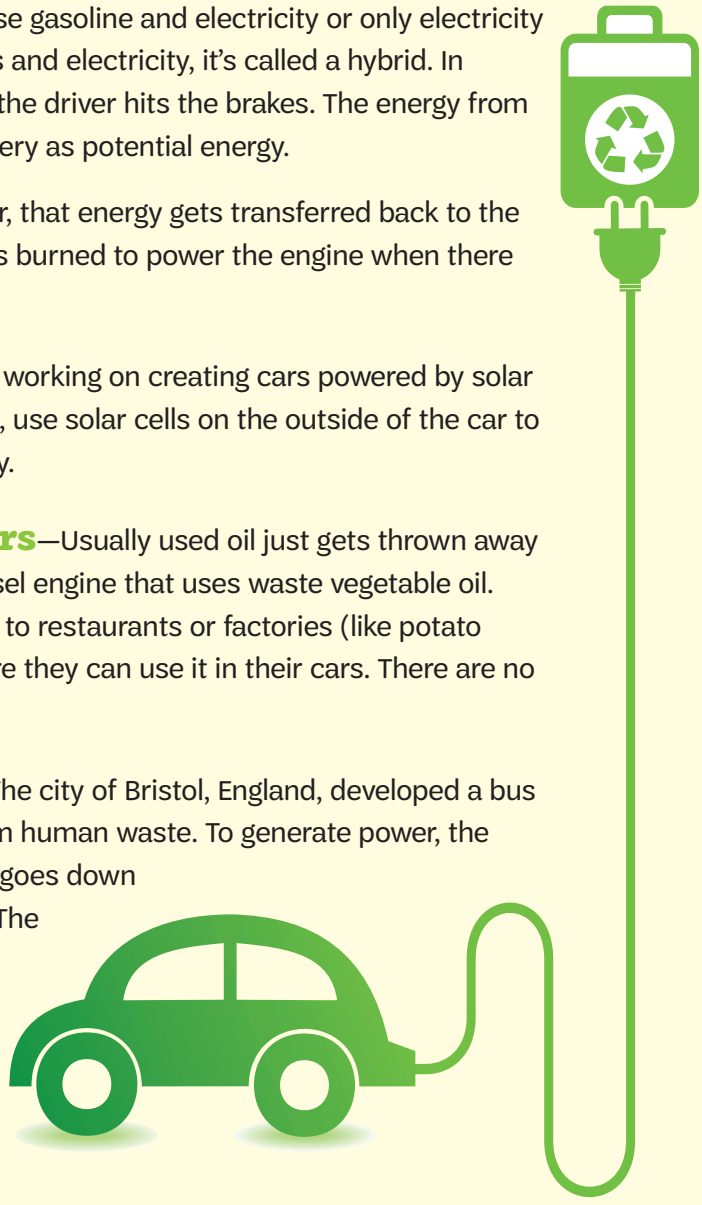
Electric cars—You can buy cars that use gasoline and electricity or only electricity to make them run. When a car uses both gas and electricity, it's called a hybrid. In hybrids, the electric energy is created when the driver hits the brakes. The energy from the moving wheels gets transferred to a battery as potential energy.

Then, when the driver pushes the accelerator, that energy gets transferred back to the axle and wheels as kinetic energy. Gasoline is burned to power the engine when there isn't enough energy in the battery.

Solar-powered cars—Engineers are working on creating cars powered by solar energy. Some designs, like the German Sono, use solar cells on the outside of the car to collect solar energy and turn it into electricity.

Used vegetable oil-powered cars—Usually used oil just gets thrown away after cooking, but it's possible to make a diesel engine that uses waste vegetable oil. The main challenge is that drivers have to go to restaurants or factories (like potato chip factories) to get the oil and filter it before they can use it in their cars. There are no veggie oil filling stations yet!

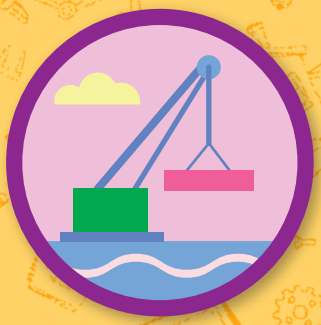
Human waste-powered cars—The city of Bristol, England, developed a bus that runs on biomethane—a gas created from human waste. To generate power, the local sewage treatment plant converts what goes down the toilet and food waste into methane gas. The bus fills up its tank at the sewage treatment plant and drives all over town. These buses produce less pollution than traditional buses, and they are quieter, too!



Now that I've earned this badge, I can give service by:

- Encouraging my friends and Girl Scout sisters to explore science and engineering.
- Using the Design Thinking Process to solve problems for others.
- Teaching others about the scientific concepts I learned, such as jet propulsion, thrust, and potential and kinetic energy.

I'm inspired to:



Badge 3: Crane Design Challenge

For thousands of years, people have used cranes to build very tall buildings and move heavy objects. As the size and shape of the buildings we make change, so has the crane's design. A crane might look complicated, but it's just a combination of simple machines. Learn about simple machines, and how they work together, and then build your own heavy-lifting crane.

Steps

1. **Explore simple and compound machines**
2. **Design and build a crane**
3. **Test your crane**
4. **Analyze and share your results**
5. **Brainstorm ways to improve your design**

Purpose

When I've earned this badge, I will know how to build and test a crane and understand simple and compound machines.

Heavy Lifting

The ancient Greeks and Romans used cranes to lift heavy objects and construct some of their most famous buildings. They used people or animals to pull the ropes that would run through pulleys and along the arm of the crane to lift.

The French improved on crane design in the Middle Ages to move freight out of ships and to build Gothic cathedrals.

Today, cranes use internal combustion engines (like the ones in cars), electric motors, or hydraulics for power. Cranes are still used in shipyards and construction sites, and there are even floating cranes to help with bridge and offshore construction projects.

STEP 1 Explore simple and compound machines

Archimedes was an ancient Greek philosopher, but he was also a scientist and an engineer. He discovered the principles of mechanical advantage, or how using a tool like a lever can multiply a person's strength or ability. He explored different types of simple machines and how they can be used together to make compound machines.

Be like Archimedes and learn about what simple and compound machines can do for you!

STEP 2 Design and build a crane

If you aren't super strong, you'll need help lifting something really heavy. That's ok, though, because as an engineer, you can design and build a crane to help you.

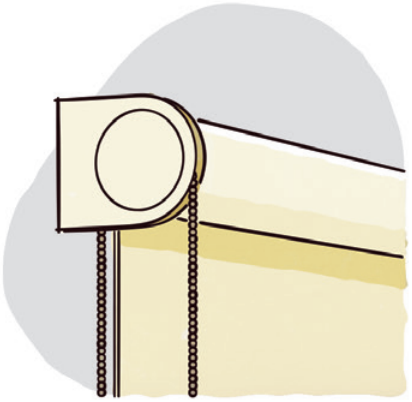
Engineers use the Design Thinking Process to imagine solutions to their problems, and then design and build a product that might work. They apply scientific ideas and use the materials available to make their invention.

Now it's your turn to engineer a heavy-lifting crane. Use what you know about simple machines and the materials you have on hand to build your crane.

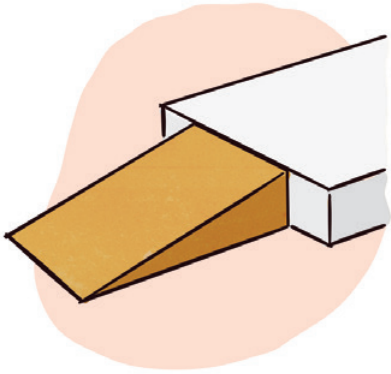
IDEAS

SIMPLE MACHINES

People use versions of simple machines every day, either on their own or together as compound machines.



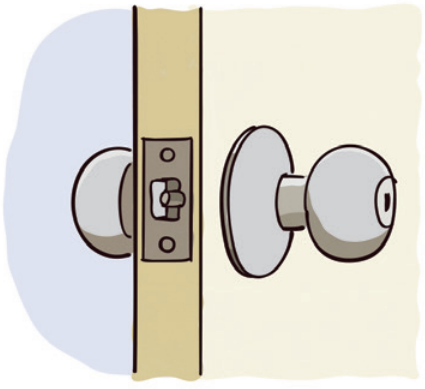
PULLEY



WEDGE

LEVER

SCREW



WHEEL AND AXLE

RESULTS

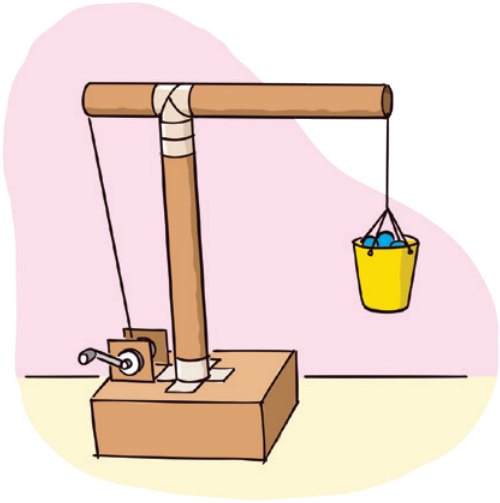
STEP 3 Test your crane

Before an engineer sends her newly designed crane to work on a big job, she wants to be sure her crane will perform the way she needs it to.

Engineers test their inventions as part of the Design Thinking Process, so that they can fix or improve things that don't work as well as they could.

Testing provides valuable information, or data, that engineers use to make a better final product.

Test your crane to see how much weight it can lift. Record your observations and results each time you test.



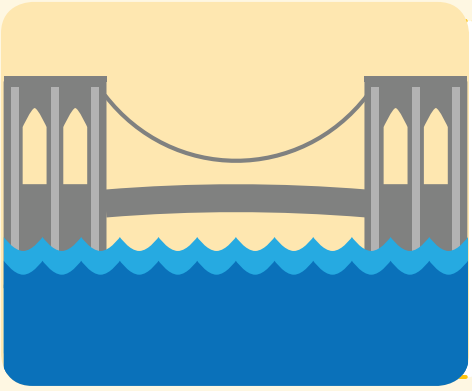
STEP 4 Analyze and share your restults

Data is information that engineers receive, collect, or observe about their design. Collecting data about how an invention performs is one task an engineer does all the time. Using that data is another.

Engineers think carefully, or analyze, their test results to better understand how their inventions work or don't work. They share their results and analysis with others to get feedback on their project, looking for the best possible understanding of what happened.

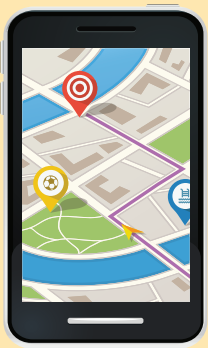
When you analyze and share the results of your crane test with your fellow engineers, you are taking an important step in making a better crane.

WOMEN ENGINEERS



In the late 1800s, **Emily Warren Roebling** took over the job of chief engineer during the construction of the Brooklyn Bridge when her husband, who had the job, was too sick to work. She ended up overseeing the completion of the biggest engineering project of its time.

Actress Hedy Lamarr created the basis for today's Wi-Fi, GPS, and Bluetooth when she was trying to make a secret way for soldiers to talk to each other during World War II. She also improved airplane design by studying birds and fish, combining different features from both animals to make planes that can fly faster.



Special superstrong fabric isn't just for superhero capes. **Stephanie Kwolek,** a research chemist, invented Kevlar, a fire-resistant, lightweight, strong material that is used in bulletproof vests, crash helmets, and other protective clothing.

Job Opening

If you want to work in a crane, you'd better like climbing! You also need to be really good at moving small objects, concentrating, and communicating with others.

The operators for tower cranes, like the ones you see at construction sites, have to climb up ladders (200 to 500 feet every day) to get to their "offices." Once they are in their "cab," they sit in a special moving chair and work a joystick and a lever to move the crane arm and to lift and lower things.

Crane operators have to be very precise because an inch of movement in the lever or joystick translates into a much larger movement by the crane and its cargo. When you're moving heavy objects through the air, you have to talk with folks on the ground to make sure you're doing that safely. While construction jobs used to be only done by men, more and more women are getting into the industry, including doing jobs as crane operators.

STEP 5

Brainstorm ways to improve your design

Engineers love solving problems and working together to make the best inventions possible. Brainstorming, or working with others to imagine all kinds of improvements, is one way engineers help each other make their designs better.

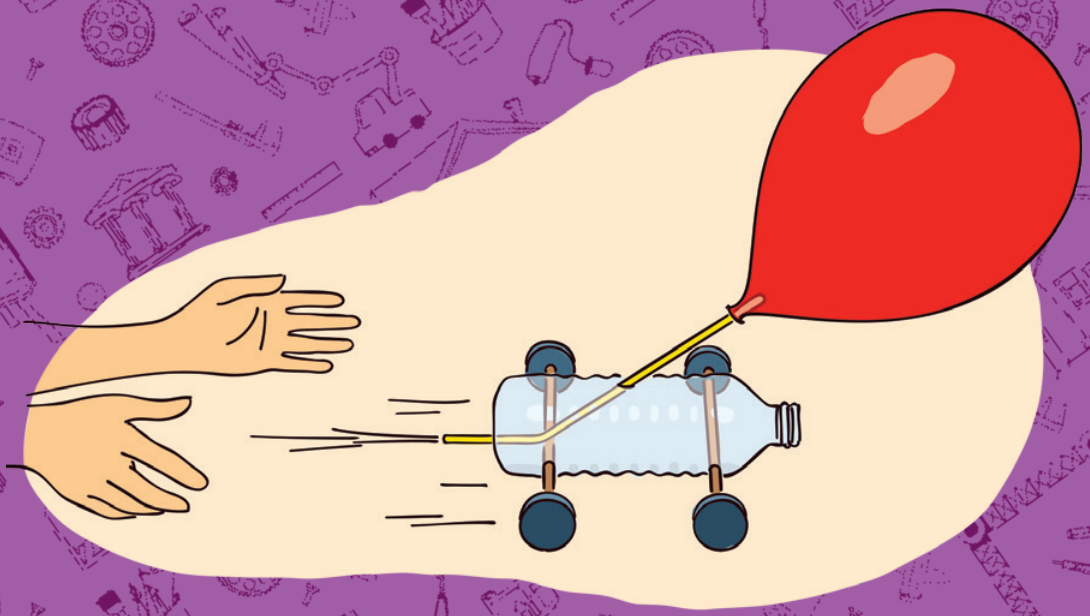
When you are brainstorming, no idea is too crazy, so write them all down. Brainstorm ways to improve your heavy-lifting crane by analyzing your test results and using what you've learned.

IMPROVEMENTS

Now that I've earned this badge, I can give service by:

- Encouraging my friends and Girl Scout sisters to explore science and engineering.
- Using the Design Thinking Process to solve problems in my community.
- Teach others about simple or compound machines or the Design Thinking Process.

I'm inspired to:



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