

GRADE 1 ENGINEERING & PHYSICS

First edition

8 units

32 lessons + Toy Lab

A video for every lesson

FIRST EDITION

COURSE GUIDE

This course is a first year of engineering for six- and seven-year-olds. It follows the same eight strands every School Launch grade follows: machines, bridges, buildings, electricity, the water and power that come to our homes, boats, flight and robots. Each week begins with a true story: farmers lifting water with a shadoof, George Ferris building his giant wheel, the Roeblings and the Brooklyn Bridge, Gustave Eiffel's iron tower, Benjamin Franklin and his kite, the Pilgrims' *Mayflower*, and the Montgolfier brothers' balloon.

Every lesson follows the same simple path, written to be read aloud. First comes **Long ago**, the story. Then **Why does it work?**, the science underneath, in a few short sentences. Then **How do builders use it?**, the way engineers turn the idea into something safe and useful today. Then your child builds a small version with cardboard, paper cups, craft sticks, foil and pennies, makes a guess, tests it, counts or measures what happens, and tries to make it better.

God made an orderly world that we can test and understand, and He made people in His image to be makers. A strong bridge, clean water and a light in a dark room are ways of loving our neighbors. The old Latin saying *Fabricando fit faber*, "by making, one becomes a maker," is the whole idea of this course.

Most videos come from trusted children's science channels, chiefly SciShow Kids, Free School and Next Generation Science, with others from NASA, Maddie Moate, Design Squad, the Science Channel, and water and power companies. Each one was previewed for content, accuracy and age. Videos for this grade are short, usually two to seven minutes. Some end with an invitation to subscribe or a few seconds of other video suggestions; you can stop when the teaching ends. Watch together, and pause where the lesson suggests so your child can guess what comes next.

WHO IT IS FOR

Written for first graders (about ages 6–7). A parent reads the lessons aloud; no reading is required of the child, though early readers will enjoy the key words. Builds are made for small hands with a grown-up helping. No kits are required: every build uses household or inexpensive craft-store materials. A few units list optional kits for families who want them.

HOW TO USE THIS COURSE

1. **The weekly rhythm.** The year has 32 lessons, one a week. Session 1 (about 30 minutes) is the warm-up, the story, the video and the picture study. Session 2 (about 30 minutes) is the build and the engineer's notebook. In the last week of each unit, add a short third session for the unit review and the portfolio build.
2. **Reading aloud.** The core ideas are short paragraphs written for you to read aloud. After each one, stop and ask your child to tell it back in his or her own words. Let your child hold or point to real things as you read: a spoon for a lever, a toy car for a wheel and axle, a cup of water for a boat.
3. **Picture study.** Each lesson has one old photograph, drawing or painting. Look at it together quietly for one or two minutes. Then turn it over and ask your child to tell everything he or she remembers. Turn it back and go through the “look for” items and questions, which point to how the thing in the picture works.
4. **The engineer's notebook.** Give your child a sturdy notebook with blank or graph-paper pages for the whole year. For each build, your child draws a picture first and makes a guess (“I think it will hold 10 pennies”). Then you help write down what happened: counts, tally marks, “farther” or “not as far.” Last, draw what you would change. Write the date on every page. Honest records matter more than big numbers: “a just weight is his delight” (Proverbs 11:1).
5. **Fair tests and trying again.** First graders can learn the most important rule of testing: change only one thing at a time. Most builds ask your child to test two versions the same way and compare them. Every build ends with a “make it better” round. A build that fails and is then improved has taught more than one that worked the first time.

6. **Optional kits.** Some units list kits such as a KiwiCo Kiwi Crate, KEVA Planks, Snap Circuits or a Bee-Bot floor robot. They are extras for families who enjoy them. Every lesson can be done without them.
7. **Unit review and portfolio.** Each unit ends with a friendly oral review with no points: you ask, and your child answers by telling, pointing, drawing or building. Then comes a portfolio build that uses the unit's ideas, such as a craft-stick bridge tested with pennies or a boat that carries a cargo. Keep the notebook pages and a photograph in a folder for the year.
8. **Safety.** Read the safety note before each build. A grown-up stays close for every build. Electricity in this course comes only from AA, C or D batteries, never from the outlets in the wall. A grown-up handles scissors with points, hot glue and anything sharp. Wear safety glasses for anything that flies or snaps. Never fly a kite near power lines or in a storm.
9. **Toy Lab (optional).** Unit 9 is a bonus unit about the science of toys: the yo-yo, marbles, the kaleidoscope and the jack-in-the-box. Use it after the family engineering fair, over the summer, or any week that needs something fun. It follows the same pattern as every other unit, with a story, a build and a friendly review.
10. **The family engineering fair.** In the last week, set out your child's favorite build from each unit with its notebook page, and invite family or friends. Let your child explain each one. Telling others how your work was made is part of being an engineer.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–4

Simple Machines

Levers and the seesaw, the wheel and axle and George Ferris’s great wheel, ramps that carried canal boats over hills, and pulleys for lifting a bucket on a rope.

- 1.1 Levers and the Seesaw
- 1.2 The Wheel and Axle: George Ferris’s Great Wheel
- 1.3 Ramps: Boats That Climbed Hills
- 1.4 Pulleys: A Bucket on a Rope

UNIT 3 • WEEKS 9–12

Buildings

Building materials and the wise man who built on the rock, strong shapes and the triangle, the pyramids of Egypt, and Gustave Eiffel’s iron tower.

- 3.1 Building Materials and the House on the Rock
- 3.2 Strong Shapes: The Triangle and the Barn Raising
- 3.3 The Pyramids of Egypt
- 3.4 The Eiffel Tower

UNIT 2 • WEEKS 5–8

Bridges

Beam, arch and suspension bridges; a craft-stick beam bridge tested with pennies; the Roman arch and the aqueducts; and the story of the Roebling family and the Brooklyn Bridge.

- 2.1 Beam, Arch and Suspension Bridges
- 2.2 A Craft-Stick Beam Bridge
- 2.3 The Roman Arch and the Aqueducts
- 2.4 The Brooklyn Bridge: A Family Builds a Bridge

UNIT 4 • WEEKS 13–16

Electricity

A battery-and-bulb circuit and Volta’s first battery, conductors and insulators, magnets and the compass, and Benjamin Franklin’s kite and the lightning rod.

- 4.1 A Battery and a Bulb: Volta’s Pile
- 4.2 Conductors and Insulators: Stephen Gray’s Long Thread
- 4.3 Magnets and the Compass
- 4.4 Benjamin Franklin’s Kite

UNIT 5 • WEEKS 17–20

Water, Power and Roads

Water towers and pipes, how electricity travels from a power plant to your lamp, sewers and the treatment plant, and the mail, telephone lines and roads that connect us.

- 5.1 Water Towers and Pipes
- 5.2 From Power Plant to Your Lamp
- 5.3 Sewers and the Treatment Plant
- 5.4 Mail, Telephone Lines and Roads

UNIT 7 • WEEKS 25–28

Flight

Air is real and pushes hard, parachutes and the first parachute jump, gliders and Otto Lilienthal, and the Montgolfier brothers' hot-air balloon.

- 7.1 Air Is Real: Guericke's Two Bowls
- 7.2 Parachutes: Garnerin's Jump
- 7.3 Gliders: Otto Lilienthal's Wings
- 7.4 The Montgolfier Hot-Air Balloon

UNIT 6 • WEEKS 21–24

Boats

Floating and sinking and the first iron steamship, boat shapes and the fast clipper ships, paddles and sails with Joshua Slocum's *Spray*, and the voyage of the *Mayflower*.

- 6.1 Floating and Sinking: The Iron Ship
- 6.2 Boat Shapes: The Fast Clipper Ships
- 6.3 Paddles and Sails: Joshua Slocum's *Spray*
- 6.4 The *Mayflower*

UNIT 8 • WEEKS 29–32

Robots and Inventions

Robots that help people, step-by-step code without a computer, sensors that work like our senses, and a marble-run invention for the family engineering fair.

- 8.1 Robots That Help People: The Space Shuttle's Arm
- 8.2 Step-by-Step Code Without a Computer
- 8.3 Sensors Are Like Our Senses: The Sojourner Rover
- 8.4 A Marble-Run Invention and the Engineering Fair

UNIT 9 • WEEKS 33–36

Toy Lab

Optional bonus unit: the yo-yo and its spin, marbles and the machine that made them round, the kaleidoscope, and the jack-in-the-box and its spring.

9.1 The Yo-Yo

9.2 Marbles and the Marble Machine

9.3 The Kaleidoscope

9.4 The Jack-in-the-Box and Springs

WEEKLY PACING CALENDAR

WEEK	PLAN
1	• Session 1: Lesson 1.1 Levers and the Seesaw: warm-up, video, teaching and picture study • Session 2: Lesson 1.1 build project and engineer's notebook <i>Two sessions a week is the usual rhythm. Younger children can split a long session in two; older students can do both sessions in one sitting.</i>
2	• Session 1: Lesson 1.2 The Wheel and Axle: George Ferris's Great Wheel: warm-up, video, teaching and picture study • Session 2: Lesson 1.2 build project and engineer's notebook
3	• Session 1: Lesson 1.3 Ramps: Boats That Climbed Hills: warm-up, video, teaching and picture study • Session 2: Lesson 1.3 build project and engineer's notebook
4	• Session 1: Lesson 1.4 Pulleys: A Bucket on a Rope: warm-up, video, teaching and picture study • Session 2: Lesson 1.4 build project and engineer's notebook • Session 3: Unit 1 review and portfolio project
5	• Session 1: Lesson 2.1 Beam, Arch and Suspension Bridges: warm-up, video, teaching and picture study • Session 2: Lesson 2.1 build project and engineer's notebook

WEEK	PLAN
6	• Session 1: Lesson 2.2 A Craft-Stick Beam Bridge: warm-up, video, teaching and picture study • Session 2: Lesson 2.2 build project and engineer's notebook
7	• Session 1: Lesson 2.3 The Roman Arch and the Aqueducts: warm-up, video, teaching and picture study • Session 2: Lesson 2.3 build project and engineer's notebook
8	• Session 1: Lesson 2.4 The Brooklyn Bridge: A Family Builds a Bridge: warm-up, video, teaching and picture study • Session 2: Lesson 2.4 build project and engineer's notebook • Session 3: Unit 2 review and portfolio project
9	• Session 1: Lesson 3.1 Building Materials and the House on the Rock: warm-up, video, teaching and picture study • Session 2: Lesson 3.1 build project and engineer's notebook
10	• Session 1: Lesson 3.2 Strong Shapes: The Triangle and the Barn Raising: warm-up, video, teaching and picture study • Session 2: Lesson 3.2 build project and engineer's notebook
11	• Session 1: Lesson 3.3 The Pyramids of Egypt: warm-up, video, teaching and picture study • Session 2: Lesson 3.3 build project and engineer's notebook
12	• Session 1: Lesson 3.4 The Eiffel Tower: warm-up, video, teaching and picture study • Session 2: Lesson 3.4 build project and engineer's notebook • Session 3: Unit 3 review and portfolio project
13	• Session 1: Lesson 4.1 A Battery and a Bulb: Volta's Pile: warm-up, video, teaching and picture study • Session 2: Lesson 4.1 build project and engineer's notebook
14	• Session 1: Lesson 4.2 Conductors and Insulators: Stephen Gray's Long Thread: warm-up, video, teaching and picture study • Session 2: Lesson 4.2 build project and engineer's notebook

WEEK	PLAN
15	• Session 1: Lesson 4.3 Magnets and the Compass: warm-up, video, teaching and picture study • Session 2: Lesson 4.3 build project and engineer's notebook
16	• Session 1: Lesson 4.4 Benjamin Franklin's Kite: warm-up, video, teaching and picture study • Session 2: Lesson 4.4 build project and engineer's notebook • Session 3: Unit 4 review and portfolio project
17	• Session 1: Lesson 5.1 Water Towers and Pipes: warm-up, video, teaching and picture study • Session 2: Lesson 5.1 build project and engineer's notebook
18	• Session 1: Lesson 5.2 From Power Plant to Your Lamp: warm-up, video, teaching and picture study • Session 2: Lesson 5.2 build project and engineer's notebook
19	• Session 1: Lesson 5.3 Sewers and the Treatment Plant: warm-up, video, teaching and picture study • Session 2: Lesson 5.3 build project and engineer's notebook
20	• Session 1: Lesson 5.4 Mail, Telephone Lines and Roads: warm-up, video, teaching and picture study • Session 2: Lesson 5.4 build project and engineer's notebook • Session 3: Unit 5 review and portfolio project
21	• Session 1: Lesson 6.1 Floating and Sinking: The Iron Ship: warm-up, video, teaching and picture study • Session 2: Lesson 6.1 build project and engineer's notebook
22	• Session 1: Lesson 6.2 Boat Shapes: The Fast Clipper Ships: warm-up, video, teaching and picture study • Session 2: Lesson 6.2 build project and engineer's notebook
23	• Session 1: Lesson 6.3 Paddles and Sails: Joshua Slocum's Spray: warm-up, video, teaching and picture study • Session 2: Lesson 6.3 build project and engineer's notebook

WEEK	PLAN
24	• Session 1: Lesson 6.4 The Mayflower: warm-up, video, teaching and picture study • Session 2: Lesson 6.4 build project and engineer's notebook • Session 3: Unit 6 review and portfolio project
25	• Session 1: Lesson 7.1 Air Is Real: Guericke's Two Bowls: warm-up, video, teaching and picture study • Session 2: Lesson 7.1 build project and engineer's notebook
26	• Session 1: Lesson 7.2 Parachutes: Garnerin's Jump: warm-up, video, teaching and picture study • Session 2: Lesson 7.2 build project and engineer's notebook
27	• Session 1: Lesson 7.3 Gliders: Otto Lilienthal's Wings: warm-up, video, teaching and picture study • Session 2: Lesson 7.3 build project and engineer's notebook
28	• Session 1: Lesson 7.4 The Montgolfier Hot-Air Balloon: warm-up, video, teaching and picture study • Session 2: Lesson 7.4 build project and engineer's notebook • Session 3: Unit 7 review and portfolio project
29	• Session 1: Lesson 8.1 Robots That Help People: The Space Shuttle's Arm: warm-up, video, teaching and picture study • Session 2: Lesson 8.1 build project and engineer's notebook
30	• Session 1: Lesson 8.2 Step-by-Step Code Without a Computer: warm-up, video, teaching and picture study • Session 2: Lesson 8.2 build project and engineer's notebook
31	• Session 1: Lesson 8.3 Sensors Are Like Our Senses: The Sojourner Rover: warm-up, video, teaching and picture study • Session 2: Lesson 8.3 build project and engineer's notebook
32	• Session 1: Lesson 8.4 A Marble-Run Invention and the Engineering Fair: warm-up, video, teaching and picture study • Session 2: Lesson 8.4 build project and engineer's notebook • Session 3: Unit 8 review and portfolio project

WEEK	PLAN
	<i>Last week. Hold a family engineering fair: set out the best build from each unit with its notebook pages, and let the student show guests how one of them works.</i>
33	• Session 1: Lesson 9.1 The Yo-Yo: warm-up, video, teaching and picture study • Session 2: Lesson 9.1 build project and engineer's notebook <i>Optional bonus unit: Toy Lab. Do it after the fair, over the summer, or slip a lesson in whenever a week needs something fun.</i>
34	• Session 1: Lesson 9.2 Marbles and the Marble Machine: warm-up, video, teaching and picture study • Session 2: Lesson 9.2 build project and engineer's notebook
35	• Session 1: Lesson 9.3 The Kaleidoscope: warm-up, video, teaching and picture study • Session 2: Lesson 9.3 build project and engineer's notebook
36	• Session 1: Lesson 9.4 The Jack-in-the-Box and Springs: warm-up, video, teaching and picture study • Session 2: Lesson 9.4 build project and engineer's notebook • Session 3: Unit 9 review and portfolio project

MATERIALS

Engineer's notebook (a sturdy notebook with blank or graph-paper pages)

One for the whole year: drawings, guesses, tally marks and “what I would change.”

Crayons, colored pencils, a pencil and a ruler

For notebook drawings and simple measuring.

Cardboard (cereal boxes and shipping boxes), paper, card stock, masking tape, clear tape and white glue

The main building materials all year.

Craft sticks (about 100), straws, string, rubber bands, paper clips and paper cups

For levers, bridges, towers, pulleys and parachutes.

About 100 pennies

Our standard weights for every load test.

Toy cars, a few blocks or books, a cardboard tube or two, and some marbles

For ramps, wheels, foundations and the marble run.

An empty thread spool or a smooth broom handle, and a small bucket or basket

For the pulley build in Unit 1.

Aluminum foil, modeling clay, a plastic tub or the kitchen sink

For the boat builds in Unit 6. A grown-up stays near the water.

Two D-cell or AA batteries with a battery holder, a small flashlight bulb in a holder (or an LED), and three or four alligator clip leads

For Unit 4 and the robot sensor in Unit 8. Batteries only; never the outlets in the wall.

A bar magnet or a few strong refrigerator magnets, a sewing needle, a cork and a compass

For the magnet and compass lesson.

Balloons, coffee filters, plastic grocery bags and a small paper bag

For the air, parachute and balloon builds in Unit 7.

A hair dryer, used only by a grown-up

For the warm-air balloon in Lesson 7.4.

A kitchen timer or a phone stopwatch, and a tape measure

For timing parachutes and measuring how far gliders and cars travel.

Safety glasses (child size)

For load tests, rubber bands and anything that flies.

Optional: one kit, such as a KiwiCo Kiwi Crate, KEVA Planks, Snap Circuits or a Bee-Bot

Never required. See the kits listed in each unit.

GRADING

There are no letter grades in first grade. Keep a portfolio and give warm, specific feedback about how your child tested, recorded and improved each build.

- After each build, tell your child one thing done well (“You tested both bridges with the same pennies, just like a real engineer”) and one thing to try next time.
- Praise careful testing and honest records more than winning results. A boat that sank and was then made better is a success.
- Use each unit’s mastery checklist as a guide. Check off each “I can” statement when your child can show it or tell it.
- Keep a portfolio folder with notebook pages, photographs of builds and each unit’s portfolio project. At the end of the year, look back through it together and

see how much your young engineer has learned.

A NOTE TO PARENTS

You do not need to know any engineering to teach this course. Read the story aloud, watch the short video together, and then be your child's helper at the build: hold the cardboard, count the pennies, write down the numbers, and ask two questions over and over: "What do you think will happen?" and "Why do you think that happened?" Those two questions are most of good science teaching.

Expect things to fall down. Towers will tip, bridges will sag and foil boats will sink. That is not failure; it is how engineers learn. The Wright brothers crashed many gliders before they flew. Cheer the second try more than the first. *Fabricando fit faber*: by making, one becomes a maker.

The stories in this course are told gently for young children. Where something went wrong in history, the lessons speak about what the builders learned and how they made things safer for others.

UNIT 1

SIMPLE MACHINES

People have always needed to lift heavy things, move big loads and get water up from the river. Long before engines, they did it with simple machines: a long pole on a post, a wheel on a rod, a ramp and a rope over a wheel. In this unit you will meet farmers in Egypt lifting water with a shadoof, George Ferris and his giant wheel, canal boats that rode up hills on ramps, and builders who lifted stones with great wooden cranes.

You will build a seesaw that lifts pennies, a cardboard car, a ramp test and a spool pulley. Each time you will guess first, then test, then count what happened, then try to make it better. That is what engineers do. “Wisdom is better than strength,” says the Bible, and a simple machine is a little bit of wisdom that makes our strength go further.

PREREQUISITES

- Can count to 20
- Can use tape and child-safe scissors with help
- Knows the words push and pull

MASTERY CHECKLIST

- ☐ I can show how a lever lifts a load and point to its fulcrum.
- ☐ I can tell why wheels make things easier to move, and point to a wheel and its axle.
- ☐ I can show that a gentle ramp takes a smaller pull than lifting straight up.
- ☐ I can use a pulley to lift a cup by pulling down.
- ☐ I can do a fair test by changing only one thing, and I can count and record what happened.

OPTIONAL KITS FOR THIS UNIT

- **KiwiCo Kiwi Crate:** Ages 5–8. A monthly box with one hands-on science or building project and a short booklet; several crates build simple machines such as launchers and cranks. Fits Unit 1 and many later units.
- **LEGO Education:** LEGO Education sells classroom sets for the early grades with gears, wheels, axles and levers. A family LEGO collection with wheels and axles also works well for Lessons 1.2–1.4.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

1.1 Levers and the Seesaw	2 sessions of 30 minutes
1.2 The Wheel and Axle: George Ferris’s Great Wheel	2 sessions of 30 minutes
1.3 Ramps: Boats That Climbed Hills	2 sessions of 30 minutes
1.4 Pulleys: A Bucket on a Rope	2 sessions of 30 minutes

UNIT 1 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation to see what has been learned. Have a ruler, a marker, a toy car, a book, a spool and some pennies ready.

1. Use the ruler and marker to make a lever. Show me the fulcrum. Where should the fulcrum go to make lifting easy?
2. Why is it easier to move a heavy box on wheels than to drag it?
3. Tell me the story of the Ferris wheel. Who built it, and where?
4. Show me with the book and the toy car: is it easier to pull the car up a gentle ramp or a steep ramp? What do you give up with the gentle ramp?
5. How did the Morris Canal boats get over the hills?

6. With a pulley, which way do you pull to lift something up? What happens when two pulleys work together?

ANSWER KEY

1. The marker under the ruler is the fulcrum. Putting the fulcrum close to the load makes it easier to lift.
2. Wheels roll instead of rubbing along the floor, so there is much less friction.
3. George Ferris, a bridge engineer, built a giant wheel for the Chicago World's Fair in 1893. People rode in cars on its rim.
4. The gentle ramp takes a smaller pull, but the path is longer.
5. They floated into a big cart on rails and were pulled up a ramp by a rope. At the top they floated back into the canal.
6. You pull down to lift the load up. With two pulleys, the pull is easier, but you have to pull more rope.

PORTFOLIO PIECE: MY HELPER MACHINE

Build a machine that lifts a cup of 20 pennies from the floor up onto a chair, using a lever, a ramp or a pulley (or two of them together). First lift the cup with a rubber band straight up and measure the stretch. Then lift it with your machine and measure again. Draw your machine in your notebook, write both measurements, and show your family how it works.

LOOK FOR	WHAT IT MEANS
It works	The machine lifts the cup of pennies onto the chair.
Fair test	Measured the pull with and without the machine, using the same cup and the same rubber band.
Tried again	Changed one thing after the first try to make the machine work better.
Notebook page	Drew the machine with labels and wrote down both measurements.
Telling	Explained to the family which simple machine was used and why it helps.

1.1 LEVERS AND THE SEESAW

OBJECTIVES

- Name the parts of a lever: the bar, the fulcrum, the load and the push.
- Tell how farmers in Egypt used a shadoof to lift water.
- Build a ruler seesaw and find out how moving the fulcrum changes how many pennies it takes to lift a load.

Warm-up. Go to a playground seesaw, or make one with a board over a log. If a grown-up sits on one end and a child on the other, what happens? Where should the grown-up sit so the child can lift him? Try it, or act it out with two stuffed animals on a ruler.

WATCH

Super Simple Machines: Levers

[SciShow Kids](#) · 3:20

<https://www.youtube.com/watch?v=lueqE0lxLyc>

WHEN TO WATCH

After the first two core ideas. Pause when the lever first appears and ask, “Where is the fulcrum?”

BACKUP VIDEO

Simple Machines: The Lever

[funsciencedemos](#) · 5:50

<https://www.youtube.com/watch?v=n7dUtwejenQ>

Any time this week, to see a teacher measure the push on a lever with a spring scale.

KEY TERMS

lever

A stiff bar that turns on one point to help lift or move a load.

fulcrum

The point a lever rests and turns on.

load

The thing you want to lift or move.

simple machine

A simple tool that makes a job easier, like a lever, a wheel and axle, a ramp or a pulley.

CORE IDEAS

Long ago. In Egypt, farmers needed water from the Nile River for their fields. Carrying bucket after bucket up the riverbank was hard work. So they built a **shadoof**. It is a long pole that rests on top of a post. A bucket hangs from one end of the pole. A heavy lump of mud or stone is tied to the other end.

The farmer pulls the bucket down into the river and fills it. Then the heavy lump on the other end helps swing the full bucket up. The farmer turns the pole and pours the water into a ditch. People in some places still use shadoofs today.

Why does it work? A shadoof is a **lever**. A lever is a stiff bar that turns on one point. That point is called the **fulcrum**. When you push down on one end, the other end goes up. Here is the secret: if the fulcrum is close to the heavy load, a small push on the far end can lift it. Your end has to move a long way, but you do not have to push as hard.

How do builders use it? Levers are everywhere. A seesaw is a lever. So is a crowbar, a bottle opener, a wheelbarrow and the arm of a big crane. A Greek thinker named Archimedes, who lived long ago, studied levers carefully. He is remembered for saying that with a long enough lever and a place to stand, he could move the whole world.

Try it. Today you will be an engineer. You will make a seesaw from a ruler and test where to put the fulcrum.

PICTURE STUDY



The Seesaw, Francisco de Goya, 1791–1792 · Oil on canvas · Philadelphia Museum of Art

Image: [Wikimedia Commons](#), public domain

The Spanish painter Francisco de Goya painted many pictures of children at play. Here the children have made a seesaw from a beam and a log, a lever you could build in any field.

Look closely

- Find the long beam. This is the lever.
- Find the log the beam rests on. That is the fulcrum.
- Find the boy at the high end. Where are the children at the low end?
- Is the fulcrum in the middle of the beam, or closer to one end?

Talk about it

1. Why can the children at the low end lift the boy at the high end?
2. Where would you move the log to make the boy easier to lift?
3. How is this seesaw like a shadoof?

BUILD

A Penny Seesaw

You will make a seesaw from a ruler and a marker. Then you will test how many pennies it takes to lift a load when the fulcrum is in different places.

You will need

- A flat ruler (30 cm or 12 inches)
- A round marker or a thick pencil (the fulcrum)
- Two small paper cups or bottle caps, and tape
- About 30 pennies
- Engineer's notebook and a pencil

Steps

1. Tape a small cup to each end of the ruler. Lay the ruler across the marker so it balances in the middle.
2. Put 5 pennies in one cup. This is your load.
3. **Guess** how many pennies you will need in the other cup to lift the load. Draw your guess in your notebook.
4. Add pennies one at a time to the other cup until the load lifts. Count them and write the number down.
5. Now slide the ruler so the fulcrum is closer to the load cup. Keep the same 5 pennies as the load. Guess again, then test again.
6. Slide the fulcrum close to the other cup and test one more time.
7. With a grown-up, make a small chart with three rows: middle, near the load, far from the load. Write how many pennies each one took.
8. **Make it better.** Find the spot where the fewest pennies can lift your 5-penny load. Mark that spot on the ruler with a pencil.

Tips

- Tape the marker to the table so it does not roll away.
- Use the same load every time. That is what makes it a fair test.

- If the ruler slides, put a small piece of tape around the marker to make it a little sticky.

Check your work

- ☐ I can point to the fulcrum, the load and where I push.
- ☐ I can tell where the fulcrum should go to make lifting easier.
- ☐ I wrote down how many pennies each test took.

ENGINEER'S NOTEBOOK

1. Draw your penny seesaw. Label the lever, the fulcrum and the load.
2. Draw a chart of your three tests with the number of pennies for each.
3. Draw two levers you can find in your house or yard.

From history. The shadoof is drawn in very old Egyptian tomb paintings, and farmers along the Nile were still using it when this picture was made in 1890. A good simple machine can be useful for a very long time.

COMMON MISTAKES

- Changing the load and the fulcrum at the same time. Change only one thing.
- Thinking the fulcrum always goes in the middle. Moving it changes how hard you must push.

Make it a game • Name the Lever Parts. Set a ruler on a pencil to make a seesaw, with a penny on each end. Point to the bar, the fulcrum, the load and the push, and say each name. Your parent covers one part with a hand, and you name the hidden one. Then tell how Egyptian farmers used a shadoof to lift water. Get all four right in a row.

Scripture. “Wisdom is better than strength” (Ecclesiastes 9:16, KJV)

A child with a lever can lift more than a strong man without one. God gave us minds to think of wise ways to do hard work.

1.2 THE WHEEL AND AXLE:

GEORGE FERRIS’S GREAT WHEEL

OBJECTIVES

- Tell the story of George Ferris and his wheel at the 1893 World’s Fair.
- Point to a wheel and its axle and tell why rolling is easier than sliding.
- Build a cardboard car and test it, then make it roll farther.

Warm-up. Put a few heavy books in a shoebox and drag it across the floor. Then set the box on top of three round pencils or markers and push it. Which was easier? Why do you think so?

WATCH

Let's Get Rolling! | Physics for Kids

SciShow Kids · 3:18

<https://www.youtube.com/watch?v=YIV9IUHqW3A>

WHEN TO WATCH

After the story of the Ferris wheel. Pause before Jessi tries the wagon and ask, “What do you think will help?”

BACKUP VIDEO

Simple Machines: The Wheel & Axle

funsciencedemos · 6:04

<https://www.youtube.com/watch?v=vYoWCn5r3rQ>

Any time this week. A teacher shows how much easier it is to pull a heavy load on wheels.

KEY TERMS

wheel

A round disk or ring that turns.

axle

The rod in the middle that a wheel turns on, or turns with.

friction

The rubbing that slows things down when two surfaces slide against each other.

CORE IDEAS

Long ago. In 1893 the city of Chicago held a giant World's Fair. Four years before, Paris had built the tall Eiffel Tower for its own fair. The people in Chicago wanted something just as amazing. A young bridge engineer named **George Ferris** had an idea: a huge wheel that people could ride, high into the sky.

Many people said it could not be done. It would fall down, they said. But Ferris and his team planned it carefully. They made it of steel. The wheel stood 264 feet tall, taller than a 20-story building. It had 36 cars, and each car could carry 60 people. In the middle was a giant steel axle, one of the biggest pieces of steel anyone had ever made. The wheel opened on June 21, 1893, and it turned safely all summer long.

Why does it work? A **wheel** turns around a rod called an **axle**. When you drag a box, the bottom of the box rubs on the floor. That rubbing is called **friction**, and it slows you down. A wheel does not drag. It rolls. Only a tiny part of the wheel touches the ground at a time, so there is much less rubbing.

How do builders use it? Wheels and axles are in wagons, cars, bicycles, doorknobs, faucet handles and the steering wheel of a car. A big wheel on a small axle is also a kind of lever that goes around and around. The Ferris wheel was so loved that people have built them all over the world ever since.

PICTURE STUDY



The Ferris Wheel at the World's Fair, B. L. Singley, 1893 · Photograph

Image: [Wikimedia Commons](#), public domain

This photograph was taken at the Chicago World's Fair in 1893, the year George Ferris's wheel was built. Look at how it is made before you look at how big it is.

Look closely

- Find the axle in the very center of the wheel.
- Find the thin spokes. Where do they go?
- Count the cars you can see along the rim.
- Find the tall towers that hold up the axle.

Talk about it

1. Why do you think the spokes are so thin? Would thick ones be better or worse?
2. Why is the axle held up by two tall towers?
3. Would you like to ride in one of those cars? What would you see?

Safety first. A grown-up pokes holes in the cardboard and trims any sharp tips from the skewers.

BUILD

A Cardboard Car

You will build a small car with real wheels and axles. Then you will roll it down a ramp, measure how far it goes, and find ways to make it go farther.

You will need

- A piece of stiff cardboard about the size of your hand (the car's body)
- Two drinking straws and two wooden skewers or thin dowels (the axles)
- Four bottle caps or four cardboard circles the same size (the wheels)
- Tape and modeling clay
- A board or a big book for a ramp, and a few books to prop it up
- A tape measure or ruler

Steps

1. Tape the two straws across the bottom of the cardboard, one near the front and one near the back.
2. Slide a skewer through each straw. A grown-up pokes a hole in the middle of each wheel. Push one wheel onto each end of each skewer and hold it on with a dab of clay.
3. Make a ramp by propping a board on two books.
4. **Guess** how far your car will roll past the bottom of the ramp. Then let it go from the top. Do not push!
5. Measure how far it went with a tape measure. Roll it three times and write each number down.
6. Look closely. Do the wheels wobble? Do they rub on the cardboard or the straw?
7. **Make it better.** Fix one thing, like straightening a wheel or making the wheels the same size. Roll it three more times and write down the new numbers. Did your change help?

Tips

- Always start the car from the same spot. That keeps the test fair.

- Wheels that are not round or not in the middle will bump and slow down.
- If the car turns to one side, check that both axles are straight across.

Check your work

- ☐ I can point to the wheels and the axles on my car.
- ☐ I can tell why rolling is easier than dragging.
- ☐ I measured my car three times before and after my change.

ENGINEER'S NOTEBOOK

1. Draw your car from the side and label the wheels, the axles and the body.
2. Make a chart of your rolls before and after your change.
3. Draw the Ferris wheel and color one car where you would like to ride.

From history. After the fair the great wheel was taken apart, moved and built again two more times, until it was finally taken down in 1906. Today there are giant observation wheels in many cities, and they all carry George Ferris's name.

COMMON MISTAKES

- Pushing the car instead of letting it go. A push changes the test.
- Taping the axle so tightly that the wheels cannot turn.

Make it a game • Ferris Wheel Teach-Back. You are the teacher and your parent is a new student who knows nothing about George Ferris. Tell the story of his great wheel at the 1893 World's Fair. Point to a wheel and its axle on a toy car. Your parent asks one silly question, such as, why not just slide? Answer using the word friction.

1.3 RAMPS: BOATS THAT CLIMBED HILLS

OBJECTIVES

- Tell how canal boats in New Jersey rode up hills on giant ramps.
- Explain that a gentle ramp needs a smaller pull than lifting straight up, but a longer path.
- Measure the pull on a toy car with a rubber band on ramps of different steepness.

Warm-up. Look for ramps this week: a driveway, a slide, a ramp at a store door, a loading ramp on a truck. Why do you think each one is there? Which ones are steep and which ones are gentle?

WATCH

Ramps: A Super, Simple Machine! - #sciencegoals

SciShow Kids · 4:09

<https://www.youtube.com/watch?v=3COvm0TtxWg>

WHEN TO WATCH

After the story. Ask your child to say “stop” each time a ramp makes a job easier.

KEY TERMS

ramp

A slanted surface that helps you move things up or down. Engineers call it an inclined plane.

steep

Slanting up sharply, like a tall slide.

gentle

Slanting up slowly, like a long, low ramp.

canal

A river made by people for boats to travel on.

CORE IDEAS

Long ago. About two hundred years ago there were not many good roads. Heavy loads, like coal and iron, often traveled by boat. In New Jersey, people dug the **Morris Canal**, a long ditch full of water for boats. It opened in 1831. Mules walked along the bank and pulled the boats with ropes.

But there was a problem. New Jersey has big hills, and water does not flow uphill. How could a boat get over a hill? The engineers built **ramps**! At each hill, the boat floated into a giant wooden cart on rails. Rushing water turned a machine that pulled the cart, boat and all, up a long ramp with a strong rope. At the top, the boat floated off into the canal again. The Morris Canal had 23 of these ramps.

Why does it work? Lifting something straight up takes a big pull. A ramp lets you go up a little at a time. A gentle ramp takes a smaller pull, but the path is longer. A steep ramp is shorter, but it takes a bigger pull. You trade a long walk for an easier push.

How do builders use it? Ramps help people in wheelchairs get into buildings. Movers roll heavy boxes up ramps into trucks. Roads that climb mountains go back and forth in zigzags so cars can climb a gentle slope instead of a steep one. A slide is a ramp too, for coming down!

PICTURE STUDY



A Canal Boat at the Top of an Inclined Plane, Unknown photographer, before 1924 · Photograph · Historic American Buildings Survey, Library of Congress

Image: [Wikimedia Commons](#), public domain

This old photograph shows a Morris Canal boat that has just ridden up one of the canal's great ramps. It is being let back into the water at the top.

Look closely

- Find the boat. What do you think it carried?
- Find the cart, or cradle, that the boat is sitting in.
- Find the water at the top of the hill.
- Look for the rails or the track the cart rode on.

Talk about it

1. Why could the boat not just float up the hill?
2. What would be harder, pulling the boat up a gentle ramp or a steep one?
3. What do you think made the strong rope pull?

Safety first. Wear safety glasses if you stretch rubber bands, in case one snaps.

BUILD

The Rubber-Band Ramp Test

You will pull a toy car up ramps of different steepness with a rubber band, and measure how far the rubber band stretches. A longer stretch means a bigger pull.

You will need

- A toy car or truck, with a few pennies taped on top for a load
- A long rubber band and a piece of string
- A board or a strong piece of cardboard about as long as your arm
- Books to prop up the ramp
- A ruler
- Safety glasses

Steps

1. Tie the string to the front of the car. Loop the rubber band onto the other end of the string.
2. Hold the rubber band and lift the car straight up off the table. A grown-up measures how long the rubber band stretches with a ruler. Write it down.
3. Make a gentle ramp with the board on one book. **Guess:** will the rubber band stretch more or less than before?
4. Pull the car slowly up the ramp by the rubber band. Measure the stretch while the car is moving. Write it down.
5. Make a steeper ramp with three books. Guess, pull and measure again.
6. Make a chart: straight up, gentle ramp, steep ramp. Which one took the smallest pull? Which one had the longest path?
7. **Make it better.** Find a way to make the pull even smaller. You could try a longer board, a smoother board, or a car with smoother wheels. Change one thing and test again.

Tips

- Pull slowly and steadily. Measure while the car is moving, not when it starts.

- Use the same car, the same pennies and the same rubber band every time.

Check your work

- ☐ I can show that a gentle ramp takes a smaller pull than lifting straight up.
- ☐ I can tell what you give up when you use a gentle ramp: a longer path.
- ☐ I wrote down the stretch for each test.

ENGINEER'S NOTEBOOK

1. Draw the gentle ramp and the steep ramp. Write the rubber-band stretch beside each one.
2. Draw a canal boat riding up a ramp in its cart.
3. Draw a ramp you saw this week and tell what it helps people do.

From history. Railroads later carried coal faster and cheaper than the canal, and the Morris Canal closed in 1924. You can still walk along parts of the old canal and see where the great ramps were.

COMMON MISTAKES

- Thinking a ramp makes the load lighter. The load weighs the same; the ramp makes the pull smaller and the path longer.
- Measuring the stretch when you first jerk the car. Pull slowly and measure while it moves.

Make it a game · Gentle or Steep Guess. Build two ramps from a board and books, one gentle and one steep. Before each pull of a rubber-banded toy up the ramps, guess which needs a smaller stretch. Measure the stretch with your fingers. Say gentle, steep and canal in a sentence about the New Jersey boats. Score a point for every correct guess, up to five.

1.4 PULLEYS: A BUCKET ON A ROPE

OBJECTIVES

- Tell how builders long ago lifted heavy stones with cranes, ropes and pulleys.
- Show that one pulley lets you lift a load by pulling down.
- Count how many pennies it takes to lift a cup with one pulley and with two.

Warm-up. Watch a flag go up a flagpole, or think about one. The person pulls the rope down, but the flag goes up. How can that be? Look at the top of the pole for a little wheel.

WATCH

Need a Lift? Try a Pulley!

SciShow Kids · 3:27

<https://www.youtube.com/watch?v=Nj4J7QNeBNk>

WHEN TO WATCH

After the first core idea. Pause when the rope goes over the wheel and ask, “Which way is Jessi pulling? Which way does the load go?”

BACKUP VIDEO

Simple Machines – Pulleys

Next Generation Science · 2:26

<https://www.youtube.com/watch?v=pxD3SHMp9Es>

Before the build, to see one pulley and then two working together.

KEY TERMS

pulley

A wheel with a groove around it that holds a rope.

crane

A machine for lifting heavy things high.

block and tackle

Two or more pulleys working together, so a small pull can lift a big load.

CORE IDEAS

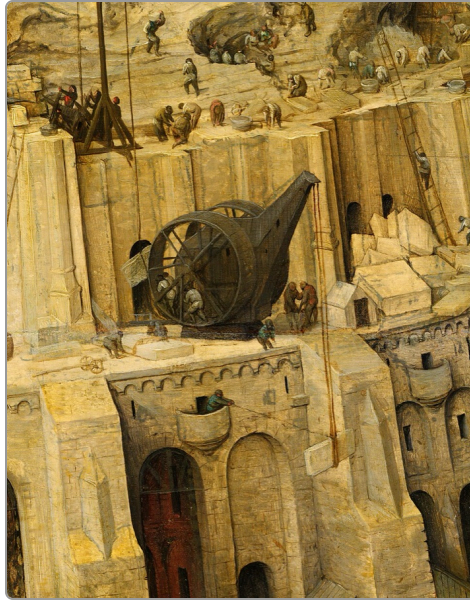
Long ago. Builders of castles and cathedrals had to lift huge stones high into the air. They had no engines. So they built wooden **cranes**. Some cranes had a giant wheel that men walked inside, like a hamster in a wheel. As they walked, the wheel turned and wound up a rope. The rope went up over a **pulley** at the top of the crane and down to the stone. Step by step, the stone rose up.

There is an old story about Archimedes, the Greek thinker who studied levers. A king asked him to move a great ship that was stuck on the shore. Archimedes set up a rope with many pulleys. The story says that he pulled the rope by himself, and the big ship slid slowly into the water.

Why does it work? A pulley is a wheel with a groove for a rope. With one pulley at the top, you pull down and the load goes up. That is easier, because you can use your own weight to pull. When two or more pulleys work together, a small pull can lift a big load. But you have to pull a lot more rope. You trade a long pull for an easier pull, just like a ramp.

How do builders use it? Pulleys are on flagpoles, window blinds, sailboats, wells and the giant cranes you see at building sites. Elevators in tall buildings hang from strong steel ropes that run over pulleys. A crane with many pulleys can lift a load as heavy as a house.

PICTURE STUDY



A Treadwheel Crane (detail of The Tower of Babel), Pieter Bruegel the Elder, 1563 · Oil on panel ·
Kunsthistorisches Museum, Vienna
Image: [Wikimedia Commons](#), public domain

The painter Pieter Bruegel loved to paint how people worked. In his large painting of the Tower of Babel, he painted the builders' machines very carefully. This is one small part of it: a crane with a big wheel.

Look closely

- Find the big wooden wheel. Can you see where a man would walk inside it?
- Follow the rope from the wheel. Where does it go?
- Find the wooden arm at the top that holds the rope.
- Look for the stones and the workers.

Talk about it

1. When the men walk inside the wheel, what happens to the rope?
2. Why do you think the rope goes up over the top of the crane before it comes down to the stone?
3. How is this crane like the pulley you will build?

Safety first. A grown-up sets up the broom handle across two chairs and stays nearby. Keep fingers away from the string where it runs over the spool.

BUILD

The Spool Pulley

You will make a pulley from a thread spool and use a cup of pennies to pull up another cup of pennies. Then you will add a second pulley and see if lifting gets easier.

You will need

- An empty thread spool and a pencil, or a smooth broom handle
- Two chairs
- Two paper cups with string handles (poke two holes and tie on string)
- About 1 meter (3 feet) of string
- A second spool and a paper clip bent into a hook (for the second pulley)
- About 60 pennies

Steps

1. Push the pencil through the spool. Lay the pencil across the backs of two chairs and tape it down, so the spool can turn. (Or lay a smooth broom handle across the chairs.)
2. Tie one cup to each end of the string. Hang the string over the spool so one cup is on each side. Put 10 pennies in the first cup. This is the load.
3. **Guess** how many pennies you must put in the second cup to lift the load. Add pennies one at a time. Count how many it took and write it down.
4. Now make two pulleys. Tie one end of the string to the pencil. Hang the second spool on the string with the paper-clip hook, and hang the load cup from that spool. Run the other end of the string up over the first spool and tie on the second cup.
5. Guess again. Then add pennies to the pulling cup until the load rises. Count and write it down.
6. Compare your two numbers. Which way needed fewer pennies? Which way did you have to pull more string to lift the load the same height?
7. **Make it better.** If your pulley sticks, find a way to help it turn more easily, like a smoother pencil or a little bit of soap on the pencil. Test again.

Tips

- Lift the load slowly. A quick jerk is not a fair test.
- Use the same 10-penny load both times.
- If the moving pulley tips over, tape a penny to the bottom of its cup to steady it.

Check your work

- ☐ I can show that one pulley lets me lift by pulling down.
- ☐ I can tell which way needed fewer pennies, and what I had to give up.
- ☐ I counted and wrote down my results.

ENGINEER'S NOTEBOOK

1. Draw your one-pulley test and your two-pulley test. Write how many pennies each one took.
2. Draw the crane from the picture study. Draw arrows to show which way the rope moves.
3. Draw three places where you have seen a pulley.

From history. Treadwheel cranes were used to build cathedrals for hundreds of years. A few old ones are still inside the roofs of churches in Europe, right where the builders left them.

COMMON MISTAKES

- Thinking a pulley makes the load lighter. The load is the same; two pulleys make the pull easier but the rope longer.
- Letting the string slip off the spool. Keep it in the groove.

Make it a game • Pulley Pull Down. Hang a rope over a chair rung or spool pulley with a small basket of socks. Lift the basket by pulling down, and call out pulley each time. Your parent says a heavy load name, such as a stone or a bucket, and you tell how a crane would lift it. See how many loads you can lift in one minute.

UNIT 1

SIMPLE MACHINES

People have always needed to lift heavy things, move big loads and get water up from the river. Long before engines, they did it with simple machines: a long pole on a post, a wheel on a rod, a ramp and a rope over a wheel. In this unit you will meet farmers in Egypt lifting water with a shadoof, George Ferris and his giant wheel, canal boats that rode up hills on ramps, and builders who lifted stones with great wooden cranes.

You will build a seesaw that lifts pennies, a cardboard car, a ramp test and a spool pulley. Each time you will guess first, then test, then count what happened, then try to make it better. That is what engineers do. “Wisdom is better than strength,” says the Bible, and a simple machine is a little bit of wisdom that makes our strength go further.

PREREQUISITES

- Can count to 20
- Can use tape and child-safe scissors with help
- Knows the words push and pull

MASTERY CHECKLIST

- ☐ I can show how a lever lifts a load and point to its fulcrum.
- ☐ I can tell why wheels make things easier to move, and point to a wheel and its axle.
- ☐ I can show that a gentle ramp takes a smaller pull than lifting straight up.
- ☐ I can use a pulley to lift a cup by pulling down.
- ☐ I can do a fair test by changing only one thing, and I can count and record what happened.

OPTIONAL KITS FOR THIS UNIT

- **KiwiCo Kiwi Crate:** Ages 5–8. A monthly box with one hands-on science or building project and a short booklet; several crates build simple machines such as launchers and cranks. Fits Unit 1 and many later units.
- **LEGO Education:** LEGO Education sells classroom sets for the early grades with gears, wheels, axles and levers. A family LEGO collection with wheels and axles also works well for Lessons 1.2–1.4.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

1.1 Levers and the Seesaw	2 sessions of 30 minutes
1.2 The Wheel and Axle: George Ferris’s Great Wheel	2 sessions of 30 minutes
1.3 Ramps: Boats That Climbed Hills	2 sessions of 30 minutes
1.4 Pulleys: A Bucket on a Rope	2 sessions of 30 minutes

UNIT 1 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation to see what has been learned. Have a ruler, a marker, a toy car, a book, a spool and some pennies ready.

1. Use the ruler and marker to make a lever. Show me the fulcrum. Where should the fulcrum go to make lifting easy?
2. Why is it easier to move a heavy box on wheels than to drag it?
3. Tell me the story of the Ferris wheel. Who built it, and where?
4. Show me with the book and the toy car: is it easier to pull the car up a gentle ramp or a steep ramp? What do you give up with the gentle ramp?
5. How did the Morris Canal boats get over the hills?

6. With a pulley, which way do you pull to lift something up? What happens when two pulleys work together?

ANSWER KEY

1. The marker under the ruler is the fulcrum. Putting the fulcrum close to the load makes it easier to lift.
2. Wheels roll instead of rubbing along the floor, so there is much less friction.
3. George Ferris, a bridge engineer, built a giant wheel for the Chicago World's Fair in 1893. People rode in cars on its rim.
4. The gentle ramp takes a smaller pull, but the path is longer.
5. They floated into a big cart on rails and were pulled up a ramp by a rope. At the top they floated back into the canal.
6. You pull down to lift the load up. With two pulleys, the pull is easier, but you have to pull more rope.

PORTFOLIO PIECE: MY HELPER MACHINE

Build a machine that lifts a cup of 20 pennies from the floor up onto a chair, using a lever, a ramp or a pulley (or two of them together). First lift the cup with a rubber band straight up and measure the stretch. Then lift it with your machine and measure again. Draw your machine in your notebook, write both measurements, and show your family how it works.

LOOK FOR	WHAT IT MEANS
It works	The machine lifts the cup of pennies onto the chair.
Fair test	Measured the pull with and without the machine, using the same cup and the same rubber band.
Tried again	Changed one thing after the first try to make the machine work better.
Notebook page	Drew the machine with labels and wrote down both measurements.
Telling	Explained to the family which simple machine was used and why it helps.

UNIT 2

BRIDGES

A bridge carries people over something they cannot walk across: a creek, a river, a valley or a busy road. The first bridges were simple: a log across a stream, or ropes woven from grass. Later, the Romans built great stone arches that still stand today, and engineers in New York hung a road from steel wires over a wide river.

In this unit you will learn the three main kinds of bridges, beam, arch and suspension, and you will build each one. You will load your bridges with pennies, count how many they hold, and make them stronger. You will also hear the true story of a family who built the Brooklyn Bridge together. “Through wisdom is an house builded,” says Proverbs, and the same is true of a bridge.

PREREQUISITES

- Knows what a fair test is: change only one thing (Unit 1)
- Can count pennies to 50 with help

MASTERY CHECKLIST

- ☐ I can name and draw a beam bridge, an arch bridge and a suspension bridge.
- ☐ I can show that a beam standing on its edge bends less than a beam lying flat.
- ☐ I can tell why the keystone matters in an arch.
- ☐ I can tell the story of the Roeblings and the Brooklyn Bridge.
- ☐ I can test a bridge with pennies, count the load and make it stronger.

OPTIONAL KITS FOR THIS UNIT

- **KEVA Planks**: Plain, identical wooden planks with no pegs or glue. Good for building beams, arches and towers with a parent, and for Units 2 and 3.
- **KiwiCo Kiwi Crate**: Ages 5–8. Some crates are building projects with bridges, towers or ramps; a fun extra for Units 1–3.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

2.1 Beam, Arch and Suspension Bridges	2 sessions of 30 minutes
2.2 A Craft-Stick Beam Bridge	2 sessions of 30 minutes
2.3 The Roman Arch and the Aqueducts	2 sessions of 30 minutes
2.4 The Brooklyn Bridge: A Family Builds a Bridge	2 sessions of 30 minutes

UNIT 2 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have paper, a ruler, two stacks of books, string and the pictures from this unit ready.

1. Draw or build a beam bridge, an arch bridge and a suspension bridge. Tell me the name of each one.
2. Show me with a ruler: which way does a beam bend less, lying flat or standing on its edge?
3. Look at the picture of the Pont du Gard. What did this bridge carry? Which stone holds an arch together?
4. Where does an arch push? Show me with your hands.
5. Tell me the story of the Brooklyn Bridge. Who helped build it?
6. Predict: if you take away half the hangers on a suspension bridge, will it hold more or fewer pennies? Why?

ANSWER KEY

1. A flat piece across a gap (beam), a curve under the road (arch), and a road hanging from cables on towers (suspension).
2. Standing on its edge.
3. It carried water to a Roman city. The keystone at the top locks the arch.
4. Out and down into the ground at both ends.
5. John Roebling planned it; his son Washington led the building; when Washington was sick, his wife Emily carried his instructions and learned about bridges. It opened in 1883.
6. Fewer, because each hanger has to carry more of the road.

PORTFOLIO PIECE: MY PENNY-TESTED BRIDGE

Choose the kind of bridge you like best and build it from craft sticks, cardboard, paper and string across a gap of 30 cm (12 inches) between two stacks of books. Test it with a cup of pennies and count how many it holds. Then make one change to make it stronger and test it again. Draw both tests in your notebook and show your family how your bridge carries its load to the ground.

LOOK FOR	WHAT IT MEANS
It spans the gap	The bridge crosses the whole gap and stands on its own.
Fair test	Tested with the cup in the same place both times and counted the pennies carefully.
Tried again	Made one change after the first test and tested again.
Notebook page	Drew the bridge, named its kind, and wrote both penny counts.
Telling	Explained what kind of bridge it is and how it holds up the load.

2.1 BEAM, ARCH AND SUSPENSION BRIDGES

OBJECTIVES

- Name and draw the three main kinds of bridges: beam, arch and suspension.
- Tell how the Inca people of Peru crossed deep valleys on bridges made of grass rope.
- Build all three kinds of bridges from paper and string, and test each one with pennies.

Warm-up. Lay a sheet of paper across a gap between two stacks of books. Set a penny on it. What happens? Now think: how could you make the paper hold the penny without adding anything else to it?

WATCH

What Makes Bridges So Strong? | Engineering for Kids | STEAM | SciShow Kids

SciShow Kids · 3:45

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

WHEN TO WATCH

After the core ideas. Pause each time a new bridge appears and ask, “What kind of bridge is this?”

KEY TERMS

bridge

Something built to carry a road or path over a gap, like a river or a valley.

beam bridge

A bridge made of a flat, stiff piece that rests on each side, like a log across a creek.

arch bridge

A bridge held up by a curved arch that pushes down into the ground at each end.

suspension bridge

A bridge whose road hangs from long ropes or cables held up by towers.

CORE IDEAS

Long ago. The first bridge was probably a tree that fell across a creek. People walked across it and stayed dry. That kind of bridge is a **beam bridge**. A beam is a long, stiff

piece that rests on each side.

High in the mountains of Peru, the Inca people had deep valleys to cross, much too wide for a log. So they twisted grass into strong ropes, as thick as a man's body. They tied the ropes to stone walls on each side of the valley and hung a walkway from them. That kind of bridge is a **suspension bridge**, a bridge that hangs. One Inca rope bridge is still rebuilt by the people of the villages near it every year.

Why does it work? Every bridge must carry its load to the ground. A beam bridge holds the load by being stiff, but a long beam sags in the middle. An **arch bridge** has a curve under it. The load pushes on the arch, and the arch pushes out and down into the ground at both ends. A suspension bridge hangs the road from strong ropes or cables. The cables are pulled tight, and tall towers hold them up.

How do builders use it? Engineers choose the kind of bridge that fits the gap. Beam bridges are good for short gaps, like a creek or a highway. Arches are good where there is strong rock on each side. Suspension bridges can cross the widest rivers, like the Golden Gate Bridge in San Francisco.

PICTURE STUDY



The Rope Bridge over the Apurímac River, E. George Squier, 1877 · Engraving · From Peru: Incidents of Travel and Exploration in the Land of the Incas

Image: [Wikimedia Commons](#), public domain

An American traveler named E. George Squier crossed this rope bridge in the mountains of Peru and had it drawn for his book. It was made the old Inca way, from ropes of twisted grass.

Look closely

- Find the ropes that hold up the walkway.
- Find the stone tower at the end. What is it for?
- Look at how the bridge sags in the middle.
- Find the river far below.

Talk about it

1. What kind of bridge is this: beam, arch or suspension? How can you tell?
2. Why do you think the ropes are tied to strong stone at each end?
3. Would you like to walk across this bridge? Why or why not?

BUILD

Three Paper Bridges

You will build a beam bridge, an arch bridge and a suspension bridge from paper, all across the same gap. Then you will test each one with pennies to see which holds the most.

You will need

- Four stacks of books the same height, or two shoeboxes
- Several sheets of paper or card stock
- Tape and string
- Two cereal boxes or tall blocks for towers
- A small paper cup and about 50 pennies

Steps

1. Set two stacks of books a little closer together than the length of your paper. This is your gap. Keep it the same for every test.
2. **Beam bridge.** Lay a flat sheet of paper across the gap. Set the cup in the middle. Add pennies one at a time until the bridge sags to the table. Count and write it down.
3. **Arch bridge.** Bend a second sheet into a curve and wedge its ends between the book stacks, under the flat sheet. **Guess** first, then test with the cup of pennies again.
4. **Suspension bridge.** Stand a tall box at each end of the gap. Tape string across the tops of the boxes and down to the table on the outside. Hang the flat paper from the string with short pieces of string. Guess, then test again.
5. Make a chart of your three bridges and the number of pennies each one held.
6. **Make it better.** Choose the bridge that held the fewest pennies and change one thing to make it stronger. Test it again.

Tips

- Always put the cup in the same spot, right in the middle.
- Add pennies gently. Dropping them is not a fair test.

Check your work

- ☐ I can name the beam, arch and suspension bridges I built.
- ☐ I can tell which bridge held the most pennies.
- ☐ I tested every bridge across the same gap.

ENGINEER'S NOTEBOOK

1. Draw the three kinds of bridges side by side and label each one.
2. Make a chart of how many pennies each bridge held.
3. Draw a bridge you have crossed. What kind is it?

From history. The Inca rope bridge called Q'eswachaka still crosses the Apurímac River. Each year the families nearby twist new grass ropes and weave the bridge again in a few days, as their people have done for hundreds of years.

COMMON MISTAKES

- Moving the books between tests. The gap must stay the same.
- Calling every curved bridge a suspension bridge. Suspension bridges hang down from cables; arch bridges curve up underneath.

Make it a game • Three Bridge Sketch Race. Set a one-minute timer. Draw a beam bridge, an arch bridge and a suspension bridge as fast as you can, and label each one out loud. Your parent guesses which is which from the drawing alone. Then tell how the Inca people crossed deep valleys with grass rope. Beat your own time on the next round.

2.2 A CRAFT-STICK BEAM BRIDGE

OBJECTIVES

- Tell how early settlers built log bridges across rivers.
- Show that a beam on its edge bends less than a beam lying flat.
- Build a craft-stick beam bridge, test it with pennies and make it stiffer.

Warm-up. Hold a ruler flat across two stacks of books and press on the middle. Now turn the ruler on its edge and press again. Which way bends more? Why do you think that is?

WATCH

Beam Bridges 101

Builder Bunch • 2:13

<https://www.youtube.com/watch?v=WFP8UF-zvHg>

WHEN TO WATCH

Before the build, to see beam bridges and how they are held up.

Note: A short, silent LEGO demonstration with no narration; talk through it together.

KEY TERMS

beam

A long, stiff piece that carries a load across a gap.

pier

A post or pile of stone in the middle of a river that holds up a bridge.

sag

To bend down in the middle under a load.

span

The distance a bridge crosses between two supports.

CORE IDEAS

Long ago. About two hundred thirty years ago, Elizabeth Simcoe came from England to live in the woods of Canada. Her husband was the governor there. Elizabeth loved to draw and paint. As she traveled, she painted the rivers, the forests and the simple bridges that settlers built.

Many of those bridges were logs. A settler cut down a tall, straight tree so that it fell across the river. Then he laid more logs beside it to make a wider path. If the river was too wide, he built a **pier**, a pile of stones in the middle of the river, and laid logs from the bank to the pier and from the pier to the other bank.

Why does it work? When you stand on a beam, it bends down a little in the middle. That is called **sagging**. The top of the beam is squeezed, and the bottom is stretched. A thick beam sags less than a thin one. A beam standing on its edge sags much less than the same beam lying flat. And a short **span** sags less than a long one.

How do builders use it? Beam bridges are the most common bridges in the world. When you drive under a highway, you often pass under a beam bridge. Engineers make the beams tall and stand them on edge, and they add piers so that each span is not too long.

PICTURE STUDY



A Log Bridge over the Don River, Elizabeth Simcoe, about 1793–1796 · Watercolor sketch

Image: [Wikimedia Commons](#), public domain

Elizabeth Simcoe painted this log bridge near the town that later grew into the city of Toronto. It is one of the simplest bridges there is: a beam bridge made from a tree.

Look closely

- Find the log that crosses the river.
- Where does each end of the log rest?
- Look for any branches that were left on the log.
- Look at the water and the trees on each bank.

Talk about it

1. What kind of bridge is this?
2. What do you think would happen if the river were twice as wide?
3. How could a settler make this bridge safer to walk across?

Safety first. Wear safety glasses when you load the bridge until it breaks, in case a stick snaps.

BUILD

The Craft-Stick Beam Bridge

You will build beams from craft sticks, lay them across a gap, and hang a cup of pennies from the middle. You will find out which beam sags least.

You will need

- About 20 craft sticks
- White glue or masking tape
- Two stacks of books the same height
- A paper cup with a string handle, and about 60 pennies
- A ruler
- Safety glasses

Steps

1. Set the two stacks of books so the gap is a little shorter than a craft stick laid end to end with another (about 20 cm or 8 inches).
2. Make **Beam 1**: tape two sticks end to end with a short stick taped across the joint. Lay it flat across the gap.
3. Hang the cup from the middle. Add pennies one at a time until the beam sags so much that the cup touches the table. Count the pennies and write it down.
4. Make **Beam 2** the same way, but tape or glue three layers of sticks together so it is thicker. **Guess** how many pennies it will hold. Test it the same way.
5. Make **Beam 3**: take Beam 2 and turn it on its edge, held up by a stick taped on each side so it does not tip. Guess and test again.
6. Make a chart of your three beams. Which one held the most?
7. **Make it better**. Add a pier in the middle of the gap, such as a small stack of books, and test Beam 1 again. What happened?

Tips

- Let glue dry overnight before testing, or use tape.
- Hang the cup in the very same spot each time.

Check your work

- ☐ I can show that a beam on its edge sags less than a beam lying flat.
- ☐ I can tell how a pier helps a beam bridge.
- ☐ I counted the pennies for each beam.

ENGINEER'S NOTEBOOK

1. Draw Beam 1, Beam 2 and Beam 3. Write how many pennies each one held.
2. Draw a log bridge with a stone pier in the middle of the river.
3. Draw a ruler lying flat and a ruler on its edge. Circle the one that bends less.

From history. Elizabeth Simcoe kept a diary and made hundreds of drawings of early Canada. Many of them are kept today in the Archives of Ontario, and they show us how people built and traveled long ago.

COMMON MISTAKES

- Changing the gap between tests.
- Thinking a beam is only strong if it is heavy. Its shape matters too: tall and on edge is stiffer.

Make it a game • Flat Versus Edge Sag. Lay a craft stick flat between two stacks of books and hang a small cup of pennies from the middle. Now turn it on its edge. Before the test, guess which sags less. Earn a bean for each right guess. Use the words span, pier and sag. Tell how settlers made log bridges.

2.3 THE ROMAN ARCH AND THE AQUEDUCTS

OBJECTIVES

- Tell how the Romans carried water to their cities on bridges of stone arches.
- Explain what the keystone does in an arch.
- Build an arch from cardboard blocks and test a paper arch with pennies.

Warm-up. Push your two hands together, fingertips touching, so they make a pointed roof. Have someone press down on top. Can your hands hold it? Now try with your hands flat on the table. Which way is stronger?

WATCH

Fun with Arches

Engineering Models · 5:48

<https://www.youtube.com/watch?v=CP3fMa9iq8w>

WHEN TO WATCH

Before the build. Pause after the first arch is built and ask, “Which block do you think holds it all together?”

BACKUP VIDEO

The Engineering of Roman Aqueducts (in 2 minutes)

Learn History Simply · 2:07

<https://www.youtube.com/watch?v=bF66fGcG2zk>

With the story of the aqueducts, to see how water flowed gently downhill.

KEY TERMS

arch

A curved shape built of pieces that press against each other and hold each other up.

keystone

The wedge-shaped stone at the very top of an arch that locks the other stones in place.

aqueduct

A channel built to carry water a long way, sometimes on a bridge of arches.

CORE IDEAS

Long ago. About two thousand years ago, the Romans built great cities. A city needs lots of clean water. Often the best water was in springs far away in the hills. So Roman engineers built **aqueducts**, long stone channels that carried water to the city. The water flowed gently downhill the whole way, without any pumps.

Sometimes the aqueduct had to cross a deep valley. Then the Romans built a bridge of arches to carry it. The most famous is the Pont du Gard in France. It has three rows of arches, one on top of another, and it is taller than a fifteen-story building. The stones of its arches were cut to fit so well that the builders used no mortar to hold them. It still stands today.

Why does it work? An **arch** is made of wedge-shaped stones. Each stone leans on the stones beside it. When weight presses down on top, the stones squeeze together tighter instead of falling. The push travels around the curve and down into the ground at each end. The stone at the very top is the **keystone**. Until it is put in, the arch cannot stand by itself. So builders held the stones up on a curved wooden frame, set the keystone, and then took the frame away.

How do builders use it? Arches are in bridges, doorways, windows, tunnels and great churches. Engineers still build arch bridges today from stone, concrete and steel. An arch needs strong ground at each end to push against.

PICTURE STUDY



The Pont du Gard, Photochrom Print Collection (Detroit Publishing Company), between 1890 and 1900 ·
Photochrom print (a colored photograph) · Library of Congress
Image: [Wikimedia Commons](#), public domain

This old colored photograph shows the Pont du Gard, a Roman aqueduct bridge in the south of France. The water channel ran along the very top row.

Look closely

- Count the rows of arches.
- Find the biggest arches and the smallest arches. Where are they?
- Find the top row where the water once flowed.
- Look for the river under the bridge.

Talk about it

1. Why do you think the bottom arches are the biggest?
2. Where does each arch push down into the ground?
3. How did the Romans get water across this valley without pumps?

BUILD

A Cardboard Arch

You will build an arch from cardboard blocks over a curved frame, then take the frame away and see if it stands. Then you will test whether an arch makes a paper bridge stronger.

You will need

- A cereal box or thin cardboard for blocks
- A paper towel tube cut in half the long way (the frame)
- Two heavy books
- Card stock and a sheet of paper
- Tape, scissors and about 50 pennies in a small cup

Steps

1. A grown-up helps cut 9 cardboard blocks, each a little wider at the top than at the bottom, like a slice of pie with the tip cut off.
2. Lay the half tube on the table, curved side up. This is the frame. Stand a book at each end of it.
3. Lay the blocks over the frame from each side, wide end out. Put the last block, the keystone, at the very top.
4. **Guess:** will the arch stand if you slide the frame out? Gently pull the frame out and see.
5. Press down gently on the keystone. What happens to the books at the ends? Try it with no books.
6. Now set two book stacks apart and lay a flat sheet of paper across the gap. Test how many pennies it holds in the cup.
7. Bend a strip of card stock into an arch and wedge it between the stacks under the paper. Test again with the same cup. Write both numbers down.
8. **Make it better.** Try a taller arch or a flatter arch. Which held more?

Tips

- If the blocks slide, make them a little more wedge-shaped.

- The books at the ends are like the strong ground the arch pushes against.

Check your work

- ☐ I can point to the keystone and tell what it does.
- ☐ I can show that an arch pushes out at both ends.
- ☐ I tested a paper bridge with and without an arch.

ENGINEER'S NOTEBOOK

1. Draw your cardboard arch. Color the keystone and draw arrows where the arch pushes on the books.
2. Draw the Pont du Gard with its three rows of arches. Draw the water at the top.
3. Write how many pennies the paper bridge held with and without the arch.

From history. The Romans built aqueducts all over their empire. The city of Rome itself had eleven of them. Some Roman arches still carry water or traffic today, nearly two thousand years after they were built.

COMMON MISTAKES

- Taking the frame away before the keystone is in place.
- Forgetting the ends. An arch needs something strong to push against.

Make it a game • Keystone Says. Build an arch from folded cardboard strips or blocks, with one block as the keystone. Play Keystone Says: your parent gives a command, like point to the arch or touch the keystone, but only obey if they say Keystone Says first. Then tell how Romans carried water over stone arches, and name the aqueduct.

2.4 THE BROOKLYN BRIDGE: A FAMILY BUILDS A BRIDGE

OBJECTIVES

- Tell the story of John, Washington and Emily Roebling and the Brooklyn Bridge.
- Explain how a suspension bridge hangs from cables held up by towers.
- Build a string suspension bridge and make it stronger by adding more hangers.

Warm-up. Tie a string between two chair backs and pull it tight. Hang a paper clip from the middle. What happens to the string? Now pull the string tighter. Does the paper clip go up or down?

WATCH

Brooklyn Bridge Elephant Crossing | Attenborough and the Giant Elephant | BBC America

BBC America · 1:29

<https://www.youtube.com/watch?v=ULrYSNuqet8>

WHEN TO WATCH

After the story. Was the new bridge strong enough? In 1884, a year after it opened, a circus walked twenty-one elephants across it to show everyone. Watch the old pictures of the towers and cables, then ask: why could the bridge hold all those elephants?

BACKUP VIDEO

Brooklyn Bridge | How It Was Built

Structures Simplified · 6:50

https://www.youtube.com/watch?v=Y5Mc97_rW14

Any time this week, for more about the towers, the cables and the elephants that walked across.

KEY TERMS

cable

A thick, strong rope made of many steel wires twisted or bundled together.

tower

A tall, strong post that holds up the cables of a suspension bridge.

hanger

A thin cable that hangs down from the main cable and holds up the road.

engineer

A person who plans and builds useful things so that they are safe and strong.

CORE IDEAS

Long ago. Long ago, Brooklyn and New York were two cities with a wide river between them, the East River. People crossed by ferry boat. In winter the river filled with ice, and the boats could not always cross. An engineer named **John Roebling** drew plans for the longest suspension bridge in the world. But just as the work began, John was badly hurt in an accident at the river and could not finish it.

His son, **Washington Roebling**, took over. He worked deep under the river to build the bottoms of the two giant towers. Working down there made him very sick, and he could no longer go to the bridge. So he watched from his window through a telescope. His wife, **Emily Roebling**, studied hard and learned about bridges. Every day she carried his instructions to the builders and brought back their questions. For eleven years, the family kept working.

On May 24, 1883, the Brooklyn Bridge opened. Emily Roebling was the first person to ride across it. The next year, a circus walked 21 elephants over the bridge to show everyone how strong it was.

Why does it work? The road of a suspension bridge hangs from thin **hangers**. The hangers hang from four huge **cables**. Each cable is made of thousands of steel wires bundled together. The cables go over the tops of two tall stone **towers** and are tied down in giant blocks at each end. The weight of the road pulls on the cables, and the towers carry that weight down to the ground.

How do builders use it? Suspension bridges can cross the widest rivers. The Brooklyn Bridge also has extra slanting cables from the towers, to make it extra stiff and safe. It still carries people every day, more than 140 years later.

PICTURE STUDY



The Great East River Suspension Bridge, Currier and Ives, 1881 · Hand-colored lithograph · National Gallery of Art, Washington

Image: [Wikimedia Commons](#), public domain

Currier and Ives made popular colored prints of American scenes. They printed this picture of the Brooklyn Bridge two years before it opened, to show people what the finished bridge would look like.

Look closely

- Find the two tall towers. What shape are the openings in them?
- Follow one main cable from one end of the bridge to the other.
- Find the thin hangers that hold up the road.
- Look at the boats on the river. Why did the bridge need to be so high?

Talk about it

1. What holds up the road of this bridge?
2. What would happen if one hanger broke? What if all of them broke?
3. How did Emily Roebling help build the bridge?

BUILD

A String Suspension Bridge

You will hang a paper road from string cables between two box towers. Then you will test it with pennies and find out if more hangers make it stronger.

You will need

- Two tall cereal boxes or stacks of blocks (the towers)
- Heavy books to hold the cable ends down
- String, tape and scissors
- A strip of card stock about as long as your arm (the road)
- A paper cup and about 50 pennies

Steps

1. Stand the two towers about as far apart as your road strip is long.
2. Run two long strings over the tops of both towers, one on each side. Hold down each string end on the table with a heavy book. These are your main cables.
3. Cut 4 short strings for hangers. Tie or tape them from the main cables down to the road, two on each side.
4. Set the cup in the middle of the road. **Guess** how many pennies it will hold. Add pennies until the road sags to the table. Count and write it down.
5. Now add 4 more hangers, so you have 8. Guess again and test again.
6. Compare your two numbers. Did more hangers help?
7. **Make it better.** Try pulling the main cables tighter, or taping the towers so they do not lean in. Change one thing and test again.

Tips

- If the towers fall inward, the cables are pulling them. Tape them to the table or put a book inside each box.
- Space the hangers evenly along the road.

Check your work

- ☐ I can point to the towers, the main cables and the hangers.

- ☐ I can tell the story of the Roebling family.
- ☐ I tested my bridge with 4 hangers and with 8 hangers.

ENGINEER'S NOTEBOOK

1. Draw your string bridge. Label the towers, the cables, the hangers and the road.
2. Write how many pennies it held with 4 hangers and with 8 hangers.
3. Draw Emily Roebling riding across the finished bridge.

From history. When it opened, the Brooklyn Bridge was the longest suspension bridge in the world. A plaque on the bridge today honors Emily Warren Roebling for the faith and courage that helped her husband finish the work.

COMMON MISTAKES

- Thinking the towers hold up the road directly. The road hangs from the cables, and the cables rest on the towers.
- Forgetting to hold down the cable ends. Without anchors, a suspension bridge falls.

Make it a game • Roebling Story Chain. Tell the Brooklyn Bridge story in a chain with your parent, one sentence each. You start with John Roebling, your parent adds Washington, then you add Emily. Keep going until the bridge opens. Then draw a quick bridge with towers, cables and hangers, and label each part. Who tells the last sentence?

Scripture. “Through wisdom is an house builded; and by understanding it is established:” (Proverbs 24:3, KJV)

The Roeblings needed wisdom and understanding, and they needed each other. Great building is often the work of a whole family or team.

UNIT 2

BRIDGES

A bridge carries people over something they cannot walk across: a creek, a river, a valley or a busy road. The first bridges were simple: a log across a stream, or ropes woven from grass. Later, the Romans built great stone arches that still stand today, and engineers in New York hung a road from steel wires over a wide river.

In this unit you will learn the three main kinds of bridges, beam, arch and suspension, and you will build each one. You will load your bridges with pennies, count how many they hold, and make them stronger. You will also hear the true story of a family who built the Brooklyn Bridge together. “Through wisdom is an house builded,” says Proverbs, and the same is true of a bridge.

PREREQUISITES

- Knows what a fair test is: change only one thing (Unit 1)
- Can count pennies to 50 with help

MASTERY CHECKLIST

- ☐ I can name and draw a beam bridge, an arch bridge and a suspension bridge.
- ☐ I can show that a beam standing on its edge bends less than a beam lying flat.
- ☐ I can tell why the keystone matters in an arch.
- ☐ I can tell the story of the Roeblings and the Brooklyn Bridge.
- ☐ I can test a bridge with pennies, count the load and make it stronger.

OPTIONAL KITS FOR THIS UNIT

- **KEVA Planks**: Plain, identical wooden planks with no pegs or glue. Good for building beams, arches and towers with a parent, and for Units 2 and 3.
- **KiwiCo Kiwi Crate**: Ages 5–8. Some crates are building projects with bridges, towers or ramps; a fun extra for Units 1–3.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

2.1 Beam, Arch and Suspension Bridges	2 sessions of 30 minutes
2.2 A Craft-Stick Beam Bridge	2 sessions of 30 minutes
2.3 The Roman Arch and the Aqueducts	2 sessions of 30 minutes
2.4 The Brooklyn Bridge: A Family Builds a Bridge	2 sessions of 30 minutes

UNIT 2 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have paper, a ruler, two stacks of books, string and the pictures from this unit ready.

1. Draw or build a beam bridge, an arch bridge and a suspension bridge. Tell me the name of each one.
2. Show me with a ruler: which way does a beam bend less, lying flat or standing on its edge?
3. Look at the picture of the Pont du Gard. What did this bridge carry? Which stone holds an arch together?
4. Where does an arch push? Show me with your hands.
5. Tell me the story of the Brooklyn Bridge. Who helped build it?
6. Predict: if you take away half the hangers on a suspension bridge, will it hold more or fewer pennies? Why?

ANSWER KEY

1. A flat piece across a gap (beam), a curve under the road (arch), and a road hanging from cables on towers (suspension).
2. Standing on its edge.
3. It carried water to a Roman city. The keystone at the top locks the arch.
4. Out and down into the ground at both ends.
5. John Roebling planned it; his son Washington led the building; when Washington was sick, his wife Emily carried his instructions and learned about bridges. It opened in 1883.
6. Fewer, because each hanger has to carry more of the road.

PORTFOLIO PIECE: MY PENNY-TESTED BRIDGE

Choose the kind of bridge you like best and build it from craft sticks, cardboard, paper and string across a gap of 30 cm (12 inches) between two stacks of books. Test it with a cup of pennies and count how many it holds. Then make one change to make it stronger and test it again. Draw both tests in your notebook and show your family how your bridge carries its load to the ground.

LOOK FOR	WHAT IT MEANS
It spans the gap	The bridge crosses the whole gap and stands on its own.
Fair test	Tested with the cup in the same place both times and counted the pennies carefully.
Tried again	Made one change after the first test and tested again.
Notebook page	Drew the bridge, named its kind, and wrote both penny counts.
Telling	Explained what kind of bridge it is and how it holds up the load.

UNIT 3

BUILDINGS

Every building must stand up against its own weight, the wind, the rain and the people inside it. Builders long ago learned which materials are strong, which shapes do not wobble, and why a wide base is steady. In this unit you will hear the story Jesus told of the wise man who built his house upon the rock, watch farm families raise a barn in a single day, visit the great pyramids of Egypt, and see Gustave Eiffel build an iron tower taller than anything people had ever made.

You will test straws, sticks and blocks to find the best material for a little house. You will build shapes from straws and find out why engineers love triangles. You will stack cups into a tower and a pyramid and shake them, and you will build the tallest paper tower you can that stands up to a fan. Every time, you will guess, test, record and make it better.

PREREQUISITES

- Knows how to run a fair test (Units 1 and 2)
- Can name a triangle, a square and a circle

MASTERY CHECKLIST

- ☐ I can tell why builders choose different materials for different jobs.
- ☐ I can tell why a house needs a strong foundation, as Jesus taught.
- ☐ I can show that a triangle keeps its shape and a square can be pushed over.
- ☐ I can tell why the pyramids have stood for so long.
- ☐ I can tell the story of the Eiffel Tower and build a paper tower that stands up to wind.

OPTIONAL KITS FOR THIS UNIT

- **KEVA Planks:** Plain, identical wooden planks with no pegs or glue. Children can build towers, pyramids and walls and test them, as in Lessons 3.1–3.4.
- **Magna-Tiles:** Flat magnetic squares and triangles that snap together at the edges. Made for young children. Good for comparing squares and triangles in Lesson 3.2 and building towers in Lesson 3.4.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

3.1	Building Materials and the House on the Rock	2 sessions of 30 minutes
3.2	Strong Shapes: The Triangle and the Barn Raising	2 sessions of 30 minutes
3.3	The Pyramids of Egypt	2 sessions of 30 minutes
3.4	The Eiffel Tower	2 sessions of 30 minutes

UNIT 3 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have straws, pipe cleaners, a few cups and the pictures from this unit ready.

1. Tell me Jesus’s story of the two builders. Why did one house stand?
2. Why did London build with brick and stone after the Great Fire?
3. Make a square and a triangle from straws. Which one keeps its shape? How can you fix the square?
4. Show me with cups: which is steadier, a tall thin tower or a pyramid? Why?
5. How did the Egyptians move huge stones? What trick did they use with the sand?
6. Look at the picture of the Eiffel Tower. Why can the wind not push it over?

ANSWER KEY

1. The wise man built on the rock and the foolish man built on the sand. The house on the rock stood in the storm because its foundation was strong.
2. Wood burns, but brick and stone do not, so the city was safer.
3. The triangle keeps its shape. Add a brace from corner to corner to turn the square into triangles.
4. The pyramid, because it has a wide base and most of its weight is low.
5. They dragged the stones on wooden sleds with ropes, and poured water on the sand in front so the sled slid more easily.
6. It is an open lattice of iron triangles, so the wind blows through it, and its legs spread out wide at the bottom.

PORTFOLIO PIECE: MY STRONG TOWER

Using what you learned about materials, foundations, triangles and wide bases, plan and build a tower at least as tall as your knee from straws, paper, craft sticks or blocks. It must hold a small toy on top and stand for ten seconds in front of a fan. Draw your plan first, test the tower, make one change, and test it again. Show your family your plan, your tower and your notebook page.

LOOK FOR	WHAT IT MEANS
Planned first	Drew a plan before building, like Eiffel's engineers.
Strong shapes	Used triangles, braces and a wide base.
Fair test	Tested the tower with the fan at the same distance both times.
Tried again	Made one change after the first test and tested again.
Telling	Explained why the tower stands, using the words base and triangle.

3.1 BUILDING MATERIALS AND THE HOUSE ON THE ROCK

OBJECTIVES

- Tell Jesus's story of the wise and foolish builders, and why a foundation matters.
- Tell how London changed its building materials after the Great Fire of 1666.
- Test little houses of straws, sticks and blocks against wind, and test a foundation of sand against one of rock.

Warm-up. Walk around your home and look at what it is made of. Find wood, brick, stone, glass, metal or concrete. Make a list with a grown-up. Why do you think the builders used each one where they did?

WATCH

How to construct stronger buildings - from Fun Kids Inspiring Engineers

Fun Kids Learn · 2:17

<https://www.youtube.com/watch?v=iGRLY08Kn2o>

WHEN TO WATCH

After the core ideas, before the build.

BACKUP VIDEO

Engineering for the Three Little Pigs

Teach Engineering · 2:50

<https://www.youtube.com/watch?v=zrlRunvUI3A>

For parents before the build: a teacher shows children testing sand houses for strength, much like today's build.

KEY TERMS

material

What something is made of, like wood, brick, stone or steel.

foundation

The strong bottom part of a building that sits in or on the ground and holds the building up.

brick

A block of clay baked hard in a hot oven, used to build walls.

CORE IDEAS

Long ago. Jesus told a story about two builders. A wise man built his house upon a rock. A foolish man built his house upon the sand. Then the rain came down, the floods came up and the wind blew. The house on the rock stood firm. The house on the sand fell. Jesus said that people who hear His words and do them are like the wise builder.

Builders also learned about materials the hard way. In 1666 a great fire burned through the city of London for four days. Most houses there were made of wood, and wood burns. When London was built again, the new rules said that houses must be made of brick or stone, which do not burn. The city was much safer after that.

Why does it work? Every **material** is good at some things and not at others. Straw is light but weak. Wood is strong and easy to cut, but it can burn or rot. **Brick** and stone are heavy and do not burn, but they are hard to lift. Steel is very strong but costs more. And every building needs a strong **foundation**. If the ground underneath washes away or sinks, even a strong house will crack and fall.

How do builders use it? Engineers choose the right material for each job. They dig down to firm ground or solid rock before they build. Tall buildings stand on deep foundations of concrete and steel that reach down to rock.

PICTURE STUDY



The House on the Rock, Jan Luyken, 1681 · Etching · Rijksmuseum, Amsterdam

Image: [Wikimedia Commons](#), public domain

The Dutch artist Jan Luyken made small pictures of the stories Jesus told. This one shows the wise man's house on the rock in a great storm, with the foolish man's house in the distance.

Look closely

- Find the house on the rock. Is it standing?
- Find the house far away. What is happening to it?
- Look for the wind, the waves and the lightning.
- Find the two men on the shore. What are they looking at?

Talk about it

1. Why did the house on the rock stand while the other one fell?
2. What materials do you think the strong house is made of?
3. Where would you build your house, and what would you make it from?

Safety first. Only a grown-up uses the hair dryer, on the cool setting.

BUILD

The Wind and the Flood Test

You will build three little houses from straws, craft sticks and blocks, and test which stands up to wind. Then you will build on sand and on a rock and pour on a flood.

You will need

- Drinking straws, craft sticks, and small blocks or sugar cubes
- Tape and modeling clay
- A hair dryer on the cool setting, or a box fan, used by a grown-up
- A baking pan, some sand, a flat rock or a brick, and a cup of water
- A timer

Steps

1. Build three small houses about the same size: one from straws, one from craft sticks and one from blocks. Use only a little clay at the corners.
2. **Guess** which house will stand longest in the wind. Draw your guess.
3. A grown-up holds the hair dryer on cool at the same distance from each house. Count or time how long each house stands. Write it down.
4. Now pour sand in one end of the baking pan. Set the flat rock at the other end. Build a small block house on the sand and one on the rock.
5. Guess which will stand. Then slowly pour water into the pan, like a flood, and watch.
6. Make a chart of all your tests.
7. **Make it better.** Choose your weakest house and change one thing to make it stronger, like a wider base or a different material. Test it again.

Tips

- Hold the dryer the same distance away every time. Measure with a ruler.
- Pour the water slowly, from the same corner each time.

Check your work

- ☐ I can tell which material stood best in the wind and why.

- ☐ I can tell why the house on the rock stood in the flood.
- ☐ I made one house stronger and tested it again.

ENGINEER'S NOTEBOOK

1. Draw your three houses and write how long each one stood in the wind.
2. Draw the house on the sand and the house on the rock before and after the flood.
3. Draw your own home and label what it is made of.

From history. After the Great Fire, the scientist and builder Robert Hooke helped measure out the streets of London again, and the architect Christopher Wren built more than fifty new churches of stone, including St Paul's Cathedral.

COMMON MISTAKES

- Holding the hair dryer closer to one house than another.
- Thinking only the walls matter. The foundation under the house matters just as much.

Make it a game • Wise Builder Wind Test. Build one little house on a tray of dry sand and one on a flat board. Pretend to be the wind and the rain with a fan or your breath. Say which house stands and why a foundation matters. Then tell what London did after the Great Fire of 1666. Retell the story without peeking.

Scripture. “Therefore whosoever heareth these sayings of mine, and doeth them, I will liken him unto a wise man, which built his house upon a rock: And the rain descended, and the floods came, and the winds blew, and beat upon that house; and it fell not: for it was founded upon a rock.” (Matthew 7:24-25, KJV)

Builders know a house is only as strong as what it stands on. Jesus said our lives are the same: we are wise when we build them on His words.

3.2 STRONG SHAPES: THE TRIANGLE AND THE BARN RAISING

OBJECTIVES

- Tell how farm families raised a barn frame together in one day.
- Show that a triangle keeps its shape while a square can be pushed over.
- Build a cube from straws, test it, and make it stiff with triangles.

Warm-up. Look for triangles in buildings and other things around you: a roof, a bicycle frame, a swing set, a bridge, a tower. Make a tally mark for every triangle you find in ten minutes.

WATCH

Strong Structures with Triangles | Design Squad

Design Squad • 5:02

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

WHEN TO WATCH

After the first core idea. Pause when the square leans over and ask, “How could you fix it?”

BACKUP VIDEO

Why Are Triangles Stronger Than Squares?

Science Channel • 1:18

<https://www.youtube.com/watch?v=AoS0UVfxRQ>

A short review before the build.

KEY TERMS

frame

The strong framework of beams and posts inside a building.

brace

A slanting piece added to a frame to keep it from leaning over.

triangle

A shape with three straight sides. It cannot change its shape unless a side bends or breaks.

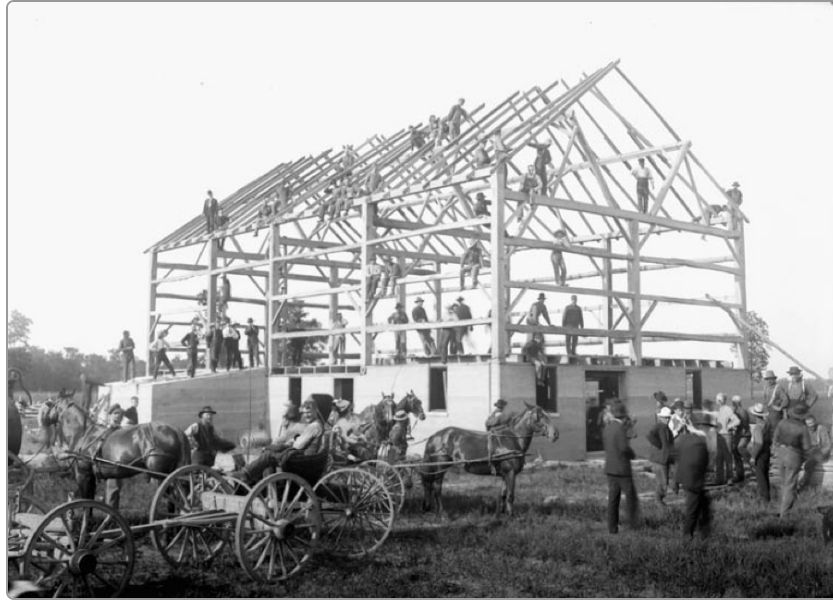
CORE IDEAS

Long ago. A farmer needs a big barn for his hay and his animals. But a barn is too big for one family to build alone. So in farming country in America and Canada, neighbors came together for a **barn raising**. Before the day, the carpenters cut all the big wooden beams and fitted their ends together. On the day itself, dozens of men lifted the walls of the **frame** into place with long poles and ropes, while the women cooked a great meal for everyone. By evening, the whole frame could be standing.

Why does it work? Make a square from four sticks with loose corners and push on one side. It leans over and squashes flat. Now make a **triangle** from three sticks and push on it. It will not change shape! The only way to change a triangle is to bend or break one of its sides. That is why builders add a slanting piece called a **brace** across the corner of a square frame. The brace turns the square into triangles, and the frame stands straight.

How do builders use it? Look closely at a barn frame and you will see short braces in the corners. Roofs are held up by triangles. Bridges, towers, cranes and bicycle frames are full of triangles. When engineers want something to be strong but light, they very often use triangles.

PICTURE STUDY



Barn Raising: Leckie's Barn in Frame, John Boyd, June 2, 1908 · Photograph

Image: [Wikimedia Commons](#), public domain

This photograph was taken in Canada on the day neighbors raised a barn for the Leckie family. The frame is finished, and the men are still standing up on the beams.

Look closely

- Find the tall posts and the long beams across the top.
- Look for short slanting braces in the corners. What shape do they make?
- Find the triangle shapes in the roof.
- Count how many people you can see on the frame.

Talk about it

1. What would happen to this frame in a strong wind if it had no braces?
2. Why did the farmer need so many neighbors to help?
3. How is this barn frame like the straw cube you will build?

BUILD

The Straw Cube Test

You will build a square and a triangle from straws and test which keeps its shape. Then you will build a cube, find out how wobbly it is, and make it stiff with triangles.

You will need

- About 20 drinking straws
- Pipe cleaners cut into short pieces, or paper clips, to join the corners
- Scissors and tape
- A light book or a small box for a load

Steps

1. Join 4 straws at the corners with pipe cleaner pieces to make a square. Join 3 straws to make a triangle.
2. Push gently on the side of each one. Which one changes shape? Write down what you see.
3. Build a cube: two squares for the top and bottom, joined by 4 straws standing up.
4. **Guess:** will your cube hold up a light book? Set the book on top and watch.
5. Push gently on one side of the cube. Does it lean over?
6. Add one straw across one face of the cube from corner to corner to make triangles. Push again. Then add braces to more faces, one at a time, and test after each one.
7. Write down how many braces it took before your cube stayed square and held the book.
8. **Make it better.** Try to use the fewest braces that still make the cube strong.

Tips

- Bend the pipe cleaner pieces into a V and push one end into each straw.
- Push gently with one finger each time, in the same place.

Check your work

- ☐ I can show that a triangle keeps its shape and a square does not.
- ☐ I can tell what a brace does.
- ☐ I counted how many braces my cube needed.

ENGINEER'S NOTEBOOK

1. Draw your cube before and after you added braces. Color the triangles.
2. Draw the barn frame from the picture and circle every brace you can find.
3. Draw three things at home or outside that use triangles.

From history. Barn raisings were a happy time of work and fellowship. Neighbors knew that one day they might need a barn raised too. Amish communities in America still raise barns together this way today.

COMMON MISTAKES

- Thinking straws are too weak to build with. The shape you make matters more than how thick the straw is.
- Adding braces that do not go corner to corner.

Make it a game • Brace Me Up. Build a cube of straws and tape with no braces. Push it over with a finger, then add triangle braces and push again. Say frame, brace and triangle as you fix it. Tell your parent how neighbors raised a barn in one day. Whoever makes the stiffest cube wins, and your parent tests it.

3.3 THE PYRAMIDS OF EGYPT

OBJECTIVES

- Tell how the Great Pyramid was built by many workers moving huge stone blocks.
- Explain why a wide base and a narrow top make a building steady.
- Build a cup tower and a cup pyramid and test which one stands when the table shakes.

Warm-up. Stand with your feet close together and have someone give you a gentle push on the shoulder. Now stand with your feet wide apart and try again. Which way is it harder to tip you over?

WATCH

The Pyramids of Egypt and the Giza Plateau: Ancient Egyptian History for Kids - FreeSchool

Free School • 5:45

<https://www.youtube.com/watch?v=Xtc0LQuA3z4>

WHEN TO WATCH

After the story. Pause at the picture of the blocks and ask, “How would you move a stone that heavy?”

BACKUP VIDEO

Building The Great Pyramid of Giza | Lost Treasures Of Egypt | National Geographic UK

National Geographic UK • 2:02

<https://www.youtube.com/watch?v=dWq0iC4YqbE>

Any time this week, to see a model of how the blocks may have been moved.

KEY TERMS

pyramid

A building with a square bottom and four slanting sides that meet in a point at the top.

base

The bottom part of something, the part it stands on.

stable

Steady; hard to tip over.

sled

A flat platform that slides along the ground, used to drag heavy loads.

CORE IDEAS

Long ago. About 4,500 years ago, in the land of Egypt, a king named Khufu ordered a great **pyramid** to be built. Thousands of workers cut more than two million blocks of stone. Many blocks weighed as much as two cars. The workers had no trucks or cranes. They dragged the blocks on wooden **sleds**, pulled by teams with ropes, and moved them up ramps.

An old Egyptian painting shows a team pulling a huge statue on a sled, while one worker pours water on the sand in front of it. Scientists have tested this. Wet sand is firmer than dry sand, so a sled slides over it much more easily. The Egyptians had found a clever trick.

When it was done, the Great Pyramid was the tallest building in the world, and it stayed the tallest for almost four thousand years. Its four sides face almost exactly north, south, east and west.

Why does it work? A pyramid has a wide **base** and a narrow top. Most of its weight is low and close to the ground. That makes it very **stable**. Wind, rain and even earthquakes have not knocked it down. A thin tower can tip, but a pyramid is very hard to tip over.

How do builders use it? Engineers still give tall buildings and towers wide bases. Look at the bottom of a tall radio tower or the Eiffel Tower: they are wide at the bottom and narrow at the top, a bit like a pyramid.

PICTURE STUDY



Pyramids of Gizeh, Louis Haghe, after David Roberts, 1838 (printed in the 1840s) · Hand-colored lithograph · Cleveland Museum of Art
Image: [Wikimedia Commons](#), public domain

The Scottish artist David Roberts traveled through Egypt and drew what he saw. Louis Haghe turned his drawings into prints for a famous book. This one shows the pyramids at Giza.

Look closely

- Find the two big pyramids. Where are they widest?
- Find the tiny travelers at the bottom. How big are the pyramids next to them?
- Look at the sand and rock around the pyramids.
- Look at the top of the pyramids. Are they sharp or a little flat?

Talk about it

1. Why do you think the pyramids are still standing after so many years?
2. How would you move a stone block across this sand?
3. Why are the pyramids wide at the bottom and narrow at the top?

BUILD

Tower or Pyramid?

You will build a tall, thin tower and a pyramid from the same number of cups, and test which one stands when the table shakes. Then you will try the Egyptians' wet-sand trick.

You will need

- 10 paper or plastic cups for each building (20 in all)
- A table you can shake gently, or a tray on a cookie sheet
- A baking pan with sand, a small box filled with pennies for a block, string and a rubber band
- A cup of water and a ruler

Steps

1. Stack 10 cups straight up into a tall, thin tower.
2. Build a second building from 10 cups as a pyramid: 4 cups on the bottom row, then 3, then 2, then 1.
3. **Guess** which one will fall first when the table shakes.
4. Shake the table gently, the same for both, and count to five. Which one fell? Try it three times and make tally marks.
5. Now the sled test. Tie a string to the box of pennies and tie a rubber band to the string. Drag the box across dry sand. A grown-up measures how long the rubber band stretches.
6. Sprinkle water on the sand until it is damp, but not muddy. Guess, then drag the box again and measure.
7. Make a chart of all your tests.
8. **Make it better.** Build the tallest cup building you can that still stands when the table shakes. How wide does the base need to be?

Tips

- Shake the table the same way for both buildings. Count out loud.
- Damp sand works best. Too much water makes mud.

Check your work

- ☐ I can tell why a wide base makes a building stable.
- ☐ I can tell why the Egyptians poured water on the sand.
- ☐ I tested each building three times and made tally marks.

ENGINEER'S NOTEBOOK

1. Draw your tower and your pyramid. Write how many times each one fell.
2. Draw a team pulling a stone block on a sled, with one worker pouring water.
3. Write the rubber-band stretch on dry sand and on damp sand.

From history. Tools and work camps found near the pyramids show that the builders were organized into teams. They had bakeries, and doctors to set broken bones. Building a pyramid took the work of a whole nation for many years.

COMMON MISTAKES

- Shaking harder for one building than the other.
- Thinking the pyramids are steady just because they are heavy. Their shape, wide at the bottom, matters too.

Make it a game • Pyramid or Tower Duel. Build a block pyramid and a block tower of the same height. Shake the table gently and see which one stays. Then explain why a wide base steadies a building, using the word stable. Pretend your parent is a worker pulling a block on a sled, and count how many workers it takes to move a giant stone.

3.4 THE EIFFEL TOWER

OBJECTIVES

- Tell how Gustave Eiffel planned and built his iron tower for the 1889 World's Fair.
- Explain why a tower made of iron triangles can be both light and strong, and why it lets the wind through.
- Build the tallest paper tower you can that stands up to a fan.

Warm-up. Hold up a sheet of paper in front of a fan. Feel how hard the wind pushes. Now cut many holes in an old sheet of paper and hold it up again. Does the wind push as hard? Why not?

WATCH

The Eiffel Tower for Kids: Famous World Landmarks for Children - FreeSchool

Free School · 3:14

<https://www.youtube.com/watch?v=DUafW5QkASA>

WHEN TO WATCH

After the story.

BACKUP VIDEO

The Eiffel Tower for Kids

Homeschool Pop · 6:33

<https://www.youtube.com/watch?v=-LYh7Npojn0>

Any time this week, for more fun facts about the tower.

KEY TERMS

iron

A strong, hard metal. Steel is made from iron.

rivet

A metal pin, put in red-hot, that holds two pieces of metal together tightly.

lattice

A pattern of crossing pieces with open spaces between them.

CORE IDEAS

Long ago. In 1889 the city of Paris held a World's Fair. The leaders wanted a great tower to welcome visitors. An engineer named **Gustave Eiffel** won the contest. His company had already built many iron bridges. Now he would build a tower of **iron** almost a thousand feet tall, nearly twice as tall as anything people had ever built.

Before any building began, Eiffel's engineers made thousands of drawings. Every one of the 18,000 iron pieces was planned on paper and made in a factory, with the holes already in the right places. At the tower, workers lifted the pieces with cranes and joined them with red-hot **rivets**, millions of them. The tower was finished in just over two years, in time for the fair. Some people said it was ugly. But soon almost everyone loved it.

Why does it work? The Eiffel Tower is not a solid wall of iron. It is a **lattice**, a pattern of iron bars that make triangles, with open spaces between them. Triangles keep the tower stiff, so it can be strong without being too heavy. The open spaces let the wind blow right through, so the wind cannot push it over. And its four legs spread out wide at the bottom, like a pyramid, to keep it steady.

How do builders use it? Radio towers, power-line towers and many cranes are built as lattices of triangles, just like the Eiffel Tower. The tower itself turned out to be useful too. Its height made it a perfect place for radio antennas, and that is one reason it was never taken down.

PICTURE STUDY



The Eiffel Tower under Construction, Louis-Émile Durandelle, November 23, 1888 · Photograph

Image: [Wikimedia Commons](#), public domain

A photographer named Louis-Émile Durandelle took pictures of the Eiffel Tower again and again as it rose. This one shows it about four months before it was finished.

Look closely

- Find the four legs. How far apart are they at the bottom?
- Find the crisscross pattern of iron bars. What shape do you see again and again?
- Find the unfinished top.
- Look for the open spaces between the bars.

Talk about it

1. Why do you think the legs are so wide apart at the bottom?
2. Why is it important that the wind can blow through the tower?
3. How is this tower like the pyramids? How is it different?

BUILD

The Paper Tower Challenge

You will build the tallest tower you can from ten sheets of paper and some tape. It must stand by itself, hold a small toy on top, and stand up to the wind of a fan.

You will need

- 10 sheets of newspaper or printer paper
- Masking tape (about one arm's length)
- A small toy or a ball of clay for the top
- A box fan, used by a grown-up
- A tape measure

Steps

1. Look at your materials. Make a plan by drawing your tower in your notebook first, the way Eiffel's engineers did.
2. Roll some sheets into tight tubes and tape them. Tubes are much stiffer than flat paper.
3. Build your tower. Try a wide base and use triangles to brace it.
4. Measure how tall it is and write it down. Set the toy on top. Does it hold?
5. **Guess:** will your tower stand in the wind? A grown-up turns the fan on low, the same distance away each time. Watch for ten seconds.
6. Write down what happened: stood, leaned or fell.
7. **Make it better.** Change one thing, like a wider base or more triangles. Measure and test again. Can you make it taller and still standing?

Tips

- Roll the paper around a pencil, then slide the pencil out, to make thin, strong tubes.
- Tape the bottom of the tower to a piece of cardboard to make a strong foundation.

Check your work

- ☐ I drew a plan before I built.

- ☐ I can tell why triangles and a wide base help a tower stand.
- ☐ I measured my tower and tested it in the wind twice.

ENGINEER'S NOTEBOOK

1. Draw your plan, then draw how your tower really turned out.
2. Write how tall your tower was and what happened in the wind, before and after your change.
3. Draw the Eiffel Tower and color every triangle you can find.

From history. The Eiffel Tower was the tallest structure in the world for about forty years. Eiffel used it as a laboratory, too. He studied the wind and the weather from the top, and he dropped objects from it to learn how air pushes on falling things.

COMMON MISTAKES

- Building tall first and wide later. Start with a strong, wide base.
- Moving the fan closer for the second test. Keep it the same distance.

Make it a game • Eiffel Triangle Hunt. Make a paper tower from rolled newspaper tubes and tape, and add triangles on the sides. Use a 3-minute timer. Then hold up a hand fan and test how well wind goes through. Tell your parent why Gustave Eiffel made his tower of iron triangles. Say iron, rivet and lattice in one sentence to win.

Scripture. “For which of you, intending to build a tower, sitteth not down first, and counteth the cost, whether he have sufficient to finish it?” (Luke 14:28, KJV)

Jesus said a wise builder plans before he builds. Eiffel’s engineers drew every piece on paper first, so the tower could be finished on time.

UNIT 3

BUILDINGS

Every building must stand up against its own weight, the wind, the rain and the people inside it. Builders long ago learned which materials are strong, which shapes do not wobble, and why a wide base is steady. In this unit you will hear the story Jesus told of the wise man who built his house upon the rock, watch farm families raise a barn in a single day, visit the great pyramids of Egypt, and see Gustave Eiffel build an iron tower taller than anything people had ever made.

You will test straws, sticks and blocks to find the best material for a little house. You will build shapes from straws and find out why engineers love triangles. You will stack cups into a tower and a pyramid and shake them, and you will build the tallest paper tower you can that stands up to a fan. Every time, you will guess, test, record and make it better.

PREREQUISITES

- Knows how to run a fair test (Units 1 and 2)
- Can name a triangle, a square and a circle

MASTERY CHECKLIST

- ☐ I can tell why builders choose different materials for different jobs.
- ☐ I can tell why a house needs a strong foundation, as Jesus taught.
- ☐ I can show that a triangle keeps its shape and a square can be pushed over.
- ☐ I can tell why the pyramids have stood for so long.
- ☐ I can tell the story of the Eiffel Tower and build a paper tower that stands up to wind.

OPTIONAL KITS FOR THIS UNIT

- **KEVA Planks:** Plain, identical wooden planks with no pegs or glue. Children can build towers, pyramids and walls and test them, as in Lessons 3.1–3.4.
- **Magna-Tiles:** Flat magnetic squares and triangles that snap together at the edges. Made for young children. Good for comparing squares and triangles in Lesson 3.2 and building towers in Lesson 3.4.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

3.1 Building Materials and the House on the Rock	2 sessions of 30 minutes
3.2 Strong Shapes: The Triangle and the Barn Raising	2 sessions of 30 minutes
3.3 The Pyramids of Egypt	2 sessions of 30 minutes
3.4 The Eiffel Tower	2 sessions of 30 minutes

UNIT 3 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have straws, pipe cleaners, a few cups and the pictures from this unit ready.

1. Tell me Jesus’s story of the two builders. Why did one house stand?
2. Why did London build with brick and stone after the Great Fire?
3. Make a square and a triangle from straws. Which one keeps its shape? How can you fix the square?
4. Show me with cups: which is steadier, a tall thin tower or a pyramid? Why?
5. How did the Egyptians move huge stones? What trick did they use with the sand?
6. Look at the picture of the Eiffel Tower. Why can the wind not push it over?

ANSWER KEY

1. The wise man built on the rock and the foolish man built on the sand. The house on the rock stood in the storm because its foundation was strong.
2. Wood burns, but brick and stone do not, so the city was safer.
3. The triangle keeps its shape. Add a brace from corner to corner to turn the square into triangles.
4. The pyramid, because it has a wide base and most of its weight is low.
5. They dragged the stones on wooden sleds with ropes, and poured water on the sand in front so the sled slid more easily.
6. It is an open lattice of iron triangles, so the wind blows through it, and its legs spread out wide at the bottom.

PORTFOLIO PIECE: MY STRONG TOWER

Using what you learned about materials, foundations, triangles and wide bases, plan and build a tower at least as tall as your knee from straws, paper, craft sticks or blocks. It must hold a small toy on top and stand for ten seconds in front of a fan. Draw your plan first, test the tower, make one change, and test it again. Show your family your plan, your tower and your notebook page.

LOOK FOR	WHAT IT MEANS
Planned first	Drew a plan before building, like Eiffel's engineers.
Strong shapes	Used triangles, braces and a wide base.
Fair test	Tested the tower with the fan at the same distance both times.
Tried again	Made one change after the first test and tested again.
Telling	Explained why the tower stands, using the words base and triangle.

UNIT 4

ELECTRICITY

Electricity lights our lamps and runs our machines, but you cannot see it. Long ago, people only knew it as a crackle when they rubbed amber or a spark from a cat's fur. Then curious men began to test it. Alessandro Volta built the first battery. Stephen Gray found that some things carry electricity and some do not. William Gilbert showed that the whole Earth is a magnet. And Benjamin Franklin flew a kite into a storm cloud and proved that lightning is electricity.

In this unit you will light a bulb with a battery, test which things in your house carry electricity, make a compass from a needle, and make paper jump with a balloon. You will use only small batteries, never the outlets in the wall. Electricity is a wonderful servant, and a wise engineer always treats it with care.

PREREQUISITES

- Can follow a safety rule every time
- Knows how to make a chart of guesses and results (Units 1–3)

MASTERY CHECKLIST

- ☐ I can light a bulb with a battery and wires, and I can tell why the circuit must be a complete loop.
- ☐ I can sort things into conductors and insulators, and I tested them to find out.
- ☐ I can make a compass from a needle and tell why it points north.
- ☐ I can tell the story of Benjamin Franklin's kite and why we never fly kites in storms.
- ☐ I can say the safety rules: batteries only, never outlets, and stay far from power lines.

OPTIONAL KITS FOR THIS UNIT

- **Snap Circuits (Elenco):** Parts snap together on a plastic grid with no wires to strip and no soldering. Elenco makes a Snap Circuits Beginner set for young children; it fits Lessons 4.1 and 4.2 and the sensor in Lesson 8.3.
- **KiwiCo Kiwi Crate:** Ages 5–8. Some crates include simple battery circuits with lights; a fun extra for this unit.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

4.1 A Battery and a Bulb: Volta’s Pile	2 sessions of 30 minutes
4.2 Conductors and Insulators: Stephen Gray’s Long Thread	2 sessions of 30 minutes
4.3 Magnets and the Compass	2 sessions of 30 minutes
4.4 Benjamin Franklin’s Kite	2 sessions of 30 minutes

UNIT 4 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have the battery, bulb and clip leads, a few small objects, a magnet and a balloon ready.

1. Light the bulb with the battery and wires. Now make it go out without unhooking the bulb. Why did it go out?
2. Here are a spoon, a coin, a crayon and a rubber band. Which are conductors and which are insulators? How could you test to be sure?
3. Why does a wire have metal inside and plastic outside?
4. What does a compass needle do? What did William Gilbert say about the Earth?
5. Tell me the story of Franklin’s kite. What did he learn, and what did he invent?
6. Tell me the electricity safety rules.

ANSWER KEY

1. Opening the loop anywhere stops the flow; a circuit must be a complete loop.
2. Metal spoon and coin are conductors; crayon and rubber band are insulators. Test each with the battery-and-bulb tester.
3. The metal carries the electricity, and the plastic is an insulator that keeps it from touching people or other wires.
4. It turns to point north. Gilbert said the whole Earth is a giant magnet.
5. He flew a kite with a key under a storm cloud, saw a spark jump from the key, and learned lightning is electricity. He invented the lightning rod.
6. Use only small batteries; never touch outlets or plugged-in cords; never go near power lines; never fly kites in storms or near power lines.

PORTFOLIO PIECE: MY LIGHTED ROOM

Make a small room from a shoebox and light it with your battery, bulb and paper-clip switch. Poke the bulb through the ceiling so it shines inside, and put the switch on the outside wall. Test it: does the switch turn the light on and off every time? Then add something to your room that is a conductor and something that is an insulator, and label them. Draw your circuit in your notebook and show your family how the light works.

LOOK FOR	WHAT IT MEANS
The light works	The bulb lights when the switch is closed and goes out when it is open.
Complete loop	Can trace the loop with a finger from the battery, through the switch and bulb, and back.
Conductors and insulators	Labeled one conductor and one insulator correctly.
Safe work	Used only batteries and followed every safety rule.
Telling	Explained how the switch turns the light on and off.

4.1 A BATTERY AND A BULB: VOLTA'S PILE

OBJECTIVES

- Tell how Alessandro Volta built the first battery.
- Explain that a circuit must be a complete loop for the bulb to light.
- Light a bulb with a battery and wires, and add a paper-clip switch.

Warm-up. Turn a flashlight on and off. What do you think happens inside when you push the button? With a grown-up, take out the batteries and look at them. Find the bump on one end (+) and the flat end (-).

WATCH

The Power of Circuits! | Technology for Kids | SciShow Kids

SciShow Kids · 4:42

<https://www.youtube.com/watch?v=HOFp8bHTN30>

WHEN TO WATCH

After the core ideas, before the build. Pause when the bulb lights and ask, “What made the loop complete?”

BACKUP VIDEO

Setting Up a Simple Circuit

Next Generation Science · 1:25

<https://www.youtube.com/watch?v=x4pdzG-DHnY>

Right before the build, to see a battery, bulb and switch connected in a loop.

KEY TERMS

battery

A small container that stores energy and pushes electricity around a circuit.

circuit

A complete loop that electricity can flow around, from the battery and back again.

switch

A part that opens or closes the loop to turn something on or off.

wire

A thin metal thread, usually covered in plastic, that carries electricity.

CORE IDEAS

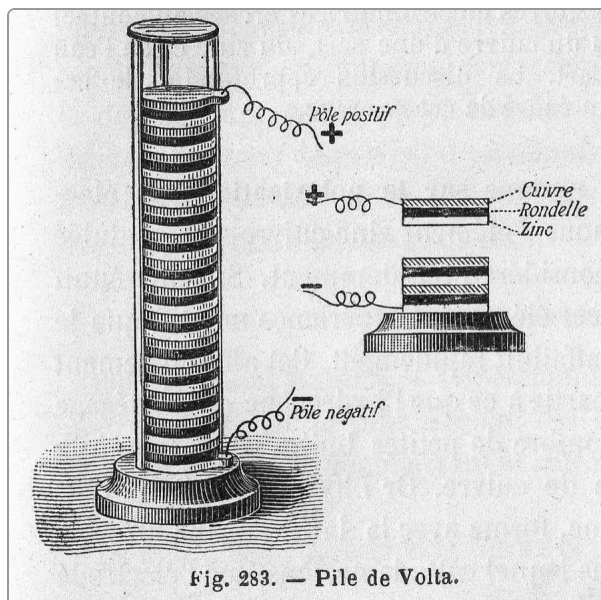
Long ago. More than two hundred years ago, people could only make electricity in quick sparks that were gone in a moment. In Italy, a scientist named **Alessandro Volta** wanted to make electricity that kept flowing. In 1800 he made a stack of little round metal disks, zinc and copper, one on top of the other, with pieces of cloth soaked in salty water between them. When he touched wires to the top and bottom of his stack, electricity flowed and kept on flowing. It was the very first **battery**. People called it Volta's pile.

Volta was asked to show his pile to the ruler of France, Napoleon, in Paris in 1801. Today, when you see the word **volt** on a battery, it is named after Alessandro Volta.

Why does it work? A battery pushes electricity out of one end. The electricity can only flow if it has a path all the way around and back into the other end of the battery. That complete path is called a **circuit**. A bulb in the path lights up when electricity flows through it. If there is a gap anywhere in the loop, the flow stops and the light goes out.

How do builders use it? Every light switch in your house opens and closes a circuit. When you flip the **switch** on, the loop is closed and the light shines. When you flip it off, the loop is opened. Flashlights, toys and cars all use circuits like the one you will build.

PICTURE STUDY



Volta's Pile, Gillard, 1904 · Engraving from a French science book

Image: [Wikimedia Commons](#), public domain

This drawing from an old French science book shows how Volta's pile was built: a tall stack of the same three layers, again and again.

Look closely

- Find the tall stack of disks.
- Find the wire at the top marked + and the wire at the bottom marked -.
- Find the small drawing of one layer. The French words say copper (*cuivre*), cloth disk (*rondelle*) and zinc.
- Find the glass rods that hold the stack straight.

Talk about it

1. Why do you think Volta stacked so many layers?
2. Where would you connect a bulb to make a circuit?
3. How is a battery today like Volta's pile?

Safety first. Use only AA, C or D batteries, never the outlets in the wall. Never connect the two ends of a battery with just a wire and no bulb; the wire gets hot and the battery is ruined.

BUILD

Light the Bulb

You will connect a battery, wires and a bulb into a loop to make the bulb light. Then you will add a switch made from a paper clip.

You will need

- A D-cell or AA battery in a battery holder
- A small flashlight bulb in a holder (or an LED)
- Three alligator clip leads
- Two brass paper fasteners, a paper clip and a small piece of cardboard (for the switch)

Steps

1. Look at the battery, the bulb and the wires. **Guess:** how will you connect them to light the bulb? Draw your guess.
2. Clip one wire from one end of the battery holder to one side of the bulb holder.
3. Clip a second wire from the other side of the bulb holder. Touch its free end to the other end of the battery holder. Does the bulb light?
4. Unclip one wire. What happens? Clip it back. Talk about why.
5. Make a switch: push two paper fasteners through the cardboard, a little apart. Hook a paper clip over one fastener so it can swing to touch the other.
6. Put the switch into your loop with the third wire. Swing the paper clip on and off and watch the bulb.
7. **Make it better.** Can you find a way to light the bulb with only one wire? Try it and draw what worked.

Tips

- If the bulb does not light, check every clip. The loop must be complete.
- An LED only works one way around. If it does not light, turn it around.

Check your work

- ☐ I can make a bulb light with a battery and wires.

- ☐ I can tell why a gap in the loop turns the light off.
- ☐ I made a switch that turns my light on and off.

ENGINEER'S NOTEBOOK

1. Draw your circuit with the battery, the wires and the bulb. Draw arrows around the loop.
2. Draw your circuit with the switch open and the switch closed. Color the bulb that is lit.
3. Draw three things in your house that use batteries.

From history. Volta's battery let scientists make steady electricity for the first time. Within a few years they were using batteries to make bright sparks of light and to discover new things, and every flashlight and phone battery since then comes from his idea.

COMMON MISTAKES

- Connecting both wires to the same end of the battery.
- Thinking electricity only needs to go one way. It needs a complete loop, out and back.

Make it a game • Complete the Loop. Use a battery, a bulb and wire, with a grown-up. Find a way to light the bulb. Then break the loop on purpose and ask your parent, why did it go dark? Answer with the word circuit. Retell Volta's story in two sentences, and say what a switch does. Make it light five times in a row.

Scripture. "Neither do men light a candle, and put it under a bushel, but on a candlestick; and it giveth light unto all that are in the house." (Matthew 5:15, KJV)

A light is made to shine for others. Jesus told His followers to let their good works shine like a lamp in a house.

4.2 CONDUCTORS AND INSULATORS: STEPHEN GRAY'S LONG THREAD

OBJECTIVES

- Tell how Stephen Gray found that some things carry electricity and some do not.
- Sort everyday things into conductors and insulators by testing them.
- Explain why wires have metal inside and plastic outside.

Warm-up. Look at the cord of a lamp (unplugged) or a phone charger. What is on the outside? What do you think is on the inside? Why would it be made that way?

WATCH

Electrical Conductors and Insulators

Next Generation Science • 2:32

<https://www.youtube.com/watch?v=qZjDMQbn3a0>

WHEN TO WATCH

Before the build. Pause after each object and let your child guess, “Conductor or insulator?”

Note: Some clips show grown-ups plugging cords into outlets and stripping wires. Remind your child that only trained grown-ups work with wall electricity; we use batteries.

KEY TERMS

conductor

A material that lets electricity flow through it easily, like metal.

insulator

A material that stops electricity from flowing, like plastic, rubber, glass, wood or cloth.

power line

A thick wire on tall poles or towers that carries electricity to homes.

CORE IDEAS

Long ago. Almost three hundred years ago, in England, a man named **Stephen Gray** loved to test electricity. He rubbed a glass tube to fill it with static electricity. Then he

found that the electricity could travel from the tube along a long thread, and make tiny bits of feather jump at the other end.

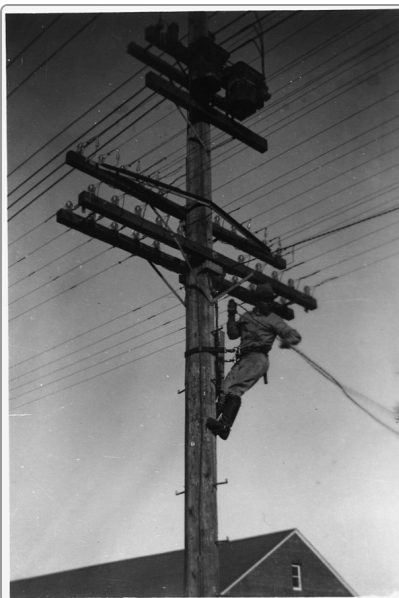
Gray wanted the thread to be as long as possible. When he held it up with hooks of brass wire, the electricity leaked away into the wire. When he held it up with loops of silk, the electricity stayed in the thread and traveled hundreds of feet. Gray had found something important: some things carry electricity, and some things stop it.

Why does it work? Things that let electricity flow easily are called **conductors**. Metals like copper, iron and aluminum are good conductors. Things that stop electricity are called **insulators**. Plastic, rubber, glass, wood and cloth are insulators.

How do builders use it? Engineers use both. A wire has copper metal inside to carry the electricity, and plastic outside to keep it from touching you or other wires. Look up at a **power line**. The wires hang from bumpy glass or ceramic pieces on the poles. Those are insulators. They keep the electricity in the wire and out of the pole.

A safety rule. The electricity in power lines and the outlets in the wall is much, much stronger than a battery. It can badly hurt a person. We test only with small batteries. Never touch a power line, and never put anything into an outlet.

PICTURE STUDY



A Lineman Climbing a Telephone Pole, Unknown photographer, September 1938 · Photograph · U.S. National Archives

Image: [Wikimedia Commons](#), public domain

Linemen are the workers who build and fix the wires that carry electricity and telephone calls. This lineman is climbing a pole crowded with wires about ninety years ago.

Look closely

- Find the wooden crossbars on the pole.
- Find the little knobs on the crossbars that hold the wires. Those are insulators.
- Find the lineman's safety belt and the spikes on his boots.
- Count how many wires you can see.

Talk about it

1. Why do you think the wires sit on glass knobs instead of touching the wood?
2. What would happen if a wire touched another wire?
3. Why does a lineman need special training and gear to do his work?

Safety first. Test only with the battery circuit. Never test anything with the outlets in the wall or a plugged-in cord.

BUILD

The Conductor Tester

You will make a circuit with a gap in it. When you touch something to both sides of the gap, the bulb will tell you whether it is a conductor or an insulator.

You will need

- Your battery, bulb and three clip leads from Lesson 4.1
- A collection of small things to test: a metal spoon, a coin, a paper clip, foil, a key, a plastic spoon, a crayon, an eraser, a rubber band, a craft stick, a glass marble, a cloth scrap, paper
- Two sheets of paper labeled Conductor and Insulator

Steps

1. Connect the battery and the bulb into a loop, but leave two clip ends free and not touching. This is the gap.
2. Touch the two free clips together. The bulb lights. Pull them apart. It goes out.
3. Pick up the first object. **Guess:** will it make the bulb light? Put it on the paper where you guess it goes.
4. Clip both free ends onto the object (or touch them to it, a little apart). Does the bulb light?
5. Move the object to the right paper if your guess was wrong.
6. Test every object the same way. Make a chart with two columns and draw each object in the right one.
7. Look at your Conductor list. What is the same about those things?
8. **Make it better.** Find three more things in the house to test. Can you find a conductor that is not shiny metal? (Try pencil lead, the gray part of a sharpened pencil.)

Tips

- Painted or plastic-coated metal may not light the bulb. Test a bare spot.
- Count how many guesses you got right.

Check your work

- ☐ I can sort things into conductors and insulators by testing them.
- ☐ I can tell why wires have metal inside and plastic outside.
- ☐ I can tell the safety rule about power lines and outlets.

ENGINEER'S NOTEBOOK

1. Make a two-column chart: Conductor and Insulator. Draw every object you tested.
2. Draw a wire cut in half and show the metal inside and the plastic outside.
3. Draw a power pole and color the insulators that hold the wires.

From history. Stephen Gray did his long-thread tests in 1729 with his friends Granville Wheler and John Godfrey, stringing the thread through the rooms and gardens of a big house. Another scientist soon gave us the names conductor and insulator.

COMMON MISTAKES

- Thinking all metal-colored things are conductors. Some are painted or coated with plastic.
- Holding the clips with wet fingers. Keep hands dry.

Make it a game • Conductor Prediction Duel. Collect eight things like a coin, a spoon, a crayon and a rubber band. Before testing each one with your tester, say conductor or insulator. Your parent guesses too. The closest guesser wins a paper chip. Test and sort the objects into two piles. Then tell how Stephen Gray found out about long threads and electricity.

4.3 MAGNETS AND THE COMPASS

OBJECTIVES

- Tell how sailors used compasses to find their way, and how William Gilbert showed that the Earth is a giant magnet.
- Find out what magnets pull and how two magnets push and pull each other.
- Make a floating needle compass and test it.

Warm-up. Go on a magnet hunt with a refrigerator magnet. Touch it to ten things in your kitchen. Make tally marks for “sticks” and “does not stick.” What kind of things does a magnet pull?

WATCH

Make Your Own Compass!

SciShow Kids · 5:38

https://www.youtube.com/watch?v=ldSG_qVF83M

WHEN TO WATCH

Before the build. You may make the compass right along with the video.

BACKUP VIDEO

How does a compass work? | General KnOWLedge

Owlkids · 2:10

<https://www.youtube.com/watch?v=LroX6ThIDpw>

After the build, for a short look inside a real compass.

KEY TERMS

magnet

A piece of metal or stone that pulls on iron and steel.

pole

One end of a magnet. Every magnet has a north pole and a south pole.

compass

A tool with a magnet needle that always points north, used to find directions.

CORE IDEAS

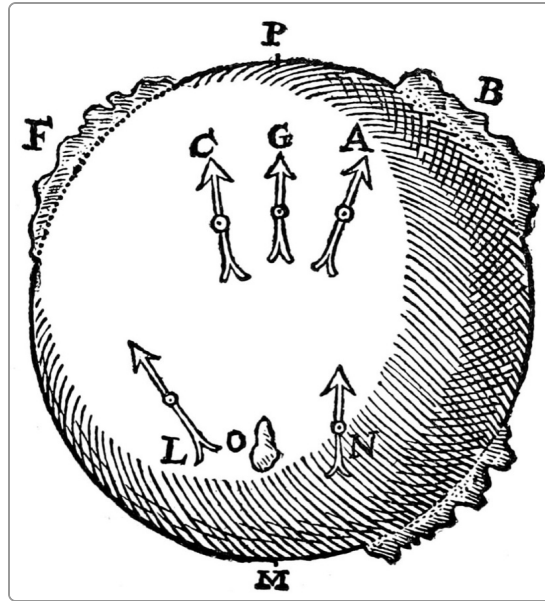
Long ago. Far out at sea there are no roads and no signs. On a cloudy night, sailors could not even see the stars. How could they find their way? Long ago, people in China and then in Europe found that a needle rubbed on a special stone, a lodestone, would turn and point north when it floated on water. That was the first **compass**. With a compass, sailors could steer a straight course even in fog.

In 1600 an English doctor named **William Gilbert** wrote a book about magnets. He carved a lodestone into a ball like a little Earth and moved tiny compass needles around it. They pointed toward its ends, just as compasses point on the real Earth. Gilbert said the whole Earth is a giant **magnet**!

Why does it work? Every magnet has two ends called **poles**, a north pole and a south pole. Two different poles pull together. Two poles that are the same push apart. Magnets pull on things made of iron and steel, but not on wood, plastic, paper or most coins. A compass needle is a thin magnet that can turn freely. The Earth's magnetism turns the needle so that one end points north.

How do builders use it? Ships and airplanes carry compasses. Your refrigerator door has a magnet strip to keep it shut tight. Magnets are inside speakers, motors and many toys. Even a phone has a tiny compass inside it to help its maps.

PICTURE STUDY



Gilbert's Little Earth, William Gilbert, 1600 · Woodcut from the book *De Magnete*

Image: [Wikimedia Commons](#), public domain

This picture is from William Gilbert's famous book about magnets, written in Latin. It shows his ball-shaped lodestone, his "little Earth," with small compass needles set on it.

Look closely

- Find the round ball. It is a magnet stone shaped like the Earth.
- Find the small needles. Which way do most of them point?
- Find the letters Gilbert put beside each needle.
- Look for the rough edge of the stone.

Talk about it

1. Why did Gilbert shape his magnet like a ball?
2. What did he learn about the real Earth from his little Earth?
3. Why are the letters there? How do they help a reader?

Safety first. A grown-up handles the sewing needle. Keep small magnets away from babies and toddlers; magnets can be very dangerous if swallowed.

BUILD

A Floating Needle Compass

You will turn a sewing needle into a magnet and float it on water. Then you will test whether it points the same way every time.

You will need

- A sewing needle (a grown-up handles it)
- A strong magnet
- A small slice of cork, or a small circle cut from a plastic lid or a leaf
- A shallow bowl of water
- A real compass to check your work, if you have one
- Masking tape and a marker

Steps

1. **Guess:** will a plain needle point north if you float it? Float it on the cork and watch.
2. Now a grown-up strokes the needle along the magnet about 30 times, always in the same direction, from the eye to the point.
3. Lay the needle gently on the cork in the middle of the bowl. Watch it turn and settle.
4. Put a piece of tape on the bowl where the point of the needle stops. Spin the cork gently and let it settle. Does it stop in the same place? Try it 5 times and make tally marks.
5. Check with a real compass, or ask a grown-up which way is north. Write N on the tape.
6. Bring the magnet close to the bowl. What happens to the needle? Take it away again.
7. **Make it better.** Does stroking the needle 10 times or 50 times make it turn faster? Try one and then the other.

Tips

- Keep the bowl away from metal things like the refrigerator or a metal table.

- Let the water get still before you watch the needle.

Check your work

- ☐ I can tell what things a magnet pulls.
- ☐ I can show that two magnets push or pull depending on their poles.
- ☐ My compass pointed the same way at least 4 times out of 5.

ENGINEER'S NOTEBOOK

1. Draw your floating needle compass. Label north.
2. Make a chart from your magnet hunt: sticks and does not stick.
3. Draw a ship at sea at night with a compass to guide it.

From history. Gilbert tested ideas instead of just believing old stories. People had said that garlic could stop a magnet from working. Gilbert tried it and found it was not true. Testing what we believe is a good habit for every engineer.

COMMON MISTAKES

- Stroking the needle back and forth. Always stroke in one direction.
- Thinking magnets pull all metals. They pull iron and steel, not aluminum foil or most coins.

Make it a game • Compass Needle Hunt. Float your magnetized needle in a bowl of water and watch it point. Your parent turns the bowl, and you tell which way the needle points after it settles. Say the words pole and compass. Then tell how sailors used compasses and how William Gilbert saw the Earth as a giant magnet. Try three spins.

4.4 BENJAMIN FRANKLIN'S KITE

OBJECTIVES

- Tell how Benjamin Franklin showed that lightning is electricity, and how he invented the lightning rod.
- Make static electricity with a balloon and test how the number of rubs changes it.
- Say the safety rules: never fly a kite in a storm or near power lines.

Warm-up. Rub a balloon on your hair or a wool sweater and hold it near your hair. What happens? Then hold it near a wall and let go. Have you ever felt a tiny shock after walking on a rug? These are all static electricity.

WATCH

Benjamin Franklin for Kids – Ben Franklin Kite Experiment – Electricity for Kids

Socratica Kids · 4:18

<https://www.youtube.com/watch?v=rriVOlbw8Tg>

WHEN TO WATCH

After the story.

BACKUP VIDEO

What Causes Thunder and Lightning? | Weather Science | SciShow Kids

SciShow Kids · 3:38

https://www.youtube.com/watch?v=fEiVi9TB_RQ

With “Why does it work?”, to learn how lightning and thunder happen.

KEY TERMS

static electricity

Electricity that builds up on something, often by rubbing, and stays until it jumps away as a spark.

spark

A tiny flash when electricity jumps across the air.

lightning rod

A pointed metal rod on top of a building, joined by a wire to the ground, that carries lightning safely into the earth.

CORE IDEAS

Long ago. In Philadelphia, about 270 years ago, lived a printer and inventor named **Benjamin Franklin**. He loved to experiment with **static electricity**. He noticed that its **sparks** crackled and flashed, a little like lightning. Could lightning be a giant spark of electricity?

In June 1752, Franklin and his son William made a kite from a silk handkerchief, with a pointed wire at the top. They tied a metal key near the bottom of the string. When a storm cloud passed over, the loose threads on the kite string stood up on end. Franklin moved his knuckle near the key, and a spark jumped to it. Lightning really was electricity!

Franklin was in great danger that day. If lightning had struck his kite, he could have been badly hurt. **Never fly a kite in a storm or near power lines.** Scientists today study lightning with careful instruments, from far away.

Why does it work? When you rub some things together, tiny bits of electricity move from one to the other and build up. When enough builds up, it jumps away in a spark. In a storm cloud, wind and ice rub and bump together high in the sky, and a huge amount of electricity builds up. Lightning is a giant spark from the cloud.

How do builders use it? Franklin used what he learned to invent the **lightning rod**. It is a pointed metal rod on the top of a roof, joined by a thick wire down into the ground. If lightning strikes, it goes down the rod and the wire safely into the earth, instead of through the house. Tall buildings, church steeples and barns still have lightning rods today.

PICTURE STUDY



Franklin's Experiment, June 1752, Currier and Ives, 1876 · Lithograph · Library of Congress

Image: [Wikimedia Commons](#), public domain

This print was made more than a hundred years after Franklin flew his kite. It shows Franklin and his son in a field, waiting for the storm cloud.

Look closely

- Find Benjamin Franklin and his son.
- Follow the kite string up into the sky.
- Look at the clouds. What kind of weather is coming?
- Look for the key on the string, and the jar on the ground for storing electricity.

Talk about it

1. What did Franklin want to find out?
2. Why was this experiment so dangerous?
3. How does a lightning rod keep a house safe?

Safety first. Never fly a kite in a storm or near power lines. If you hear thunder, go indoors.

BUILD

The Balloon Spark Test

You will make static electricity by rubbing a balloon, and test whether more rubs pick up more bits of paper.

You will need

- Two balloons, blown up and tied
- A wool sweater or your own clean, dry hair
- Tissue paper torn into tiny bits (about 30)
- A thin stream of water from a faucet
- A timer

Steps

1. Spread the tissue bits on the table.
2. **Guess:** if you rub the balloon 5 times, how many bits will it pick up? What about 20 times?
3. Rub the balloon on the sweater 5 times. Hold it just above the bits for 3 seconds. Count how many bits stick. Write it down.
4. Brush the bits off. Rub the balloon 10 times and test again. Then rub it 20 times and test again.
5. Make a chart: 5 rubs, 10 rubs, 20 rubs. Which picked up the most?
6. Now rub the balloon and hold it close to a thin stream of water from the faucet. Watch the stream bend!
7. **Make it better.** Try rubbing on a different material, like a cotton shirt or a plastic bag, with the same number of rubs. Which works best?

Tips

- This works best on a dry day. On a damp day, the electricity leaks away fast.
- Hold the balloon the same height above the bits each time.

Check your work

- ☐ I can tell how Franklin showed that lightning is electricity.
- ☐ I can tell how a lightning rod keeps a house safe.

- I tested 5, 10 and 20 rubs and wrote down my counts.

ENGINEER'S NOTEBOOK

1. Draw Franklin's kite with the key on the string and the storm cloud above.
2. Make a chart of how many bits of paper your balloon picked up after 5, 10 and 20 rubs.
3. Draw a house with a lightning rod. Draw the path the lightning takes into the ground.

From history. Franklin did not keep his lightning rod a secret. He printed how to make one in his almanac so that anyone could protect their home. He wanted his inventions to help his neighbors.

COMMON MISTAKES

- Thinking lightning hit Franklin's kite. It did not; the electricity in the storm cloud traveled down the wet string.
- Rubbing more for one test and holding the balloon closer at the same time. Change one thing only.

Make it a game • Balloon Rub Score. Rub a balloon on your hair or a sweater five times, then hold it near small bits of paper. Count the bits that jump. Now rub ten times and count again. Say static electricity out loud each time. Tell your parent what Benjamin Franklin learned about lightning and what a lightning rod does.

Scripture. "Canst thou send lightnings, that they may go, and say unto thee, Here we are?" (Job 38:35, KJV)

God asked Job whether he could command the lightning. Only God rules the storm. Men like Franklin can study how lightning works and learn to keep their neighbors safe.

UNIT 4

ELECTRICITY

Electricity lights our lamps and runs our machines, but you cannot see it. Long ago, people only knew it as a crackle when they rubbed amber or a spark from a cat's fur. Then curious men began to test it. Alessandro Volta built the first battery. Stephen Gray found that some things carry electricity and some do not. William Gilbert showed that the whole Earth is a magnet. And Benjamin Franklin flew a kite into a storm cloud and proved that lightning is electricity.

In this unit you will light a bulb with a battery, test which things in your house carry electricity, make a compass from a needle, and make paper jump with a balloon. You will use only small batteries, never the outlets in the wall. Electricity is a wonderful servant, and a wise engineer always treats it with care.

PREREQUISITES

- Can follow a safety rule every time
- Knows how to make a chart of guesses and results (Units 1–3)

MASTERY CHECKLIST

- ☐ I can light a bulb with a battery and wires, and I can tell why the circuit must be a complete loop.
- ☐ I can sort things into conductors and insulators, and I tested them to find out.
- ☐ I can make a compass from a needle and tell why it points north.
- ☐ I can tell the story of Benjamin Franklin's kite and why we never fly kites in storms.
- ☐ I can say the safety rules: batteries only, never outlets, and stay far from power lines.

OPTIONAL KITS FOR THIS UNIT

- **Snap Circuits (Elenco):** Parts snap together on a plastic grid with no wires to strip and no soldering. Elenco makes a Snap Circuits Beginner set for young children; it fits Lessons 4.1 and 4.2 and the sensor in Lesson 8.3.
- **KiwiCo Kiwi Crate:** Ages 5–8. Some crates include simple battery circuits with lights; a fun extra for this unit.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

4.1 A Battery and a Bulb: Volta’s Pile	2 sessions of 30 minutes
4.2 Conductors and Insulators: Stephen Gray’s Long Thread	2 sessions of 30 minutes
4.3 Magnets and the Compass	2 sessions of 30 minutes
4.4 Benjamin Franklin’s Kite	2 sessions of 30 minutes

UNIT 4 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have the battery, bulb and clip leads, a few small objects, a magnet and a balloon ready.

1. Light the bulb with the battery and wires. Now make it go out without unhooking the bulb. Why did it go out?
2. Here are a spoon, a coin, a crayon and a rubber band. Which are conductors and which are insulators? How could you test to be sure?
3. Why does a wire have metal inside and plastic outside?
4. What does a compass needle do? What did William Gilbert say about the Earth?
5. Tell me the story of Franklin’s kite. What did he learn, and what did he invent?
6. Tell me the electricity safety rules.

ANSWER KEY

1. Opening the loop anywhere stops the flow; a circuit must be a complete loop.
2. Metal spoon and coin are conductors; crayon and rubber band are insulators. Test each with the battery-and-bulb tester.
3. The metal carries the electricity, and the plastic is an insulator that keeps it from touching people or other wires.
4. It turns to point north. Gilbert said the whole Earth is a giant magnet.
5. He flew a kite with a key under a storm cloud, saw a spark jump from the key, and learned lightning is electricity. He invented the lightning rod.
6. Use only small batteries; never touch outlets or plugged-in cords; never go near power lines; never fly kites in storms or near power lines.

PORTFOLIO PIECE: MY LIGHTED ROOM

Make a small room from a shoebox and light it with your battery, bulb and paper-clip switch. Poke the bulb through the ceiling so it shines inside, and put the switch on the outside wall. Test it: does the switch turn the light on and off every time? Then add something to your room that is a conductor and something that is an insulator, and label them. Draw your circuit in your notebook and show your family how the light works.

LOOK FOR	WHAT IT MEANS
The light works	The bulb lights when the switch is closed and goes out when it is open.
Complete loop	Can trace the loop with a finger from the battery, through the switch and bulb, and back.
Conductors and insulators	Labeled one conductor and one insulator correctly.
Safe work	Used only batteries and followed every safety rule.
Telling	Explained how the switch turns the light on and off.

UNIT 5

WATER, POWER AND ROADS

When you turn on a faucet, clean water comes out. When you flip a switch, a light comes on. When you flush, the dirty water goes away. Letters come to your mailbox, and your family can talk by telephone to someone far away. All of this happens because engineers and workers built and keep running great systems of pipes, wires and roads, most of them hidden under the streets or high on poles. Engineers call them public utilities.

In this unit you will learn how a water tower pushes water into your house, how a power plant sends electricity to your lamp, how sewers and the treatment plant clean dirty water, and how a telephone carries a voice. You will build a water tower, a pinwheel turbine, a settling jar and a cup telephone. And you will learn to say thank you to the people who keep it all working, day and night, as a way of serving their neighbors.

PREREQUISITES

- Knows that a circuit is a complete loop (Unit 4)
- Knows the safety rule about power lines (Unit 4)

MASTERY CHECKLIST

- ☐ I can tell how a water tower pushes water into houses.
- ☐ I can tell the path of electricity from a power plant to my lamp.
- ☐ I can tell where dirty water goes and how it is cleaned.
- ☐ I can make a cup telephone and tell how sound travels along the string.
- ☐ I can say the safety rules: stay away from power lines, manholes and storm drains, and never drink water from a homemade filter.

LESSONS IN THIS UNIT

5.1 Water Towers and Pipes

2 sessions of 30 minutes

5.2 From Power Plant to Your Lamp

2 sessions of 30 minutes

5.3 Sewers and the Treatment Plant

2 sessions of 30 minutes

UNIT 5 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have a cup, a bottle of water, the pinwheel and the cup telephone ready.

1. Why are water towers built up high? Show me with a cup of water and a straw.
2. Tell me the path of electricity from the power plant to our lamp.
3. Predict: if you hold the pinwheel very close to the fan, will it spin faster or slower than far away? Why?
4. Where does dirty water go when it leaves our house? How is it cleaned?
5. Who made the first telephone call, and what did he say?
6. Name some workers who keep our water, power and roads working, and tell me one safety rule.

ANSWER KEY

1. Water high up pushes hard, so it flows with strong pressure through the pipes into the houses below.
2. A turbine spins a generator at the power plant; electricity travels on tall power lines, then lines on poles in our street, into the house, through the wires in the walls, to the lamp.
3. Faster, because the wind is stronger close to the fan, just as stronger steam or water spins a turbine faster.
4. Down the drain into the sewer, which slopes downhill to a treatment plant. The dirt settles, tiny living things eat the waste, and the clean water goes back to the river.
5. Alexander Graham Bell, in 1876: “Mr. Watson, come here, I want to see you.”
6. Water workers, linemen, wastewater workers, mail carriers, telephone workers and road crews. Safety: stay away from power lines, manholes and storm drains.

PORTFOLIO PIECE: MY TOWN MAP

On a big sheet of paper or a flattened cardboard box, draw a small town with a few houses. Add a water tower on a hill with blue pipes to every house, a power plant with red power lines to every house, brown sewer pipes sloping down to a treatment plant, and roads joining it all. Use your model water tower to show how the water flows. Then give your family a tour of your town, and tell them who keeps each part working.

LOOK FOR	WHAT IT MEANS
Water	The water tower is up high, and the pipes reach every house.
Power	Power lines go from the power plant to every house.
Sewers	The sewer pipes slope downhill to the treatment plant.
Roads and people	Roads join the town, and the map shows at least two kinds of workers.
Telling	Gave a clear tour, telling how water, power and dirty water travel.

5.1 WATER TOWERS AND PIPES

OBJECTIVES

- Tell how a town's water gets from a water tower to every house.
- Show that deeper water pushes harder, and that water from a higher tank flows with more push.
- Build a model water tower and measure how far the water squirts from different heights.

Warm-up. Look for a water tower in your town, or look at a picture of one. Why do you think it is built so high? Where do you think the pipes go?

WATCH

How Does Water Get to Your House?

SciShow Kids · 3:36

<https://www.youtube.com/watch?v=cGi4PugN4qY>

WHEN TO WATCH

After the first core idea. Pause when the water reaches the tower and ask, “How will it get to the houses?”

BACKUP VIDEO

How it Works: Water Tower

City of Bloomington, Minnesota · 2:20

<https://www.youtube.com/watch?v=Zl8WOzqHl7w>

With “How do builders use it?”, to see inside a real water tower.

KEY TERMS

water tower

A tall tower holding a big tank of water up high, so the water flows with strong push into the pipes below.

water pressure

How hard water pushes. Deeper or higher water pushes harder.

pipe

A long tube that carries water. Big pipes called water mains run under the streets.

pump

A machine that pushes water through pipes or lifts it up high.

CORE IDEAS

Long ago. Long ago, people carried water home in buckets from a well or a river. As towns grew, engineers built a better way. In 1890 the town of Ypsilanti, Michigan, finished a tall stone water tower on the highest hill in town. Inside it was a huge tank. **Pumps** filled the tank with water. Then the water flowed down from the tank through **pipes** under the streets into the homes of the town.

Why does it work? Water always flows downhill. Water that is high up pushes down hard on the water below it. The higher the water, the harder it pushes. That push is called **water pressure**. Because the tank sits high above the town, the water in the pipes pushes hard enough to flow up into sinks, showers and even the second floor of a house.

How do builders use it? Today many towns still have **water towers**, made of steel or concrete. At night, when few people use water, pumps fill the tank. In the morning, when everyone is washing and making breakfast, the tower sends water out quickly. Water towers also keep water ready for firefighters. Under the streets runs a web of big and small pipes, with valves that workers can close to fix a pipe.

Say thank you. Water workers test the water every day to make sure it is clean and safe. They fix broken pipes, even in the middle of a cold night.

PICTURE STUDY



The Ypsilanti Water Tower, Detroit Publishing Company, between 1900 and 1910 · Photograph (glass plate) · Library of Congress

Image: [Wikimedia Commons](#), public domain

This photograph shows the Ypsilanti Water Tower about twenty years after it was built. The town built it on its highest hill so the water would flow down to every home.

Look closely

- Find the water tower at the end of the street.
- Look at its shape. Where do you think the tank is?
- Look at the street. What do you think is under it?
- Find the trees and look for any houses.

Talk about it

1. Why was the tower built on the highest hill in town?
2. How does the water get from the tower into a house?
3. What would happen to the water if the tower were built in the lowest place in town?

Safety first. A grown-up pokes the holes in the bottle. Do this build outside, in the bathtub or over the sink.

BUILD

My Water Tower

You will find out whether deeper water pushes harder, and then build a water tower from a cup and a straw and measure how far its water squirts from different heights.

You will need

- A plastic bottle with three small holes poked by a grown-up, one near the bottom, one in the middle and one near the top
- Tape to cover the holes
- A paper or plastic cup, a bendy straw and modeling clay
- Books or blocks to stack
- A pitcher of water, a baking pan or the bathtub, and a ruler

Steps

1. Cover the three holes in the bottle with tape and fill it with water.
2. **Guess:** which hole will squirt the farthest? Pull off all three pieces of tape and watch. Which stream went farthest? Write it down.
3. Now build a water tower. Poke the short end of the bendy straw through a hole near the bottom of the cup. Seal around it with clay so it does not leak.
4. Set the cup on one book at the edge of the pan. Put your finger over the end of the straw, fill the cup, and let go. Measure how far the water squirts.
5. Stack two books and then three books, filling the cup the same way each time. Guess first, then measure.
6. Make a chart: 1 book, 2 books, 3 books. Which tower made the water go farthest?
7. **Make it better.** How could your tower keep the water flowing strongly for longer? Try one idea, like a bigger cup, and test it.

Tips

- Fill the cup to the same line each time. Mark it with a marker.
- Point the straw the same way for each test.

Check your work

- ☐ I can show that deeper water pushes harder.
- ☐ I can tell why water towers are built up high.
- ☐ I measured how far the water squirted from three heights.

ENGINEER'S NOTEBOOK

1. Draw the bottle with its three streams. Circle the one that went farthest.
2. Draw a water tower on a hill with pipes going down to houses. Draw arrows showing the water moving.
3. Write how far your water squirted from 1, 2 and 3 books.

From history. Many old water towers were built of stone or brick and made to look like castles or lighthouses, because towns were proud of their clean water. The Ypsilanti Water Tower is still standing, and people still come to see it.

COMMON MISTAKES

- Filling the cup to a different level for each test.
- Thinking water can only flow down. Water from a high tank can push up into a house that is lower than the tank.

Make it a game • Tower Pressure Duel. Poke two holes in a bottle, one high and one low, and fill it over a sink or tub, with a grown-up. Which stream goes farther? Tell why. Then hold the bottle up higher and see what changes. Say water tower, pipe and pump in order as you tell how water gets to a house.

Scripture. “All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again.” (Ecclesiastes 1:7, KJV)

God made water to travel in a great circle: from the sea to the clouds, to the rain and rivers, and back to the sea. Water engineers borrow some of that water and send it back clean.

5.2 FROM POWER PLANT TO YOUR LAMP

OBJECTIVES

- Tell how Thomas Edison opened the Pearl Street power station in New York.
- Tell the path of electricity from a power plant, along power lines, to a lamp.
- Build a pinwheel turbine and count how fast it spins in strong and weak wind.

Warm-up. Find a light switch, a lamp and an outlet in your home (do not touch inside the outlet!). Where do you think the electricity comes from before it gets to the wall? Trace a path with your finger as far as you can guess.

WATCH

How does electricity get into our homes?

Fun Kids Learn · 2:07

<https://www.youtube.com/watch?v=39DHRal-uzM>

WHEN TO WATCH

After the core ideas.

BACKUP VIDEO

How Power Gets to Your House

EPCOR · 2:35

https://www.youtube.com/watch?v=_eKivDH3w0w

Any time this week, to see power-line workers keeping the electricity on.

KEY TERMS

power plant

A place where big machines make electricity for a whole town or city.

generator

A machine that makes electricity when its magnets and wires are turned around and around.

turbine

A wheel with blades that is spun by moving steam, water or wind.

lineman

A worker who builds and fixes power lines.

CORE IDEAS

Long ago. Long ago, homes were lit by candles and oil lamps. Then **Thomas Edison** made a light bulb that could glow for many hours. But a light bulb needs electricity, and homes had none. So Edison built a **power plant** on Pearl Street in New York City. Steam engines turned giant machines called **generators**, so big that people called them Jumbos, after a famous circus elephant. Wires under the street carried the electricity to nearby buildings.

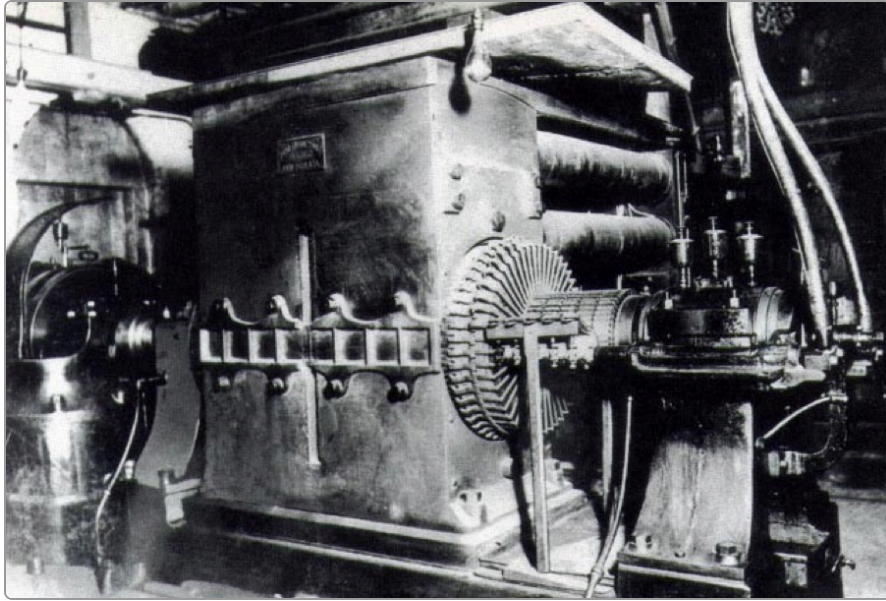
On September 4, 1882, the workers turned it on, and lamps lit up in houses and offices all around. It was one of the first power plants in the world built to light a whole neighborhood.

Why does it work? Inside a generator, magnets and coils of wire spin past each other. That spinning makes electricity flow in the wires. Something has to do the spinning. In most power plants, a **turbine** does it. A turbine is like a big pinwheel. Steam, falling water from a dam, or wind pushes on its blades and spins it fast.

How do builders use it? Power plants make electricity in different ways. Some burn coal or gas to make steam. Some use the heat from uranium to make steam. Some use falling water at a dam, wind, or sunlight. Each way has good points and hard points, and engineers choose what works best for each place. The electricity travels along tall power lines, then through smaller lines on poles in your street, into your house, through the wires in the walls, and to your lamp.

Say thank you. **Linemen** climb poles in wind, rain and snow to fix broken lines and bring the lights back on. Never go near a power line, especially one that has fallen down. Tell a grown-up right away.

PICTURE STUDY



Edison's Jumbo Dynamo at Pearl Street, Unknown photographer, about 1882–1885 · Photograph
Image: [Wikimedia Commons](#), public domain

This old photograph shows one of the giant generators, called dynamos, in Edison's Pearl Street power station. Each one was big enough to light hundreds of lamps.

Look closely

- Find the big round part that spins.
- Find the heavy iron frame around it.
- Look for bolts, pipes and wires.
- Look for anything that shows how big the machine is.

Talk about it

1. What do you think made this machine spin?
2. Why do you think people called it a Jumbo?
3. Where did the electricity go after it left this machine?

Safety first. A grown-up pushes the pin through the pinwheel and runs the fan. Keep fingers away from the fan blades.

BUILD

The Pinwheel Turbine

You will make a pinwheel, the simplest kind of turbine. Then you will count how fast it spins in strong wind and weak wind, just as engineers test a real turbine.

You will need

- A square of stiff paper (15 cm or 6 inches)
- A pushpin, a pencil with an eraser, and a small bead
- A marker
- A box fan or a hair dryer on cool, used by a grown-up
- A timer and a tape measure

Steps

1. Fold the paper corner to corner both ways and unfold it. Cut along each fold line about halfway to the center.
2. Bring every other point to the center and hold them with the pushpin. A grown-up pushes the pin through a bead and into the side of the pencil eraser.
3. Draw a big dot on one blade so you can count turns.
4. **Guess:** how many times will your pinwheel spin in 10 seconds close to the fan? Far from the fan?
5. Hold the pinwheel 1 meter (3 feet) from the fan on low. A helper times 10 seconds while you count each time the dot goes around. Write it down.
6. Test again at 2 meters and at 3 meters.
7. Make a chart. Where did it spin fastest? What does this tell you about a real turbine?
8. **Make it better.** Try bigger blades or a different number of blades. Change one thing and count again at 1 meter.

Tips

- If the pinwheel will not turn, loosen the pin a little.

- Counting fast spins is hard. Count only the dot.

Check your work

- ☐ I can tell how a turbine spins a generator.
- ☐ I can tell the path of electricity from the power plant to my lamp.
- ☐ I counted spins at three distances.

ENGINEER'S NOTEBOOK

1. Draw the path of electricity: power plant, tall power lines, the pole in your street, your house, your lamp.
2. Make a chart of how many spins your pinwheel made at 1, 2 and 3 meters.
3. Draw a lineman on a pole fixing a wire, and write a thank-you note to a lineman.

From history. Edison's Pearl Street station began with 85 customers and about 400 lamps. Within a few years, power stations were being built in towns all over the country.

COMMON MISTAKES

- Thinking electricity is stored in the wall. It is made at the power plant and travels to your home the moment you use it.
- Holding the pinwheel at a different angle for each test.

Make it a game • Lamp Path Story. Put a lamp, a pinwheel, a toy truck and a string on the table. Walk the electricity from the power plant to the lamp by touching each thing in order and naming it: power plant, generator, turbine, power line, lamp. Then tell how Edison opened the Pearl Street station. Do it again with eyes closed.

5.3 SEWERS AND THE TREATMENT PLANT

OBJECTIVES

- Tell how Joseph Bazalgette built the sewers of London.
- Tell where dirty water goes when it leaves a house, and how a treatment plant cleans it.
- Watch dirty water settle in a jar and measure how fast the layers form.

Warm-up. Watch a sink drain. Where do you think the water goes after it disappears? Draw your guess. Then find the pipe under the sink (just look; do not take it apart).

WATCH

How Water Gets to Your Home—And Back to the River

EPCOR • 2:32

<https://www.youtube.com/watch?v=Msqu4cAQ76U>

WHEN TO WATCH

After the story of London, to follow water from the river to the tap, down the drain, and back to the river.

KEY TERMS

sewer

A big underground pipe or tunnel that carries dirty water away from homes and buildings.

wastewater

Dirty water that goes down drains and toilets.

treatment plant

A place where dirty water is cleaned before it goes back into a river.

settle

To sink slowly to the bottom of water.

CORE IDEAS

Long ago. About 170 years ago, London was the biggest city in the world. But its dirty water ran straight into the River Thames, the same river where people got their drinking water. Many people got sick. In the hot summer of 1858, the river smelled so terrible that people called it “the Great Stink.”

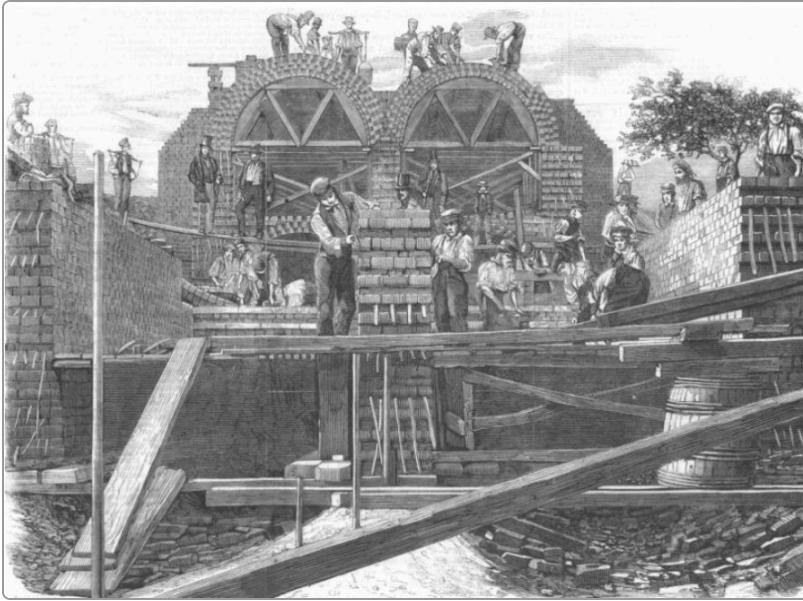
The city asked an engineer named **Joseph Bazalgette** to fix it. He planned huge brick tunnels called **sewers** under the streets. They caught the dirty water and carried it far away from the city. The workers used more than three hundred million bricks! Bazalgette also made his tunnels twice as big as the city needed at the time, because he knew London would grow. After his sewers were built, London became a much healthier place to live.

Why does it work? Sewers slope gently downhill, so the dirty water flows away by itself. Where it must go uphill, pumps lift it. Today the sewers lead to a **treatment plant**. There the water sits in big tanks, and the heavy dirt **settles** to the bottom. Then tiny living things, too small to see, eat up the waste. Last, the cleaned water is sent back into the river.

How do builders use it? Every town has sewers under its streets. Engineers plan them to slope just right and to be big enough for the future. **Safety:** never go near an open manhole or a storm drain. Water there can be deep and fast. Only trained workers go into sewers.

Say thank you. Wastewater workers keep our towns clean and healthy, though most people never think about them.

PICTURE STUDY



Building London's Main Sewer at Old Ford, Illustrated London News, August 27, 1859 · Wood engraving

Image: [Wikimedia Commons](#), public domain

A London newspaper printed this picture while Bazalgette's sewers were being built. The artist cut away the ground so readers could see the giant brick tunnels.

Look closely

- Find the big round tunnels. How many are there?
- Find the workers laying bricks.
- Find the wooden boards and frames holding things up while the bricks are laid.
- Look for the piles of bricks.

Talk about it

1. Why do you think the tunnels are round?
2. Why did Bazalgette make them so big?
3. Would you rather have built these tunnels or walked by the smelly river? Why?

Safety first. Never drink the water in this build, even after it looks clean. Wash your hands when you are done.

BUILD

The Settling Jar

The first step at a treatment plant is letting the heavy dirt settle. You will make muddy water in two jars and watch the dirt settle, timing how fast the water clears.

You will need

- Two clear jars with lids, the same size
- Garden soil and sand
- A few small leaves or bits of grass
- Water
- A timer and a marker

Steps

1. Put two spoonfuls of sand in one jar and two spoonfuls of garden soil in the other. Add a few leaf bits to each.
2. Fill both jars with water almost to the top. Put the lids on tight.
3. **Guess:** which jar will clear first?
4. Shake both jars the same, for 10 seconds. Set them down side by side.
5. Look after 1 minute, 10 minutes and 1 hour. Each time, draw the jars and mark the dirt line with the marker.
6. What sank to the bottom? What floated on top? What stayed cloudy?
7. **Make it better.** Pour the top water from the soil jar slowly through a coffee filter into a third jar. Is it clearer? Is it clean enough to drink? (No! It still has tiny things you cannot see.)

Tips

- Do not move the jars while they settle.
- Hold the jars up to a window to see the layers better.

Check your work

- ☐ I can tell where dirty water goes when it leaves my house.
- ☐ I can tell how settling helps clean water.

- I drew my jars at three different times.

ENGINEER'S NOTEBOOK

1. Draw your two jars at 1 minute, 10 minutes and 1 hour.
2. Draw the path of water from your sink, through the sewer, to the treatment plant, and back to the river.
3. Write a thank-you note to a wastewater worker.

From history. Bazalgette also built wide stone walls along the Thames, called embankments, with the sewers hidden inside them and new roads and gardens on top. Londoners still walk along them today.

COMMON MISTAKES

- Thinking water that looks clear is clean enough to drink. Germs are too small to see.
- Shaking one jar harder than the other.

Make it a game · Settling Jar Wait. Shake a jar of muddy water and set a timer. Watch for dirt to settle, and every 30 seconds call out what you see. Tell your parent where dirty water goes when it leaves a house, and name the treatment plant. Then explain what Joseph Bazalgette did in London. Predict how clear it will be.

5.4 MAIL, TELEPHONE LINES AND ROADS

OBJECTIVES

- Tell how Alexander Graham Bell made the first telephone call.
- Explain that sound is a shaking that can travel along a tight string or a wire.
- Build a cup telephone and test which string carries a voice best.

Warm-up. Put your hand on your throat and hum. What do you feel? Now press your ear to a table while someone taps gently on the other end. Can you hear it through the table?

WATCH

The Science of the String Phone! - #sciencegoals

SciShow Kids · 4:38

<https://www.youtube.com/watch?v=3yqB2KFwJCo>

WHEN TO WATCH

Before the build. Pause when the string goes slack and ask, “Why did the sound stop?”

KEY TERMS

telephone

A machine that carries a voice far away along a wire or by radio.

vibrate

To shake back and forth very fast.
Sound is made by things that vibrate.

road

A wide, hard path built in layers so that wagons, cars and trucks can travel on it.

CORE IDEAS

Long ago. Long ago, if you wanted to tell something to someone in another town, you sent a letter. Benjamin Franklin, the man with the kite, became the first head of the post office for the United States. Mail carriers on horseback and in wagons carried letters along the roads.

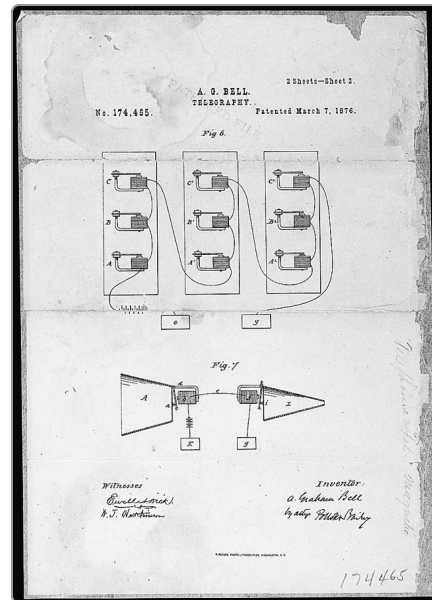
Then, on March 10, 1876, in Boston, a teacher and inventor named **Alexander Graham Bell** spoke into a new machine. His helper, Thomas Watson, was in another room with the other end of the wire. Watson heard Bell's voice say, "Mr. Watson, come here, I want to see you." It was the first telephone call.

Why does it work? Sound is made by things that **vibrate**, or shake back and forth very fast. When you talk, your voice makes the air shake. In Bell's **telephone**, the shaking air made a thin sheet shake, and the telephone turned that shaking into electricity in the wire. At the other end, the electricity made another thin sheet shake, and that made sound again. In a cup telephone, the shaking travels along a tight string instead.

How do builders use it? Soon telephone wires were strung on poles along every road. Today many calls travel through cables under the ground, through thin glass threads, and by radio to cell towers. **Roads** connect us too. Engineers build them in layers: packed earth, then crushed stone, then a smooth top of asphalt or concrete, curved a little so rain runs off to the sides.

Say thank you. Mail carriers, telephone workers and road crews help us stay close to the people we love.

PICTURE STUDY



Bell's Telephone Patent Drawing, Alexander Graham Bell, 1876 · Patent drawing · U.S. National Archives
Image: [Wikimedia Commons](#), public domain

When an inventor wants to protect his idea, he sends drawings to the government for a patent. These are some of Bell's drawings from 1876, the year of the first telephone call. Figure 7, at the bottom, shows the telephone.

Look closely

- Find Figure 7 at the bottom of the page.
- Find the cone where a person would speak.
- Follow the wire from one end to the other.
- Find Bell's signature.

Talk about it

1. What do you think the cone is for?
2. Why does an inventor make careful drawings of his invention?
3. How is Bell's telephone like your cup telephone? How is it different?

BUILD

The Cup Telephone Test

You will build a cup telephone and test it in a fair way: is the string better tight or loose, and which kind of string carries a voice best?

You will need

- Four paper cups
- A pencil or a pushpin to poke holes (a grown-up helps)
- Three kinds of string, each about 5 meters (15 feet) long: cotton string, yarn and fishing line
- Paper clips
- A partner

Steps

1. A grown-up pokes a small hole in the bottom of two cups. Push the ends of the cotton string through the holes and tie each end to a paper clip inside the cup.
2. Walk apart until the string is tight. One person speaks softly into a cup; the other listens.
3. **Guess:** will it work if the string is loose? Walk closer so it sags, and try again. Write down: loud, soft or cannot hear.
4. Try with the string touching a chair. What happens?
5. Now make two more phones with yarn and fishing line. Use the same cups and the same length. Guess which will be loudest.
6. Test each string the same way, with the same quiet voice and the same words. Write down loud, soft or cannot hear for each one.
7. **Make it better.** Try a longer string, or two cups joined in the middle so three people can talk. What works best?

Tips

- Speak in the same quiet voice every time, or the test is not fair.
- Keep the string tight and not touching anything.

Check your work

- ☐ I can tell how Alexander Graham Bell made the first telephone call.
- ☐ I can tell why the string must be tight.
- ☐ I tested three strings and wrote down which was loudest.

ENGINEER'S NOTEBOOK

1. Draw your cup telephone. Draw wavy lines along the string to show the sound shaking.
2. Make a chart of your three strings: loud, soft or cannot hear.
3. Draw a road cut open to show its layers: earth, stones and a smooth top.

From history. Bell gave the first public showing of his telephone at the great Centennial Exhibition in Philadelphia in 1876. Within ten years, more than a hundred thousand people in the United States had telephones.

COMMON MISTAKES

- Letting the string sag. A loose string cannot carry the shaking.
- Testing one string with a loud voice and another with a soft voice.

Make it a game • Cup Phone Message. Make a cup telephone with a tight string. Whisper a short message into the cup while your parent listens at the other end. Then let the string go slack and try again. Say vibrate, and tell why tight works better. Count how many messages your parent gets exactly right out of five, and tell about Bell.

UNIT 5

WATER, POWER AND ROADS

When you turn on a faucet, clean water comes out. When you flip a switch, a light comes on. When you flush, the dirty water goes away. Letters come to your mailbox, and your family can talk by telephone to someone far away. All of this happens because engineers and workers built and keep running great systems of pipes, wires and roads, most of them hidden under the streets or high on poles. Engineers call them public utilities.

In this unit you will learn how a water tower pushes water into your house, how a power plant sends electricity to your lamp, how sewers and the treatment plant clean dirty water, and how a telephone carries a voice. You will build a water tower, a pinwheel turbine, a settling jar and a cup telephone. And you will learn to say thank you to the people who keep it all working, day and night, as a way of serving their neighbors.

PREREQUISITES

- Knows that a circuit is a complete loop (Unit 4)
- Knows the safety rule about power lines (Unit 4)

MASTERY CHECKLIST

- ☐ I can tell how a water tower pushes water into houses.
- ☐ I can tell the path of electricity from a power plant to my lamp.
- ☐ I can tell where dirty water goes and how it is cleaned.
- ☐ I can make a cup telephone and tell how sound travels along the string.
- ☐ I can say the safety rules: stay away from power lines, manholes and storm drains, and never drink water from a homemade filter.

LESSONS IN THIS UNIT

5.1 Water Towers and Pipes

2 sessions of 30 minutes

5.2 From Power Plant to Your Lamp

2 sessions of 30 minutes

5.3 Sewers and the Treatment Plant

2 sessions of 30 minutes

UNIT 5 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have a cup, a bottle of water, the pinwheel and the cup telephone ready.

1. Why are water towers built up high? Show me with a cup of water and a straw.
2. Tell me the path of electricity from the power plant to our lamp.
3. Predict: if you hold the pinwheel very close to the fan, will it spin faster or slower than far away? Why?
4. Where does dirty water go when it leaves our house? How is it cleaned?
5. Who made the first telephone call, and what did he say?
6. Name some workers who keep our water, power and roads working, and tell me one safety rule.

ANSWER KEY

1. Water high up pushes hard, so it flows with strong pressure through the pipes into the houses below.
2. A turbine spins a generator at the power plant; electricity travels on tall power lines, then lines on poles in our street, into the house, through the wires in the walls, to the lamp.
3. Faster, because the wind is stronger close to the fan, just as stronger steam or water spins a turbine faster.
4. Down the drain into the sewer, which slopes downhill to a treatment plant. The dirt settles, tiny living things eat the waste, and the clean water goes back to the river.
5. Alexander Graham Bell, in 1876: “Mr. Watson, come here, I want to see you.”
6. Water workers, linemen, wastewater workers, mail carriers, telephone workers and road crews. Safety: stay away from power lines, manholes and storm drains.

PORTFOLIO PIECE: MY TOWN MAP

On a big sheet of paper or a flattened cardboard box, draw a small town with a few houses. Add a water tower on a hill with blue pipes to every house, a power plant with red power lines to every house, brown sewer pipes sloping down to a treatment plant, and roads joining it all. Use your model water tower to show how the water flows. Then give your family a tour of your town, and tell them who keeps each part working.

LOOK FOR	WHAT IT MEANS
Water	The water tower is up high, and the pipes reach every house.
Power	Power lines go from the power plant to every house.
Sewers	The sewer pipes slope downhill to the treatment plant.
Roads and people	Roads join the town, and the map shows at least two kinds of workers.
Telling	Gave a clear tour, telling how water, power and dirty water travel.

UNIT 6

BOATS

Some things float and some things sink. A pebble sinks, but a great ship made of iron floats. Why? In this unit you will learn the secret of floating, see how boat builders shaped fast clipper ships, sail with Joshua Slocum, the first man to sail alone around the world, and cross the ocean with the Pilgrims on the *Mayflower*.

You will turn a lump of clay that sinks into a boat that floats, test foil boats of different shapes for speed, build a paddle boat and a sailboat, and load a cargo boat until it is full. Each time you will guess, test, count and improve. The Bible speaks of “they that go down to the sea in ships,” and of Noah, who built an ark just as God told him. Boat builders have always had to plan carefully, because the sea is strong.

PREREQUISITES

- Knows how to run a fair test and make a chart (Units 1–5)
- Can count pennies to 50

MASTERY CHECKLIST

- ☐ I can tell why a boat floats: it pushes aside water, and the water pushes back up.
 - ☐ I can show that shape, not only weight, decides whether something floats.
 - ☐ I can tell why a narrow, pointed boat is fast and a wide boat carries more.
 - ☐ I can tell how paddles, sails and a rudder move and steer a boat.
 - ☐ I can tell the story of the *Mayflower* and how the Pilgrims fixed the cracked beam.
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OPTIONAL KITS FOR THIS UNIT

- **KiwiCo Kiwi Crate:** Ages 5–8. Some crates are water projects, such as boats you build and float; a fun extra for this unit.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

6.1	Floating and Sinking: The Iron Ship	2 sessions of 30 minutes
6.2	Boat Shapes: The Fast Clipper Ships	2 sessions of 30 minutes
6.3	Paddles and Sails: Joshua Slocum's Spray	2 sessions of 30 minutes
6.4	The Mayflower	2 sessions of 30 minutes

UNIT 6 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have clay, foil, a tub of water and some pennies ready.

1. Show me with clay: how can the same clay sink and float?
2. How did Brunel's iron ship float if iron is heavy?
3. Predict: which foil boat will cross the tub faster, a wide flat one or a narrow pointed one? Which will carry more pennies?
4. What pushes a sailboat? What pushes a canoe? What steers a ship?
5. Tell me about Joshua Slocum and the *Spray*.
6. Tell me the story of the *Mayflower*. How did they fix the cracked beam? How should cargo be packed?

ANSWER KEY

1. A ball sinks; a hollow boat shape floats because it pushes aside more water, and the water pushes back up.
2. Its hull was big and hollow, full of air, so it pushed aside enough water to hold it up.
3. The narrow pointed one is faster; the wide one carries more.
4. The wind on the sails; the paddle pushing water back; the rudder.
5. He rebuilt an old boat himself and was the first person to sail alone around the world, from 1895 to 1898.
6. In 1620 the Pilgrims crossed the ocean in 66 days; a storm cracked a beam, and they pushed it up with a great iron screw and set a post under it. Cargo should be packed low and even.

PORTFOLIO PIECE: MY CARGO SHIP

Design and build a boat from foil, a carton or a plastic container that can carry as many pennies as possible across a tub and survive three waves. Draw your plan first. Test it, count the pennies it carries, then make one change and test it again. Give your ship a name, draw it in your notebook with both counts, and tell your family about its shape and how you packed the cargo.

LOOK FOR	WHAT IT MEANS
It floats and carries	The boat floats and carries pennies across the tub.
Packed well	Packed the pennies low and even, so the boat stayed steady in the waves.
Fair test	Made the same waves for both tests and counted carefully.
Tried again	Made one change after the first test and tested again.
Telling	Explained why the boat floats and why its shape was chosen.

6.1 FLOATING AND SINKING: THE IRON SHIP

OBJECTIVES

- Tell how Isambard Kingdom Brunel built a great ship of iron that floated.
- Explain that a boat floats because it pushes aside water, and the water pushes back up.
- Turn a lump of clay that sinks into a boat that floats, and count how many pennies it can carry.

Warm-up. Fill a tub or sink with water. Gather ten small things: a coin, a cork, a spoon, a crayon, an apple, a key, a leaf, a plastic lid, a pebble and a rubber duck. Guess which will float and which will sink, then test each one and make two piles.

WATCH

Sink or Float?

SciShow Kids · 5:50

https://www.youtube.com/watch?v=eQuW8G2QV_Q

WHEN TO WATCH

After the warm-up, before the core ideas. Play along and guess with Jessi before each test.

BACKUP VIDEO

Buoyancy: What Makes Something Float or Sink?

Kids Want to Know · 3:29

<https://www.youtube.com/watch?v=nMIXU97E-uQ>

Any time this week, for another look at why things float or sink.

KEY TERMS

float

To stay on top of water.

sink

To go down to the bottom of water.

hull

The body of a boat, the part that sits in the water.

buoyancy

The push of water up on a thing that is in it.

CORE IDEAS

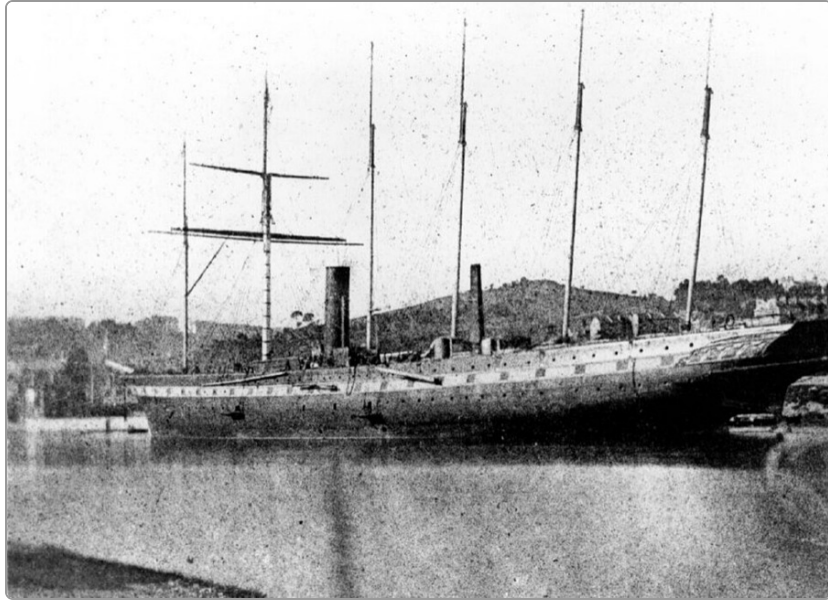
Long ago. For thousands of years, ships were made of wood. Wood floats, so that made sense. But about 180 years ago, an English engineer named **Isambard Kingdom Brunel** had a bold idea. He would build a giant ship of iron! Many people laughed. Iron is heavy. A nail sinks. Surely an iron ship would sink too.

Brunel did not guess. He knew how floating works. In 1843 his great iron ship, the SS *Great Britain*, slid into the water at Bristol, England, and it floated. It was the biggest ship in the world. Two years later it steamed across the Atlantic Ocean to New York. Soon most big ships were made of iron and then steel.

Why does it work? When a boat sits in the water, it pushes some water out of the way. The water pushes back up on the boat. That upward push is called **buoyancy**. A lump of iron is small, so it pushes aside only a little water, and it sinks. But if you shape the same iron into a big, hollow **hull** full of air, it pushes aside a lot of water. Then the water pushes up hard enough to hold it up. Shape matters, not just weight!

How do builders use it? Engineers design ship hulls big and hollow, so they push aside a lot of water. They also paint a line on the side of the ship. If the ship is loaded so heavily that the line goes under the water, it is carrying too much.

PICTURE STUDY



The SS Great Britain at Bristol, William Henry Fox Talbot, April 1844 · Photograph

Image: [Wikimedia Commons](#), public domain

This is one of the first photographs of a ship ever taken. William Henry Fox Talbot, one of the inventors of photography, made it while the *Great Britain* was being finished in Bristol.

Look closely

- Find the long dark hull. It is made of iron.
- Count the masts. Why would a steamship also have masts for sails?
- Find the smokestack in the middle.
- Look at the water line along the hull.

Talk about it

1. How can a ship made of heavy iron float?
2. What would happen if this ship were loaded with too much cargo?
3. Why do you think people laughed at Brunel's idea?

Safety first. A grown-up stays near the tub of water the whole time.

BUILD

The Clay Boat

You will drop a ball of clay into water and watch it sink. Then you will shape the very same clay into a boat and see how many pennies it can carry.

You will need

- A piece of modeling clay about the size of a golf ball
- A tub, sink or large bowl of water
- About 50 pennies
- Paper towels

Steps

1. Roll the clay into a ball. **Guess:** will it float or sink? Drop it in the water gently.
2. Take it out and dry it. Now shape the same clay into a boat with a flat bottom and walls. Make the walls thin and high.
3. Guess again: will it float now? Set it on the water.
4. Guess how many pennies your boat can carry. Then add pennies one at a time, gently, until it sinks. Count and write it down.
5. Dry the clay and try a different boat shape: wider, or with taller walls.
6. Test the new shape the same way. Make a chart of your shapes and how many pennies each one carried.
7. **Make it better.** What shape carried the most? Make one more boat to beat your best number.

Tips

- Pinch the walls thin. A thin, wide boat pushes aside more water.
- Spread the pennies out evenly so the boat does not tip.

Check your work

- ☐ I can show that the same clay can sink or float, depending on its shape.
- ☐ I can tell why a hollow hull floats.

- ☐ I counted the pennies for at least two boat shapes.

ENGINEER'S NOTEBOOK

1. Draw your clay ball sinking and your clay boat floating. Draw arrows for the water pushing up.
2. Make a chart of your boat shapes and how many pennies each one carried.
3. Draw the *SS Great Britain*.

From history. The *SS Great Britain* sailed for many years and carried thousands of passengers. Today she has been brought home to the very dock in Bristol where she was built, and visitors can walk on her decks.

COMMON MISTAKES

- Thinking heavy things always sink. A heavy thing with the right shape can float.
- Dropping pennies in one spot so the boat tips over.

Make it a game • Clay Boat Cargo Duel. Squeeze a ball of clay and drop it in water, then shape another into a boat and try again. Say float and sink for each. Then load pennies one at a time, and count how many the clay boat holds. Tell why a boat pushes aside water, using the word buoyancy. Beat your best count.

Scripture. “Make thee an ark of gopher wood; rooms shalt thou make in the ark, and shalt pitch it within and without with pitch.” (Genesis 6:14, KJV)

God gave Noah exact plans for the ark, even the pitch to keep the water out. A good boat must be planned carefully and sealed tight.

6.2 BOAT SHAPES: THE FAST CLIPPER SHIPS

OBJECTIVES

- Tell how the clipper ship *Flying Cloud* set a record sailing to San Francisco.
- Explain that a long, narrow, pointed hull moves fast, but a wide hull carries more.
- Build foil boats of different shapes and test each one for speed and for cargo.

Warm-up. In a tub of water, push your flat hand through the water palm first. Then turn your hand sideways and push it through with the edge first. Which way is easier? Why do you think so?

WATCH

Why Do Ships Float?

[SciShow Kids](#) · 3:52

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

WHEN TO WATCH

After the core ideas.

BACKUP VIDEO

Float a Boat! - #sciencegoals

[SciShow Kids](#) · 3:35

<https://www.youtube.com/watch?v=jj-vKtmtljw>

Before the build. Jessi and Squeaks make and test their own boats.

KEY TERMS

bow

The front of a boat.

stern

The back of a boat.

clipper ship

A fast sailing ship with a long, narrow, pointed hull and many sails.

cargo

The goods a ship carries.

CORE IDEAS

Long ago. About 175 years ago, many people wanted to travel from New York to California, where gold had been found. There was no railroad across the country yet. The fastest way was by ship, all the way around the bottom of South America. A ship

builder named **Donald McKay** built a ship for speed. He made it long and narrow, with a sharp, pointed **bow**, and gave it tall masts covered with sails.

His ship was called the *Flying Cloud*. In 1851 it sailed from New York to San Francisco in just 89 days, faster than any ship before it. Ships like it were called **clipper ships**, because they “clipped” along so fast.

Why does it work? When a boat moves, it must push the water out of its way. A wide, flat front has to shove a lot of water, which slows it down. A narrow, pointed bow cuts through the water and slides it aside, so the boat goes faster. But there is a trade-off. A narrow boat has less room inside, so it carries less **cargo**. A wide boat is slower but carries more, and it is harder to tip over.

How do builders use it? Engineers choose the hull shape for the job. Racing boats and canoes are long and narrow. Barges that carry coal and grain are wide and flat. Big cargo ships are long, wide and deep, with a rounded bow, so they can carry huge loads across the ocean.

PICTURE STUDY



The Clipper Ship Flying Cloud, Nathaniel Currier, after E. Brown Jr., 1852 · Hand-colored lithograph ·
National Maritime Museum, Greenwich
Image: [Wikimedia Commons](#), public domain

This print was made the year after the *Flying Cloud* set her record. People loved to hang pictures of the beautiful, fast clipper ships in their homes.

Look closely

- Find the long, narrow hull. Where is the bow?
- Count the masts.
- Look at all the sails. How many can you count?
- Look at the waves at the bow. What is the ship doing to the water?

Talk about it

1. Why did McKay make the hull so narrow and pointed?
2. What would the ship be able to carry if it were wider? What would it lose?
3. Why do you think a fast ship was worth so much in 1851?

Safety first. A grown-up stays near the tub of water the whole time.

BUILD

The Foil Boat Speed Test

You will make a wide, flat foil boat and a narrow, pointed foil boat from the same size of foil. You will time them across a tub, and then test how many pennies each can carry.

You will need

- Aluminum foil cut into squares the same size (about 20 cm or 8 inches)
- A tub or bathtub of water
- String, tape and a paper clip
- Pennies
- A timer

Steps

1. Make Boat A: a wide, flat, square boat with low walls.
2. Make Boat B from the same size of foil: a long, narrow boat with a pointed bow.
3. Tape a string to the bow of Boat A. Lay the string across the tub and over the far edge. Hang a paper clip on the end as a pulling weight.
4. **Guess:** which boat will cross faster? Let go and time how long Boat A takes to cross. Do it three times.
5. Do the same with Boat B, with the same string and the same paper clip.
6. Now test cargo: add pennies one at a time to each boat until it sinks. Count and write it down.
7. Make a chart: speed and pennies for each boat. Which was faster? Which carried more?
8. **Make it better.** Design Boat C to be fast and still carry a lot. Test it both ways.

Tips

- Start each run with the boat at the same spot.
- If the paper clip pulls too fast, use a lighter one, or a small piece of tape as the weight.

Check your work

- ☐ I can tell why a pointed bow is faster.
- ☐ I can tell why a wide boat carries more.
- ☐ I timed each boat three times and counted the pennies.

ENGINEER'S NOTEBOOK

1. Draw Boat A and Boat B from above. Label the bow and the stern.
2. Make a chart of each boat's crossing times and penny count.
3. Draw the *Flying Cloud* under full sail.

From history. The *Flying Cloud* broke her own record three years later, in 1854. But soon steamships, and then the railroad across America, took the place of the clippers.

COMMON MISTAKES

- Using a bigger piece of foil for one boat. Both boats need the same amount.
- Thinking the fastest boat is always the best. It depends on the job.

Make it a game • Long or Wide Boat. Make a long narrow foil boat and a wide round foil boat. Race them across a tub by blowing gently, and note the winner. Then load each with pennies and see which carries more. Use the words bow, stern and cargo. Tell how the clipper ship *Flying Cloud* sailed fast to San Francisco.

6.3 PADDLES AND SAILS: JOSHUA SLOCUM'S SPRAY

OBJECTIVES

- Tell how Joshua Slocum sailed alone around the world in a boat he rebuilt himself.
- Explain how a paddle pushes a boat and how a sail catches the wind, and what a rudder does.
- Build a rubber-band paddle boat and test sails of different sizes.

Warm-up. Sit in a chair with wheels, or on a scooter, on a smooth floor. Push against a wall with your hands. Which way do you roll? Now think: how does a paddle push a boat forward?

WATCH

Learn About Sailboats for Children | Educational Video for Kids by Brain Candy TV

Brain Candy TV · 6:41

<https://www.youtube.com/watch?v=6pM96WzoY48>

WHEN TO WATCH

After the core ideas. It names the parts of a sailboat; pause and have your child point to the hull, mast, sails and rudder.

BACKUP VIDEO

How Sails Work or How Sailboats Sail into the Wind

Stick Science · 2:59

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

For parents or older siblings: how a sailboat can even sail into the wind.

KEY TERMS

paddle

A flat blade that pushes water backward to move a boat forward.

sail

A large sheet of strong cloth that catches the wind to push a boat.

rudder

A flat board under the back of a boat that turns to steer it.

CORE IDEAS

Long ago. Joshua Slocum was a sea captain. When he was about fifty years old, a friend gave him an old fishing boat called the *Spray*. It was falling apart in a field. Slocum cut down oak trees and rebuilt the boat, piece by piece, by himself. It took him more than a year.

In 1895 Slocum sailed the *Spray* out of Boston, all alone. For three years he sailed across oceans and around the whole world, and in 1898 he came home safely. He was the first person ever to sail alone around the world. He set the sails so carefully that the *Spray* could often steer herself while he slept or read a book.

Why does it work? When you push the water backward with a **paddle** or an oar, the water pushes the boat forward. A **sail** catches the wind. The wind pushes on the sail, and the sail pushes the boat. A bigger sail catches more wind. At the back of the boat, under the water, is the **rudder**. When the rudder turns, the water pushes on it and turns the boat.

How do builders use it? Rowboats and canoes use paddles and oars. Old steamboats had big paddle wheels that turned around and around. Sailboats use sails, and big ships use propellers, which are like spinning paddles. Every ship, large or small, steers with a rudder.

PICTURE STUDY



Joshua Slocum's Spray, Unknown photographer, 1898 · Photograph
Image: [Wikimedia Commons](#), public domain

This photograph shows the *Spray* in 1898, the year Joshua Slocum came home from sailing around the world alone.

Look closely

- Find the sails. How many are there?
- Find the masts that hold up the sails.
- Find the flag. Which way is the wind blowing it?
- Look at the back of the boat. Where do you think the rudder is?

Talk about it

1. How did one man sail this boat all the way around the world?
2. What would Slocum do if the wind stopped?
3. Why do you think he rebuilt the boat himself instead of buying a new one?

Safety first. A grown-up helps cut the carton and stays near the water. Wear safety glasses when winding rubber bands.

BUILD

Paddle Boat and Sail Test

You will build a paddle boat powered by a rubber band, and then add a sail and test whether a bigger sail makes a faster boat in front of a fan.

You will need

- An empty juice or milk carton cut in half the long way (a grown-up cuts it), or a foam tray
- Two craft sticks, a rubber band and a small piece of plastic cut from a lid (the paddle)
- A straw or skewer for a mast, clay, and paper for sails in two sizes
- A tub or bathtub of water, a box fan used by a grown-up, and a timer
- Tape and safety glasses

Steps

1. Tape two craft sticks to the sides of the carton so they stick out past the back.
2. Stretch the rubber band between the ends of the sticks. Slide the plastic paddle into the middle of the rubber band.
3. Wind the paddle backward 10 times. Hold it, set the boat in the water, and let go. Time how long it takes to cross the tub.
4. **Fair test.** Try 10 turns, then 20 turns. Time each one. Which went farther or faster?
5. Take off the paddle. Stand a straw mast in a lump of clay in the boat. Tape on a small sail.
6. A grown-up turns on the fan at one end of the tub. **Guess**, then time the boat across.
7. Change to a big sail. Keep everything else the same. Time it again.
8. **Make it better.** Add a small rudder from a piece of plastic at the back. Can you make your boat sail straight across?

Tips

- Wind the paddle the same number of turns for each test.

- Keep the fan the same distance from the tub.

Check your work

- ☐ I can tell how a paddle and a sail push a boat.
- ☐ I can tell what a rudder does.
- ☐ I timed my boat with 10 turns and 20 turns, and with a small sail and a big sail.

ENGINEER'S NOTEBOOK

1. Draw your paddle boat. Draw arrows to show the paddle pushing water back and the boat going forward.
2. Make a chart of your times for each test.
3. Draw the *Spray* on the ocean, and draw a map line around the world.

From history. Slocum wrote a book about his trip called *Sailing Alone Around the World*. It is still read today. He sailed about 46,000 miles in the little *Spray*.

COMMON MISTAKES

- Winding the paddle the wrong way, so the boat goes backward.
- Changing the sail and the fan distance at the same time.

Make it a game • Slocum Sails Alone. Be Captain Joshua Slocum sailing alone, with your parent as the ocean. Show a paddle push, a sail catch the wind and a rudder steer, using your hands and your body. Your parent calls out a job, such as turn left, and you pick paddle, sail or rudder. Tell the first five correct answers in a row.

Scripture. “Behold also the ships, which though they be so great, and are driven of fierce winds, yet are they turned about with a very small helm, whithersoever the governor listeth.” (James 3:4, KJV)

The helm is the rudder. A very small rudder can turn a great ship. James says our small tongues steer our lives in the same way, so we should use our words well.

6.4 THE MAYFLOWER

OBJECTIVES

- Tell the story of the *Mayflower's* voyage in 1620 and how the Pilgrims mended the cracked beam.
- Explain why cargo must be packed low and even to keep a boat from tipping.
- Build a cargo boat, load it with passengers, and test it in waves.

Warm-up. Float a plastic container in water. Put a few coins all on one side. What happens? Now spread them evenly on the bottom. What changes?

WATCH

All About the Mayflower for Children: Learn Facts About the Mayflower for Kids - FreeSchool

Free School · 5:52

<https://www.youtube.com/watch?v=sm7O4R1uN9s>

WHEN TO WATCH

After the story.

KEY TERMS

voyage

A long trip by sea.

beam

On a ship, a big wooden timber that goes across from side to side and holds the ship together.

balance

Being steady, with the weight spread out evenly.

CORE IDEAS

Long ago. In September 1620, a small wooden ship called the *Mayflower* sailed from Plymouth, England. On board were 102 passengers. Many of them were Pilgrims, who wanted a place where they could worship God freely. They were crossing the wide Atlantic Ocean to a new land.

Halfway across, great storms came. The ship rolled and leaked, and one of the big wooden **beams** in the middle of the ship bent and cracked. The sailors were afraid. But the passengers had brought a great iron screw, a kind of jack for lifting. They used it to push the beam back up into place. Then the carpenter set a strong post under it. The ship held together.

After 66 days at sea, the passengers saw land: Cape Cod. Their governor, William Bradford, later wrote that they fell on their knees and blessed God, who had brought them safely over the ocean.

Why does it work? A ship must stay in **balance**. If heavy cargo is piled high or all on one side, the ship can tip over in the waves. Heavy things are packed low and spread evenly in the hold, the bottom of the ship. Then the ship rocks in the waves but stands back up again.

How do builders use it? Shipbuilders make the hull strong with big beams and frames, like ribs. Sailors pack cargo low and even. And every good ship carries tools and spare parts to make repairs at sea.

PICTURE STUDY



The Mayflower in Plymouth Harbor, William Halsall, 1882 · Oil on canvas · Pilgrim Hall Museum, Plymouth, Massachusetts

Image: [Wikimedia Commons](#), public domain

The painter William Halsall imagined the *Mayflower* resting in Plymouth Harbor after her long voyage. The storms are over, and the water is calm.

Look closely

- Find the *Mayflower*. Count her masts.
- Look at the shape of the hull. Is it tall at the front and back?
- Find the small rowboat. What do you think it is for?
- Look at the sky and the water. How does the picture make you feel?

Talk about it

1. Why are the sails rolled up?
2. What would it be like to live on this small ship for 66 days?
3. How did the passengers fix the cracked beam?

Safety first. A grown-up stays near the tub of water the whole time.

BUILD

The Cargo Boat

You will build a boat to carry passengers and cargo across a stormy tub. You will find out how many it can carry, and whether packing the load low and even keeps it from tipping.

You will need

- A small plastic container, a foil boat, or a boat made from a milk carton
- About 50 dried beans or pennies (the passengers)
- A few small blocks or clay lumps (the cargo)
- A tub of water
- A ruler or your hand to make waves

Steps

1. Float your boat. **Guess** how many passengers it can carry.
2. Add passengers one at a time, spread evenly, until the water is almost at the top edge. Count and write it down.
3. Now pile all the cargo on one side. Make three gentle waves with the ruler. Does it tip? Write it down.
4. Spread the same cargo low and even on the bottom. Make the same three waves. Does it tip now?
5. Make the waves bigger, the same for each test. Which way of packing survives the storm?
6. **Make it better.** Strengthen your boat or change its shape to carry more passengers safely through the waves. Test it again and count.

Tips

- Make the waves the same way each time: the same ruler, the same number of pushes.
- Leave a little space between the water and the top of the boat. Real ships do too.

Check your work

☐ I can tell the story of the

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☐ I can tell why cargo should be low and even.

☐ I counted how many passengers my boat could carry.

ENGINEER'S NOTEBOOK

1. Draw your cargo boat from the side with the load low and even. Then draw it with the load on one side, tipping.
2. Write how many passengers your boat carried.
3. Draw the cracked beam and the great iron screw pushing it back up.

From history. The *Mayflower* sailed home to England the next spring. In 1957, a copy called *Mayflower II* was built in England and sailed across the ocean. It floats today in Plymouth, Massachusetts, where visitors can go aboard.

COMMON MISTAKES

- Piling cargo high in the middle. High loads tip easily.
- Making bigger waves for one test than for another.

Make it a game • Load It Low. Float a foil cargo boat in a tub. Pack pennies low and even, then pile them high on one side. Which one tips? Count how many pennies you can load before it tips. Say the word balance and tell the Pilgrims' story, including the cracked beam and how they mended it. Beat your own score.

BOATS

Some things float and some things sink. A pebble sinks, but a great ship made of iron floats. Why? In this unit you will learn the secret of floating, see how boat builders shaped fast clipper ships, sail with Joshua Slocum, the first man to sail alone around the world, and cross the ocean with the Pilgrims on the *Mayflower*.

You will turn a lump of clay that sinks into a boat that floats, test foil boats of different shapes for speed, build a paddle boat and a sailboat, and load a cargo boat until it is full. Each time you will guess, test, count and improve. The Bible speaks of “they that go down to the sea in ships,” and of Noah, who built an ark just as God told him. Boat builders have always had to plan carefully, because the sea is strong.

PREREQUISITES

- Knows how to run a fair test and make a chart (Units 1–5)
- Can count pennies to 50

MASTERY CHECKLIST

- ☐ I can tell why a boat floats: it pushes aside water, and the water pushes back up.
 - ☐ I can show that shape, not only weight, decides whether something floats.
 - ☐ I can tell why a narrow, pointed boat is fast and a wide boat carries more.
 - ☐ I can tell how paddles, sails and a rudder move and steer a boat.
 - ☐ I can tell the story of the *Mayflower* and how the Pilgrims fixed the cracked beam.
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OPTIONAL KITS FOR THIS UNIT

- **KiwiCo Kiwi Crate:** Ages 5–8. Some crates are water projects, such as boats you build and float; a fun extra for this unit.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

6.1	Floating and Sinking: The Iron Ship	2 sessions of 30 minutes
6.2	Boat Shapes: The Fast Clipper Ships	2 sessions of 30 minutes
6.3	Paddles and Sails: Joshua Slocum's Spray	2 sessions of 30 minutes
6.4	The Mayflower	2 sessions of 30 minutes

UNIT 6 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have clay, foil, a tub of water and some pennies ready.

1. Show me with clay: how can the same clay sink and float?
2. How did Brunel's iron ship float if iron is heavy?
3. Predict: which foil boat will cross the tub faster, a wide flat one or a narrow pointed one? Which will carry more pennies?
4. What pushes a sailboat? What pushes a canoe? What steers a ship?
5. Tell me about Joshua Slocum and the *Spray*.
6. Tell me the story of the *Mayflower*. How did they fix the cracked beam? How should cargo be packed?

ANSWER KEY

1. A ball sinks; a hollow boat shape floats because it pushes aside more water, and the water pushes back up.
2. Its hull was big and hollow, full of air, so it pushed aside enough water to hold it up.
3. The narrow pointed one is faster; the wide one carries more.
4. The wind on the sails; the paddle pushing water back; the rudder.
5. He rebuilt an old boat himself and was the first person to sail alone around the world, from 1895 to 1898.
6. In 1620 the Pilgrims crossed the ocean in 66 days; a storm cracked a beam, and they pushed it up with a great iron screw and set a post under it. Cargo should be packed low and even.

PORTFOLIO PIECE: MY CARGO SHIP

Design and build a boat from foil, a carton or a plastic container that can carry as many pennies as possible across a tub and survive three waves. Draw your plan first. Test it, count the pennies it carries, then make one change and test it again. Give your ship a name, draw it in your notebook with both counts, and tell your family about its shape and how you packed the cargo.

LOOK FOR	WHAT IT MEANS
It floats and carries	The boat floats and carries pennies across the tub.
Packed well	Packed the pennies low and even, so the boat stayed steady in the waves.
Fair test	Made the same waves for both tests and counted carefully.
Tried again	Made one change after the first test and tested again.
Telling	Explained why the boat floats and why its shape was chosen.

UNIT 7

FLIGHT

You cannot see air, but it is real. It fills the room, it pushes on everything, and it can hold things up. People who wanted to fly first had to learn about air. In this unit you will meet Otto von Guericke, whose horses could not pull apart two metal bowls held together by air; André-Jacques Garnerin, who floated down from the sky under the first parachute; Otto Lilienthal, who glided on wings like a bird; and the Montgolfier brothers, whose hot-air balloon carried the first people into the sky.

You will push a cup of air under water, drop parachutes and time them, fly paper gliders and measure how far they go, and watch a bag of warm air rise. “The way of an eagle in the air” was a wonder to King Solomon. By careful testing, people learned to follow it.

PREREQUISITES

- Can use a timer or count seconds with help
- Knows how to run a fair test and make a chart (Units 1–6)

MASTERY CHECKLIST

- ☐ I can show that air is real: it takes up space and pushes on things.
- ☐ I can tell why a bigger parachute falls more slowly, and I timed my parachutes.
- ☐ I can tell how a glider stays up, and I tested a glider and made it fly farther.
- ☐ I can tell why warm air rises and how the Montgolfier brothers used it.
- ☐ I can say the safety rules for flying things: open spaces, never near power lines, and a grown-up for anything hot.

LESSONS IN THIS UNIT

7.1 Air Is Real: Guericke’s Two Bowls

2 sessions of 30 minutes

7.2 Parachutes: Garnerin’s Jump

2 sessions of 30 minutes

7.3 Gliders: Otto Lilienthal’s Wings

2 sessions of 30 minutes

UNIT 7 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have a cup, a bowl of water, a paper towel, a parachute and a paper glider ready.

1. Show me with the cup and the paper towel that air is real. Why did the paper stay dry?
2. Tell me about Guericke's horses. Why couldn't they pull the two bowls apart?
3. Predict: will a big parachute or a small parachute fall more slowly? Why?
4. Fly your glider. What holds it up? What did Lilienthal learn from storks?
5. Why does a hot-air balloon rise? Who flew the first one with animals?
6. Tell me the safety rules for flying things.

ANSWER KEY

1. The cup was full of air, and the air took up space and kept the water out.
2. He pumped the air out from inside, and the air outside pushed the halves together very hard.
3. The big one, because it catches more air and the air pushes up harder.
4. The wings push air down and the air pushes them up (lift). He learned that curved wings work well.
5. Warm air is lighter than cool air, so it rises. The Montgolfier brothers, in 1783, with a sheep, a duck and a rooster.
6. Fly in open spaces away from people's faces, never near power lines, and only a grown-up uses anything hot.

PORTFOLIO PIECE: MY BEST FLYER

Choose one flyer from this unit, a parachute or a glider, and make it as good as you can. For a parachute, try to make the slowest, steadiest fall with the same passenger. For a glider, try to make the longest flight. Test it three times, change one thing, and test it three times again. Draw it in your notebook with your chart of times or distances, and show your family your best flight.

LOOK FOR	WHAT IT MEANS
It flies	The parachute opens and floats down, or the glider glides straight.
Fair test	Dropped or threw it the same way every time and measured each try.
Tried again	Changed one thing and tested again three times.
Notebook page	Drew the flyer with labels and a chart of results.
Telling	Explained how air helps the flyer stay up or fall slowly.

7.1 AIR IS REAL: GUERICKE'S TWO BOWLS

OBJECTIVES

- Tell how Otto von Guericke showed that air pushes hard on everything.
- Show that air takes up space and pushes on things.
- Test whether a paper towel stays dry inside a cup pushed under water.

Warm-up. Wave a big piece of cardboard back and forth fast. What do you feel on your face? Blow up a balloon and let it go (without tying it). What pushed it? Is air nothing, or is it something?

WATCH

Exploring Air & Air Pressure

[funsciencedemos](https://www.youtube.com/watch?v=Grziaq-caVE) · 8:49

<https://www.youtube.com/watch?v=Grziaq-caVE>

WHEN TO WATCH

After the story. Pause before each test and ask, “What will happen?”

BACKUP VIDEO

Very simple demonstration that shows air takes up space

[Fizzics Education](https://www.youtube.com/watch?v=WBNNfKT6Kk0) · 1:13

<https://www.youtube.com/watch?v=WBNNfKT6Kk0>

Right before the build; it shows the same paper-in-a-cup test you will do.

KEY TERMS

air

The invisible gases all around us that we breathe.

air pressure

The push of the air on everything it touches.

vacuum

A space with the air taken out of it.

CORE IDEAS

Long ago. Long ago, many people thought air was nothing at all. In Germany, a man named **Otto von Guericke**, the mayor of the town of Magdeburg, wanted to find out. He invented a pump that could suck the air out of a container. Then he made two big

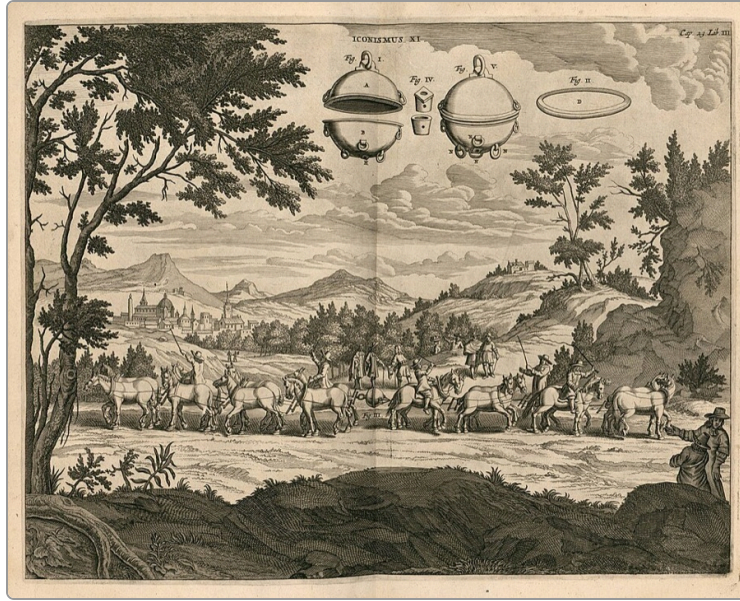
metal half-balls that fit together into one ball. He put them together and pumped the air out from inside.

Then he did a famous test. He hitched a team of horses to each half and had them pull in opposite directions. The horses pulled and pulled, but they could not pull the two halves apart! Then Guericke opened a little valve and let the air back in. The halves fell apart by themselves.

Why does it work? Air is real. It takes up space, and it presses on everything, all the time, from every side. That push is called **air pressure**. We do not feel it because air presses on us from the inside and the outside equally. But when Guericke took the air out from inside the ball, making a **vacuum**, only the outside air was pushing. It pushed the halves together so hard that the horses could not pull them apart.

How do builders use it? Air pressure is all around us. Engineers use it in air pumps, bicycle tires, drinking straws and suction cups. And because air is real, it can push on wings and parachutes. That is why we start our study of flight by learning that air is something.

PICTURE STUDY



The Magdeburg Hemispheres, Gaspar Schott, 1657 · Engraving

Image: [Wikimedia Commons](#), public domain

This old engraving was made to show people Otto von Guericke's famous test. Drawings of the two metal half-balls are shown at the top.

Look closely

- Find the metal ball in the middle.
- Count the horses on each side.
- Find the drawings of the half-balls at the top of the picture.
- Look for the people watching.

Talk about it

1. What was inside the ball when the horses were pulling?
2. What pushed the two halves together so hard?
3. Why did the halves fall apart when Guericke let the air back in?

Safety first. Do the water tests over a sink or tub, with a grown-up nearby.

BUILD

The Dry Paper Test

You will push a cup with a paper towel inside it straight down into water. Will the paper get wet? Then you will test what happens if you tilt the cup.

You will need

- A clear plastic cup
- Paper towels
- A large bowl or tub of water, deeper than the cup
- A straw

Steps

1. Crumple a piece of paper towel and push it tightly into the bottom of the cup so it will not fall out when you turn the cup over.
2. **Guess:** if you push the cup straight down, upside down, into the water, will the paper get wet?
3. Turn the cup upside down and push it straight down into the water, all the way. Hold it there and count to 10.
4. Lift it straight up. Feel the paper. Write down: wet or dry.
5. Now do it again with a fresh paper, but tilt the cup while it is under the water. Watch for bubbles. Feel the paper.
6. Make a chart: straight down and tilted, wet or dry. Talk about why.
7. **Make it better.** Push the cup under straight, then slip a bent straw under its edge and blow gently. What happens to the water inside the cup?

Tips

- Push the paper in tightly so it stays at the bottom.
- Go straight down and straight up, slowly.

Check your work

- ☐ I can show that air takes up space.
- ☐ I can tell why the paper stayed dry.

- ☐ I tested the cup straight and tilted.

ENGINEER'S NOTEBOOK

1. Draw the cup under the water. Color the air inside and the water outside.
2. Draw the tilted cup with bubbles escaping.
3. Draw Guericke's horses pulling on the ball, with arrows showing the air pushing in.

From history. Guericke spent much of his own money on his experiments. He also built a tall water barometer on the side of his house, which rose and fell with the air pressure and helped him guess when storms were coming.

COMMON MISTAKES

- Thinking air is nothing. Air is real; it fills the cup and keeps the water out.
- Tilting the cup by accident in the first test.

Make it a game • Air Pushes Back. Crumple a dry paper into a cup and push the cup upside down into a tub of water. Does the paper get wet? Say air takes up space. Then blow up a balloon and squeeze it, and feel the air push. Tell your parent about Otto von Guericke and the two bowls, using the words air pressure.

Scripture. "The wind bloweth where it listeth, and thou hearest the sound thereof, but canst not tell whence it cometh, and whither it goeth" (John 3:8, KJV)

We cannot see the wind, but we hear it and feel its push. Jesus used the wind to teach Nicodemus that God's Spirit is real and at work, even though we cannot see Him.

7.2 PARACHUTES: GARNERIN'S JUMP

OBJECTIVES

- Tell the story of André-Jacques Garnerin and the first parachute jump from a balloon.
- Explain how air pushes up on a parachute and slows its fall.
- Build parachutes of different sizes, time their falls and make one fall slower and steadier.

Warm-up. Drop a flat sheet of paper and a crumpled ball of paper at the same time from the same height. Which lands first? They weigh the same. Why do you think one falls more slowly?

WATCH

Playtime with Parachutes | Physics for Kids

SciShow Kids · 3:37

https://www.youtube.com/watch?v=Ab_g5sLoXoY

WHEN TO WATCH

After the core ideas, before the build.

BACKUP VIDEO

Parachute Adventure! - #sciencegoals

SciShow Kids · 4:47

<https://www.youtube.com/watch?v=w4Jgh9V9gwE>

During the build, to see Jessi and Squeaks make and test their own parachutes.

KEY TERMS

parachute

A big cloth canopy that catches air to slow down a fall.

canopy

The big round cloth top of a parachute.

air resistance

The push of air against something moving through it. Engineers also call it drag.

CORE IDEAS

Long ago. On October 22, 1797, a crowd gathered in a park in Paris, France. A Frenchman named **André-Jacques Garnerin** rose high into the sky under a balloon. Below the balloon hung a small basket, and above the basket was a big folded cloth. High up, Garnerin cut the rope that held him to the balloon.

The crowd gasped as the basket dropped. Then the cloth filled with air and opened like a giant umbrella. Garnerin floated down to the ground. He was the first person to jump from a balloon with a **parachute**. His parachute swung back and forth a lot on the way down. Later, a scientist friend suggested a small hole in the top to let some air out smoothly, and that stopped much of the swinging.

Why does it work? When something falls, it has to push the air out of its way. The air pushes back. That push is called **air resistance**. A crumpled paper ball pushes on very little air, so it falls fast. A parachute's big **canopy** catches a lot of air, so the air pushes up hard and the fall is slow and gentle. A bigger canopy catches more air.

How do builders use it? Engineers design parachutes for many jobs. They bring astronauts' capsules gently down into the ocean, slow down fast jet airplanes when they land, and drop supplies to people in places that trucks cannot reach. NASA used a giant parachute to slow down the rover it landed on Mars.

PICTURE STUDY



The First Parachute Descent of Jacques Garnerin, Unknown artist, 1797 · Colored print · Library of Congress

Image: [Wikimedia Commons](#), public domain

This print was made the same year as Garnerin's jump. It shows the parachute coming down while the empty balloon drifts away.

Look closely

- Find the parachute and the little basket under it.
- Find the balloon. What happened to it after Garnerin cut the rope?
- Find the people on the ground. What are they doing?
- Look at the shape of the open parachute.

Talk about it

1. Why did the parachute open when Garnerin fell?
2. Why do you think his parachute swung back and forth?
3. Would you have been brave enough to make this jump?

Safety first. Drop parachutes from a safe place, such as a staircase landing with a grown-up or standing on the floor with your arm stretched up high. Never climb on furniture or lean out of windows.

BUILD

The Parachute Drop Test

You will make parachutes in two sizes, drop them from the same height, and time how long each takes to land. Then you will try to make your parachute fall slowly and without swinging.

You will need

- A plastic grocery bag or a large coffee filter
- String (four pieces about 30 cm or 12 inches long for each parachute)
- Tape and scissors
- A small toy figure, a clothespin, or a large paper clip for a passenger
- A timer

Steps

1. Cut a square from the plastic bag, 20 cm (8 inches) on each side. Tape a string to each corner. Tie the four strings together to your passenger.
2. Make a second parachute exactly the same way, but 40 cm (16 inches) on each side.
3. **Guess:** which will take longer to fall?
4. Drop the small parachute from the same high spot three times. A helper times each fall. Write the times down.
5. Drop the big parachute three times from the same spot, with the same passenger. Time and write it down.
6. Drop the passenger with no parachute. How long did that take?
7. Make a chart. Which one fell most slowly?
8. **Make it better.** Cut a small hole in the middle of your big parachute, like Garnerin's friend suggested. Does it swing less? Does it fall faster or slower?

Tips

- Hold the parachute open by its middle when you drop it, so it opens quickly.
- Drop from exactly the same height every time.

Check your work

- ☐ I can tell why a parachute falls slowly.
- ☐ I can tell which size fell more slowly and why.
- ☐ I timed each parachute three times.

ENGINEER'S NOTEBOOK

1. Draw your two parachutes with arrows: one arrow down for the weight and one arrow up for the air pushing.
2. Make a chart of your drop times.
3. Draw Garnerin floating down over the crowd.

From history. Garnerin made many more jumps. His wife, Jeanne-Geneviève, also flew in balloons and became the first woman to jump with a parachute, in 1799.

COMMON MISTAKES

- Dropping one parachute from higher than the other.
- Using a different passenger for different tests.

Make it a game • Parachute Drop Duel. Make a paper parachute with string and a small weight. Drop it from a chair and count how many seconds it falls. Then drop a crumpled paper from the same height. Guess first which lands later. Say canopy and air resistance, and tell about Garnerin's jump from a balloon. Beat your best count.

7.3 GLIDERS: OTTO LILIENTHAL'S WINGS

OBJECTIVES

- Tell how Otto Lilienthal studied birds and glided on wings he built himself.
- Explain that wings push air down and the air pushes the wings up.
- Build a paper glider, measure how far it flies, and make it fly farther.

Warm-up. Watch birds outside for five minutes. Do they always flap? Look for one that glides with its wings held still. How do you think it stays up without flapping?

WATCH

How to Make a Paper Airplane

SciShow Kids · 4:17

<https://www.youtube.com/watch?v=7KPaxKUDj6I>

WHEN TO WATCH

Before the build. You may fold your first glider along with the video.

BACKUP VIDEO

Paper Airplanes and Drag | STEM Activity

Science Buddies · 3:17

<https://www.youtube.com/watch?v=6fLh8eswOn0>

After your first test, to get ideas for making your glider better.

KEY TERMS

glider

A flying machine with wings but no engine. It glides slowly down through the air.

wing

The flat or gently curved part that holds a bird or an airplane up in the air.

lift

The upward push of the air on a moving wing.

CORE IDEAS

Long ago. In Germany, about 130 years ago, an engineer named Otto Lilienthal loved to watch storks. He and his brother studied how storks fly. He saw that their wings

are not flat but gently curved, and he measured how curved wings push on the air.

Then Lilienthal built **gliders** from willow sticks covered with cloth, shaped like a bird's wings. He even had a hill built near his home so he could run down it into the wind. He hung under the wings, ran, and lifted off into the air. He steered by swinging his legs and body. From 1891 to 1896, he made about two thousand glides! Photographs of him flying went all around the world. In America, two brothers named Wilbur and Orville Wright saw them and began to study flying too.

Why does it work? A glider has no engine. It glides gently down the air, like a sled down a hill. As its **wings** move forward, they push air down. The air pushes the wings up. That upward push is called **lift**. Lift holds the glider up while it slowly slides down through the air. A tail keeps it flying straight, and the right weight in the nose keeps it from tipping up or diving.

How do builders use it? Every airplane has wings that make lift. Gliders still fly today, with long thin wings, riding on rising air for hours. And engineers test model wings and gliders many times, changing one thing at a time, just as you will today.

PICTURE STUDY



Otto Lilienthal in Flight, Richard Neuhauss (probably), June 29, 1895 · Photograph

Image: [Wikimedia Commons](#), public domain

People came to watch Lilienthal glide from his hill near Berlin. This photograph caught him in the air, with the crowd watching below.

Look closely

- Find Lilienthal under his wings.
- Look at the shape of the wings. Are they flat or curved?
- Find the tail behind him.
- Find the hill he started from, and the crowd.

Talk about it

1. Why did Lilienthal run down a hill into the wind?
2. How do you think he steered?
3. What did he learn from watching storks?

Safety first. Fly gliders in an open room or outside, away from people's faces. Never fly anything near power lines.

BUILD

The Paper Glider Test

You will fold a simple paper glider, measure how far it flies, and then change one thing at a time to make it fly farther.

You will need

- Several sheets of printer paper, all the same
- Paper clips
- Tape
- A tape measure and a piece of masking tape for a starting line

Steps

1. Fold a simple dart-style paper airplane with a helper, or follow the video.
2. Put a strip of masking tape on the floor as the starting line.
3. Throw the glider gently, the same way each time. Measure where it lands. Throw it three times and write down each distance.
4. **Guess:** will a paper clip on the nose help or hurt?
5. Add one paper clip to the nose. Throw it three times the same way and measure.
6. Now try folding the back edges of the wings up just a little. Throw three times and measure.
7. Make a chart: plain, with a paper clip, with bent wing edges. Which flew farthest?
8. **Make it better.** Make a second glider with wider wings. Test it the same way. Can you beat your best distance?

Tips

- Throw gently and level. A hard throw is not a fair test.
- Make sharp, even folds so both wings are the same.

Check your work

- ☐ I can tell how a wing makes lift.
- ☐ I changed only one thing at a time.

- I measured three flights for each version of my glider.

ENGINEER'S NOTEBOOK

1. Draw your glider from above and from the side. Label the wings and the nose.
2. Make a chart of all your flight distances.
3. Draw a stork gliding and Lilienthal gliding. How are they alike?

From history. Lilienthal wrote a book called *Birdflight as the Basis of Aviation* and shared his measurements so that others could learn. The Wright brothers studied his work, tested it carefully, and built on it.

COMMON MISTAKES

- Throwing harder for one test than another.
- Changing two things at once, like the paper clip and the wings together.

Make it a game • Lilienthal Glider Guess. Fold a paper glider and test it. Before each throw, guess how many of your footsteps it will fly. Walk heel-to-toe to measure. Change the wings, and throw again. Say lift and wing in a sentence about how air pushes the wings up. Tell about Otto Lilienthal and the birds he studied.

Scripture. “The way of an eagle in the air” (Proverbs 30:19, KJV)

Solomon wondered at how an eagle flies. God made birds to fly, and men like Lilienthal learned by watching closely what God had made.

7.4 THE MONTGOLFIER HOT-AIR BALLOON

OBJECTIVES

- Tell how the Montgolfier brothers sent up the first hot-air balloons with animals and then people.
- Explain that warm air rises because it is lighter than the cool air around it.
- Watch a bag of warm air rise and test whether a bigger bag stays up longer.

Warm-up. On a cold day, hold your hand above a warm radiator, a warm cup of cocoa or a lamp (not touching!). Then hold it below or beside it. Where do you feel the warm air? Which way does warm air go?

WATCH

How Do Hot Air Balloons Work?

[SciShow Kids](#) · 3:50

<https://www.youtube.com/watch?v=ABsVP41-EeY>

WHEN TO WATCH

After the story.

BACKUP VIDEO

The Montgolfier Brothers First Flight - X-Streame Science

[NavalAviationMuseumFoundation](#) · 6:53

<https://www.youtube.com/watch?v=eJb1njvRZNo>

Any time this week, for more of the Montgolfier story.

KEY TERMS

hot-air balloon

A big bag filled with warm air that rises and floats in the sky.

rise

To go up.

basket

The part that hangs under a balloon and carries the people.

CORE IDEAS

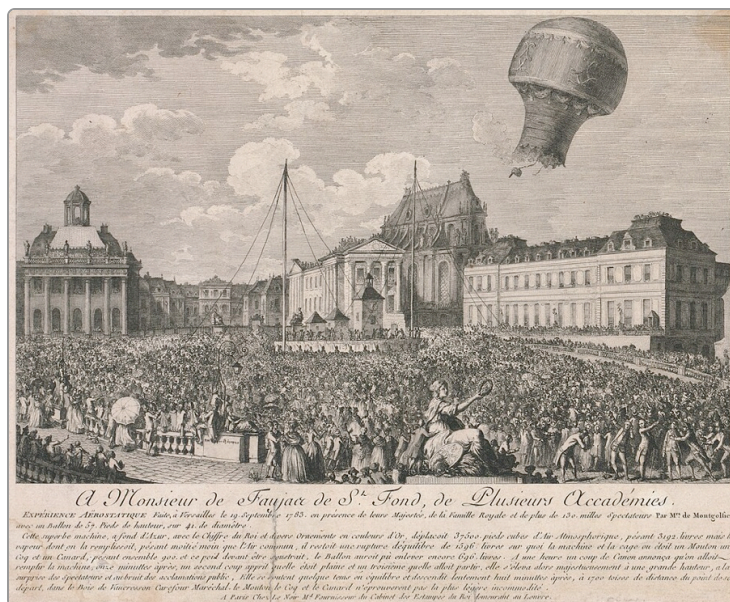
Long ago. In a town in France called Annonay, two brothers named **Joseph and Étienne Montgolfier** ran a paper factory. Joseph noticed that smoke and warm air from a fire made a cloth bag puff up and float. The brothers made bigger and bigger bags of cloth and paper.

On September 19, 1783, they sent up a beautiful blue and gold balloon at the king's palace at Versailles. In the **basket** were a sheep, a duck and a rooster! The balloon flew for about eight minutes and came down gently, and the animals were safe. Two months later, on November 21, 1783, two men rode a Montgolfier balloon high over Paris for about twenty-five minutes. For the first time ever, people had flown.

Why does it work? When air is warmed, it spreads out. A bag full of warm air weighs less than the same bag full of cool air. So the warm air **rises** through the cool air around it, like a cork rising in water. If the warm air in a balloon is light enough to carry the balloon and the basket too, the whole **hot-air balloon** goes up. When the air inside cools, the balloon comes back down.

How do builders use it? Today's hot-air balloons are made of strong, light cloth and heated by a burner. Pilots make them go up by heating the air, and let them sink by letting the air cool. Engineers also send up weather balloons every day to measure the wind and the weather high above us.

PICTURE STUDY



The Balloon at Versailles, Unknown engraver, 1783 · Engraving

Image: [Wikimedia Commons](#), public domain

This engraving was printed in 1783, the same year as the flight. It shows the Montgolfier balloon rising above the crowd at the palace of Versailles, with its three animal passengers in a basket underneath.

Look closely

- Find the balloon high in the sky.
- Look for the basket hanging under it.
- Find the palace and the huge crowd.
- Find the tall pole and the platform where the balloon was filled.

Talk about it

1. Why did the brothers send animals up first instead of people?
2. What made the balloon rise?
3. What would make the balloon come back down?

Safety first. Only a grown-up uses the hair dryer. Never use flames, candles or matches to heat a balloon. Keep plastic bags away from small children's faces.

BUILD

The Warm-Air Balloon

You will fill a very thin bag with warm air from a hair dryer and watch it rise. Then you will test whether a bigger bag stays up longer.

You will need

- Two very thin plastic bags of different sizes, such as produce bags or a dry-cleaning bag, with any holes taped shut
- A few paper clips
- A hair dryer, used only by a grown-up
- A timer

Steps

1. Hold a bag open, upside down. A grown-up holds the hair dryer under the opening, on warm, for 30 seconds.
2. **Guess:** what will happen when you let go? Let go and watch!
3. Time how long it stays up before it comes down. Do it three times and write down each time.
4. Tape two paper clips to the bottom edge to keep it upright. Try again.
5. Now test the bigger bag the same way, with the same heating time. Guess first, then time it three times.
6. Make a chart. Which bag stayed up longer?
7. **Make it better.** Try heating for 60 seconds instead of 30. Does the balloon stay up longer? Why do you think so?

Tips

- This works best in a cool room.
- Do not let the hair dryer touch the bag. It can melt.

Check your work

- ☐ I can tell why warm air rises.
- ☐ I can tell the story of the Montgolfier brothers.

- ☐ I timed both bags three times.

ENGINEER'S NOTEBOOK

1. Draw your warm-air balloon going up. Color the warm air inside red and the cool air outside blue.
2. Make a chart of your times for each bag.
3. Draw the Versailles balloon with the sheep, the duck and the rooster in the basket.

From history. The king of France gave the Montgolfier family a special honor for their work. The word “montgolfière” is still used in French for a hot-air balloon.

COMMON MISTAKES

- Thinking the balloon rises because of smoke. It rises because warm air is lighter than cool air.
- Heating one bag longer than the other in the size test.

Make it a game • Warm Air Rises Quiz. Hold a paper streamer or a tissue above a warm, safe heat source such as a mug of warm water, and watch it move. Say warm air rises. Then act out the Montgolfier balloon story: first an animal, then people. Your parent asks three questions about it and you answer each in a short sentence.

UNIT 7

FLIGHT

You cannot see air, but it is real. It fills the room, it pushes on everything, and it can hold things up. People who wanted to fly first had to learn about air. In this unit you will meet Otto von Guericke, whose horses could not pull apart two metal bowls held together by air; André-Jacques Garnerin, who floated down from the sky under the first parachute; Otto Lilienthal, who glided on wings like a bird; and the Montgolfier brothers, whose hot-air balloon carried the first people into the sky.

You will push a cup of air under water, drop parachutes and time them, fly paper gliders and measure how far they go, and watch a bag of warm air rise. “The way of an eagle in the air” was a wonder to King Solomon. By careful testing, people learned to follow it.

PREREQUISITES

- Can use a timer or count seconds with help
- Knows how to run a fair test and make a chart (Units 1–6)

MASTERY CHECKLIST

- ☐ I can show that air is real: it takes up space and pushes on things.
- ☐ I can tell why a bigger parachute falls more slowly, and I timed my parachutes.
- ☐ I can tell how a glider stays up, and I tested a glider and made it fly farther.
- ☐ I can tell why warm air rises and how the Montgolfier brothers used it.
- ☐ I can say the safety rules for flying things: open spaces, never near power lines, and a grown-up for anything hot.

LESSONS IN THIS UNIT

7.1 Air Is Real: Guericke’s Two Bowls

2 sessions of 30 minutes

7.2 Parachutes: Garnerin’s Jump

2 sessions of 30 minutes

7.3 Gliders: Otto Lilienthal’s Wings

2 sessions of 30 minutes

UNIT 7 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have a cup, a bowl of water, a paper towel, a parachute and a paper glider ready.

1. Show me with the cup and the paper towel that air is real. Why did the paper stay dry?
2. Tell me about Guericke's horses. Why couldn't they pull the two bowls apart?
3. Predict: will a big parachute or a small parachute fall more slowly? Why?
4. Fly your glider. What holds it up? What did Lilienthal learn from storks?
5. Why does a hot-air balloon rise? Who flew the first one with animals?
6. Tell me the safety rules for flying things.

ANSWER KEY

1. The cup was full of air, and the air took up space and kept the water out.
2. He pumped the air out from inside, and the air outside pushed the halves together very hard.
3. The big one, because it catches more air and the air pushes up harder.
4. The wings push air down and the air pushes them up (lift). He learned that curved wings work well.
5. Warm air is lighter than cool air, so it rises. The Montgolfier brothers, in 1783, with a sheep, a duck and a rooster.
6. Fly in open spaces away from people's faces, never near power lines, and only a grown-up uses anything hot.

PORTFOLIO PIECE: MY BEST FLYER

Choose one flyer from this unit, a parachute or a glider, and make it as good as you can. For a parachute, try to make the slowest, steadiest fall with the same passenger. For a glider, try to make the longest flight. Test it three times, change one thing, and test it three times again. Draw it in your notebook with your chart of times or distances, and show your family your best flight.

LOOK FOR	WHAT IT MEANS
It flies	The parachute opens and floats down, or the glider glides straight.
Fair test	Dropped or threw it the same way every time and measured each try.
Tried again	Changed one thing and tested again three times.
Notebook page	Drew the flyer with labels and a chart of results.
Telling	Explained how air helps the flyer stay up or fall slowly.

ROBOTS AND INVENTIONS

A robot is a machine that can sense the world around it, follow instructions, and move to do a job. Robots help people in factories, in hospitals, in homes and even in space. But a robot can only do what its engineers and programmers planned for it, one careful step at a time. In this unit you will meet the robot arm that flew on the Space Shuttle, Ada Lovelace, who wrote some of the very first instructions for a computing machine, and the little Sojourner rover that drove itself around rocks on Mars.

You will build a robot hand from straws and string, program a grown-up “robot” with arrow cards, build a touch sensor that lights a bulb, and invent a marble run for the family engineering fair. Bezalel, the builder of the tabernacle, was filled by God “in wisdom, and in understanding, and in knowledge, and in all manner of workmanship.” Inventing is one way we use the gifts God gives.

PREREQUISITES

- Can build a battery-and-bulb circuit (Unit 4)
- Can use a lever, ramp and wheel (Unit 1)
- Knows the difference between left and right

MASTERY CHECKLIST

- ☐ I can tell what makes a machine a robot: it senses, follows instructions and acts.
- ☐ I can build a robot hand and tell how its strings work like the tendons in my hand.
- ☐ I can write a step-by-step program with arrow cards and fix a bug in it.
- ☐ I can build a touch sensor and tell how robots use sensors like our senses.
- ☐ I can invent, test and improve a marble run and explain it at the family engineering fair.

OPTIONAL KITS FOR THIS UNIT

- **Bee-Bot floor robot (TTS)**: A small, sturdy floor robot made for young children. You press arrow buttons on its back to program a path, then press Go. A perfect fit for Lesson 8.2.
- **Snap Circuits (Elenco)**: Snap-together electronics with no soldering; the Beginner set is made for young children. Its switches and lights fit the touch sensor in Lesson 8.3.
- **KiwiCo Kiwi Crate**: Ages 5–8. Some crates are moving machines and simple robots; a fun extra for this unit and the engineering fair.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

8.1 Robots That Help People: The Space Shuttle's Arm	2 sessions of 30 minutes
8.2 Step-by-Step Code Without a Computer	2 sessions of 30 minutes
8.3 Sensors Are Like Our Senses: The Sojourner Rover	2 sessions of 30 minutes
8.4 A Marble-Run Invention and the Engineering Fair	2 sessions of 30 minutes, plus the fair

UNIT 8 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have the robot hand, the arrow cards, the bump sensor and a marble ready.

1. What three things does a robot do? Is a toaster a robot? Is a robot vacuum?
2. Show me how your robot hand works. What part of your own hand is like the string?
3. Here is a program with a bug. Can you find it and fix it? (Lay out arrow cards that lead the robot one square wrong.)

4. How did Sojourner miss the rocks on Mars? What sensors do robots use, and which of our senses are they like?
5. Predict: if you make the marble run's ramps steeper, will the marble take more time or less? Why?
6. Name the steps engineers use to invent something.

ANSWER KEY

1. A robot senses, follows instructions and acts. A plain toaster does not sense its surroundings much; a robot vacuum senses walls and dirt and moves, so it is a robot.
2. Pulling the string bends the fingers at the joints. The string is like a tendon.
3. The child follows the cards, finds the wrong card and replaces it.
4. It used laser stripes and cameras to see rocks and steer around them. Cameras are like eyes, microphones like ears, bump sensors like touch.
5. Less time, because the marble rolls faster down a steep ramp.
6. Ask, imagine, plan, build, test and improve.

PORTFOLIO PIECE: THE FAMILY ENGINEERING FAIR

Choose your best build from each of the eight units and set them out on a table with their notebook pages, or photographs if they are too big. Add your marble run. Make a small sign for each one. Invite your family and friends, and give each guest a tour: tell what each build does, how you tested it, and what you changed to make it better. End by telling your guests which build you are most proud of and why.

LOOK FOR	WHAT IT MEANS
A build from every unit	Showed a build or photograph from each unit, with its notebook page.
The marble run	The marble run works from top to bottom, and its times are written down.
Testing and improving	Could tell how at least three builds were tested and made better.
Clear telling	Spoke clearly, looked at the guests and answered their questions.
Thankfulness	Thanked the guests and the helpers who held, counted and recorded all year.

8.1 ROBOTS THAT HELP PEOPLE:

THE SPACE SHUTTLE'S ARM

OBJECTIVES

- Tell what a robot is: a machine that senses, follows instructions and acts.
- Tell how the Canadarm robot arm helped astronauts on the Space Shuttle.
- Build a robot hand from straws and string and test what it can pick up.

Warm-up. Name all the machines in your house that do a job by themselves after you press a button: a washing machine, a dishwasher, a microwave, maybe a robot vacuum. Which ones can sense something, like a full tub or a closed door?

WATCH

Real-Life Robots

SciShow Kids · 4:08

<https://www.youtube.com/watch?v=8wHJjLMnikU>

WHEN TO WATCH

After the first core idea.

KEY TERMS

robot

A machine that can sense what is around it, follow instructions, and move to do a job.

robot arm

A robot shaped like an arm, with joints that bend, used to lift and move things.

joint

A place where a robot or a body can bend, like an elbow or a knuckle.

tendon

A strong cord in your body that pulls on a bone to make it move.

CORE IDEAS

What is a robot? A **robot** is a machine that does three things. It **senses** the world around it. It **follows instructions** that people give it. And it **acts**: it moves to do a job. Robots help people with jobs that are hard, boring, dangerous, or too far away for us to reach.

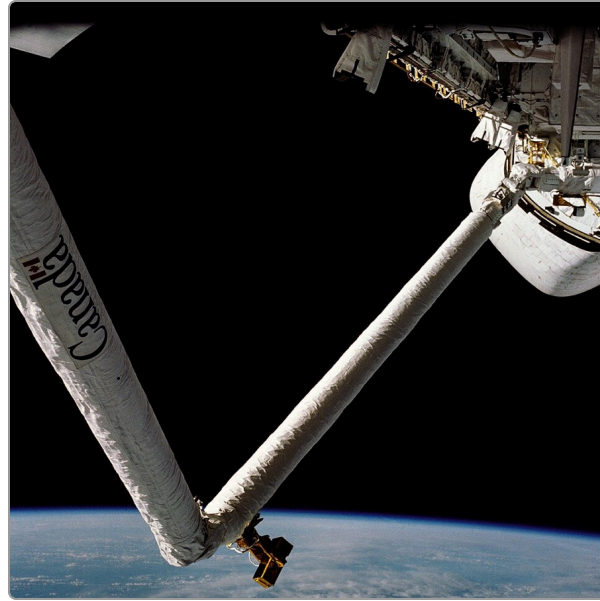
Long ago. In November 1981, the Space Shuttle *Columbia* flew into space carrying a brand-new helper: a long **robot arm**, built by engineers in Canada and called the Canadarm. It was about 50 feet long, with **joints** like a shoulder, an elbow and a wrist. An astronaut inside the shuttle steered it with hand controls and watched it with cameras.

Over the years, the Canadarm and the arms that came after it caught satellites, lifted heavy parts to build the International Space Station, and even held astronauts with their feet tied in while they worked outside. It was a very strong helper in a very dangerous place.

Why does it work? Your arm moves because muscles pull on **tendons**, strong cords that pull on your bones. A robot arm moves because motors turn its joints, or pull on cables. Sensors tell the robot where its arm is, and its instructions tell it where to move next.

How do builders use it? Robot arms build cars in factories, pack boxes, help doctors, and work deep under the sea. Engineers give each one the right joints, the right grip and the right sensors for its job.

PICTURE STUDY



The Canadarm in Space, NASA, November 1981 · Photograph

Image: [Wikimedia Commons](#), public domain

This photograph was taken from the Space Shuttle *Columbia* on the first flight of the Canadarm in 1981. The Earth is far below.

Look closely

- Find the long robot arm.
- Find the joints where the arm can bend.
- Find the hand at the end of the arm. What do you think it grabs?
- Find the Earth.

Talk about it

1. Why is a robot arm a good helper in space?
2. How did the astronaut know where the arm was?
3. What job would you give a robot arm at home?

BUILD

The Straw Robot Hand

You will build a robot finger and then a robot hand from straws and string. The strings work like the tendons in your hand. Then you will test what your hand can pick up.

You will need

- A piece of cardboard about the size of your hand (the palm)
- Four or five bendy or plain drinking straws
- String or yarn, and a large blunt needle or tape to thread it
- Scissors (a grown-up cuts small notches) and tape
- Things to pick up: a cotton ball, a paper cup, a crumpled paper ball, a small toy, a pencil

Steps

1. Trace your hand on the cardboard and cut it out with a grown-up's help.
2. Cut a straw into three short pieces for each finger. Tape the pieces in a row along each cardboard finger, with small gaps between them. The gaps are the joints.
3. Thread a string through each finger's straw pieces, from the tip down to the palm. Tape the string to the fingertip.
4. Pull a string. Watch the finger bend at the joints, just like yours!
5. **Guess** which things your robot hand can pick up. Try each one and make a chart: picked it up or did not.
6. Fold your own hand into a fist and watch the tendons move on the back of your wrist. Talk about how your hand and the robot hand are alike.
7. **Make it better.** Add rubber bands or tape on the fingertips for grip, or add a thumb. Test the same things again. Did your hand pick up more?

Tips

- Bend the cardboard a little at each gap so the fingers fold easily.
- Pull all the strings together to make a fist.

Check your work

- ☐ I can tell the three things a robot does.
- ☐ I can tell how strings in my robot hand work like tendons.
- ☐ I tested my hand on at least five things and made it better.

ENGINEER'S NOTEBOOK

1. Draw your robot hand. Label the joints and the strings.
2. Make a chart of what your hand could and could not pick up, before and after your change.
3. Draw a robot that you would like to invent to help someone. What would it sense? What would it do?

From history. The original Canadarm flew on 90 Space Shuttle missions before the shuttles retired in 2011. A bigger arm, Canadarm2, still works on the International Space Station today.

COMMON MISTAKES

- Thinking every machine is a robot. A robot must sense, follow instructions and act.
- Making the gaps between straws too small, so the fingers cannot bend.

Make it a game • Straw Hand Test. Use your straw robot hand to pick up a small cup. Count how many things it can grab in one minute. Say the words joint and tendon as you point to them. Then tell your parent what a robot is, and how the Canadarm helped astronauts on the Space Shuttle. Beat your score with one small fix.

8.2 STEP-BY-STEP CODE WITHOUT A COMPUTER

OBJECTIVES

- Tell how Ada Lovelace wrote step-by-step instructions for a calculating machine.
- Explain that a program is a list of steps in exact order, and that a bug is a mistake to fix.
- Program a grown-up “robot” to walk a path using arrow cards, and debug the program.

Warm-up. Ask your child to tell you, step by step, how to make a peanut butter sandwich, and do exactly what they say and nothing more. (If they say “put the peanut butter on the bread,” set the whole jar on the bread!) Laugh together, and talk about why exact steps matter.

WATCH

What is Sequence? | Coding for Kids | Kodable

Kodable · 2:48

https://www.youtube.com/watch?v=v_Pc3UnePZY

WHEN TO WATCH

Before the build.

BACKUP VIDEO

Introducing Kids to Coding

Lakeshore Learning · 6:15

<https://www.youtube.com/watch?v=nwMeINjRl6Y>

Any time this week, for more ideas for coding games with arrows and robots.

KEY TERMS

program

A list of exact steps, in order, that tells a machine what to do.

sequence

The order that steps go in.

bug

A mistake in a program.

debug

To find and fix a mistake in a program.

CORE IDEAS

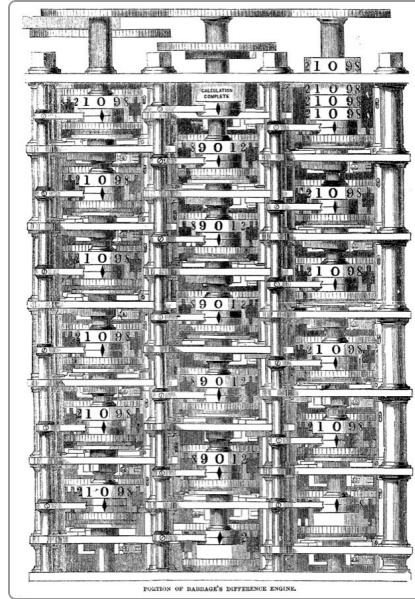
Long ago. About 190 years ago, in England, an inventor named **Charles Babbage** designed great machines of brass gears that could do arithmetic all by themselves. His friend **Ada Lovelace**, a young woman who loved mathematics, studied his plans for a new machine. In 1843 she wrote a set of step-by-step instructions to show how the machine could work out a hard list of numbers.

Her instructions are often called one of the very first computer **programs**. Babbage's new machine was never finished, but Ada Lovelace saw that a machine like it might one day do much more than arithmetic, if people gave it the right instructions.

Why does it work? A machine cannot guess what you mean. It does exactly what it is told, in exactly the order it is told. The order of the steps is called the **sequence**. If one step is wrong or missing, the machine goes the wrong way. A mistake in a program is called a **bug**. Finding and fixing it is called **debugging**. Every programmer, even the best, has to debug.

How do builders use it? Every robot, phone and computer follows programs written by people. Programmers write the steps, test them, find the bugs and fix them, again and again, until the machine does its job right.

PICTURE STUDY



*A Part of Babbage's Difference Engine, Benjamin Herschel Babbage, 1864 (printed in *Harper's New Monthly Magazine*) · Engraving*

Image: [Wikimedia Commons](#), public domain

Charles Babbage's son drew this picture of a part of his father's calculating machine. Each column is a stack of wheels with numbers on them.

Look closely

- Find the tall columns of wheels.
- Look closely for the numbers on the wheels.
- Find the rods and frames that hold the columns together.
- Count how many columns you can see.

Talk about it

1. How do you think the machine showed its answers?
2. Why would a machine need exact instructions to work?
3. How is this old machine like a computer today? How is it different?

BUILD

Program the Grown-Up Robot

You will make a grid on the floor and a set of arrow cards. Then you will write a program to move a “robot” (a grown-up or a sibling) from the start square to a treasure, step by step, and fix any bugs.

You will need

- Masking tape to make a grid of 5×5 squares on the floor (or chalk outside)
- Index cards: draw arrows on some (forward, turn left, turn right) and write “Repeat 2” on a few
- A small treasure, such as a toy or a snack
- A few pillows or books for walls

Steps

1. Make the grid. Put the robot on a start square, facing forward. Put the treasure on another square.
2. **Guess** how many cards it will take to reach the treasure. Lay your arrow cards out in a line, in order. That is your program.
3. Read the cards one at a time. The robot does exactly what each card says and nothing else: forward one square, turn left in place, or turn right in place.
4. Did the robot reach the treasure? If not, find the bug. Fix one card and run the program again.
5. Count how many cards your program used. Write it down.
6. Add pillows as walls. Write a new program that goes around them.
7. **Make it better.** Use a “Repeat 2” card in front of a forward arrow to say “go forward twice” with fewer cards. Can you make a shorter program that still works?

Tips

- The robot should only do what the card says, even if it is silly!
- Turn cards mean turn in place, without stepping.

Check your work

- ☐ I can tell what a program, a sequence and a bug are.
- ☐ I wrote a program that got the robot to the treasure.
- ☐ I found and fixed at least one bug.

ENGINEER'S NOTEBOOK

1. Draw your grid with the start, the treasure and the walls. Draw the robot's path.
2. Copy your program, arrow by arrow, and write how many cards it used. Circle the bug you fixed.
3. Write a program of arrows to get from your bed to your door.

From history. A modern computer programming language is named Ada, after Ada Lovelace. Babbage's Difference Engine No. 2 was finally built from his drawings by the Science Museum in London in 1991, and it worked.

COMMON MISTAKES

- Mixing up left and right when the robot is facing you. Stand behind the robot to see its left and right.
- Skipping a card while reading the program.

Make it a game • Bug Hunt Program. Write or say steps for your parent to walk a path across the room: forward, forward, turn, forward. Your parent follows exactly, even if there is a chair in the way. When it goes wrong, shout Bug! and find the mistake in the list. Then tell why Ada Lovelace wrote steps in exact order.

8.3 SENSORS ARE LIKE OUR SENSES: THE SOJOURNER ROVER

OBJECTIVES

- Compare robot sensors to our five senses.
- Tell how the Sojourner rover on Mars used sensors to steer around rocks by itself.
- Build a touch sensor that lights a bulb when something bumps it, and test how hard a push it needs.

Warm-up. Play a senses game. Close your eyes and let a grown-up hand you three things to feel, a sound to hear and something to smell. Guess each one. Which sense told you the most? Now think: how would a robot know what is in front of it?

WATCH

How Robots Sense, Plan, and Act

World Science Festival · 2:06

<https://www.youtube.com/watch?v=tUs2nyDcls8>

WHEN TO WATCH

After the core ideas. A robot scientist shows how a robot senses, plans and acts.

Note: Made for older viewers; pause often and explain in simple words.

KEY TERMS

sensor

A part that lets a robot notice something, such as light, touch, sound or distance.

rover

A robot car that drives over the ground of a moon or planet.

touch sensor

A sensor that notices when it is pressed or bumped.

CORE IDEAS

Our senses. God gave us five senses: sight, hearing, touch, smell and taste. Our senses tell our brains what is around us, so we know when to stop, turn or reach. Robots need to know what is around them too. They use **sensors**. A camera is

a robot's eyes. A microphone is its ears. A **touch sensor** tells it when it bumps into something.

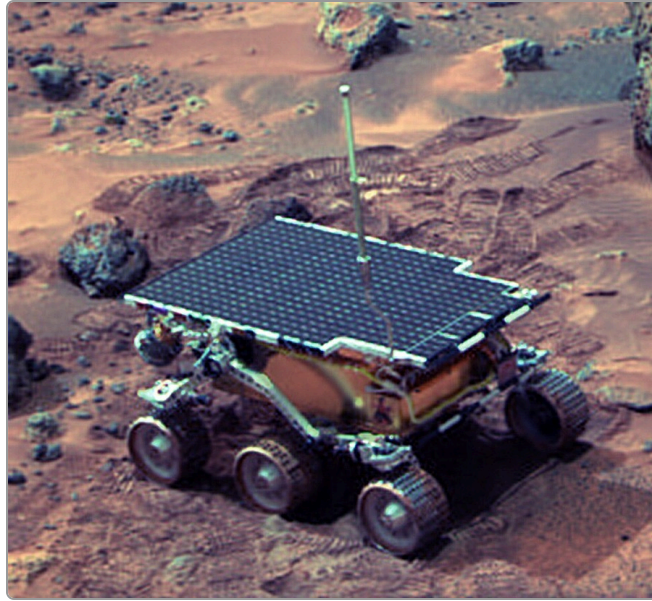
Long ago. On July 4, 1997, NASA's Mars Pathfinder landed on the planet Mars. Inside was a little **rover** named **Sojourner**, about the size of a child's wagon. Mars is so far away that a radio message takes many minutes to get there. Drivers on Earth could not steer it like a toy car, quickly enough to miss every rock.

So NASA's engineers gave Sojourner sensors. The drivers told it where to go, and Sojourner did the rest. It shined stripes of laser light ahead of it and watched them with its cameras. If a stripe bent over a rock, the rover knew something was in the way and steered around it. It also had sensors that felt if it was tipping too far. Sojourner explored Mars for nearly three months.

Why does it work? A sensor turns something in the world, like a bump or light, into a signal the robot can use. A touch sensor can be as simple as a switch: when it is pressed, the circuit closes and electricity flows. The robot's program says what to do when that happens, like "stop and turn."

How do builders use it? Automatic doors use sensors to see you coming. Cars use sensors to warn about things behind them. Robot vacuums use bump sensors to turn away from walls. Every robot needs the right sensors for its job.

PICTURE STUDY



Sojourner on Mars, NASA / Jet Propulsion Laboratory, 1997 · Photograph

Image: [Wikimedia Commons](#), public domain

This picture from Mars shows the little Sojourner rover next to a rock. Pathfinder's camera took it from the lander nearby.

Look closely

- Count the rover's wheels.
- Find the flat panel on top. It turns sunlight into electricity.
- Find the rock beside the rover.
- Look at the ground. What is Mars like?

Talk about it

1. Why couldn't people on Earth steer Sojourner quickly around rocks?
2. What sensors would you give a rover on Mars?
3. Why do you think it has six wheels?

Safety first. Use only your battery circuit. Never use the outlets in the wall.

BUILD

The Bump Sensor

You will build a touch sensor from cardboard and foil. When it is pressed, it closes a circuit and lights a bulb, the way a robot vacuum knows it has bumped a wall.

You will need

- Your battery, bulb and clip leads from Unit 4
- Two pieces of cardboard about 5 × 10 cm (2 × 4 inches)
- Aluminum foil, tape and a small sponge or folded paper
- Pennies
- A toy car or a box (the “robot”)

Steps

1. Cover one side of each piece of cardboard with foil. Tape them together at one end, foil sides facing, with a small folded piece of paper between them at the other end so the foils do not touch.
2. Clip one wire to each foil. Connect them into your battery-and-bulb loop. The foils are now a switch.
3. Press the cardboard together. Does the bulb light? Let go. Does it go out?
4. **Guess** how many pennies it will take to press your sensor closed. Stack pennies on top, one at a time, until the bulb lights. Count them and write it down.
5. Make the paper spacer thicker. Test with pennies again. Did it take more or fewer?
6. Tape your sensor to the front of a toy car. Roll it gently into a wall. Does the bulb light when it bumps?
7. **Make it better.** Make your sensor light up with a gentle bump, but not by itself when the car rolls. Change one thing and test again.

Tips

- Make sure the foil touches the metal of the clips.
- A softer spacer, like a little sponge, makes a springy sensor.

Check your work

- ☐ I can tell how a robot sensor is like one of my senses.
- ☐ I can tell how Sojourner found rocks by itself.
- ☐ I counted how many pennies it took to press my sensor, with two spacers.

ENGINEER'S NOTEBOOK

1. Draw your bump sensor and its circuit. Show it open and closed.
2. Make a chart: thin spacer and thick spacer, and how many pennies each needed.
3. Draw a robot and label its sensors: eyes (camera), ears (microphone), touch (bump sensor).

From history. Sojourner's name means a traveler who stays for a while. Since then, bigger rovers named Spirit, Opportunity, Curiosity and Perseverance have explored Mars, each with better sensors than the last.

COMMON MISTAKES

- Letting the foils touch all the time, so the bulb is always on.
- Thinking a robot can see and understand the way we do. It only notices what its sensors are built to notice.

Make it a game • Senses Versus Sensors. Match your five senses to robot sensors. Say what a robot would use in place of your eyes, your ears and your touch. Then walk with your eyes closed and a bump sensor, which is a pool noodle held in front of you, and your parent steers you. Tell how the Sojourner rover on Mars steered around rocks.

8.4 A MARBLE-RUN INVENTION AND THE ENGINEERING FAIR

OBJECTIVES

- Use the engineering steps: ask, imagine, plan, build, test and improve.
- Build a marble run from cardboard tubes and ramps, and test and improve it.
- Show your best builds from the year at a family engineering fair and explain how they work.

Warm-up. Roll a marble down a cardboard tube held at a steep slant, then a gentle slant. Time each one by counting. Which was faster? How could you make a marble run that takes as long as possible?

WATCH

Educational Activities for Kids: Marble Run Challenge

James Dyson Foundation • 5:19

<https://www.youtube.com/watch?v=IN0Wn0XgPXQ>

WHEN TO WATCH

Before the build, to see engineers plan and test a marble run.

BACKUP VIDEO

Build a Marble Run | STEM & STEAM Activity for Kids | Lakeshore® Learning

Lakeshore Learning • 5:46

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

During the build, for ideas and to see how a designer tests and improves a track.

KEY TERMS

invention

A new thing that someone designs and makes to solve a problem.

prototype

A first try at an invention, built to test the idea.

engineering design process

The steps engineers follow: ask, imagine, plan, build, test and improve.

CORE IDEAS

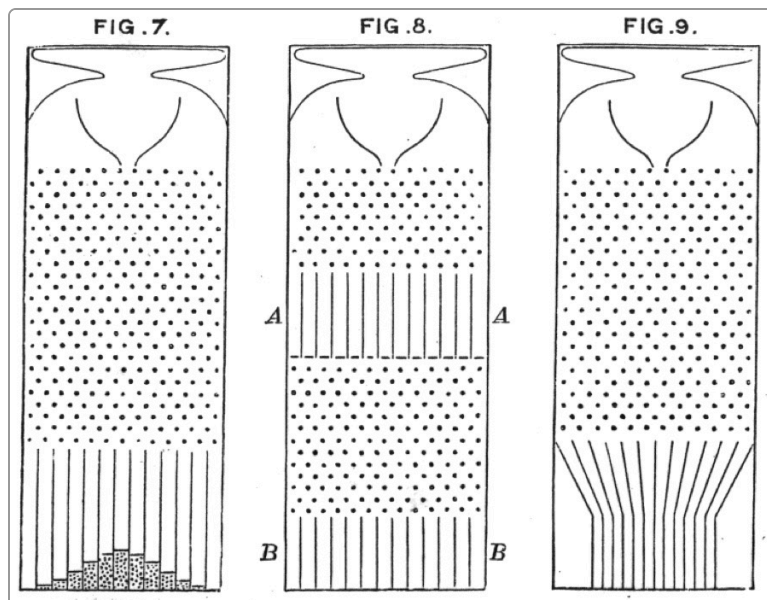
Long ago. A cartoonist named **Rube Goldberg** first studied to be an engineer. Later he drew funny pictures of giant machines that did very simple jobs, like wiping your mouth or turning on a light, in many silly steps. A ball rolls down a ramp, which tips a cup, which pulls a string, which rings a bell. People loved them. Today children and engineers build real chain-reaction machines for fun and practice.

Why does it work? A marble run uses the simple machines and ideas you learned this year. A marble rolls down a ramp because gravity pulls it down. A gentle ramp makes it roll slowly, and a steep ramp makes it roll fast. Curves and walls guide it. A marble can bump a domino or tip a lever to start the next step.

How do builders use it? Real engineers follow the **engineering design process**. They ask what the problem is. They **imagine** ideas. They **plan** with drawings. They **build** a **prototype**. They **test** it. Then they **improve** it, again and again. You have done this all year! Factories use rolling tracks, chutes and conveyor belts to move parts from machine to machine, much like a marble run.

The engineering fair. Now it is time to show what you have made. Set out your favorite build from each unit with its notebook page. Invite your family. Explain each one: what it does, how you tested it and what you changed. Telling others about your work is part of being an engineer.

PICTURE STUDY



Galton's Bean Machine, Francis Galton, 1889 · Diagram from the book *Natural Inheritance*

Image: [Wikimedia Commons](#), public domain

The scientist Francis Galton built a box like this, with rows of pins, and dropped many small balls through it. They bounced left and right off the pins and piled up in the slots at the bottom. It is a kind of marble run that he used to study chance.

Look closely

- Find the funnel at the top where the balls go in.
- Find the rows of pins.
- Find the slots at the bottom.
- In the first box, look at the pile at the bottom. Where are the most balls?

Talk about it

1. What happens to a ball each time it hits a pin?
2. Why do you think most balls end up near the middle?
3. How could you use pins or pegs in your own marble run?

Safety first. Marbles are a choking danger for babies and toddlers. Keep them away from small children, and count your marbles when you put them away.

BUILD

My Marble-Run Invention

You will invent a marble run on a wall, a door or a big box. Your goal: make the marble take as long as possible to get from the top to the bottom, without falling off.

You will need

- Cardboard tubes from paper towels and wrapping paper, cut in half the long way by a grown-up
- Cardboard, paper cups and craft sticks
- Masking tape (it will not hurt most painted walls; check with a grown-up first)
- Two or three marbles
- A timer

Steps

1. **Ask.** The problem: make a marble run that takes as long as possible.
2. **Imagine and plan.** Draw your marble run in your notebook. Think about gentle ramps, zigzags and curves.
3. **Build.** Tape the tube pieces to the wall or box, zigzagging down. Tape a cup at the bottom to catch the marble.
4. **Test.** **Guess** how many seconds the marble will take. Drop it in at the top and time it. Do it three times. Write down each time.
5. Watch where it goes too fast, gets stuck or falls off. Mark those spots.
6. **Improve.** Fix one problem at a time: make a ramp gentler, add a wall, add another zigzag. Test three times after each change and write down the times.
7. **Bonus:** add a chain reaction at the end, like a marble that knocks over a row of dominoes.

Tips

- Gentle ramps are slower, but too gentle and the marble stops.
- Make the joins smooth so the marble does not bounce out.

Check your work

- ☐ I used all the steps: ask, imagine, plan, build, test and improve.
- ☐ I timed my marble run three times before and after each change.
- ☐ I explained my builds at the family engineering fair.

ENGINEER'S NOTEBOOK

1. Draw your plan, then draw your finished marble run.
2. Make a chart of your times after each change. Did your run get slower?
3. Make a sign for the engineering fair with your name and your favorite build from the year.

From history. Francis Galton built his “bean machine” to show how many small chances add up to a pattern. Today you can find a box like his in many science museums, with balls bouncing down through the pins.

COMMON MISTAKES

- Building the whole run before testing any of it. Test each ramp as you go.
- Changing several things at once, so you cannot tell which one helped.

Make it a game • Marble Run Engineers. Build a small marble run from cardboard tubes and ramps. Say the six steps out loud: ask, imagine, plan, build, test and improve. After each test, fix one thing, and time the marble. Beat your time three times in a row. Then show your parent and explain what changed, using the word prototype.

Scripture. “And I have filled him with the spirit of God, in wisdom, and in understanding, and in knowledge, and in all manner of workmanship,” (Exodus 31:3, KJV)

God filled Bezalel with skill to design and build the tabernacle. Every good idea and every skillful hand is a gift from God, to be used well.

ROBOTS AND INVENTIONS

A robot is a machine that can sense the world around it, follow instructions, and move to do a job. Robots help people in factories, in hospitals, in homes and even in space. But a robot can only do what its engineers and programmers planned for it, one careful step at a time. In this unit you will meet the robot arm that flew on the Space Shuttle, Ada Lovelace, who wrote some of the very first instructions for a computing machine, and the little Sojourner rover that drove itself around rocks on Mars.

You will build a robot hand from straws and string, program a grown-up “robot” with arrow cards, build a touch sensor that lights a bulb, and invent a marble run for the family engineering fair. Bezalel, the builder of the tabernacle, was filled by God “in wisdom, and in understanding, and in knowledge, and in all manner of workmanship.” Inventing is one way we use the gifts God gives.

PREREQUISITES

- Can build a battery-and-bulb circuit (Unit 4)
- Can use a lever, ramp and wheel (Unit 1)
- Knows the difference between left and right

MASTERY CHECKLIST

- ☐ I can tell what makes a machine a robot: it senses, follows instructions and acts.
- ☐ I can build a robot hand and tell how its strings work like the tendons in my hand.
- ☐ I can write a step-by-step program with arrow cards and fix a bug in it.
- ☐ I can build a touch sensor and tell how robots use sensors like our senses.
- ☐ I can invent, test and improve a marble run and explain it at the family engineering fair.

OPTIONAL KITS FOR THIS UNIT

- **Bee-Bot floor robot (TTS)**: A small, sturdy floor robot made for young children. You press arrow buttons on its back to program a path, then press Go. A perfect fit for Lesson 8.2.
- **Snap Circuits (Elenco)**: Snap-together electronics with no soldering; the Beginner set is made for young children. Its switches and lights fit the touch sensor in Lesson 8.3.
- **KiwiCo Kiwi Crate**: Ages 5–8. Some crates are moving machines and simple robots; a fun extra for this unit and the engineering fair.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

8.1 Robots That Help People: The Space Shuttle's Arm	2 sessions of 30 minutes
8.2 Step-by-Step Code Without a Computer	2 sessions of 30 minutes
8.3 Sensors Are Like Our Senses: The Sojourner Rover	2 sessions of 30 minutes
8.4 A Marble-Run Invention and the Engineering Fair	2 sessions of 30 minutes, plus the fair

UNIT 8 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have the robot hand, the arrow cards, the bump sensor and a marble ready.

1. What three things does a robot do? Is a toaster a robot? Is a robot vacuum?
2. Show me how your robot hand works. What part of your own hand is like the string?
3. Here is a program with a bug. Can you find it and fix it? (Lay out arrow cards that lead the robot one square wrong.)

4. How did Sojourner miss the rocks on Mars? What sensors do robots use, and which of our senses are they like?
5. Predict: if you make the marble run's ramps steeper, will the marble take more time or less? Why?
6. Name the steps engineers use to invent something.

ANSWER KEY

1. A robot senses, follows instructions and acts. A plain toaster does not sense its surroundings much; a robot vacuum senses walls and dirt and moves, so it is a robot.
2. Pulling the string bends the fingers at the joints. The string is like a tendon.
3. The child follows the cards, finds the wrong card and replaces it.
4. It used laser stripes and cameras to see rocks and steer around them. Cameras are like eyes, microphones like ears, bump sensors like touch.
5. Less time, because the marble rolls faster down a steep ramp.
6. Ask, imagine, plan, build, test and improve.

PORTFOLIO PIECE: THE FAMILY ENGINEERING FAIR

Choose your best build from each of the eight units and set them out on a table with their notebook pages, or photographs if they are too big. Add your marble run. Make a small sign for each one. Invite your family and friends, and give each guest a tour: tell what each build does, how you tested it, and what you changed to make it better. End by telling your guests which build you are most proud of and why.

LOOK FOR	WHAT IT MEANS
A build from every unit	Showed a build or photograph from each unit, with its notebook page.
The marble run	The marble run works from top to bottom, and its times are written down.
Testing and improving	Could tell how at least three builds were tested and made better.
Clear telling	Spoke clearly, looked at the guests and answered their questions.
Thankfulness	Thanked the guests and the helpers who held, counted and recorded all year.

TOY LAB

Toys are little machines. A yo-yo climbs its own string. A marble rolls and knocks another marble away. A kaleidoscope turns a few bits of colored glass into a hundred bright patterns. A jack-in-the-box jumps up with a spring. Someone had to invent each of these toys, test it, and find a way to make it well enough and cheaply enough for children everywhere to enjoy.

This optional bonus unit is for after the family engineering fair, for the summer, or for any week that needs something fun. Each lesson tells the story of a toy, shows the science of why it works, and ends with a homemade toy to build and test. You will make a yo-yo, roll marbles into each other, build a mirror kaleidoscope and make a jumping paper spring. Play is a good gift from God, and so is understanding how it works.

PREREQUISITES

- Has finished Units 1–8, or at least Unit 1 (simple machines)
- Knows how to run a fair test and keep an engineer’s notebook

MASTERY CHECKLIST

- ☐ I can tell why a yo-yo climbs back up its string.
- ☐ I can show what happens when one marble hits another.
- ☐ I can tell how mirrors make the pattern in a kaleidoscope.
- ☐ I can show that a spring pushes back harder when it is squashed more.
- ☐ I can tell the toy safety rule: small parts and marbles are kept away from babies and toddlers.

OPTIONAL KITS FOR THIS UNIT

- **KiwiCo Kiwi Crate:** Ages 5–8. Many crates are toys that children build themselves and then play with, such as spinners, launchers and marble games.
- **CrunchLabs Build Box (Mark Rober):** Made for ages 8 and up, so a first grader will need a parent building alongside. Each box is a toy built around one idea of physics, with a video that explains it.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

9.1 The Yo-Yo	2 sessions of 30 minutes
9.2 Marbles and the Marble Machine	2 sessions of 30 minutes
9.3 The Kaleidoscope	2 sessions of 30 minutes
9.4 The Jack-in-the-Box and Springs	2 sessions of 30 minutes

UNIT 9 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have the homemade toys from this unit ready.

1. Show me your yo-yo. Why does it climb back up its string?
2. Where should you put extra weight to make a yo-yo spin longer?
3. Predict: if one marble rolls into a row of three marbles, how many will roll off the far end?
4. Who invented the kaleidoscope? How do the mirrors make a pattern?
5. Show me with your jack-in-the-box: what makes it jump? What holds it shut?
6. Tell me one toy safety rule.

ANSWER KEY

1. As it falls it spins faster and faster, and the spin winds the string back up.
2. Near the outer rim, evenly spaced.
3. One.
4. Brewster, in 1816. Light bounces back and forth between mirrors at an angle, making many copies of the bits around a circle.
5. A squashed spring pushes it up; a latch holds the lid shut.
6. Keep small parts and marbles away from babies and toddlers; never open toys with button batteries or plugs; do not swing toys near faces.

PORTFOLIO PIECE: MY TOY INVENTION

Invent a new toy that uses one idea from this unit: spin, rolling and crashing, mirrors, or a spring. Draw your plan first. Build it from household materials, test it, and make one change to make it better. Then teach a family member how to play with it, and tell them the science of why it works.

LOOK FOR	WHAT IT MEANS
It works	The toy does what it was planned to do.
Science inside	Can name the idea it uses: spin, rolling, mirrors or a spring.
Tested and improved	Tested the toy, made one change and tested it again.
Safe	Has no sharp edges and no tiny loose parts, or is clearly marked for older children.
Telling	Taught someone to play with it and explained how it works.

9.1 THE YO-YO

OBJECTIVES

- Tell the story of the yo-yo, from very old toys to the looped string that lets it “sleep.”
- Tell why a yo-yo spins as it falls and climbs back up the string.
- Build a homemade yo-yo and test whether weight near the rim helps it spin longer.

Warm-up. If you have a yo-yo, try it. If not, wind a string around a spool, hold the end and let the spool drop. What does the spool do as it falls? Does it come back up at all?

WATCH

Science off the Sphere: Yo-Yos in Space

NASA Video • 6:00

<https://www.youtube.com/watch?v=SSliaM3oNns>

WHEN TO WATCH

After the core ideas. Watch how the yo-yo acts with no gravity to pull it down.

BACKUP VIDEO

A Yoyo Can Spin as Fast as a Formula 1 Engine

Science Channel • 2:11

https://www.youtube.com/watch?v=AlO8_9CdhdY

Any time this week, to see how fast a yo-yo can spin.

KEY TERMS

yo-yo

A toy made of two disks joined by a short axle, with a string tied around the axle.

spin

To turn around and around very fast.

axle

The short rod in the middle of the yo-yo that the string wraps around.

CORE IDEAS

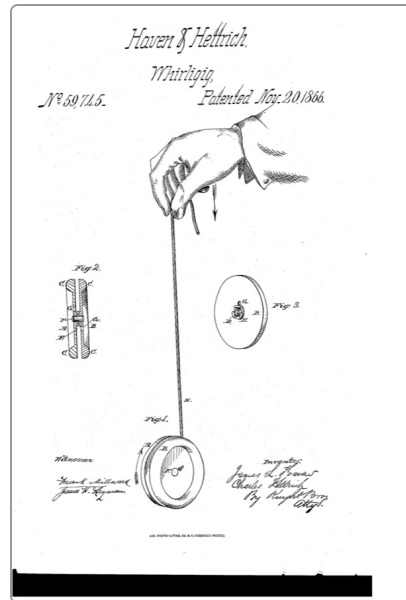
Long ago. The yo-yo is one of the oldest toys in the world. Pictures on very old Greek pottery show children playing with a spinning disk on a string. In 1866 two men in Ohio, James Haven and Charles Hettrick, received a patent for a toy they called a “whirligig,” a yo-yo with two disks on a string.

In the 1920s, a man named **Pedro Flores** began making yo-yos in California. He had learned the toy as a boy in the Philippines. His yo-yos had a clever change: the string was not tied tight to the **axle**. It was looped loosely around it. Now the yo-yo could keep spinning at the bottom of the string, which is called “sleeping,” until a little tug made it climb back up. Soon children all over America wanted one.

Why does it work? When you let a yo-yo fall, the string unwinds and makes the yo-yo **spin** faster and faster. When it reaches the bottom, it is spinning very fast. That spinning keeps going, and when the string catches, the spin winds the string back up and the yo-yo climbs. It never quite reaches your hand without a little help, because some of its energy is lost to rubbing.

How do builders use it? Toy engineers put most of a yo-yo’s weight near its outer rim, which helps it spin longer. They make the axle smooth so the string can slip, and the two halves the same weight so it spins without wobbling. **Safety:** never swing a yo-yo near someone’s face.

PICTURE STUDY



The Whirligig Patent, James L. Haven and Charles Hettrick, 1866 · Patent drawing · U.S. Patent Office

Image: [Wikimedia Commons](#), public domain

When inventors want to protect their idea, they send drawings to the government for a patent. This is the drawing for a yo-yo from 1866.

Look closely

- Find the hand holding the string.
- Find the yo-yo at the bottom of the string.
- Find the small drawing that shows the yo-yo from the side. Can you see the two disks and the axle?
- Find the inventors' names.

Talk about it

1. Why do you think the inventors drew the yo-yo from more than one side?
2. Where does the string wrap around?
3. How is this yo-yo like the ones children play with today?

Safety first. Swing and drop yo-yos only away from faces. A grown-up handles anything sharp.

BUILD

My Homemade Yo-Yo

You will build a yo-yo from two cardboard circles and a short pencil or dowel, test how long it spins, and then add weight near the rim to see if it spins longer.

You will need

- Stiff cardboard, and a cup or jar lid to trace two circles about 8 cm (3 inches) across
- A short pencil stub or a piece of dowel about 3 cm long (the axle)
- Glue or tape, string about as long as your arm
- Eight pennies and tape
- A timer

Steps

1. Trace and cut two cardboard circles the same size. A grown-up pokes a hole in the exact center of each.
2. Push the axle through both holes so the circles are a little apart. Glue or tape them on firmly.
3. Tie the string loosely around the axle and wind it up.
4. Hold the end and let the yo-yo drop. Does it climb back up? Count how many seconds it spins at the bottom. Try it three times.
5. **Guess:** will pennies near the rim help it spin longer? Tape 4 pennies on each disk, near the edge and evenly spaced.
6. Test three more times the same way. Write down the times.
7. **Make it better.** Try the pennies near the center instead. Which way spins longer? Why do you think so?

Tips

- The center holes must be right in the middle, or the yo-yo will wobble.
- Space the pennies evenly, or the yo-yo will shake.

Check your work

- ☐ I can tell why a yo-yo climbs back up its string.

- ☐ I can tell where to put weight to make a yo-yo spin longer.
- ☐ I timed my yo-yo with and without pennies.

ENGINEER'S NOTEBOOK

1. Draw your yo-yo from the side. Label the disks, the axle and the string.
2. Make a chart of your spin times: no pennies, pennies near the rim, pennies near the center.
3. Draw the yo-yo falling and climbing, with arrows to show the spin.

From history. In 1985 an astronaut took a yo-yo on the Space Shuttle to see how it would work with almost no gravity. It still spun and still came back along its string, because spinning does not need gravity.

COMMON MISTAKES

- Tying the string too tight to the axle. A loose loop lets it spin at the bottom.
- Putting the pennies on one side only, so the yo-yo wobbles.

Make it a game • Yo-Yo Sleep Count. Spin your homemade yo-yo down its string and count how many seconds before it climbs back up. Your parent keeps score on paper. Tell why it spins as it falls, and say the words spin and axle. Then tell the old story of the yo-yo and the looped string that lets it sleep. Try to beat your record.

9.2 MARBLES AND THE MARBLE MACHINE

OBJECTIVES

- Tell how marbles were made by hand long ago, and how a machine was invented to make perfectly round glass marbles.
- Show what happens when one marble hits another of the same size.
- Test how the number of marbles in a row changes what happens in a crash.

Warm-up. Roll one marble slowly into another marble that is sitting still. Watch closely. What happens to the first marble? What happens to the second?

WATCH

How are MARBLES made? | Maddie Moate

Maddie Moate • 10:22

<https://www.youtube.com/watch?v=ePf-FFZZH3E>

WHEN TO WATCH

After the story.

Note: The video runs just over ten minutes; you may stop when the marbles leave the factory. Hot glass and furnaces are handled only by trained workers.

KEY TERMS

marble

A small, hard ball, usually of glass, used in games.

round

Shaped like a ball, the same in every direction.

collide

To bump into something while moving.

CORE IDEAS

Long ago. Children have played with marbles for thousands of years. The first marbles were small, round stones or balls of clay. Later, glass makers in Germany made glass marbles by hand. They twisted hot, soft glass on a rod and cut off pieces with special scissors, then rolled each one round. It was slow work, and each marble was a little different.

In 1905, a man named **Martin Christensen** in Akron, Ohio, invented a machine to make marbles. Blobs of hot glass dropped between turning rollers, which spun them into nearly perfect balls as they cooled. Now factories could make thousands of marbles a day, all the same size, and cheaply enough for every child.

Why does it work? A round marble touches the floor at only one tiny spot, so it rolls easily. When a rolling marble **collides** head-on with a marble of the same size that is sitting still, something surprising happens: the first marble stops, and the second one rolls away. The push passes from one marble to the next.

How do builders use it? Marble makers check that every marble is round and the same size, or it will not roll straight. Tiny metal balls, called ball bearings, are put inside wheels and machines so parts can roll instead of rub. **Safety:** marbles are small enough to choke a baby or toddler. Keep them away from little children.

PICTURE STUDY



Game of Marbles, Karl Witkowski, late 1800s · Oil on canvas

Image: [Wikimedia Commons](#), public domain

The American painter Karl Witkowski loved to paint city children at play. Here two boys are deep in a game of marbles.

Look closely

- Find the marbles on the ground.
- Look at the boy's hand. How is he getting ready to shoot his marble?
- Look at their faces. Are they careful or careless?
- Look at the ground. Is it smooth or bumpy?

Talk about it

1. Why does the ground need to be smooth for marbles?
2. What do you think will happen when his marble hits another one?
3. What games have you played with marbles?

Safety first. Keep marbles away from babies and toddlers; they can choke on them. Count your marbles before and after.

BUILD

The Marble Crash Test

You will make a track from two rulers and send marbles crashing into a row of other marbles. You will count what happens and look for the pattern.

You will need

- Two rulers with a groove, or two rulers taped side by side with a small gap
- Six marbles the same size
- A book to make a small ramp
- Masking tape

Steps

1. Lay the track flat on a table. Prop the start of a second ruler on a book to make a little ramp leading onto the track.
2. Put one marble still on the track. Roll another marble down the ramp into it. What happens to each marble? Write it down.
3. Now line up 3 marbles touching each other on the track. **Guess:** when one marble crashes into them, how many will fly off the far end?
4. Roll one marble down the same ramp. Count how many fly off.
5. Now roll two marbles together, touching, down the ramp into the row. Guess first. How many fly off this time?
6. Make a chart: how many marbles you rolled and how many flew off.
7. **Make it better.** Try a big marble crashing into a small one, and a small one crashing into a big one. What changes?

Tips

- Start each marble from the same spot on the ramp.
- The marbles in the row must touch each other.

Check your work

- ☐ I can tell how Martin Christensen's machine made marbles.
- ☐ I can show that one marble crashing in sends one marble out.

- ☐ I made a chart of my crash tests.

ENGINEER'S NOTEBOOK

1. Draw your marble track before and after a crash.
2. Make a chart: marbles rolled in and marbles that flew off.
3. Draw a machine that rolls hot glass into round marbles.

From history. Before Christensen's machine, most glass marbles sold in America came from Germany. After it, marble factories grew up in Ohio and West Virginia, and some of them still make marbles today.

COMMON MISTAKES

- Leaving gaps between the marbles in the row.
- Starting marbles from different heights on the ramp.

Make it a game • Marble Crash Prediction. Roll one marble to hit another of the same size on a smooth floor. Before each roll, point where the second marble will go. Score a point for each correct guess. Say collide and round. Tell your parent how marbles were made by hand long ago and how a machine made them perfectly round.

9.3 THE KALEIDOSCOPE

OBJECTIVES

- Tell how Sir David Brewster invented the kaleidoscope while studying light.
- Show that two mirrors at an angle make many copies of a picture.
- Count how many copies two mirrors make at different angles, and build a simple kaleidoscope.

Warm-up. Look into a mirror and wave your right hand. Which hand does your reflection wave? Then hold two mirrors facing each other (with a grown-up) and peek between them. How many of you can you see?

WATCH

How It's Made: Kaleidoscopes

[Science Channel](#) • 5:24

<https://www.youtube.com/watch?v=5qnYS8vN7Gk>

WHEN TO WATCH

After the story.

BACKUP VIDEO

Easy Kaleidoscope

[madsciencestl](#) • 2:44

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

Before the build, for another easy way to make one.

KEY TERMS

kaleidoscope

A tube with mirrors inside that turns a few colored bits into a beautiful repeating pattern.

mirror

A very smooth, shiny surface that bounces light back so you can see a picture in it.

reflection

The picture you see in a mirror, made by light bouncing off it.

pattern

A design that repeats in an orderly way.

CORE IDEAS

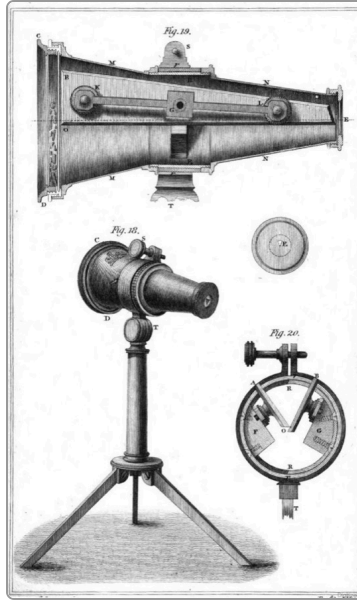
Long ago. In Scotland about two hundred years ago lived a scientist named **Sir David Brewster**. He loved to study light: how it bounces, bends and splits into colors. He was also a man of faith who believed that God's world is full of beauty and order. In 1816, while testing how light bounces between mirrors, Brewster saw beautiful patterns appear. He put the mirrors in a tube and added bits of colored glass at the end. He named his invention the **kaleidoscope**, from Greek words meaning "beautiful form to see."

Brewster got a patent in 1817, and the kaleidoscope became a craze. In London and Paris, people bought them by the hundreds of thousands. Sadly, other makers quickly copied his idea, and Brewster earned very little money from it. But people have loved kaleidoscopes ever since.

Why does it work? A **mirror** bounces light back to your eye, so you see a **reflection**. When two mirrors stand at an angle, the light bounces back and forth between them, and you see the same picture copied again and again around a circle. The narrower the angle, the more copies you see. That is why a few bits of colored glass become a whole round **pattern**. Turn the tube, the bits move, and a new pattern appears.

How do builders use it? Kaleidoscope makers fit the mirrors at an exact angle, often 60 degrees, so the pattern fits together perfectly. Engineers use mirrors in many other machines too: in telescopes, periscopes, car mirrors and the headlights that send light far down the road.

PICTURE STUDY



*Kaleidoscopes from Brewster's Book, Sir David Brewster, 1819 · Engraving from *A Treatise on the Kaleidoscope**

Image: [Wikimedia Commons](#), public domain

Brewster wrote a whole book about his invention, with drawings showing how kaleidoscopes are built. This page shows a fancy kaleidoscope that stands on legs, with parts that can be adjusted.

Look closely

- Find the long tube.
- Find the end where you would look in, and the end where the colored bits go.
- Find the stand with three legs.
- Find the round part drawn by itself. What do you think it is?

Talk about it

1. Why would a kaleidoscope need to stand on legs?
2. What do you think is inside the tube?
3. Why did Brewster draw his invention so carefully?

Safety first. Use plastic mirrors or shiny mirror card, never glass. A grown-up does the cutting.

BUILD

The Two-Mirror Test and a Kaleidoscope

You will stand two mirrors at different angles and count how many copies of a toy you see. Then you will build a kaleidoscope from mirror card.

You will need

- Two small plastic mirrors the same size, or two pieces of shiny mirror card, joined along one edge with tape like a book
- A small toy or a bead
- A protractor, or a paper angle guide drawn by a grown-up
- Mirror card (or foil glued smoothly to card), a paper towel tube, tape, plastic wrap, and some small beads or bits of colored paper

Steps

1. Stand the two mirrors up like an open book. Put the toy between them.
2. Open the mirrors to a right angle (like the corner of a book). Count how many toys you see, counting the real one.
3. **Guess:** if you close the mirrors to a narrower angle, will you see more toys or fewer?
4. Close them to 60 degrees and count. Then 45 degrees and count. Write each number down.
5. Make a chart: angle and number of toys. What is the pattern?
6. Now build a kaleidoscope. A grown-up cuts three strips of mirror card as long as the tube. Tape them into a triangle, shiny side in, and slide it into the tube.
7. Cover one end with plastic wrap. Put a few beads on it and cover them with another piece of plastic wrap, loosely, so they can tumble.
8. **Make it better.** Hold your kaleidoscope up to a window and turn it. Try different colored bits. Which make the best patterns?

Tips

- Count slowly and touch each copy with a pencil tip as you count.

- Smooth, flat mirror card makes clearer patterns than wrinkled foil.

Check your work

- ☐ I can tell the story of Brewster's kaleidoscope.
- ☐ I can tell how two mirrors make many copies.
- ☐ I counted the copies at three different angles.

ENGINEER'S NOTEBOOK

1. Make a chart of your angles and how many toys you saw.
2. Draw a pattern you saw in your kaleidoscope.
3. Draw the inside of your kaleidoscope: three mirrors in a triangle.

From history. Brewster studied light all his life. He also improved the lenses used in lighthouses, so that their beams shone farther out to sea and helped keep sailors safe.

COMMON MISTAKES

- Moving the toy between counts. Keep it in the same spot.
- Looking at a bright light. Point your kaleidoscope at a window or a lamp shade, never at the sun.

Make it a game • Mirror Copies Count. Stand two mirrors at an angle with a toy between them, with a grown-up helping hold them steady. Count how many copies you see. Make the angle smaller and count again. Say reflection and pattern. Then tell your parent how Sir David Brewster invented the kaleidoscope, and draw your favorite pattern.

Scripture. “The heavens declare the glory of God; and the firmament sheweth his handywork.” (Psalm 19:1, KJV)

Brewster believed that the order and beauty in light show the handiwork of God. A kaleidoscope shows a little of that order: a few bits and two mirrors make a perfect pattern.

9.4 THE JACK-IN-THE-BOX AND SPRINGS

OBJECTIVES

- Tell how a jack-in-the-box uses a spring and a latch.
- Show that a spring pushes back harder the more it is squashed.
- Build a cup jack-in-the-box with a paper spring and test how high different springs jump.

Warm-up. Find a spring with a grown-up: in a clicking pen, a stapler, a mattress or a door stop. Press it and let go. What does it do? (A grown-up can take apart a clicking pen to show you the little spring inside.)

WATCH

How does a Jack in the Box work? | Maddie Moate

Maddie Moate • 8:30

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

WHEN TO WATCH

After the core ideas.

KEY TERMS

spring

A coil or bend of springy metal or other material that goes back to its shape after it is squashed or stretched.

latch

A small catch that holds a lid or door shut until it is released.

energy

What lets something move or do work.
A squashed spring stores energy.

CORE IDEAS

Long ago. Toymakers in Europe have made jack-in-the-box toys for hundreds of years. A little figure hides in a box. When the lid opens, it pops up with a jump! Some boxes have a handle that plays a tune, and the lid pops open at the end of the song. Even Charles Lindbergh, the pilot who flew alone across the Atlantic Ocean in 1927, kept a tiny wooden jack-in-the-box from when he was young.

Why does it work? Inside the box is a **spring**. When you push the figure down and close the lid, you squash the spring. A squashed spring stores **energy** and pushes back. The **latch** holds the lid shut. When the latch lets go, the spring pushes the figure up and out. The more you squash a spring, the harder it pushes back.

How do builders use it? Springs are everywhere: in pens, staplers, mattresses, car wheels, door closers, toasters and clocks. Engineers choose a spring that is just strong enough for the job. Toy engineers also think about safety: the lid must not pinch fingers, and the parts must be too big for a baby to swallow.

PICTURE STUDY



*Charles Lindbergh's Wooden Jack-in-the-Box, Unknown toymaker, before 1927 · Painted wood
(photograph of the toy)*

Image: [Wikimedia Commons](#), public domain

This tiny toy belonged to Charles Lindbergh before his famous flight across the Atlantic. The little figure fits inside the wooden barrel.

Look closely

- Find the little figure. Where would it hide?
- Find the barrel-shaped box.
- Find the small peg. What do you think it is for?
- Look for the hole in the side of the barrel.

Talk about it

1. What do you think makes the figure jump out?
2. How might the peg work like a latch?
3. Why do you think a famous pilot kept such a small toy?

Safety first. Keep small toy parts away from babies and toddlers. A grown-up opens any pen or toy, and never opens anything with a button battery, a lithium battery or a wall plug.

BUILD

The Cup Jack-in-the-Box

You will fold paper springs, put one in a cup with a little figure on top, and measure how high it jumps. Then you will test whether a longer spring jumps higher.

You will need

- Two long strips of card stock, each 2 cm (1 inch) wide, in two colors
- A paper cup and a square of cardboard for a lid
- A small paper figure, or a pom-pom with a drawn face
- Tape, and a ruler taped standing up next to the cup

Steps

1. Make a paper spring: tape the ends of the two strips together at a right angle, then fold one over the other again and again, back and forth, until you have a square, springy stack. Tape the ends.
2. Make one spring with 10 folds and one with 20 folds.
3. Tape the 10-fold spring inside the bottom of the cup. Tape the figure on top of it.
4. Push the figure down and hold the lid on with your hand. **Guess** how high it will jump. Let go of the lid quickly and watch it pop up against the ruler.
5. Measure how high the top of the figure jumped. Try three times and write it down.
6. Change to the 20-fold spring. Guess, test three times and write it down.
7. Make a chart. Which spring jumped higher? Why?
8. **Make it better.** Make a paper latch for your lid, a little flap that holds the lid closed until you slide it open.

Tips

- Crease every fold sharply. A crisp spring jumps better.
- Let go of the lid the same way each time.

Check your work

- ☐ I can tell how a jack-in-the-box uses a spring and a latch.
- ☐ I can show that a squashed spring pushes back.
- ☐ I measured how high both springs jumped, three times each.

ENGINEER'S NOTEBOOK

1. Draw your jack-in-the-box closed and open. Label the spring, the lid and the latch.
2. Make a chart of your jump heights for the 10-fold and 20-fold springs.
3. Draw three things at home that have a spring inside.

From history. Toymakers in Germany and Switzerland were famous for jack-in-the-boxes and music boxes. In many old boxes, a little music box plays a tune while you turn the crank, and a bump on the turning drum releases the latch at the end of the song.

COMMON MISTAKES

- Squashing the spring more in one test than another.
- Thinking a spring makes its own push. It only gives back the push you put in when you squashed it.

Make it a game • Spring Squish Duel. Squash a spring or a sponge slowly and feel how it pushes back. Press harder, and notice it pushes harder. Say spring, latch and energy. Then pop your cup jack-in-the-box and count how many times you can set it. Tell your parent how a latch holds a spring until the jack jumps up.

TOY LAB

Toys are little machines. A yo-yo climbs its own string. A marble rolls and knocks another marble away. A kaleidoscope turns a few bits of colored glass into a hundred bright patterns. A jack-in-the-box jumps up with a spring. Someone had to invent each of these toys, test it, and find a way to make it well enough and cheaply enough for children everywhere to enjoy.

This optional bonus unit is for after the family engineering fair, for the summer, or for any week that needs something fun. Each lesson tells the story of a toy, shows the science of why it works, and ends with a homemade toy to build and test. You will make a yo-yo, roll marbles into each other, build a mirror kaleidoscope and make a jumping paper spring. Play is a good gift from God, and so is understanding how it works.

PREREQUISITES

- Has finished Units 1–8, or at least Unit 1 (simple machines)
- Knows how to run a fair test and keep an engineer’s notebook

MASTERY CHECKLIST

- ☐ I can tell why a yo-yo climbs back up its string.
- ☐ I can show what happens when one marble hits another.
- ☐ I can tell how mirrors make the pattern in a kaleidoscope.
- ☐ I can show that a spring pushes back harder when it is squashed more.
- ☐ I can tell the toy safety rule: small parts and marbles are kept away from babies and toddlers.

OPTIONAL KITS FOR THIS UNIT

- **KiwiCo Kiwi Crate:** Ages 5–8. Many crates are toys that children build themselves and then play with, such as spinners, launchers and marble games.
- **CrunchLabs Build Box (Mark Rober):** Made for ages 8 and up, so a first grader will need a parent building alongside. Each box is a toy built around one idea of physics, with a video that explains it.

Not required. Every project in this unit can be built with household materials. School Launch has no ties to these companies.

LESSONS IN THIS UNIT

9.1 The Yo-Yo	2 sessions of 30 minutes
9.2 Marbles and the Marble Machine	2 sessions of 30 minutes
9.3 The Kaleidoscope	2 sessions of 30 minutes
9.4 The Jack-in-the-Box and Springs	2 sessions of 30 minutes

UNIT 9 REVIEW

A parent asks each question aloud. Your child may answer by telling, pointing, drawing or building. There are no points; this is a friendly conversation. Have the homemade toys from this unit ready.

1. Show me your yo-yo. Why does it climb back up its string?
2. Where should you put extra weight to make a yo-yo spin longer?
3. Predict: if one marble rolls into a row of three marbles, how many will roll off the far end?
4. Who invented the kaleidoscope? How do the mirrors make a pattern?
5. Show me with your jack-in-the-box: what makes it jump? What holds it shut?
6. Tell me one toy safety rule.

ANSWER KEY

1. As it falls it spins faster and faster, and the spin winds the string back up.
2. Near the outer rim, evenly spaced.
3. One.
4. Brewster, in 1816. Light bounces back and forth between mirrors at an angle, making many copies of the bits around a circle.
5. A squashed spring pushes it up; a latch holds the lid shut.
6. Keep small parts and marbles away from babies and toddlers; never open toys with button batteries or plugs; do not swing toys near faces.

PORTFOLIO PIECE: MY TOY INVENTION

Invent a new toy that uses one idea from this unit: spin, rolling and crashing, mirrors, or a spring. Draw your plan first. Build it from household materials, test it, and make one change to make it better. Then teach a family member how to play with it, and tell them the science of why it works.

LOOK FOR	WHAT IT MEANS
It works	The toy does what it was planned to do.
Science inside	Can name the idea it uses: spin, rolling, mirrors or a spring.
Tested and improved	Tested the toy, made one change and tested it again.
Safe	Has no sharp edges and no tiny loose parts, or is clearly marked for older children.
Telling	Taught someone to play with it and explained how it works.