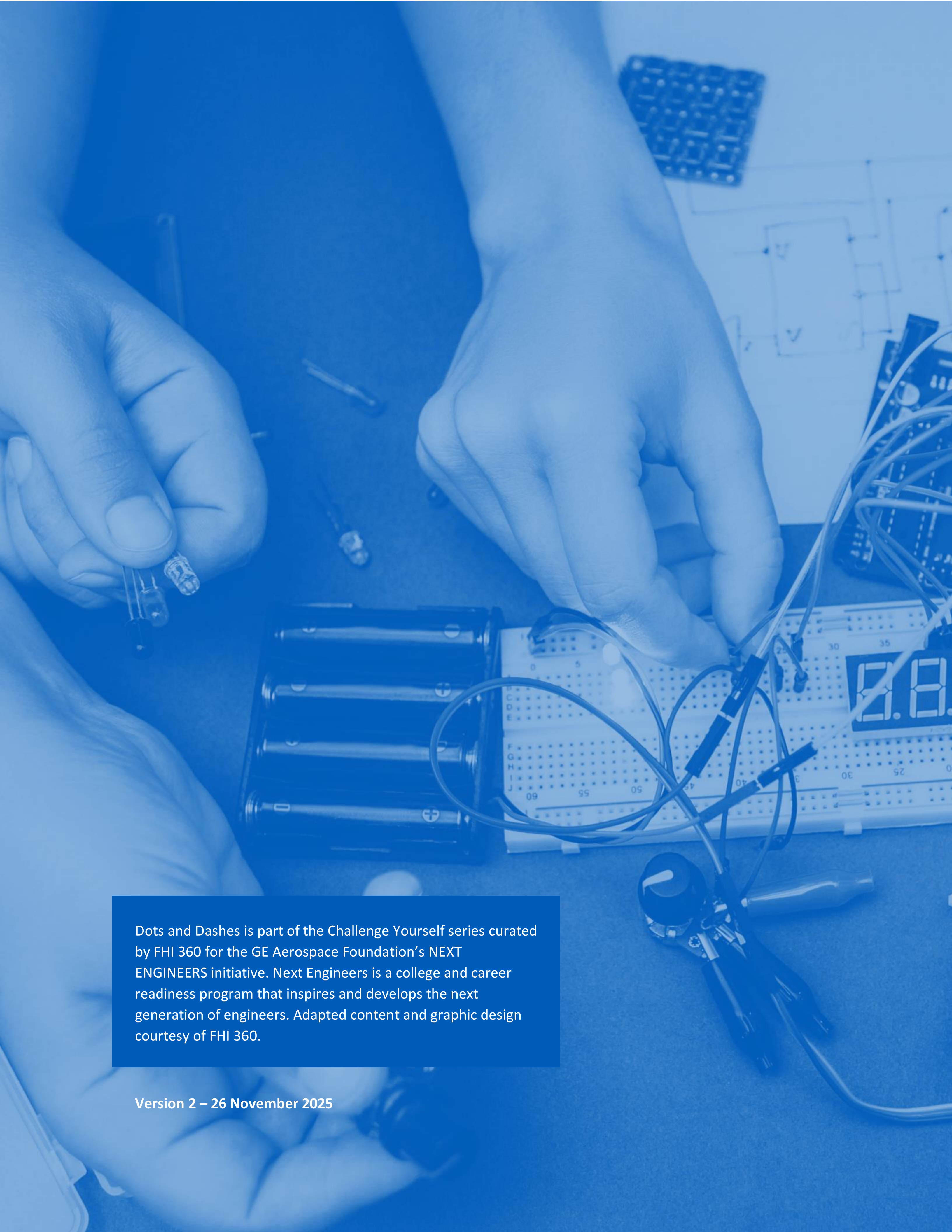
NEXT ENGINEERS

CHALLENGE YOURSELF

Dots and Dashes

Electrical Engineering
Materials Engineering

NEXT ENGINEERS



Dots and Dashes is part of the Challenge Yourself series curated by FHI 360 for the GE Aerospace Foundation's NEXT ENGINEERS initiative. Next Engineers is a college and career readiness program that inspires and develops the next generation of engineers. Adapted content and graphic design courtesy of FHI 360.

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Dots and Dashes

BUILD IT!

Ages	Cost	Time
14+	Medium	8 - 10 hours

About this challenge

Communication is a deep-seated human need. It is our ability to communicate that has allowed us to coordinate our thoughts and actions to achieve all that we have. For thousands of years, we were limited in how far and how quickly we could send communications. The telegraph machine, however, changed all that and ushered in an era of high-speed, long-distance communication that we still rely on today.

Design and build your own telegraph machine to communicate a simple message to a friend using Morse Code over a distance of at least 10 m (33 ft) and then share your design with the world at **#nextengineersdiy**.

You can design and build on your own or form a design team with some friends. You might even decide to set up your own neighborhood communication network!

Download a simple Morse code guide at https://rsgb.org/main/files/2012/10/Morse_Code_Sheet_01.pdf.

A telegraph machine
Image by John Schanlaub is released under a CC-BY 2.0 licence https://commons.wikimedia.org/wiki/File:Wallace_Study-Telegraph.jpg#filelinks

Success Criteria

- Your telegraph machine must make use of a series of electronic pulses to communicate your message.
- Your telegraph machine must be able to communicate the message over a distance of **at least** 10 m (33 ft).

Constraints

- You must send your message using Morse code.
- You can only communicate by means of the telegraph machine. No shouting, hand signals, or text messages are allowed.
- You cannot spend more than **US$15** or its equivalent on your telegraph machine.

SUCCESS CRITERIA

These are the things that your design should be able to do or the things that will help tell if your design is a success.

CONSTRAINTS

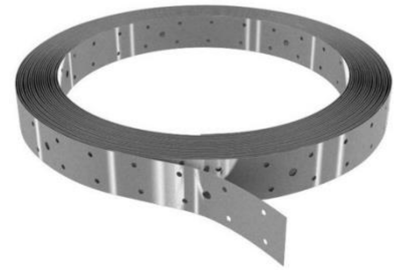
These are limitations on your design. These are the things you cannot do when designing or what your design should not be like.

What you might need

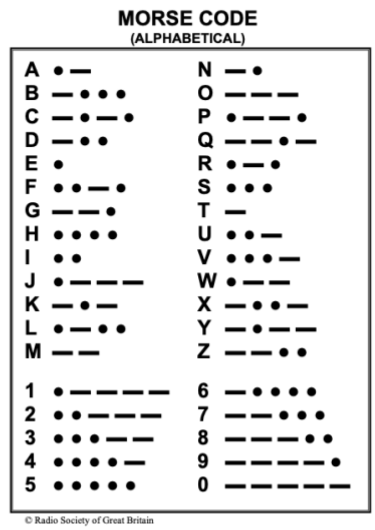
You can use any materials you like so long as you do not spend more than US$15 (or its equivalent). Remember to get the permission and/or supervision of an adult before you use any tools or equipment.

Here are some materials and equipment that you might find useful.

- An aluminum can cut into strips about 15 cm x 1.5 cm (6 in x 0.6 in). You can also use bracing strap with a thickness of about 1 mm – 1.5 mm (0.04 in – 0.06 in)
- 10 m (32 ft) 30/32 gauge enameled copper wire (about 0.2 mm (0.008 in) thick)
- 12 m (40 ft) flex cable (also called speaker wire)
- 2 wooden or cardboard boards about 40 cm x 10 cm (15 in x 4 in) or other similarly sized firm and stiff material
- A large nail about 10 cm (4 in) in length with a broad head
- Screws
- Four AA 1.5 V batteries or a 9 V battery
- A screwdriver
- Glue gun and glue sticks
- Tin snips or a craft knife
- Safety gloves
- A hammer
- Wire cutters and strippers
- Sandpaper (about 80 grit)
- Electrical tape



A roll of bracing strap



The Morse code by the Radio Society of Great Britain is used under fair use https://rsgb.org/main/files/2012/10/Morse_Code_Sheet_01.pdf

Follow the engineering design process

1. Identify and define the problem

Engineers start by asking lots of questions. What problem must be solved? Who has the problem? What do we want to accomplish? What are the project requirements? What are the limitations? What is the goal? Through this process, engineers start to identify the **criteria** (the conditions the solution must satisfy to be considered successful) and the **constraints** (the limitations they need to design within). Here are some initial questions you might like to ask yourself.

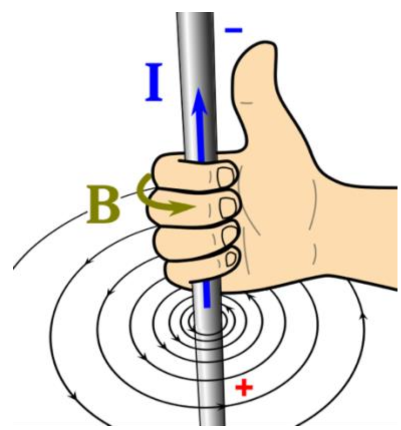
- What is Morse code and how is it used to communicate messages?
- How can I send a signal using electricity?
- How far do I need to send the message?

2. Gather information

Engineers dig deep into the problem by collecting information and data about the problem and any existing solutions that might be adaptable. They talk to people from many different backgrounds and specialties to assist with this research. Perhaps the most important question right now is:

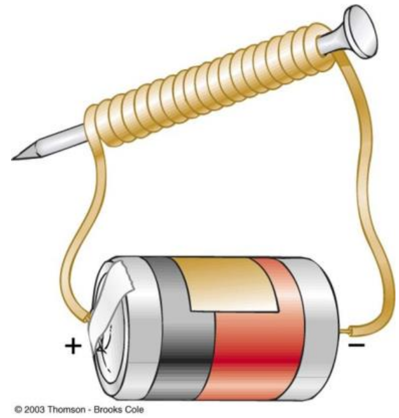
- How can you convert an electric pulse into something that a receiving person can decode and understand as a message?

To answer this question, you can either do the **Experiment and Explore** activity called *Electromagnetism* (https://www.nextengineers.org/diy/electromagnetism) or the following quick investigation yourself.



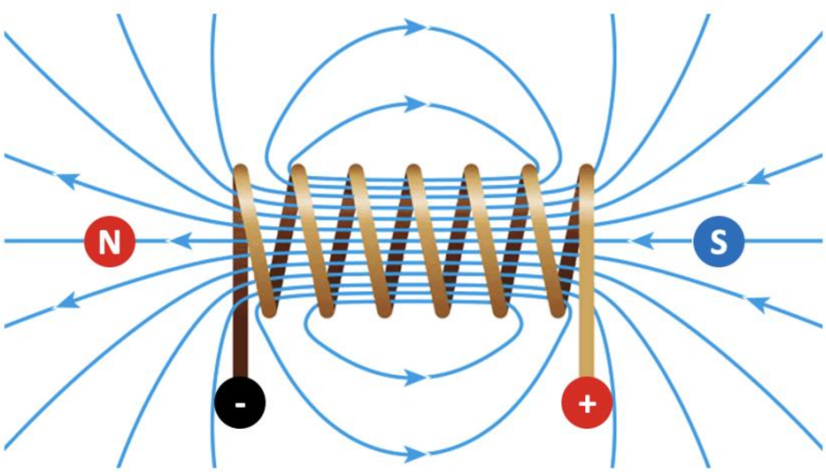
The magnetic field around a straight current carrying wire
Image by John MikeRun is released under a CC-BY-SA 4.0 license *https://commons.wikimedia.org/wiki/File:Long-wire-right-hand-rule.svg*

1. Cut or break off a short 50 cm (20 in) length of your copper wire. It has a layer of insulating enamel on it so use a piece of sandpaper to remove this enamel from the ends.
2. Connect the ends of this piece of copper wire to a battery. While it might not seem like anything is happening, the electricity through the wire generates a circular magnetic field around the wire. If you have a compass, you can check this for yourself. You can also watch the video called *Magnetic Field Around a Current Carrying Conductor* (2:25) (https://www.youtube.com/watch?v=jwB61laSq3o).
3. Now take the rest of your copper wire and wrap it around a nail or bolt. About 50 - 80 turns should be enough. You can use some electrical tape to hold it in position. Remember to remove the enamel from the ends. Connect the wire to the battery and try to pick up something metal like a pin or a screw. The magnetic field around the current carrying wire magnetizes the nail or bolt and makes it into a temporary magnet. We call this an **electromagnet**. If you disconnect the wire from the battery, the magnetic field disappears. Therefore, you can turn the magnet 'on and off' by connecting and disconnecting the circuit.
4. What happens if you add more turns to the coil of wire around the nail or bolt? What happens if you wind the wire more neatly, tightly, and compactly? What happens if you wind the wire over itself on the same part of the nail or bolt repeatedly? What happens if you add more batteries to the circuit? In each case, do you create a stronger magnet? You can check this by seeing how many pins or screws you can pick up.



A copper wire coil wound around a nail
Image by Thomson-Brooks Cole is used under fair use
https://www.quora.com/Does-an-electromagnet-need-a-core

A coil of wire like we have just created is called a **solenoid**. The magnetic field created around a solenoid looks just like the field around a bar magnet with a clear North pole and South pole.



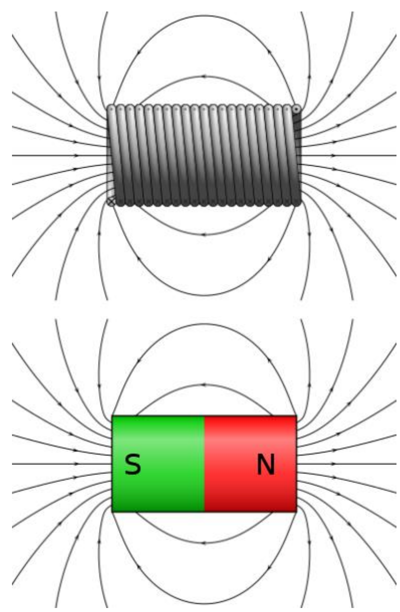


Image of the shape of the magnetic field around a tightly wound coil by Geek3 is licensed under a CC-BY-SA 3.0 license
https://commons.wikimedia.org/wiki/File:VFPt_cylindrical_tightly-wound_coil-and-bar-magnet-

If we insert a steel or iron core inside the solenoid, we can create a stronger magnetic field. Watch the video *How to Make an Electromagnet* (2:11) (https://www.youtube.com/watch?v=Wm9_DqQKmd0) to find out more.

Now, how do you think you can use an electromagnet that you can turn on and off by making and breaking an electric circuit to communicate a message using Morse code? In other words, how might you design and build your own telegraph machine? What other solutions exist already that you could learn from, adapt, or improve?

3. Generate possible solutions

Now the fun really starts! Engineers start to brainstorm ideas and develop as many different solutions as possible, sometimes even crazy ones! This is the time for wild ideas and delayed judgment. It is important to build on the ideas of others while staying focused on the core problem and keeping the criteria and constraints in mind. For example, if there is a budget, can the potential solution be developed within that budget?

- Use the Internet to look for ideas that other people have come up with. What is good about their design? What could you improve upon?
- Once you have brainstormed and gathered a few designs, look at what you have and decide on the one you think is the best. Don't worry, you can always change your mind later.
- Make sketches of your designs so that you have an idea of how you are going to build it and what materials, tools, and equipment you will need. No use designing something that needs stuff you can't get!

4. Create a prototype

Engineers choose one or more of the most promising solutions to prototype. A prototype is a model that works well enough to test part or all of the solution. The idea with prototypes is to build quickly and cheaply so that the costs of changing your mind or your design are not too high. Use prototypes to learn as much as you can about what works as quickly and as cheaply as you can.

You might want to prototype your electromagnet or the device you use to make and break the circuit. How are you going to hold your batteries together and connect them to your circuit? How will the receiver receive your messages?

5. Test and evaluate the prototype

Most prototypes fail, but that is good. It tells engineers which ideas they should focus on. Engineers also need to decide if the design really does solve the original problem.

You are eventually going to need to put your design to the test. Think about how you are going to test. What aspects are you going to test? What data will you collect? How will you analyze this data?

Remember, there is no shame in failing. All the best engineers fail **ALL THE TIME**. It's what they do when they fail that makes them great: they learn and improve.

6. Refine and/or redesign the solution

After learning through testing, engineers redesign and retest until they have the best solution possible – one that balances the criteria and constraints. This is a process called **optimization**. Great engineers are not happy with a solution that only just works. They want to create the very best solution they can within their constraints. Make sure that you do the same.

Remember that failure is not the end – it's only the beginning. Think about how you can improve your design. Maybe go back to the drawing board if necessary and choose another of your original designs to try. Which parts of your telegraph device can you improve upon? What parts of your device need a better solution altogether?

The most important thing is that you keep testing, learning, and improving.

7. **Present or communicate the solution**

Finally, engineers reach a point where they are satisfied with their solution and have optimized it as much as possible. It does not need to be perfect, but it should 'satisfice' - meet the criteria within the constraints as well as possible. Engineers now communicate their solution to others.

You can share your design however you like – a video, pictures, a blog – and on any platform you like. Just remember to tag **#nextengineersdiy**.

Some helpful resources

Here are some resources that you might find helpful to get you started:

- ***What Oersted Discovered with his Compass*** (2:59)
  https://www.youtube.com/watch?v=RwilgsQ9xaM
- ***How does an Electromagnet Work?*** (2:55)
  https://www.youtube.com/watch?v=cxELqN7wjS0
- ***Telegraph***
  https://www.britannica.com/technology/telegraph
- ***Morse Code & the Telegraph***
  https://www.history.com/topics/inventions/telegraph
- ***Telegraph Key***
  https://letstalkscience.ca/educational-resources/interactives/telegraph-key
- ***Rod's Garage: Build an Electric Telegraph*** (24:12)
  https://www.youtube.com/watch?v=79uskWrHetI
- ***How to Make a Simple Telegraph Set***
  https://www.energizer.com/science-center/how-to-make-a-simple-telegraph-set
- ***DIY Telegraph Construction*** (7:30)
  https://www.youtube.com/watch?v=McHw0tCrZe4
- ***How Does Morse Code Work?*** (3:28)
  https://www.youtube.com/watch?v=iy8BaMs_JuI

Challenge yourself

If you need more of a challenge, here are some ideas to take your design to the next level.

- Can you communicate over 20 m (65 ft), 30 m (100 ft), or even farther?
- Can you make a telegraph machine that can send and receive messages from both ends?
- Can you use other signaling devices like a lamp or a buzzer in your design?
- Can you create your own code with which to send messages?