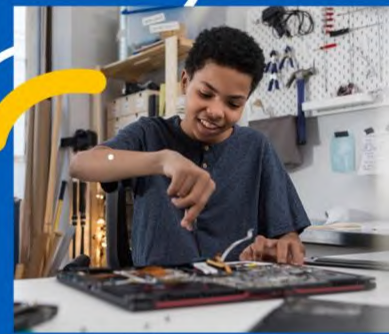
NEXT ENGINEERS

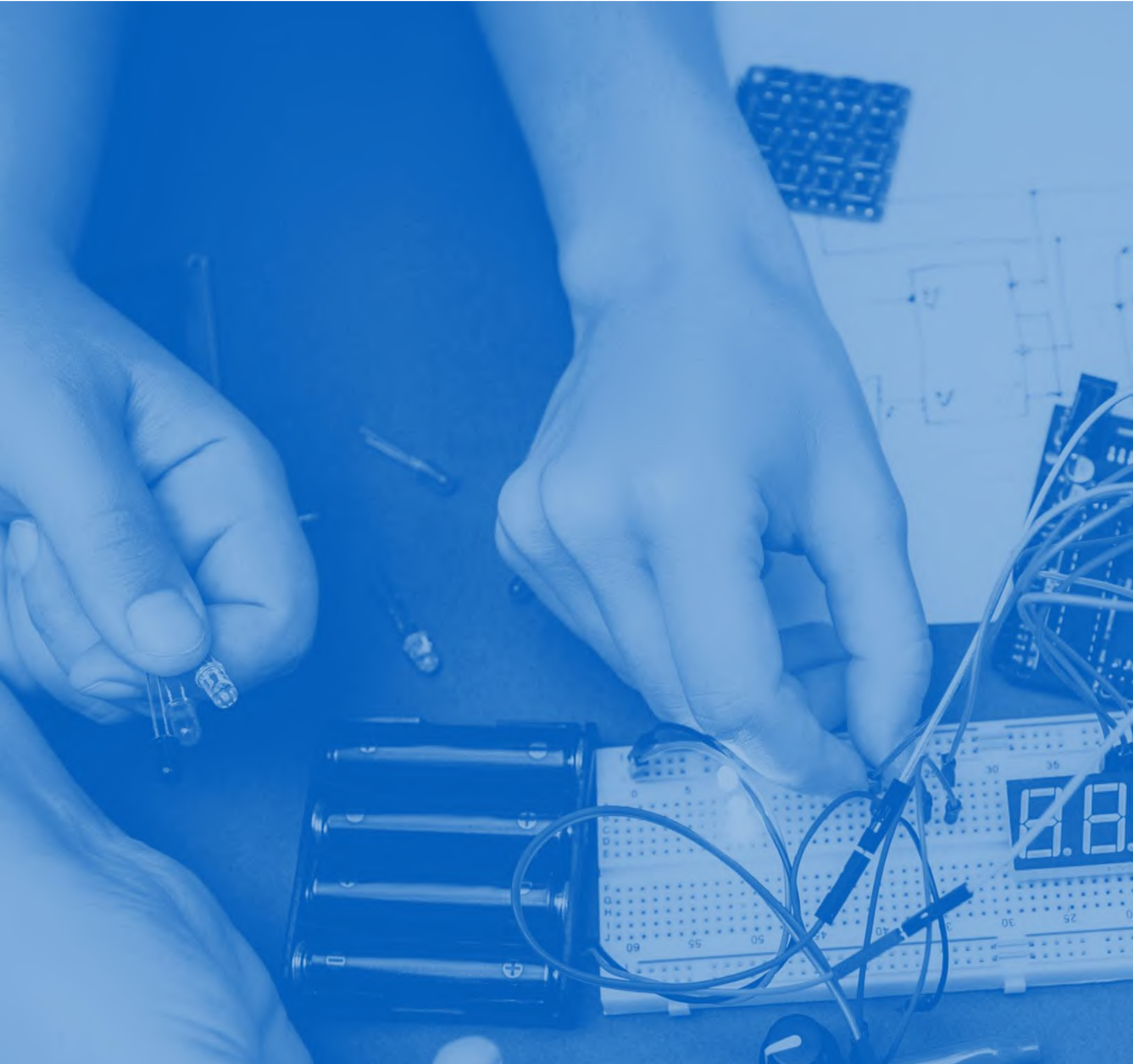


CHALLENGE YOURSELF

Electromagnetism

Electrical Engineering
Materials Engineering

GE Foundation



Electromagnetism is part of the Challenge Yourself series curated by FHI 360 for the GE Foundation's NEXT ENGINEERS and is based on a video created by Science Buddies (How to Make an Electromagnet, https://www.youtube.com/watch?v=Wm9_DqQKmd0). 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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Electromagnetism

EXPERIMENT & EXPLORE

Ages	Cost	Time
10+	Low - Medium	60 minutes (or more)
Engineering Areas		
• Electrical Engineering	• Materials Engineering	

Introduction

I bet you love playing with magnets and their invisible forcefields able to pick up metal things and make magnets snap together or fly apart. In this Experiment and Explore activity, you will discover the hidden relationship between electricity and magnetism, how electricity creates a magnetic field, how to make this field stronger and explore ways engineers put this fact to work to solve real-world problems.

What you will need

- 10 m (32 ft) 30/32 gauge enameled copper wire (about 0.2 mm (0.008 in) thick) – this is often sold as magnet wire (e.g., https://www.amazon.com/Fielect-Enamelled-Winding-Polyester-QZ-2-130/dp/B082S8668L)
- Four AA or D-cell 1.5 V batteries taped together end-to-end
- An elastic band
- A small magnetic compass (e.g. https://www.amazon.com/Skywalker-Signature-Series-Economy-Compass/dp/B009HTFJAQ/)
- About 20 pins (or safety pins)
- An old steel bolt about 10 mm (0.4 in) wide
- A piece of blank A4 or letter paper
- Scissors
- 2 electrical leads with alligator clips on both ends – optional but useful (e.g., https://www.amazon.com/WGGE-WG-026-Pieces-Colors-Alligator/dp/B06XX25HFX)

You will also need the following items to do some additional investigations.

- Another 12 V battery
- A thin wooden stick about 10 mm (0.4 in) wide (you can also use 3 pencils)
- Three plastic straws
- A piece of aluminum/aluminium/tin foil (about 10 cm x 30 cm (4x12 in))
- A stainless-steel knife, fork, or spoon

TOP TIP

While any reasonably thin but insulated copper wire can be used to create an electromagnet, best results are obtained when using 30/32 gauge enameled copper wire.

If you don't want to buy new wire, you can often find such wire in old power supplies for mobile phones, laptops, and desktop computers.

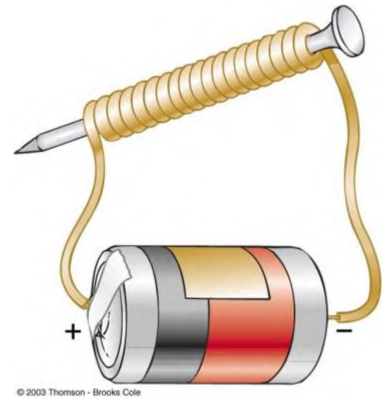
What to do

1. Cut or break a 50 cm (20 in) piece of copper wire. Use a scissor blade to scrape the enamel off the ends so that you can make an electrical connection. Hold the wire directly above your compass so that the needle and wire are parallel and connect the coil to your batteries. Use the elastic band to keep the connections firm.
2. What happens to the compass needle? What do you think this indicates? What happens to the compass needle when you disconnect the wire? Why do you think this happens?
3. Cut a strip of paper about 5 cm (2 in) wide and loosely wrap it around the steel bolt. Hold it in place with some tape. Remove the bolt and wrap your copper wire around this paper cylinder. About 50 turns should be enough. Use some electrical tape to hold the coil in place. Cut or break the coil off from the rest of your wire.
4. Use a scissor blade to scrape the enamel off the ends so that you can make an electrical connection and connect the coil to your batteries. Hold the coil vertically and bring the compass close to the coil from the left and the right. What do you notice? Why do you think this happens? Can you pick up any pins with the coil? If so, how many? Make a note. What happens to the pins if you disconnect the battery?
5. Now reverse the connection of your coil to the batteries and bring the compass near to the coil from the left and the right again. Has anything changed? If so, what? Why do you think this happened?
6. Make another paper cylinder as before and coil more copper wire around this one, but this time wrap 100 turns. Use some electrical tape to hold the coil in place. Cut or break the coil off from the rest of your wire.
7. Connect the coil to the battery, remembering to scrape the enamel off the ends so that you can make an electrical connection. Can you pick up any pins with this coil? If so, how many? Is it more or less than before? Make a note. What happens to the pins if you disconnect the battery?
8. Now insert the bolt inside your 50- and 100-turn coils and connect the batteries.
9. Can you pick up any pins with this coil and bolt? If so, how many? Is it more or less than before for each coil? Make a note. What happens to the pins if you disconnect the battery?

What's happening

If you connect a piece of wire to a battery it might not seem like anything is happening but looks can be deceiving. In fact, the electric current through the wire generates a circular **magnetic field** around the wire. If you wrap the wire into a coil, all the fields around each turn of wire add up and make a stronger magnetic field that has the same shape as the field around a bar magnet with a clear North pole on one side of the coil and a South pole on the other. Reversing the direction of the current flips the poles around. You should see this when you bring a magnet near to each side of the coil.

If you disconnect the coil from the batteries, the magnetic field disappears. Therefore, you can turn the magnet 'on and off' by connecting and disconnecting the circuit. We call this an **electromagnet**.



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

MAGNETIC FIELD

The region around a magnet or moving electric charge within which the force of magnetism acts.

ELECTROMAGNET

A type of magnet where the magnetic field is produced by an electric current flowing through a wire.

FERROMAGNETIC

A material, such as iron (*ferrum* in Latin), that can easily be magnetised by other magnets or by the magnetic field around a current carrying wire.

SOLENOID

A coil of wire (usually copper) that acts as an electromagnet when current flows through it.

The more turns of wire the coil has, the more magnetic fields there are to add together and the stronger the whole magnetic field gets. You can pick up more pins.

If you wrap the coil around a **ferromagnetic** material like iron or steel, the magnetic field gets concentrated in the material and the overall magnet is even stronger than before, even with the same number of turns.

We call coils of wire that are used to make electromagnets **solenoids**.

If you want to learn more about electromagnets and how they work watch the video called *How does an Electromagnet Work?* (2:55) (https://www.youtube.com/watch?v=cxELqN7wjS0).

Think about it

Knowing what you now know about electromagnets and how to make one, try these experiments yourself to see which ones produce a stronger electromagnet. Measure the strength of the magnetic field by counting how many pins the electromagnet can pick up. Remember to keep some notes.

1. What happens if you make a 150 and 200 turn coil?
2. What happens if you wind your coils more neatly, tightly, and compactly?
3. What happens if you wind a coil in multiple layers, i.e., having 50 turns on top of 50 turns in a 100-turn coil?
4. What happens if you connect more batteries to the coil? Add one additional battery at a time to see the effect.
5. What happens if you use a wooden core? Or a plastic core? Or a stainless-steel core? Or a tin foil core? Which of these materials work? Why do some materials not work?

Links to the real-world

Electromagnets are fun to play with, but do you think we can use then to solve real-world problems? Consider these possibilities.

- How might you use an electromagnet to lock or unlock a door?
- How might you use an electromagnet to make a burglar alarm?
- How else might you engineer a use for an electromagnet to solve a real-world problem?

Share your ideas at **#nextengineersdiy**.

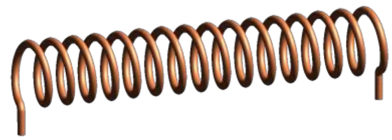


Image of a solenoid by Zureks is released into the public domain https://commons.wikimedia.org/wiki/File:Solenoid-1.png

LEARN MORE

Watch these videos to learn even more about electromagnets and their amazing properties.

- *Creating An Electromagnet* (1:16) https://www.youtube.com/watch?v=raq6pjafNKQ
- *Magnetism and Electromagnetism Tutorial* (6:22) https://www.youtube.com/watch?v=V-Gus-qIT74
- *Electromagnetism 101* (3:19) https://www.youtube.com