

A physics lesson

Magnets

Poles, domains and electromagnets

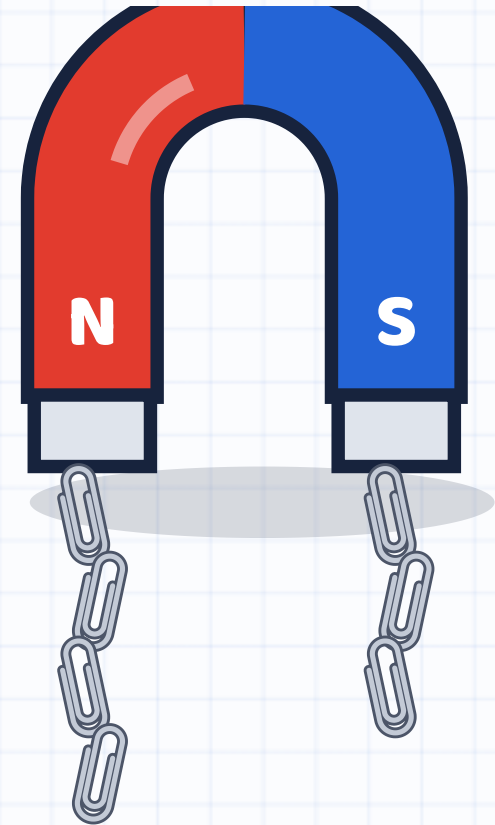
How can a magnet pull a paperclip without even touching it?

1 Poles and the magnetic field

2 What do magnets attract?

3 Inside a magnet: domains

4 Electromagnets



Two poles, always

Whatever its shape, a magnet always has two poles: a **north pole** (N) and a **south pole** (S).

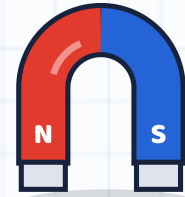
- The pull is strongest at the **poles**, near the ends.
- Bar, horseshoe or flat fridge magnet: each one has an N and an S.
- A compass needle is a tiny magnet. Its N end turns toward the north.

Earth is a giant magnet

That's why compasses work. Funny twist: the N end of a compass is pulled toward the Arctic, so Earth's magnetic pole up there is really a **south** pole!



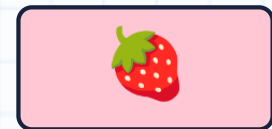
bar magnet



horseshoe magnet



compass needle



fridge magnet

Attract or repel?

Bring two magnets close together. What happens depends on which poles face each other.

Different poles **attract.**
Identical poles **repel.**

That's why two magnets can only attract each other in certain positions. Turn one around and they push apart!



Try it in Explore



S faces N: they attract



S faces S: they repel



N faces N: they repel

Break a magnet... get more magnets!

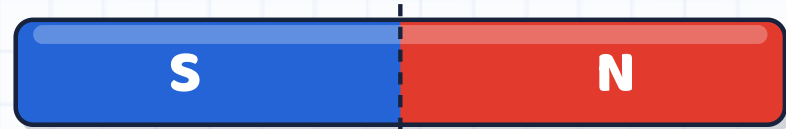
You can never get a north pole all by itself.

- Cut a magnet in two: each piece has its own N and S.
- Cut it in four: you get four magnets, so four north poles and four south poles.
- The new ends attract each other, so the pieces want to snap back together.



Cut it in 8 pieces: how many north poles?

Eight! Every piece is a whole magnet.



1 magnet



2 pieces = 2 magnets



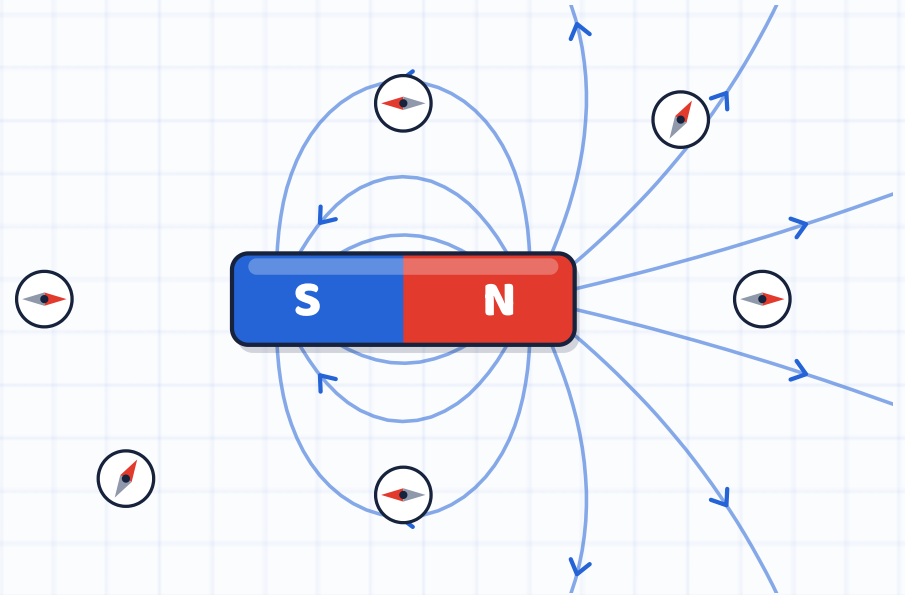
4 pieces = 4 magnets

The magnetic field

The invisible space around a magnet, where it can push or pull, is its **magnetic field**.

- **Field lines** come out of the N pole and curve around into the S pole. Compasses line up along them.
- Near the poles the lines are crowded: the field is strongest there.
- Move away and the pull drops off fast.
- The field goes right through paper, wood, plastic, water and even your hand.

 **Feel it in the Maze**



Not every metal!

People often think magnets attract all metal objects. That's wrong! Magnets only attract objects that contain **iron**, **cobalt** or **nickel**.

Attracted

-  paperclip (steel)
-  nail and screws (iron, steel)
-  food can (steel)
-  \$2 coin (nickel ring)
-  battery (steel case)

Not attracted

-  gold ring (gold)
-  electric wire (copper)
-  soda can (aluminium)
-  bottle (glass)
-  pencil (wood, graphite)

Why steel?

Steel is mostly iron. So a steel paperclip is attracted, but a copper wire or a gold ring is not, even though they are shiny metals too.

Tricky objects

Guess first, then tap a card to check.



A \$2 coin

Yes! Its outer ring is nickel or nickel-plated steel.



A penny

It depends on the year! Older pennies are mostly copper and don't stick. Most pennies made from 2000 on have steel inside and do.



A stainless steel fork

Sometimes! Some kinds of stainless steel stick and some don't. Test the forks at home.



A food can

Yes! It's steel with a thin coat of tin. But a soda can is aluminium: no!



A battery

Yes! Most batteries have a thin steel case.



A gold ring

No. Gold is a metal, but it is not magnetic.



Play Sticky or not?

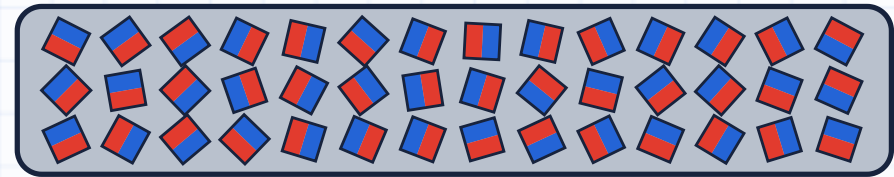
Tiny magnets inside

In some metals, the atoms are grouped in tiny units called **domains**. Each domain acts like a minuscule magnet.

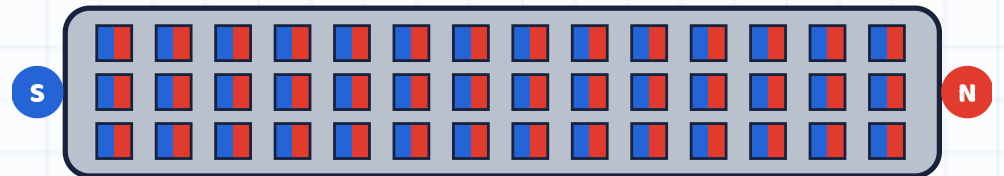
- In an ordinary piece of iron, the domains point every which way. Their pulls cancel out: the metal is **not magnetized**.
- When the domains line up, all the tiny magnets pull together: the metal is **magnetized**.
- Copper, gold and aluminium have no domains to line up. That's why magnets don't attract them.



Line up domains yourself



Domains not aligned: not magnetized

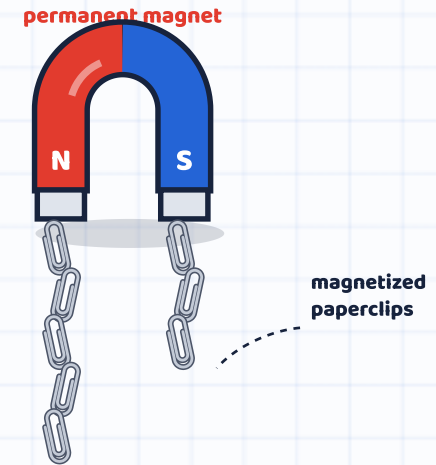


Domains aligned: magnetized!

Permanent or temporary?

Some magnets stay magnets. Others are only magnets for a while.

	Permanent magnet	Temporary magnet
Made of	an alloy of special metals	iron or steel (a nail, a paperclip)
Domains	always lined up, almost impossible to change	lined up only near a magnet or a current
How long	for years	iron: a short time; steel: longer
Examples	fridge magnet, compass needle	magnetized paperclip, electromagnet



Try it

Leave a paperclip touching a magnet long enough: it becomes magnetized and can hold another paperclip!

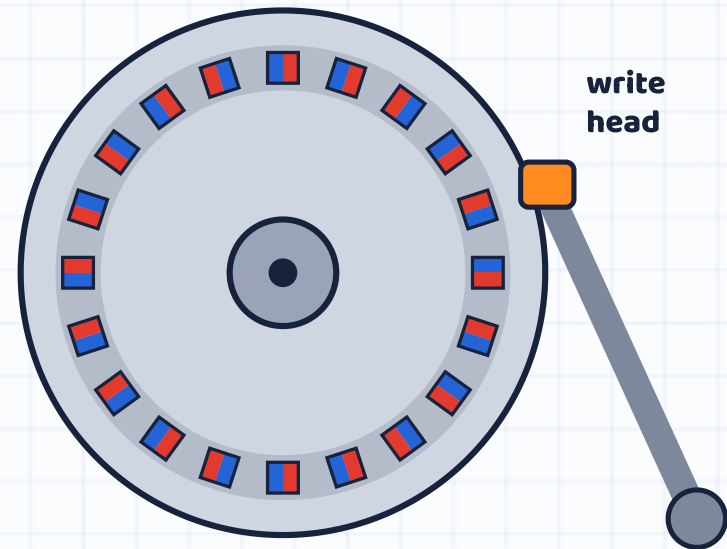
Magnets with a memory

Every day, millions of people use magnets without knowing it.

1. A computer's hard drive is covered with a material whose domains, at first, are not lined up.
2. When you save a file, the **write head** makes a magnetic field that lines up the domains, one way or the other, in a code.
3. Later, the computer reads the code back from the directions of the domains.

Never do this!

Don't bring a strong magnet near a hard drive: it could mix up the domains and erase information.



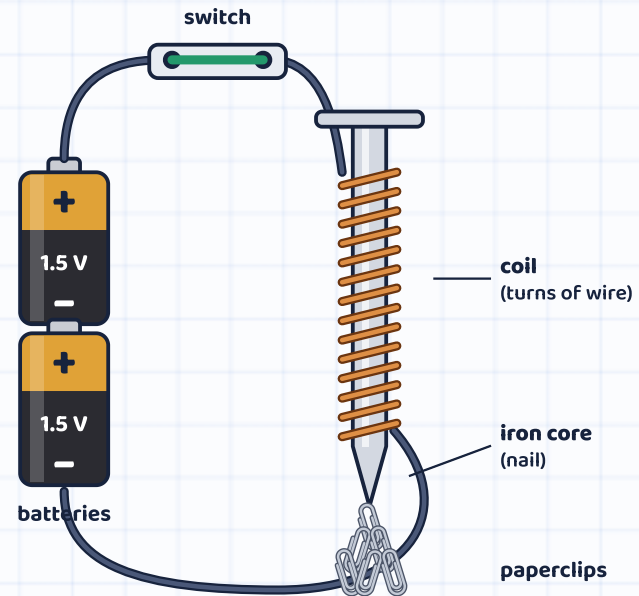
A magnet you can switch on and off

An **electromagnet** is a very strong magnet made by sending electric current through a **coil** of wire wound around an **iron core**.

- The current in the coil makes a magnetic field.
- That field lines up the domains in the iron core, which becomes a strong magnet.
- Switch off the current and the paperclips drop: it's a **temporary** magnet.

Remember the electricity lesson

Current only flows around a complete loop, so the switch must be closed. [Review circuits](#)



Experiment: a battery with muscle!

Goal: build an electromagnet and find out what makes it stronger.

Materials

- 2 batteries, 1.5 V (size C or D)
- 1 metre of electric wire, stripped at the ends
- tape
- a steel or iron nail
- paperclips

Steps

- A. Wind the wire around the nail, count the turns, connect the batteries and lift as many paperclips as you can.
- B. Add 10 turns. Predict first: what will happen?
- C. Use 20 turns fewer than in B. Predict, then test.
- D. While paperclips are hanging, disconnect a wire. What happens?

Stay safe

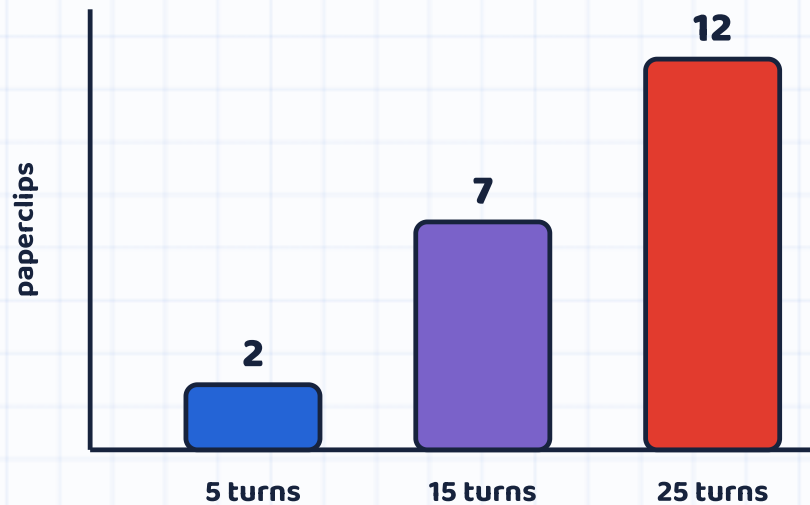
Only use small 1.5 V batteries, never a wall socket. Disconnect between steps: the wire can get warm and the batteries run down fast.



Do the experiment in Magnet Lab

What we found

In Magnet Lab, with 2 new batteries. Your real numbers will be a little different, but the pattern is the same.



The more turns, the stronger the electromagnet.

- **D.** Disconnect a wire and the paperclips fall: no current, no magnet.
- Wind the wire around a **pencil** instead: no paperclips at all. There's no iron, so no domains to line up.

Magnet or electromagnet?

Electromagnets are used wherever we need to switch a magnet on and off. Guess, then tap to check.



A scrapyard crane lifting old cars

Electromagnet. Turn off the current and the metal drops. It also sorts iron from other metals.



A fire door held open in a school hallway

Electromagnet. When the fire alarm rings, the current stops and the door swings shut.



An apartment door the tenant unlocks with a button

Electromagnet. The button cuts the current, so the door lets go.



A fridge door that resists when you open it

Permanent magnet. A magnetic strip hidden in the rubber seal pulls on the steel.



A compass needle

Permanent magnet. It needs no battery to point north.



The speaker in your headphones

Both! A small electromagnet pushes and pulls on a permanent magnet to make sound.

Three big ideas

What you've learned

1

Two poles

Different poles attract, identical poles repel. Break a magnet and every piece has an N and an S.

2

Domains

Lined-up domains make a metal magnetized. Only iron, cobalt and nickel are attracted.

3

Electromagnets

Current in a coil around an iron core. More turns, more strength. No current, no magnet.

Now play Magnet Lab



Explore



Domains



Sticky or not?



Electromagnet



Magnet maze



Quiz