Electromagnets

An electromagnet is a magnet that works with electricity. It can be switched on and off. The coils are nearly always made of copper wire because copper is such an excellent electrical conductor. Below are different sections of this e-source, for quick navigation.

Electromagnets have many uses. Here are some examples.

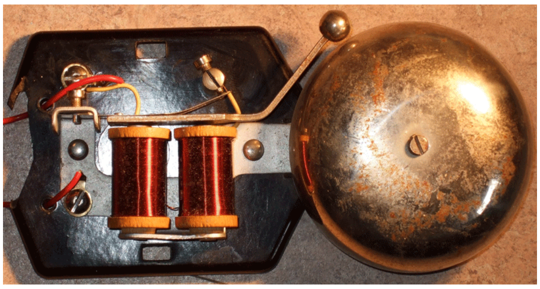
1. **An electric bell**: The electromagnets make the hammer vibrate back and forth, ringing the bell.

2. **An electric lock**: When an entry phone has been answered, the door can be unlocked from an upstairs flat. An electromagnet pulls the bolt open. Switch it off and the bolt springs back.

3. **A crane**: A crane and lifting magnet can lift tonnes of steel without hooks and ropes.

4. **A surgeon's tool:** An eye surgeon can pull scraps of steel out of a patient's eye using an electromagnet by turning up the current until it pulls just enough to gently remove the metal.

5. **Microsurgery:** Researchers are working on electromagnets that can move micro-robots around inside the body to carry out surgery without cutting a patient open.

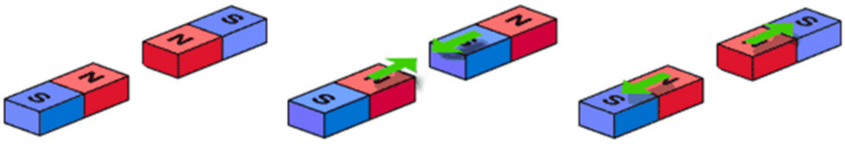


Electromagnet coils pull the armature to hit the bell. As the armature moves, it breaks the circuit and the electromagnet switches off. When it springs back the circuit is reconnected and the magnet pulls again. This repeats very quickly, causing the ringing. (Courtesy of Wikimedia.)

An electromagnet coil (protected by blue tape) pulls the door latch inwards. When the coil is switched off the spring pushes it out again. In this type of application the coil is called a solenoid. (Courtesy of Amazon.com.)

Permanent Magnet Fields

Magnets have north and south poles. The names come from the way a magnet will point on Earth, which is a giant magnet. Like poles repel and unlike poles attract.



Lifting magnets can lift and drop heavy loads like this steel pipe without the need for anyone on the ground fixing ropes, making the process safer. (Courtesy of Directindustry.)

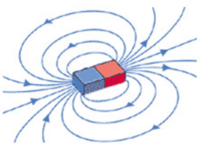
'Seeing' a Magnetic Field

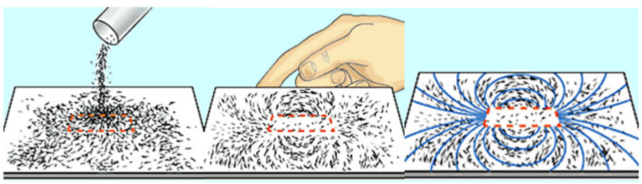
A magnet does not have to be touching another magnet to pull it or push it. The force from the magnet reaches out. It is an invisible force that works at a distance. We say that there is a magnetic field around the magnet. The magnetic field is the region in which a magnet's force works. We can use iron filings to reveal the invisible magnetic field.

- Place a piece of cardboard over the magnet
- Gently sprinkle some iron filings onto the cardboard
- Tap the cardboard so that the iron filings line up with the magnetic field.
- Look for the pattern made by the iron filings

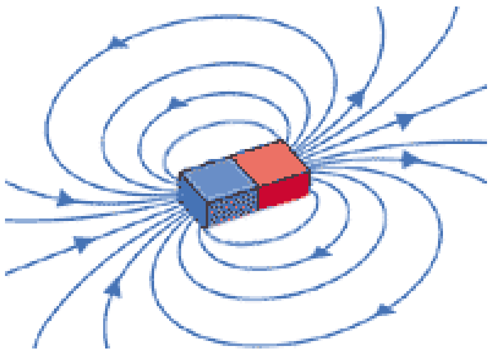
The iron filings tell us the shape of the magnetic field. However, it's also useful to know which way the field is going, i.e. will it attract or repel a north pole of another magnet.

We can find this out using a compass. The compass needle is itself a small magnet. Its arrow is a north pole, so the compass points away from the north pole of the magnet?





The field is invisible, but with a card and some iron filings: sprinkle, tap, reveal!



The field around a permanent magnet

Magnetic Fields

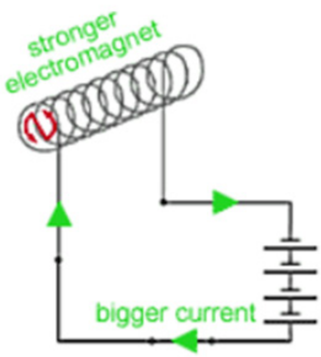
A magnet will pull on some metals like iron. We say these metals are magnetic. We can also make a magnet from soft iron. This magnet will have two poles: a north and a south. Two bar magnets will attract or repel, depending on which way they are facing. If we bring the north pole of one bar magnet up to the south pole of another one, they will attract each other. We say that **opposite poles attract.** However, if we bring a north pole up to another north pole, they will be forced apart. We say that they repel. The same happens with two south poles. We say that **like poles repel**.

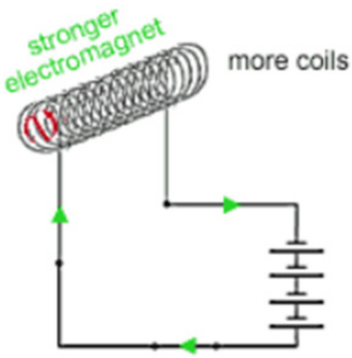
Field Lines Around a Bar Magnet

Notice from the diagram showing the magnetic field lines around a bar magnet that they:

1. Point away from the north pole
2. Point towards the south pole
3. Never cross over each other
4. Only come out of the ends of the magnet
5. Are closest together where the field is strongest, e.g. near the poles.

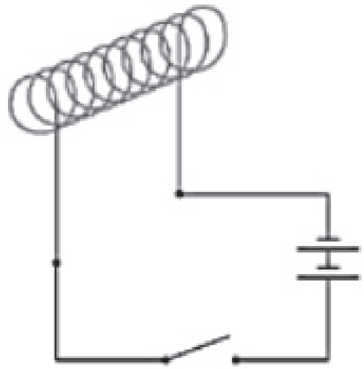
The arrows on the field lines tell us which way another north pole would move. A south pole would be pulled in the opposite direction to the arrows.



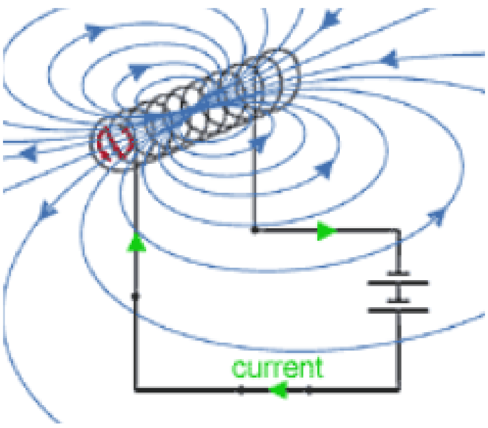


Electromagnets

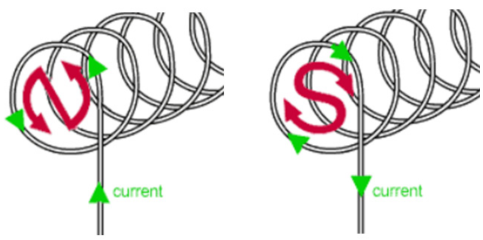
An electromagnet is a coil of wire with an electric current flowing through it. When the wire is coiled around in a cylinder, we call this a solenoid. The solenoid becomes an electromagnet when a current flows through it. Copper wire is used because it has a low electrical resistance. This means that it is easy for the current to flow through it. Also, copper wire can be easily shaped to make a coil.



The switch is open. No current flows and there is no magnetic field.



A copper coil carrying a current has a magnetic field like a bar magnet, but it can be switched on and off and reversed. In applications like MRI scanning coils the current is reversed millions of times per second.



A useful way to remember which pole the current will create.

Electromagnetic Fields

The magnetic field of an electromagnet is just like that of a permanent bar magnet. Increasing the current makes the field stronger, but a high current will heat up the coil, wasting energy as heat. Adding more turns will also increase the field strength. So we can add more and more turns to get a stronger and stronger magnet. This seems too good to be true... and it is. Adding more turns increases the coil resistance because the wire is longer. This reduces the current. Designers have to decide how many turns and how much current they need to get the right field strength.

Questions

1. **Could a crane with a lifting magnet lift bronze, brass or copper pipes?**

2. **A magnetic field acts at a distance. It exerts forces without touching. Gravitational fields also do this, but what does a magnetic field do that gravity does not?**

3. **If you bring either pole of a magnet near to a piece of steel such as a nail or a paper clip, it always attracts. It never repels. Can you explain this?**

Click here for answers

Copper Development Association is a non-profit organisation that provides information on copper's properties and applications, its essentiality for health, quality of life and its role in technology. It supports education through a collection of resources spanning biology, chemistry and physics. These materials have been developed in conjunction with the Association for Science Education, and reviewed by teachers.

For more resources, visit www.copperalliance.org.uk/education.