Homemade Magnet

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Meta Description

What are electromagnets and why do we use them? Discover the physics of electromagnetism by turning a nail into a magnet using simple, household materials.

Learning Objectives

Understanding the basic physics underlying electromagnets.
Understanding that magnetic materials can be magnetized using an electric current.

Key Terms

Dipole
Can be imagined to be a very small magnet with a North and South pole just like a normal magnet.

Divergent
In the context of magnetic fields, divergent refers to a decrease in the magnitude (strength) of the magnetic field.

Electromagnet
A type of magnet in which the magnetic field is produced by passing an electric current through a magnetic material. When the current stops flowing, the field is lost.

Ferromagnetic Material
A material which is magnetised in the presence of an external magnetic field. These materials are also attracted to permanent magnets. A good example of a ferromagnetic material is iron.

Magnetic Field
The area around a magnet where magnetic materials experience a magnetic force. The field is oriented from the North pole of the magnet to the South pole.

Magnetic Force
A force exerted by a magnet on another magnet or on a magnetic material. Magnets always attract magnetic materials, but they can attract or repel other magnets.

Permanent Magnet
An object which retains its magnetic field.

Solenoid
A coil of wire in the shape of a cylinder.

Method

Step 1
Try to use the nail to pick up the paperclips from a flat surface, such as a table. Do this by just touching the nail to the paperclips. Since the nail does not attract the paperclips, this demonstrates that it is not magnetic.

Step 2
Tightly wrap the insulated wire around the nail. Start winding at one end and distribute the coils evenly along the length of the nail – do not wind back and forth along the length of the nail. Leave 3cm of wire unwound at each end of the nail and strip 1 cm off of these ends.

Step 3
Introduce a current through the coil by connecting one end of the wire to the positive terminal and the other to the negative terminal of the battery.

Step 4
While the nail is still connected to the magnet via the wire, touch the paperclips with the nail and observe that this time the nail attracts metal just like a magnet would.

Precautions

1. Do not leave the electromagnet connected to the battery for a long time, because the circuit can heat up extensively.
2. Carefully strip the wire ends using a wire stripper or a scissors. This step should be performed by adults only.

Narrative

Did you know that you can built a magnet from scratch with household materials? The magnets you can build using household magnets aren't like the usual 'boring' permanent magnets like the ones you can stick on a fridge, but can be controlled using electricity. We call this type of magnet an*electro* magnet – 'electro' means electricity, so it is a magnet controlled by electricity. In fact, we can switch the magnet on and off whenever we want to by turning the electric circuit on and off!

If we spread some paperclips on the table you can see that the nail behaves as usual and none of the paperclips are attracted to it. However, if we tightly wrap an insulated wire around the nail and pass a current through the wire by connecting it to the battery, the nail suddenly becomes magnetic and the paperclips are attracted to the nail.

Can anyone guess what is going on here? Can you tell me how we can utilize this property of having a controllable magnet?

Questions

Why are the paperclips attracted to the nail?
When a current is passed through the solenoid a magnetic field is produced which is amplified by the iron nail core.

Can the magnetic force produced be varied?
Yes, either by changing the current or by changing the turn density of the solenoid.

Can any material be magnetized?
*No. Only ferromagnetic materials can be magnetized. For example, iron is a ferromagnetic material but*aluminium*is not.*

Why does current pass through the wire?
Current is simply the flow of electrons within the wire. When a circuit is complete, the battery drives the electrons at a flow depending on the potential difference (voltage rating) of the particular battery.

When the current is switched off, does the electromagnet retains some of its magnetic properties?
This depends on the core making the electromagnet. In the case of an iron core (a good ferromagnetic material) the electromagnetic remains slightly magnetic even when the current is switched off – this occurs because some dipoles remain aligned after the current is switched off.

Brief Explanation

The wire wrapped around the nail is referred to as a solenoid. When a current is passed through the wire, a magnetic field is produced around the wire, making the solenoid behave just like a magnet. In electromagnetism, electric and magnetic fields are deeply related to each other. While the flow of electricity in the wire generates a magnetic field, the specific shape of the solenoid allows the field to behave exactly like that of a permanent magnet. Any ferromagnetic materials (such as paperclips) in the vicinity of the magnetic field are attracted to the electromagnet. Refer to the Figure below.

If the solenoid were wound without the nail in the middle, the magnetic field generated within it would not be significantly strong and would not attract the paperclips. However, in the presence of an iron core (i.e. the nail) the magnetic field is greatly strengthened .

Homemade Magnet (steamexperiments.com) "VFPt_Solenoid_correct", is copyright (c) 2010 Geek 3 and ma

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Diagram showing the magnetic effect when applying a current through a solenoid.

Detailed Explanation

Passing a current through a solenoid generates a magnetic field having a direction that satisfies the right-hand screw rule. The magnetic field is uniformly concentrated in the center of the solenoid whilst the outside field is weak and divergent.

The magnetic field produced can be approximated using the equation,

$$B=?nI$$
[1]

Where$B$is the magnetic field, ?is the permeability,$n$is turn density and$I$ is the current supplied to the solenoid.

Equation [1] indicates that the magnet can be made stronger by increasing the number of turns of the solenoid and/or increasing the current supplied. is a property of the material and can therefore not be changed.

The ability of a material to be magnetized in an applied magnetic field is measured by the permeability of the material.The permeability of free space is given as0=1.25710^{-6}N/A^{2}while that of iron is=5000N/A^{2}, indicating that iron is much more readily magnetizable than air. This is because iron is made up of tiny magnets called dipoles which are randomly aligned. In the presence of a magnetic field these dipoles align in the direction of the field making the whole magnet stronger. The large difference in permeability between air and iron explains why an iron core greatly increases the magnetic properties of thesolenoid.

The ideal materials used as the core of the electromagnet are called ferromagnetic materials (such as iron) as their dipoles naturally line up with an external magnetic field making a much stronger resultant magnetic field.

Applications and Research

Application

Electromagnets are used to maneuver large and heavy magnetic metals in scrapyards. Electromagnets are ideal since their magnetic properties can be controlled with a flick of a switch: when the electromagnet is turned on, it can be used to extract magnetic materials from debris which may include non-magnetic materials like plastics and glass, and when it is turned off, the scrap metal is immediately deposited at its destination. The electromagnets are usually attached to cranes which can move the debris from one area of the scrapyard to the other.

Powerful electromagnets are also used in new transportation technologies. In particular, electromagnetic force is used to levitate trains above tracks in maglev trains. Such trains were developed in Japan and are known as*Bullet Trains*. Electromagnets allow the train to levitate on the tracks, providing a smoother ride. Levitation also minimises friction allowing the train to reach speeds as high as 320 km/hr.

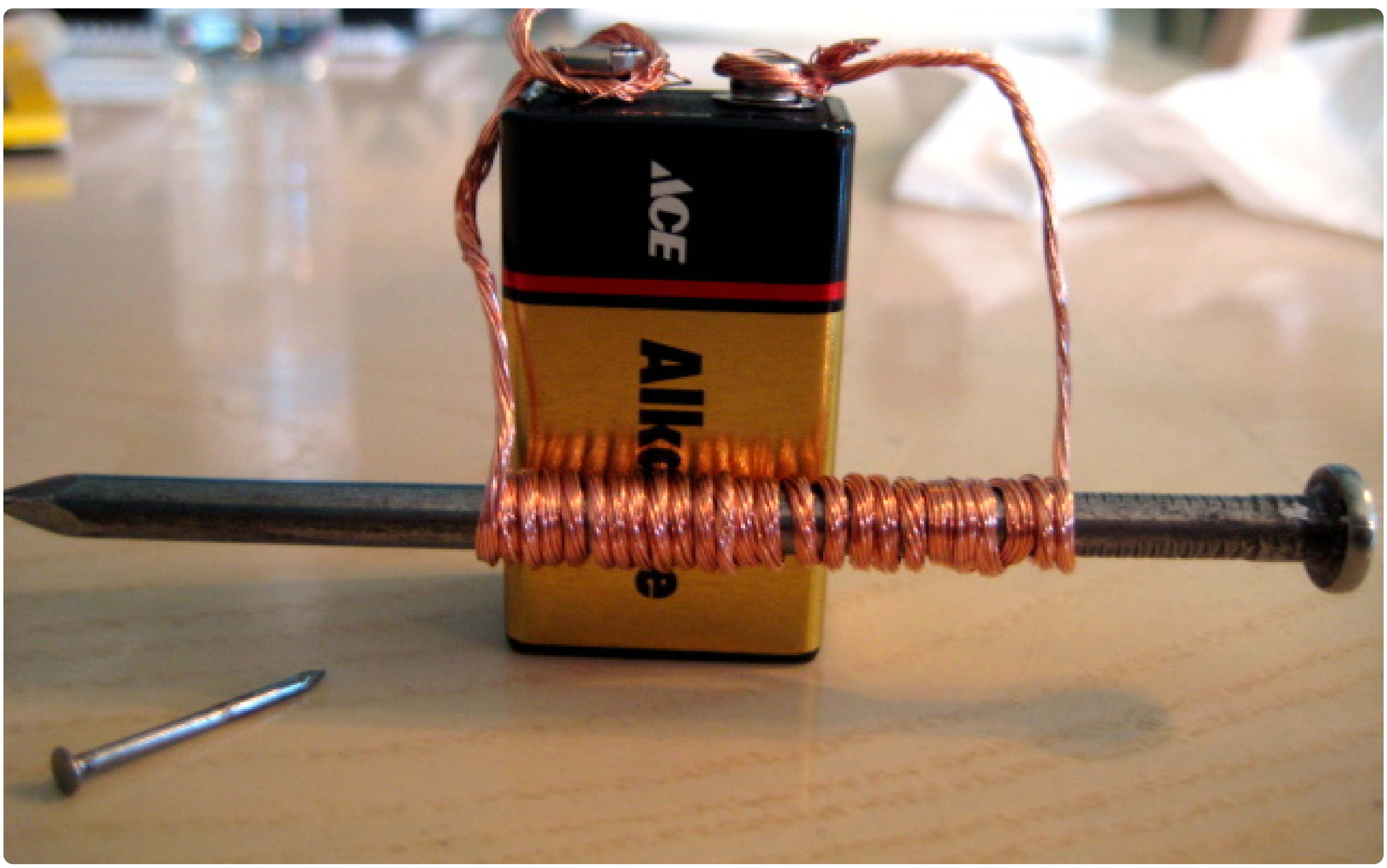
Electromagnets are also used in musical apparatus and instruments such as loudspeakers and bells.For example, a loudspeaker is essentially made up of a permanent magnet inside a wire coil. When electricity is passed through the wire coil, the coil itself becomes an electromagnet. The magnetized

coil is attached to the loudspeaker drum. As the magnetized coil is attracted to the permanent magnet and repelled from it, it moves back and forth. These vibrations are transmitted to the drum of the loudspeaker. As the drum moves back and forth, it creates sound waves. Similar mechanisms are found in electric bells and musical instruments such as the electric guitar.

Research
Busy rail networks all over Europe require extensive maintenance to ensure maximum safety. In the United Kingdom, research is being carried out to further develop inspection techniques for trainaxles. The main goal of this research project is to develop more efficient inspection techniques that are more convenient to train operators. Electromagnetic testing is on the forefront of this project. This novel technique helps to detect transverse cracking in sensitive parts of the rail track.

Investigation

- Alter the number of turns in the coil of wire and observe how the strength of the magnetic field varies. The strength of the magnetic field generated can be tested simply by counting the maximum number of paperclips that can be attracted.
- Repeat the experiment using nails of different lengths and widths and observe how the magnetic field strength varies.
- Investigate the effects of using different batteries on the field strength.
- Try using an AA battery or a C battery, for example. Try using wires of different thicknesses to make the coil.
- Test how the tightness of the turns in the wire affects the field strength.



Subject

Physics

Education

Secondary
Post Secondary
University
Informal

Time Required

~30 minutes
Preparation: 10 minutes
Conducting: 10 minutes
Clean Up: 5 minutes

Cost

10 – 25 €

Recommended Age

6 – 9
10 – 12
13 – 16
>16

Number of People

1 participant

Supervision

Required

Location

Indoors
Outdoors
Festivals
Laboratory

Materials

D battery

Insulated copper wire (approximately 25 cm)

Large iron nail (about 12 cm in length)

Metal paper clips

Wire stripper or scissors

Contributors

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Media

Sources

Homemade Magnet

Make your own Electromagnet

Solenoid

Additional Content

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Homemade Magnet(Beginner)

Japan Maglev Train Breaks World Speed Record Again (Beginner)

Physics of the Electromagnetic Ring Launcher(Intermediate)

Solenoid (Intermediate)

The World's Most Powerful Magnet(Intermediate)

Electromagnetic Warfare is Here (Advanced)

Electromagnetic Devices (Advanced)

Cite this Experiment

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