

The City School
North Nazimabad Boys Campus



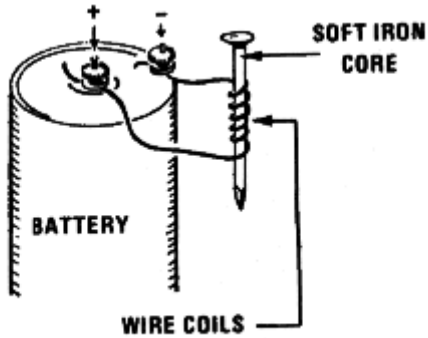
Electromagnetism

An electromagnet is an object that acts like a magnet, but its magnetic force is created and controlled by electricity—thus the name *electromagnet*.

By wrapping insulated wire around a piece of iron and then running electrical current through the wire, the iron becomes magnetized. This happens because a magnetic field is created around a wire when it has electrical current running through it. Creating a coil of wire concentrates the field. Wrapping the wire around an iron core greatly increases the strength of the magnetic field.

Making an electromagnet

If you wrap a wire around an iron core, such as a nail, and you send electrical current through the wire, the nail will become highly magnetized. You can verify that by picking up small objects or by showing its effect on a compass. This is called an electromagnet.



Creating a simple electromagnet using a nail

Insulated wire

Note that the wire must be an insulated wire. A bare wire would cause an electrical short and the current would then run through the nail or metal core. In some electromagnets, like in an electric motor, the wire will look like bare copper, but it is insulated with a thin coating of a clear material.

Also, if the wire is thin, it may get warm from the resistance to the electricity passing through it.

Turn on and off

The most interesting feature of the electromagnet is that when the electrical current is turned off, the magnetism is also turned off. This is especially true if the core is made of soft iron, which quickly loses its magnetism. Hardened steel may retain its

magnetism, so you can't use the most valuable feature of an electromagnet.

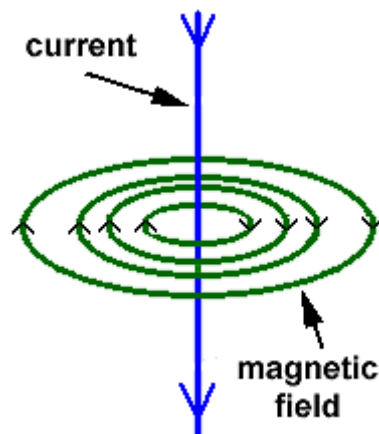
Being able to turn the magnetism on and off has led to many amazing inventions and applications.

How electromagnetism works

When electricity is passed through a wire, a magnetic field is created around the wire. Looping the wire increases the magnetic field. Adding an iron core greatly increases the effect and creates an electromagnet. You can create an electromagnet without the iron core. That is usually called a solenoid.

Magnetic field

When DC electricity is passed through a wire, a magnetic field rotates around the wire in a specific direction.



Magnetic field rotating around wire

Compass can show field

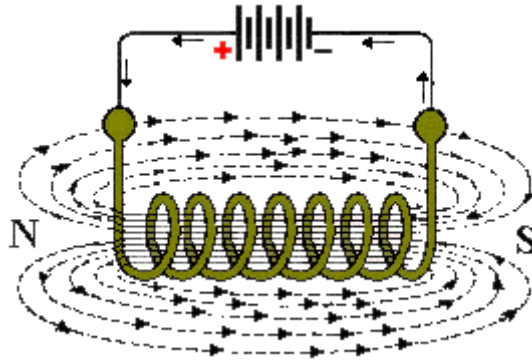
Connecting a wire to a battery and placing a compass near the wire can demonstrate a magnetic field. When the current is turned on, the compass-needle will move. If you reverse the direction of the current, the needle will move in the opposite direction.

Right hand rule

To find the direction the magnetic field is going, you can use the "right-hand rule" to determine it. If you take your right hand and wrap it around the wire, with your thumb pointing in the direction of the electrical current (positive to negative), then your fingers are pointing in the direction of the magnetic field around the wire. Try it with the picture above.

Wire in a coil

Wrapping the wire in a coil concentrates and increases the magnetic field, because the additive effect of each turn of the wire.



Coiled wire increases magnetic field

A coil of wire used to create a magnetic field is called a solenoid.

Iron core

Wrapping the wire around an iron core greatly increases the magnetic field. If you put a nail in the coil in the drawing above, it would result in an electromagnet with the a north seeking pole on the "N" side.

Using AC electricity

If AC electricity is used, the electromagnet has the same properties of a magnet, except that the polarity reverses with the AC cycle.

Note that it is **not a good idea** to try to make an AC electromagnet. This is because of the **high voltage** in house current. Using a wire around a nail would result in a blown fuse in

the AC circuit box. There is also the potential of an **electric shock**.

Strength of electromagnetic field

The strength of the electromagnetic field is determined by the amount of current, number of coils of wire, and the distance from the wire.

Current

The strength of the magnetic field is proportional to the current in the wire. If you double the current, the magnetic force is doubled.

Since **Voltage = Current x Resistance ($V = I \cdot R$)**, you can double the current in a wire by doubling the voltage of the source of electricity.

Turns of coil

If you wrap the wire into a coil, you increase the magnetic force inside the coil, proportional to the number of turns. In other words, a coil consisting of 10 loops has 10 times the magnetic force as a single wire

Varies with distance

The magnetic force decreases with distance. It varies inversely proportional to the square of the distance. For example the force at 2 cm. from a wire is $1/4$ that of at 1 cm., and the force at 3 cm. is $1/9$ the force at 1 cm.

Effect of iron core

When the coil is wrapped around an iron core, the strength of the electromagnetic field is much greater than the same coil without the iron core. This is because the atoms in the iron line up to amplify the magnetic effect. The orientation of the atoms in the iron is called its domain.

Current

When you increase the current, the magnetic strength increases, but it is not exactly linear as it is with the coil by itself. The shape of this curve depends on how well the material in the core becomes magnetized and how long it remains magnetized. Soft iron loses its magnetism readily, while hard steel tends to retain its magnetism.

Summary

By wrapping a wire around an iron core and applying an electric current through the wire, you create an electromagnet. This device is magnetic only when the current is flowing. The iron core greatly increases the magnetic strength.

Mini-quiz to check your understanding

1. If you doubled the number of coils and doubled the voltage, what would be the increase in magnetic strength?

It would remain the same, since $2 / 2 = 1$

It would be 4 times as strong, since $2 \times 2 = 4$

You can't increase magnetism by increasing the voltage

2. Why should the wire around the iron core be insulated?

So that you don't create a short circuit

To keep the iron from getting too warm

To insulate the magnetism

3. Why does an iron core increase the magnetic field of a coil of wire?

The iron atoms line up to add to the magnetic field

Iron attracts things, including magnetic fields

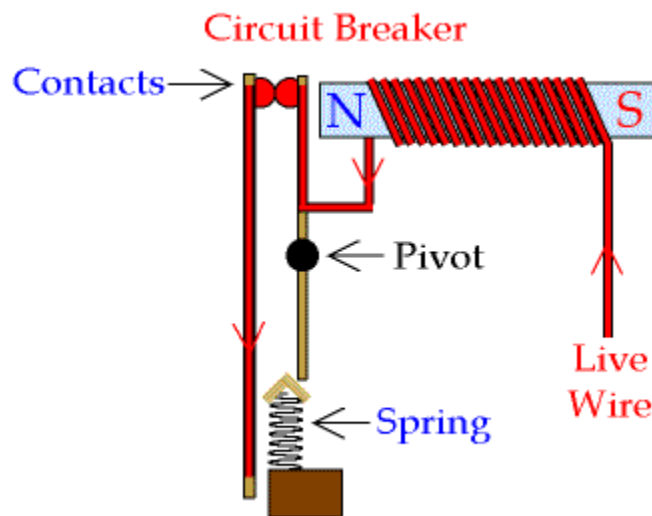
The iron core actually decreases the field, allowing it to be turned off

If you got all three correct, you are on your way to becoming a Champion in Physics. If you had problems, you had better look over the material again

Uses of electromagnets

Circuit Breaker.

The **circuit breaker** acts as a **safety device** in the same way as a **fuse**. It **disconnects** the **supply** if **too large** a **current** flows.



When the **live wire** carries the **usual operating current** the **electromagnet** is **not strong enough** to **separate** the **contacts**. If something **goes wrong** with the **appliance** and

a large current flows
the electromagnet will pull hard enough
to separate the contacts and break the circuit.
The spring then keeps the contacts apart.

After the fault is repaired, the contacts can then
be pushed back together
by pressing a button on the outside of the circuit
breaker box.

Relay.

A relay is used to operate the starter motor in cars
and the heating circuit in diesel engines.

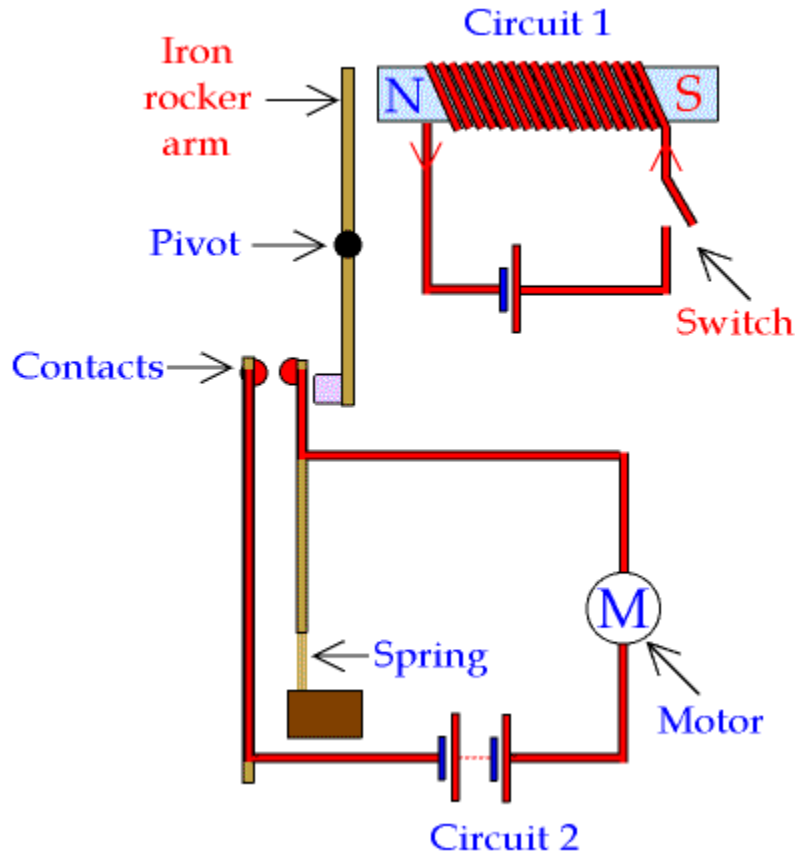
consists of two circuits.

The relay Circuit 1 is a simple electromagnet which
requires only a small current.

When the switch is closed, current flows
and the iron rocker arm is attracted to
the electromagnet.

The arm rotates about the central
pivot and pushes the contacts together.

Circuit 2 is now switched on.



Circuit 2 may have a **large current** flowing through it, to operate a **powerful motor** or **very bright lights**.

When the **switch** is **opened** the **electromagnet** releases the **rocker arm** and the **spring** moves the **contacts apart**.
Circuit 2 is now **switched off**.

The **advantage** of using a **relay** is that a **small current** (**circuit 1**) can be used to **switch on** and **off** a **circuit** with a **large current** (**circuit 2**).

This is **useful** for two reasons:
(i) **circuit 1** may contain a **component** such as

an LDR,
which only uses **small currents**,
(ii) only the **high current** circuit
needs to be made from thick wire.

Reed

Reed switch



Reed relay and reed switches

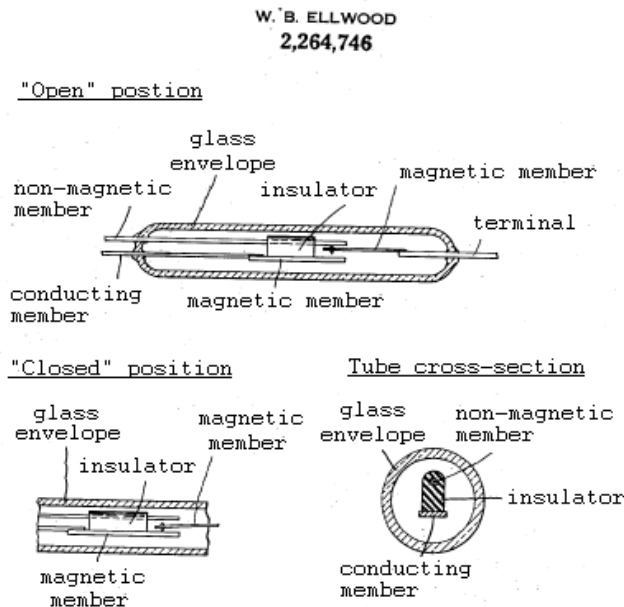


Showing the contacts clearly

The **reed switch** is an electrical switch operated by an applied magnetic field.. It consists of a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. The contacts may be normally open, closing when a magnetic field is present, or normally closed and opening when a magnetic field is applied. The reed relay is a type of relay, in which a reed switch is mounted inside a coil.^[1].

Description

The reed switch contains two magnetizable and electrically conductive metal reeds which have end portions separated by a small gap when the switch is open. The reeds are hermetically sealed in opposite ends of a tubular glass envelope.



Reed switch diagrams from Ellwood's patent, [U.S. Patent 2,264,746](#), *Electromagnetic switch*

A magnetic field (from an electromagnet or a permanent magnet) will cause the contacts to pull together, thus completing an electrical circuit.^[2] The stiffness of the reeds causes them to separate, and open the circuit, when the magnetic field ceases. A more complicated configuration contains a non-ferrous normally closed contact that opens when the ferrous normally open contact closes. Good electrical contact is assured by plating a thin layer of precious metal over the flat contact portions of the reeds.

There are also versions of reed switches with mercury"wetted" contacts.

Since the contacts of the reed switch are sealed away from the atmosphere, they are protected against atmospheric corrosion. The hermetic sealing of a reed switch make them suitable for use in explosive atmospheres where tiny sparks from conventional switches would constitute a hazard.

One important quality of the switch is its sensitivity, the amount of magnetic energy necessary to actuate it. Sensitivity is measured in units of Ampere-turns, corresponding to the current in a coil multiplied by the number of turns. Reed switches are widely used for electrical circuit control, particularly in the communications field. Reed switches are commonly used in mechanical systems as proximity as well as in door and window sensors in burglar alarm systems field. Reed switches were formerly used in the keyboards for computer terminals, where each key

had a magnet and a reed switch actuated by depressing the key. Speed sensors on bicycles use a reed switch to detect when the magnet on the wheel passes the sensor.

Reed relays

A reed switch combined with an electromagnet is a reed relay. This consists of a coil with the reed switch inside. Reed relays are used when high operating speed is required, or where very low-level signals must be switched. Millions of reed relays were used for temporarily storing information in middle 20th Century telephone exchanges. The inert atmosphere around the reed contacts ensures that oxidation will not affect the contact resistance. Mercury-wetted reed relays are sometimes used, especially in high-speed counting circuits. Such relays must be mounted in a particular orientation otherwise drops of mercury may unintentionally bridge the contacts.

