

Where do you find magnets? On the refrigerator, flashlights, speakers, motors, generators, and magnetic tape.

Magnets get their name from the word **Magnesia** because the first naturally occurring rocks that displayed magnetic properties came from **Magnesia** which is a part of modern-day Greece. This property of magnets was discovered almost 3000 years ago. These naturally occurring rocks are called **loadstones** and the mineral name is **magnetite**. The chemical formula is **Fe₃O₄**, the mineral is a lustrous black material and the crystalline structure is cubic.

Classification of magnets:

magnetically soft - easy to magnetize; loses magnetism easily

Iron is magnetically soft and may be considered a **temporary magnet**.

magnetically hard - hard to magnetize; do not easily lose magnetism

Cobalt, nickel, gadolinium, and iron alloys are magnetically hard. These are **permanent magnets**; they stay magnetic all the time.

Magnet characteristics:

magnetic poles - an area of a magnet where the magnetic force is the strongest

magnetic poles - each magnet has a north pole and a south pole

magnetic poles - like poles repel, opposite poles attract

magnets - will attract only substances that contain **iron, cobalt, nickel, and gadolinium**

magnets - cut it in half, each half will function as a complete independent magnet

magnets - the largest magnet in existence is the Earth

What is magnetism?

Matter is made of atoms. and atoms contain protons and neutrons in the nucleus. The electrons are found orbiting outside the nucleus. Electrons are always in motion orbiting the nucleus and the **spin of the electron sets up a magnetic field around the electron**. In most atoms, **electrons orbit the nucleus in pairs opposite each other**, and the fields created by the spin of the electrons **cancel each other**. No magnetism results.

Some metals have only **one electron in the outer orbit** of the atom and the atoms in the potentially magnetic metallic substances have random arrangement. The magnetic field set up by the electron is not canceled but the atoms in the metal are arranged randomly and the magnetic fields extend in many different, random directions. Small areas that show alignment of magnetic fields are called **domains**. The more domains that are in alignment with each other, the greater the magnetic field of the object.

If the electron orbits are aligned so the magnetic fields around the individual electrons are arranged to be in the same direction, the total strength of the magnetic field increases and thus, magnetism of the object (composed of iron, nickel, cobalt, or gadolinium) increases and shows direction as the invisible magnetic lines of force.

Magnetic Field - a region where a magnetic force can be detected

The **magnetic field** is an invisible **force field** as established by the orientation of atoms and their orbiting electrons in certain metals. Like the force gravity, it can't be seen but through experimentation, we know it is there and how it behaves. The force field around the magnet will push away the same force field and pull an opposite force field.

The **Earth functions** as a **bar magnet**. The magnetic poles are not located at the geographic poles. Topographic maps will have "**magnetic declination**" which is the number of degrees difference in the geographic pole and the magnetic pole. The magnetic declination will be different on every map.

Why does the North Pole on a magnet point to the North Pole on the Earth? Don't similar poles repel? The "**N**" on a bar magnet stands for **North seeking** and in Northern Canada, technically, exists the **South pole**!

Magnetism from Electric Currents

An electric current flowing through a metal wire will have a magnetic field. Since the magnetic field is caused by an electric current the field is called an **electromagnetic field**. Two methods of observing the electromagnetic field are by using **iron filings** to show the field or use a **compass** to trace the field (p. 767 Holt Physics).

Right-hand rule is used for determining the **direction** of the electromagnetic field in a single wire. Grab the wire (**INSULATED!**) and (**without the juice**) with your **right** hand, thumb is in the direction of **current** flow, and fingers indicate the direction of the **magnetic field**.

Right-hand rule is also used to determine the **direction** of the electromagnetic field of a current carrying loop. Again grab the insulated wire with your **right** hand and your thumb is in the direction of **current** flow. No matter where you apply the right hand rule, the field within the loop points in the same direction.

Take the wire and wind it into a coil. When current flows through the wire in the shape of a coil (refer back to the inductance notes), a magnetic field will build and resemble the magnetic field of a bar magnet having both a North pole and South pole. This structure is called a **solenoid**. The North Pole of the solenoid is where the current **enters** the coil and the South Pole is where the current **exits** the coil.

The **strength** of the field is **directly proportional** to the number of turns in the solenoid. An **increase in current** will also **increase the strength** of the magnetic field.

Another method of increasing the strength of the solenoid is to **insert an iron bar** into the coil. The resulting structure is now an **electromagnet**.

Electromagnetic devices:

relays - uses an electromagnet to open or close a circuit

galvanometers - devices used to measure voltage and current in a circuit

electric motors - electrical energy is converted into mechanical energy

speakers - electrical energy is converted into mechanical energy - sound

doorbells – an electromagnet causes a metal ball to hit the side of a bell.

Electric Currents from Magnetism

Passing a permanent magnet back-and-forth in a coil of wire will cause a charge to develop in the wire. This process is **electromagnetic induction**. This law of physics is also known as **Faraday's law** that states: **An electric current can be produced in a circuit by a changing magnetic field.**

Maximum current can be induced into a coil of wire as long as the wire is moving **perpendicular** to the magnetic lines of force. A charged particle will experience a force due to the magnetic field. As the angle decreases, the force on the charged particle will also decrease.

Magnetic Field devices:

generators - mechanical energy is converted to electrical energy

As a coil of wire constantly passes through a magnetic field, an electric current is induced into the wire. Generators provide the electric current to our homes to operate all the electrical devices present. The type of current produced is **AC (alternating current)** at a rate of **60 Hz**. Alternating Current reverses the current flow twice each cycle because the coil of wire first passes through the "North" magnetic field and then passes through the "South" magnetic field. If this occurs at a rate of 60 times a second, the frequency is 60 Hz.

transformers - changes the input AC voltage to a higher or lower AC voltage

step-up transformers - secondary windings (output) have a greater number of turns of wire than the primary (input) windings; develops an increase of

step-down transformers - secondary windings have less turns of wire than the primary windings; causes a decrease in voltage

Magnetic Force

A stationary charge particle does not interact with a constant magnetic field but a charge that moves through a magnetic field experiences a magnetic force.

The force has a **maximum value** when the **charge moves perpendicular** to the magnetic field.

The force has **minimum value** (zero) when the **charge moves parallel** to the magnetic field.

The formula for magnetic force is: $F_{magnetic} = qvb$

$F_{magnetic}$ – magnetic force on a charged particle (Newtons)

q – magnitude of the charge (coulombs)

v – speed of charge (m/s)

B – strength of magnetic field (tesla – T)

The Formula rearranged: $B = \frac{F_{magnetic}}{qv}$

The units in tesla (**T**) is: $T = N/(C \cdot m/s) = N/(A \cdot m) = (V \cdot s)/m^2$

A comparison: Laboratory magnet magnetic field strength $\cong 1.5 \text{ T}$
Near surface Earth's magnetic field strength $\cong 50 \text{ mT}$

Use the **right-hand rule** to find the direction of the **direction of the magnetic force** by placing your thumb along the wire in the direction of the current (also V) and with your hand open. For a **positive charge** (refer to figure 21-10 page 774):

1. The magnetic force will be directed **out of the palm** of your hand.
2. **B** shows the direction of the strength of the field.

What is the use of this? Do you watch TV? Engineers must apply a force on the moving charge due to a magnetic field to produce the picture on the TV screen. The phosphorus coating on the inside of the TV tube glows when it is struck with a beam of electrons. If a magnetic field were not present to manipulate the beam of electrons, only the center of the tube would be illuminated.

As the charge moves through a magnetic field, it follows a circular path. The right-hand rule shows that for charge q the direction of the magnetic field is to the left. The field causes a charge particle to move to the right.

The right-hand rule also shows at any point the magnetic force is always directed towards the center of the circular path. Knowing this, engineers are able to design transformers, motors, and generators.

Magnetic Force on a Current-Carrying Conductor

A straight-line wire carrying a current will have a uniform magnetic field that extends from the center of the wire. The magnitude of the magnetic force on the wire is illustrated in the following formula:

$$F_{\text{magnetic}} = BIl$$

F_{magnetic} – magnetic force on a charged particle (Newton - **N**)

B – strength of magnetic field (tesla – **T**)

I – current (Amperes – **A**)

l (script little L) – length of the conductor within B in meters (**m**)

Use the right-hand rule with your thumb in the direction of the current flow. The direction of the magnetic force on the wire is shown by the direction of your fingers, to the left.

What is the purpose of this? One wire is placed parallel and near a second wire. The current flowing in the first wire will be induced into the second wire. This is the fundament principle is increasing or decreasing voltage.

Another variation of this application is used in speakers. The wire is shaped into a coil and placed within the field of a permanent magnet and the coil is attached to a paper cone. As the pulsating current (pulsing or reversing direction due to voice or music information imposed on the current) flows through the wire in the coil, then the coil will pulse back and forth in the magnetic field of the permanent magnet. As the coil pulses back and forth, then the cone will also vibrate back and forth producing mechanical energy in the form of sound waves.

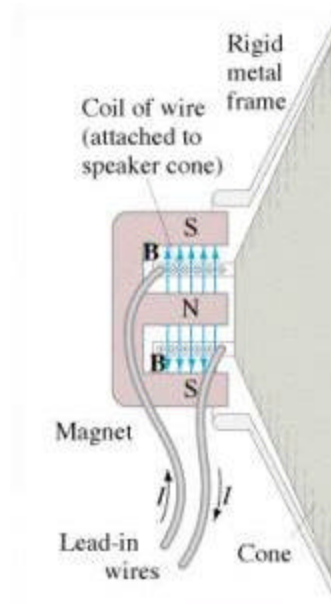


Image from:
<http://physics.usc.edu/~bars/135/LectureNotes/Magnetism.html>

Galvanometers, Ammeters, Voltmeters

In our electronics lab activities, you have been using a meter with a digital display to measure values of voltage, current and resistance. These devices sample the current and display the results on an LCD readout. Digital displays are great for precise measurements but when there is a very rapid change in current or voltage, the reading is hard to register to the human eye.

A **REAL** meter will have a coil suspended between the poles of a horseshoe-shaped permanent magnet. The force of the magnetic fields of the permanent magnet will act on the magnetic field set up by the current flowing through the coil. The coil will rotate about its axis due to the interaction of the field forces. The angular deflection is proportional to the current in the coil. This type of meter is easy to use when the source is changing rapidly. It is easy to get a good visual indication of what is taking place in the circuit.

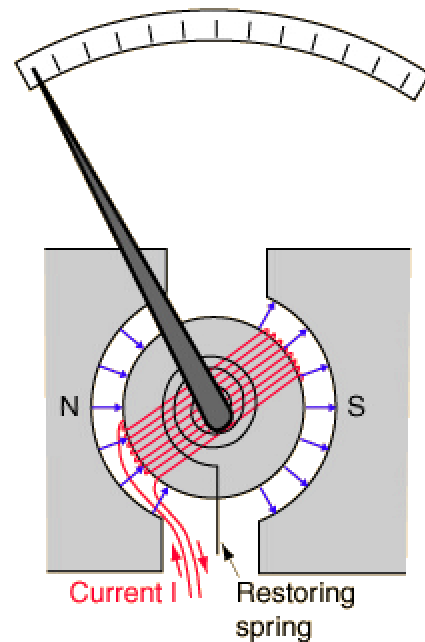


Image from: <http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/imgmag/galvan.gif>

Voltmeters – a **high resistance** is connected **in series with the galvanometer**. The voltmeter is used to measure the potential difference between two points of a circuit.

The **high series resistance** opposes the current flow as to prevent damage to the delicate wire and components in the meter. In other words, it just drops the voltage to a safe level for the meter.

Ammeters – a **low resistance** shunt is connected in **parallel with a galvanometer** and the galvanometer is placed in series within the circuit.

What is a shunt? The **shunt is a low resistance in parallel** with the galvanometer. The majority of the current will take the low resistance path through the shunt and a small amount of current will flow through the coil of the meter. The objective of the shunt is to keep high currents from damaging sensitive and delicate parts of the meter. This is also a safety issue with hands near the meter, possible exposure to high current is avoided if the meter is damaged.