

The background of the slide is a dark, atmospheric scene. On the left side, there is a bright, glowing light source, possibly a sun or moon, partially obscured by a dark, silhouetted object that looks like a large rock or a piece of machinery. The light creates a strong lens flare effect. The rest of the scene is dark, with a glowing blue-green horizon line that suggests a sunset or sunrise over a body of water or a landscape. The overall mood is mysterious and dramatic.

Chapter 36 & 37

Magnetism

What you will learn:

- You will relate **magnetism** to **electric charge** and **electricity**
- You will describe how **electromagnetism** is harnessed to produce mechanical work

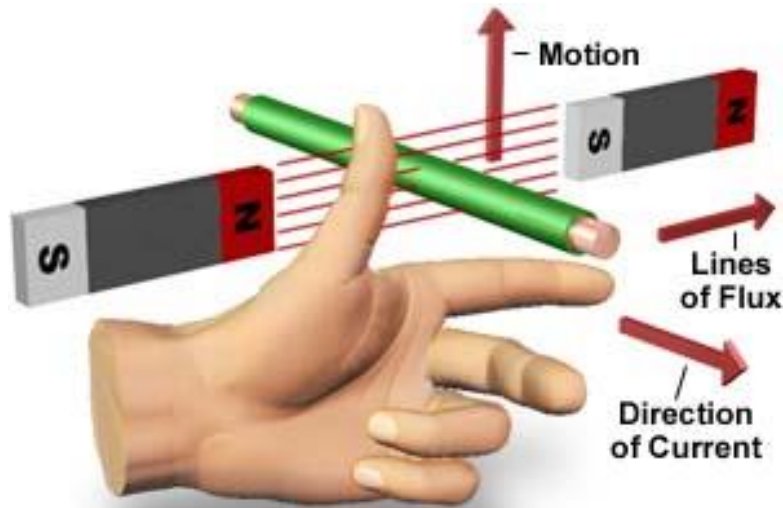


Figure 9

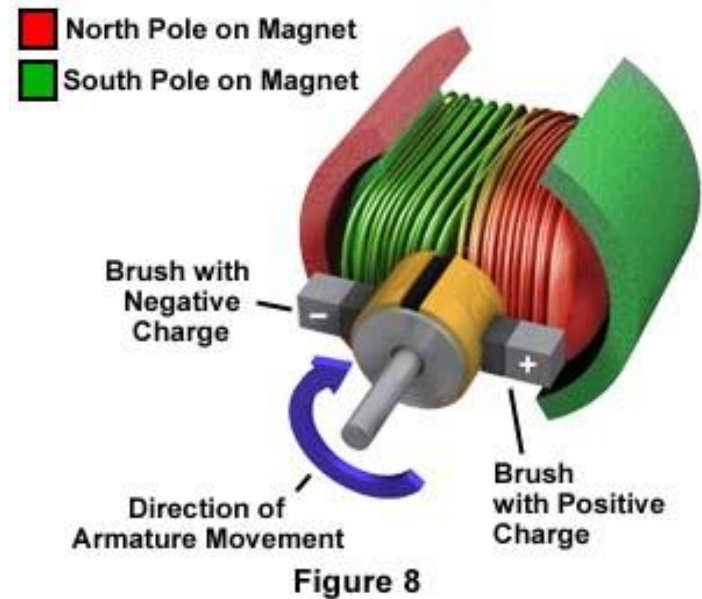
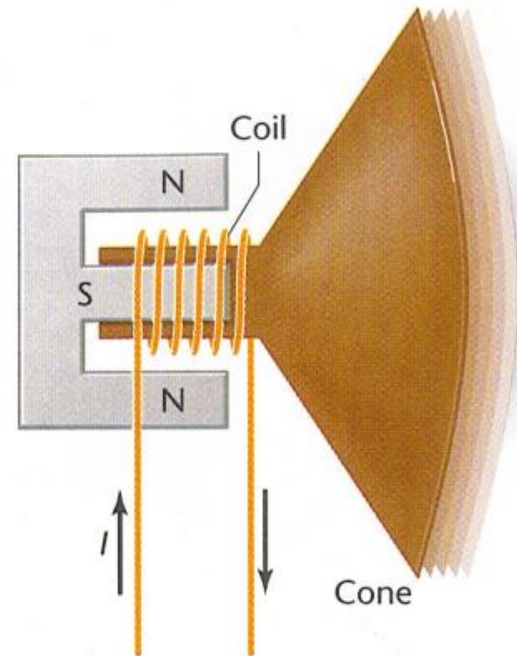


Figure 8

Why it's important:

- Using **electromagnetism** in **electric motors**, you can convert **electrical** energy to **mechanical** energy
- Every day, you apply mechanical energy produced from electrical energy



Magnetic Fields

I. Historical Background

- A. The term *magnetism* comes from region of Magnesia, a province in Greece, where certain stones (*lodestones*) had the unusual property of attracting pieces of iron
- B. The Chinese were first to fashion magnets into compasses in the 12th century



C. European explores brought back knowledge in 1500's

D. In 16th century, William **Gilbert** (Queen Elizabeth's physician) made artificial magnets by rubbing pieces of iron against **lodestone** and suggested that a compass always points **north** and south because the Earth has magnetic properties.



[William Gilbert]



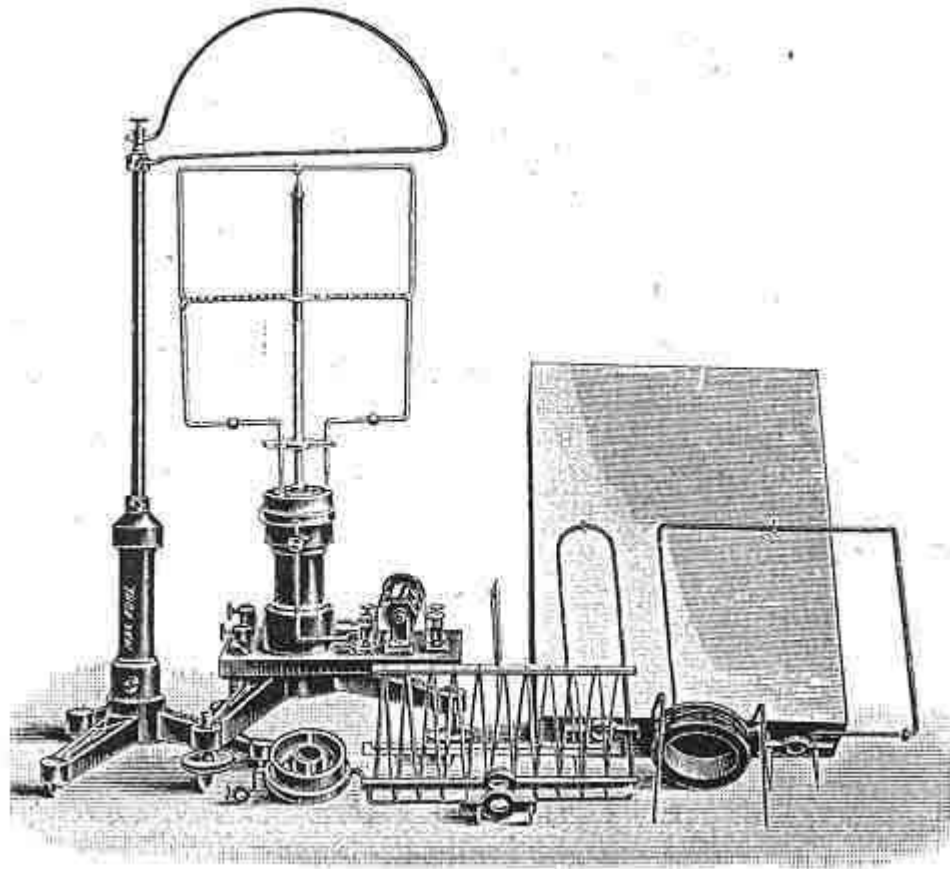
E. In 1750, **John Michell** in England found that magnetic poles obey the **inverse square law**, and his results were confirmed by **Charles Coulomb**.

F. Hans Christian **Oersted** discovered that an electric current affects a magnetic compass. He saw that **magnetism was related to electricity**



$$F \propto \frac{1}{d^2}$$

G. Shortly thereafter, the French physicist Andre-Marie **Ampere** proposed that electric currents are the source of all magnetic phenomena.



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II. Magnetic Properties

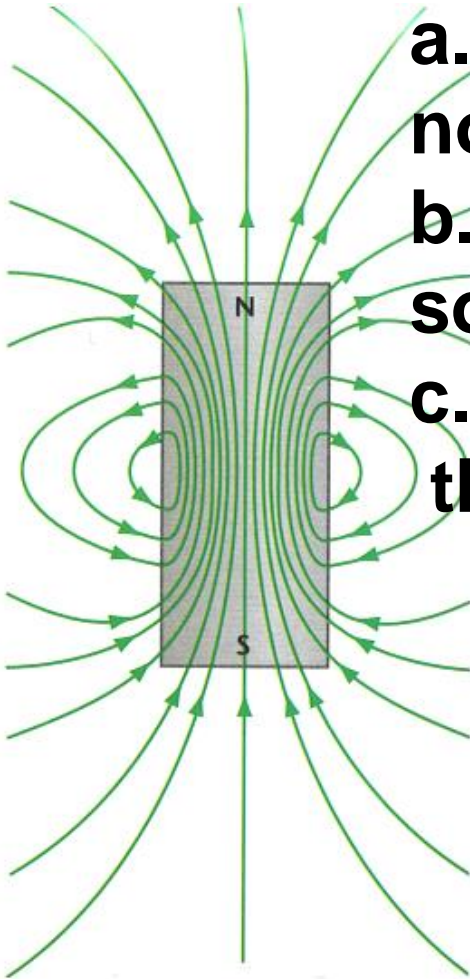
A. Magnetic Poles

1. A magnet is polarized (it has two ends)

a. **North-seeking pole-** points northward

b. **South-seeking pole-** points southward

c. **Poles are located at the end of the magnets**

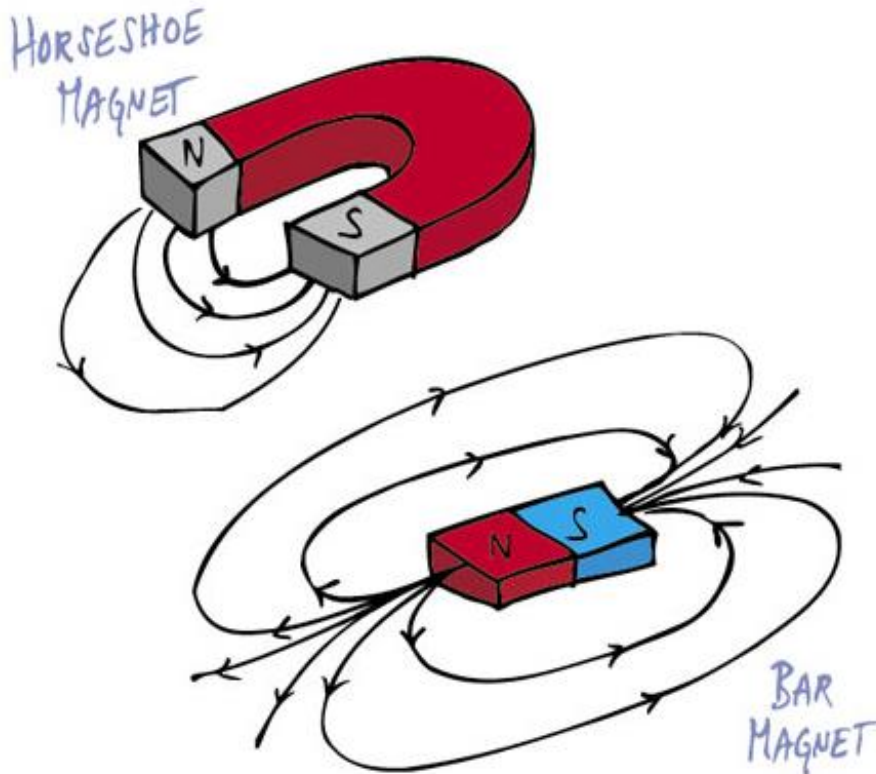


2. Like poles repel and unlike attract (just like forces between electric charges)



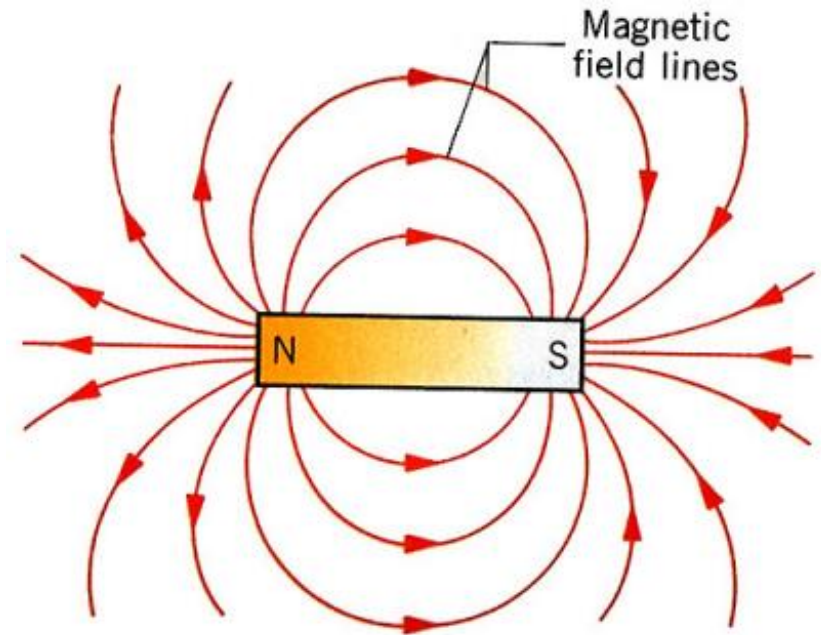
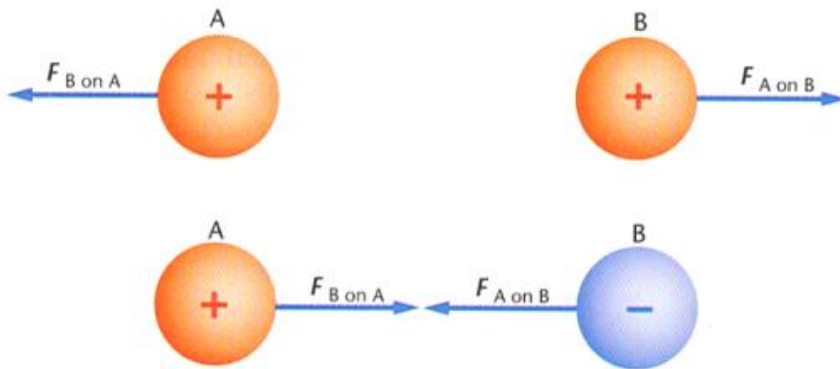
B. Magnetic Forces

1. Are similar to electric forces
 - a. Can both **attract** and **repel**
 - b. Strength of magnetic interaction depends on the **distance** between the two magnets



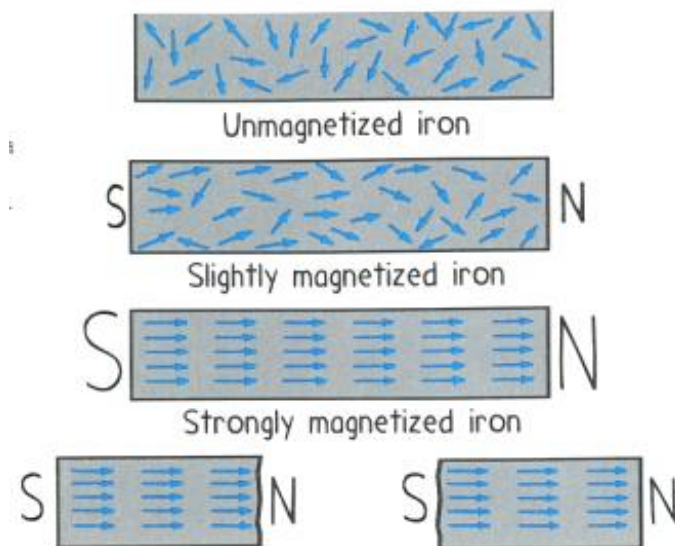
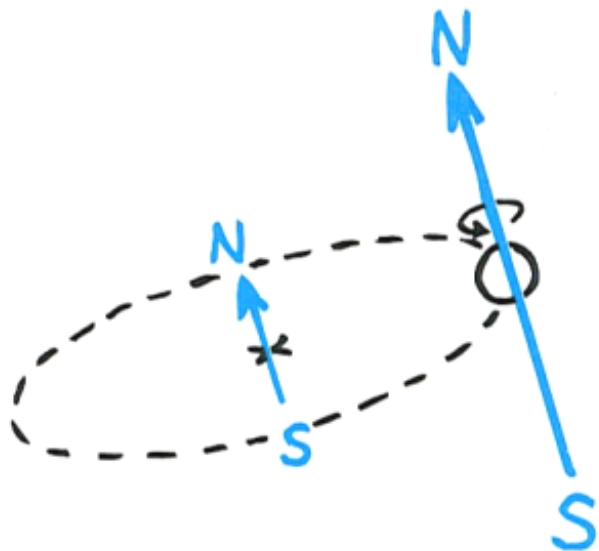
$$F \propto \frac{1}{d^2}$$

2. Whereas **electric charges produce electric forces**, regions called **magnetic poles give rise to magnetic forces**

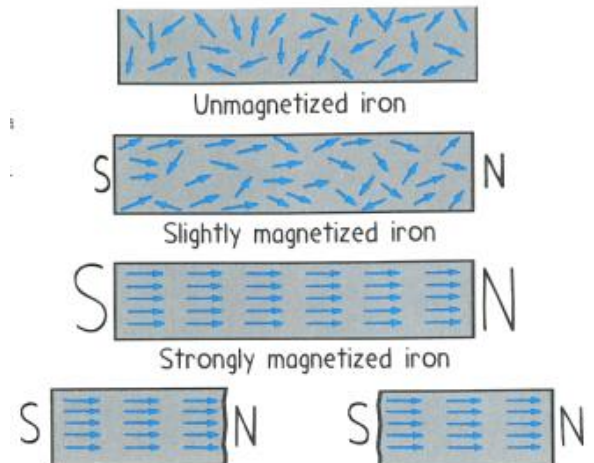
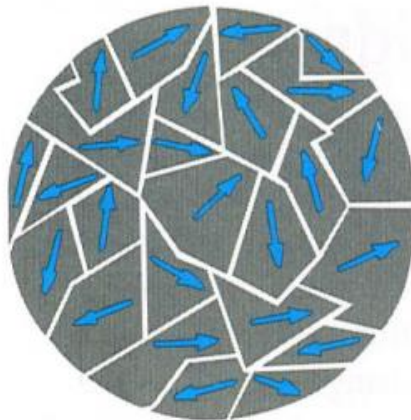


C. Permanent magnets

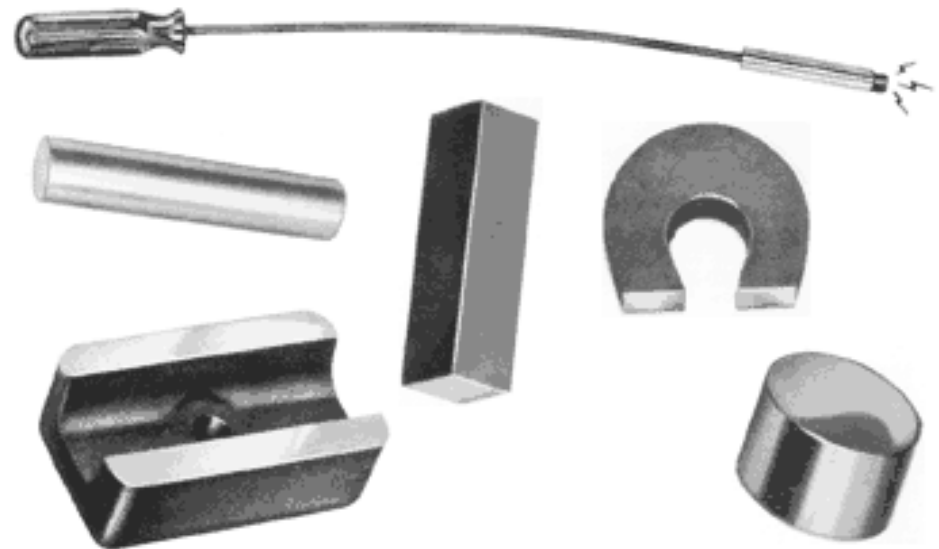
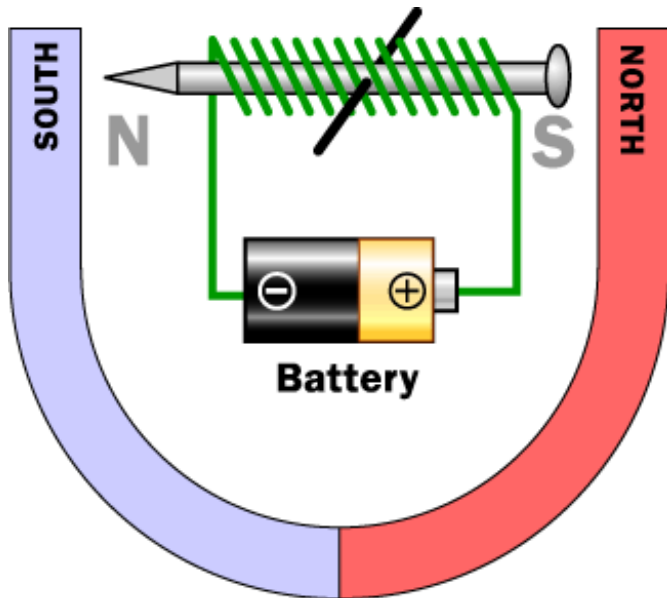
1. Caused by **motion of electrons** within the material (both **electron spin** and **revolution**)
 - a. Electrons spinning in **same** direction make up a **tiny magnet**.
 - b. A pair of electrons **spinning in opposite directions** work against each other and **magnetic fields cancel**



2. In materials such as iron, each atom has four electrons whose **spin magnetism is uncanceled**.
- a. Each iron atom is tiny magnet
 - b. The magnetic fields from groups of atoms can add together. These are called **domains** (10^{20} atoms)
 - c. When piece of iron is not in a magnetic field, the domains do not all point in same direction (magnetic fields cancel)

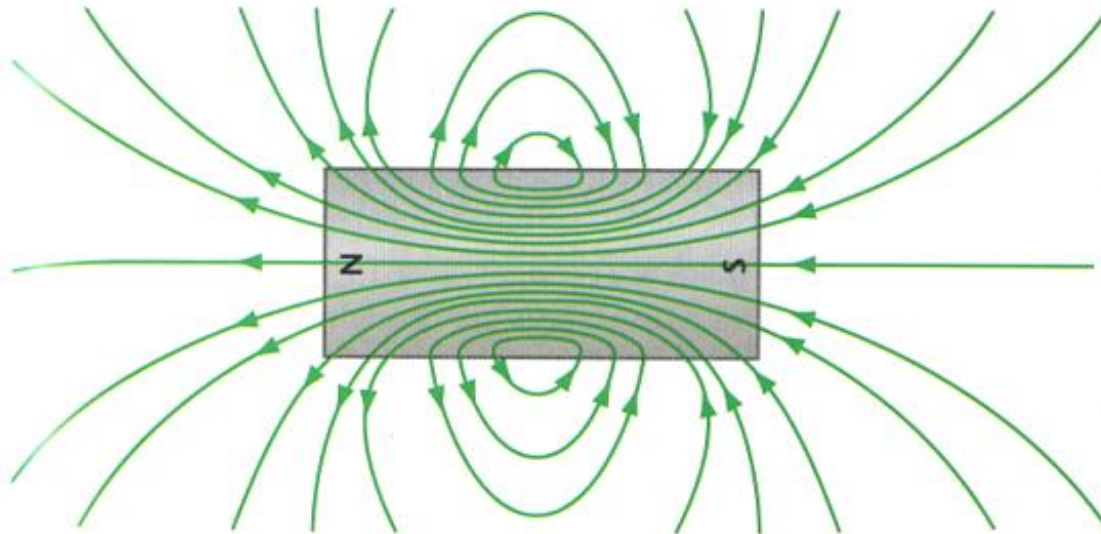


- d. When **iron** placed in **magnetic field**, **domains** tend to **align** with the external field producing a ***temporary magnet***. After removing from field domains return to random arrangement.
- e. In ***permanent magnets***, the **iron** has been **alloyed** with other substances (aluminum, cobalt, nickel) that keep domains aligned after external magnetic field is removed



D. Magnetic Fields

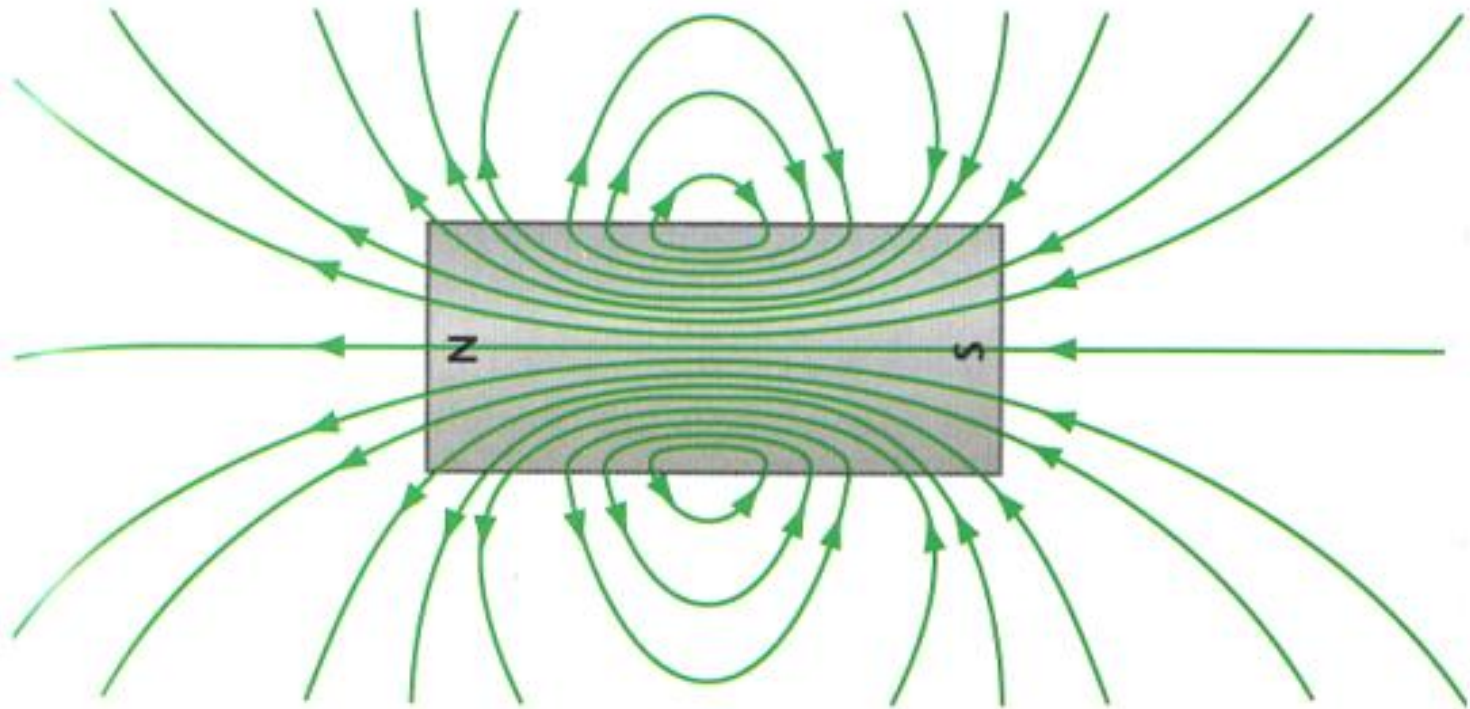
1. **Magnetic forces** can be described by existence of ***magnetic fields*** around the magnets
 - a. These lines are **imaginary**
 - b. Help **visualize** the field and provide **measure of strength**.



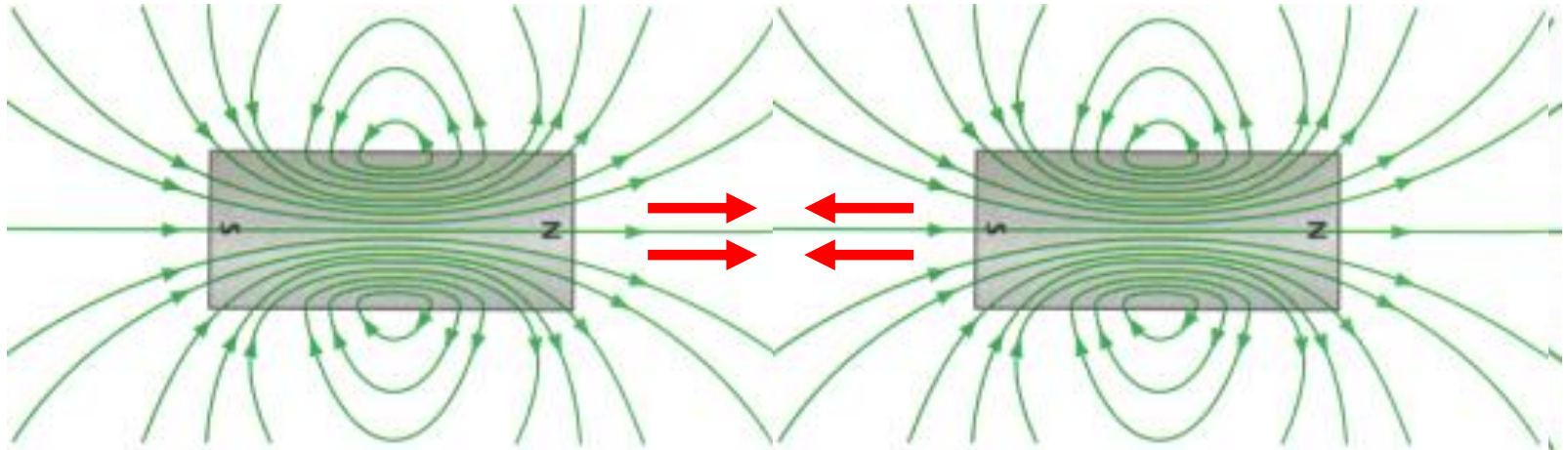
1). **magnetic flux**- *the number of field lines in any given region*

2). **The flux per unit area** is proportional to the strength of the **magnetic field**

2. Field lines **come out N-pole** of magnet and **enter magnet** at its **S-pole**.



- 3. Field lines *continue through the inside* of the magnet.**
- 4. Field lines always form *closed loops***
- 5. *Magnetic fields exert forces on other magnets***
 - a. N-pole of one magnet *pushes* N-pole of another magnet.**
 - b. N-pole of one magnet *attracts* S-pole of another magnet.**

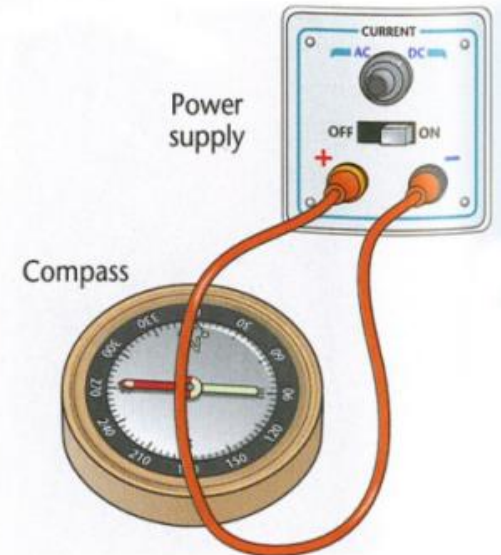
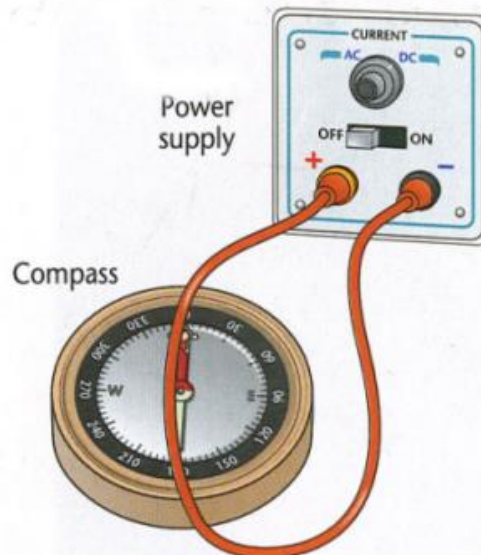


III. Electromagnetism

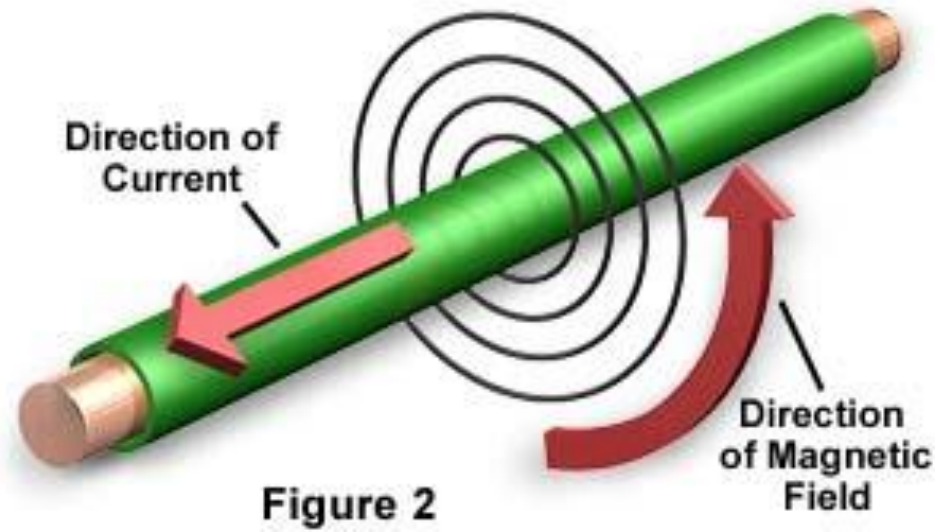
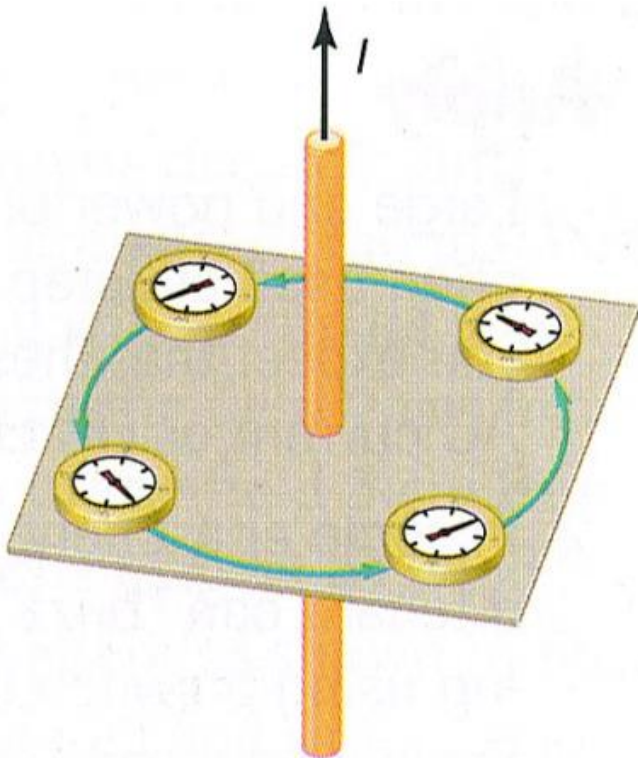
A. In 1820, Hans Christian Oersted discovered that electric currents produce magnetic fields

B. Magnetic field near a current-carrying wire

1. Force is perpendicular to direction of current in wire



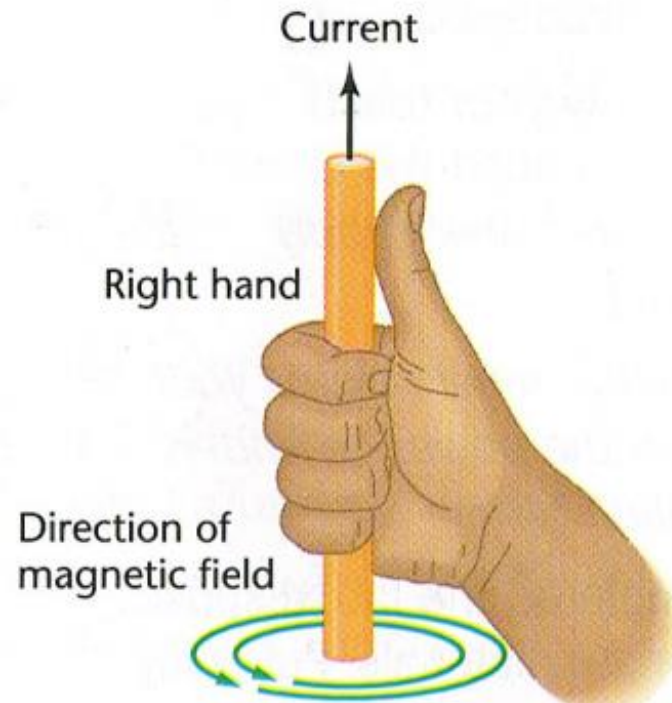
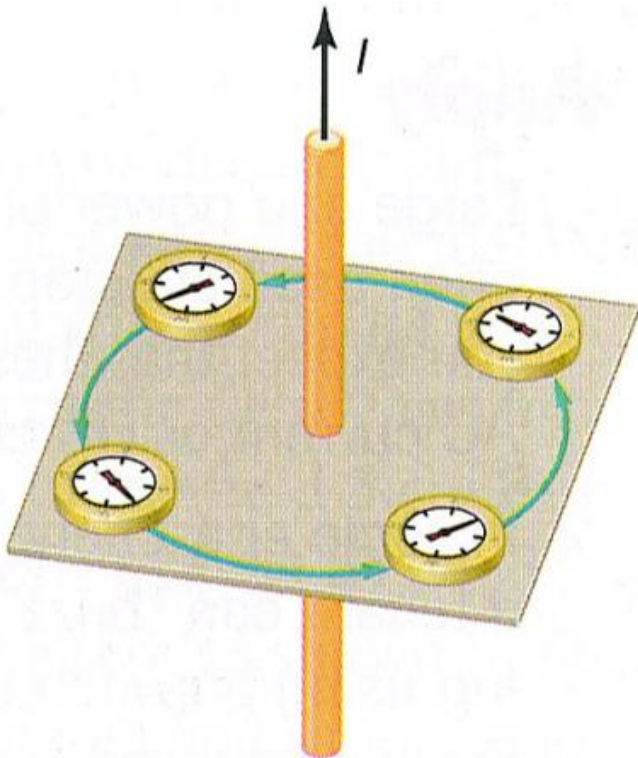
2. Magnetic field lines form **concentric circles** around the wire (**closed loops**)
- a. Strength of magnetic field is **proportional** to the **current**
 - b. Strength of field varies **inversely** with the **distance** from the wire



3. First right-hand rule- *allows you to find the direction of the field around a wire*

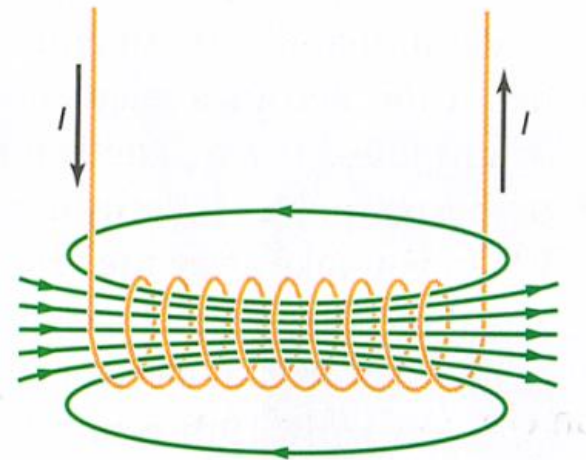
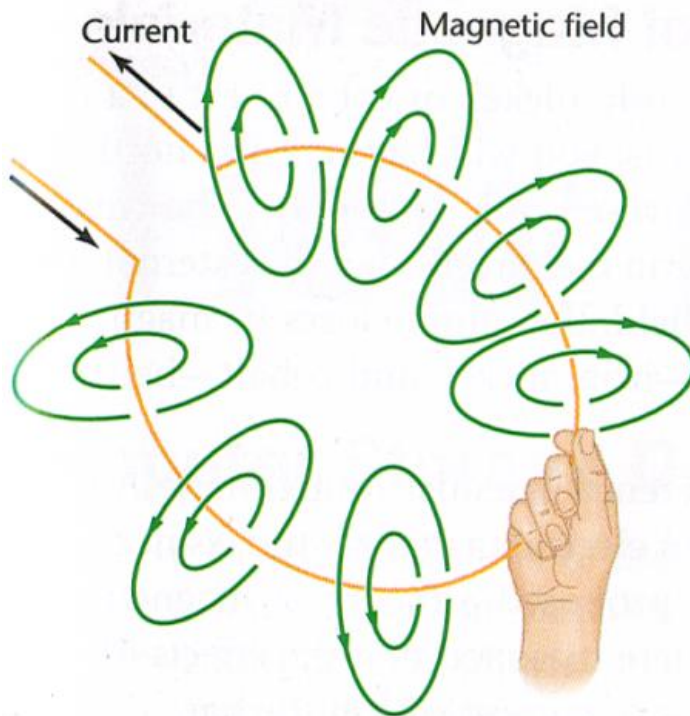
a. Thumb points in **direction of conventional current (+ flow)**

b. Fingers of hand **circle** the wire and point in **direction of magnetic field**

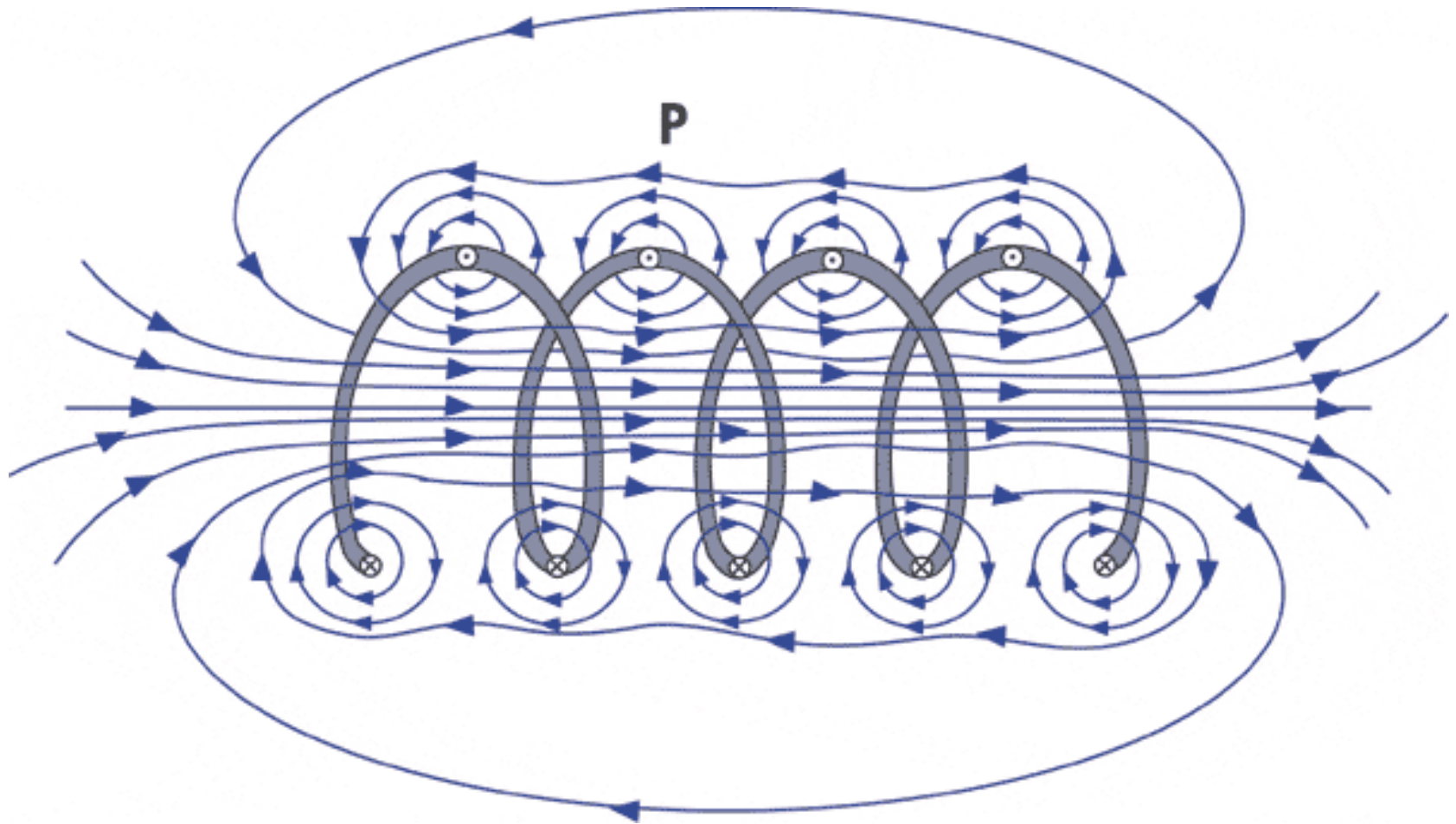


C. Magnetic field near a coil

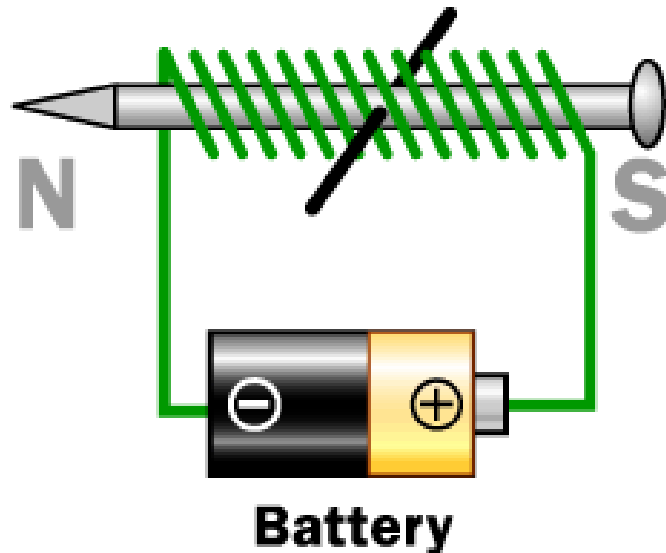
- 1. An electric current in a single circular loop of wire forms a magnetic field all around the loop*
- 2. When wire looped several times to form a coil and current is allowed to flow- **field** around all the loops is always in **same direction***



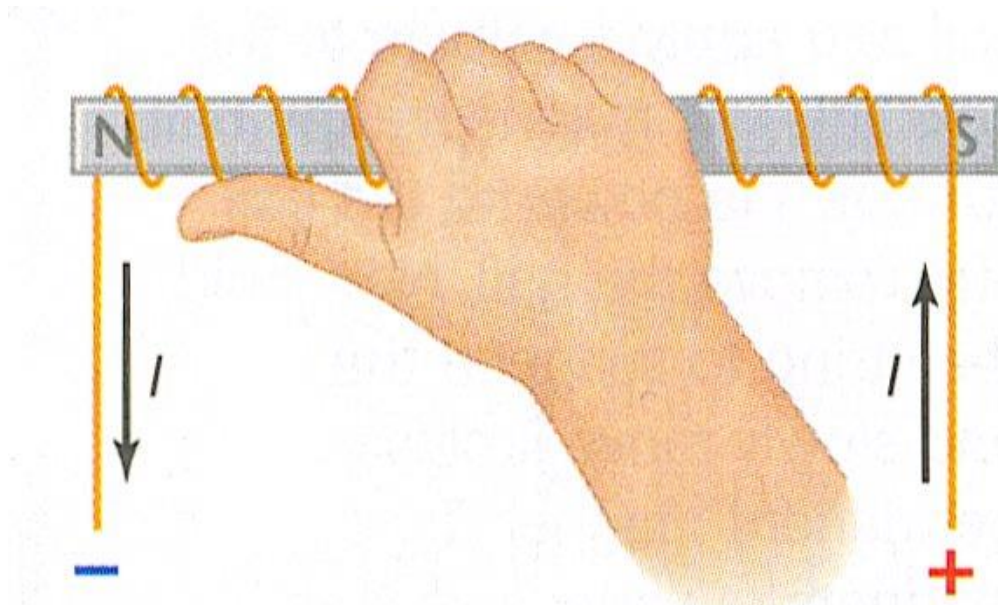
- a. **Solenoid-** *long coil of wire with many loops*
- b. Field of each loop **adds** to fields of other loops



3. Electric current in a coil of wire has a field like that of a **permanent magnet** (has N and S poles)
- called an ***electromagnet***
 - Strength of field is **proportional** to **current** in coil
 - Can increase strength by placing an iron rod inside the coil. The field inside the coil magnetizes the core. These add together



4. **Direction of field** produced by electromagnet can be found using the ***second right-hand rule***
- Imagine holding insulated coil with you right hand
 - Curl fingers around loops** in the **direction** of the **conventional current** (+ flow)
 - Thumb points toward the N-pole** of the electromagnet



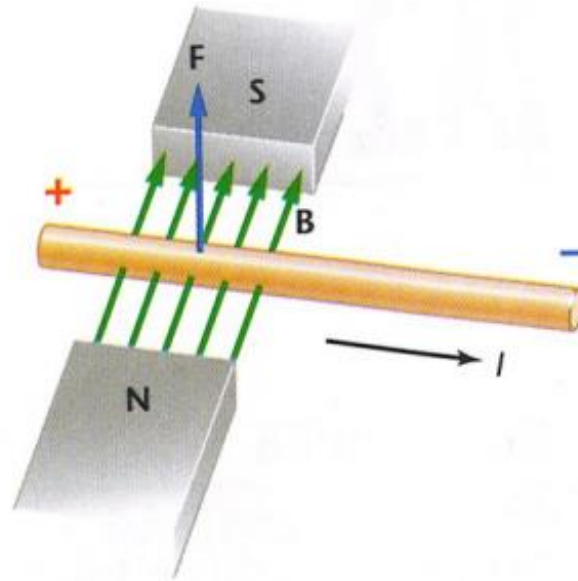
IV. Forces Caused by Magnetic Fields

A. Forces on currents in magnetic fields

1. Michael Faraday (mid 1800's)

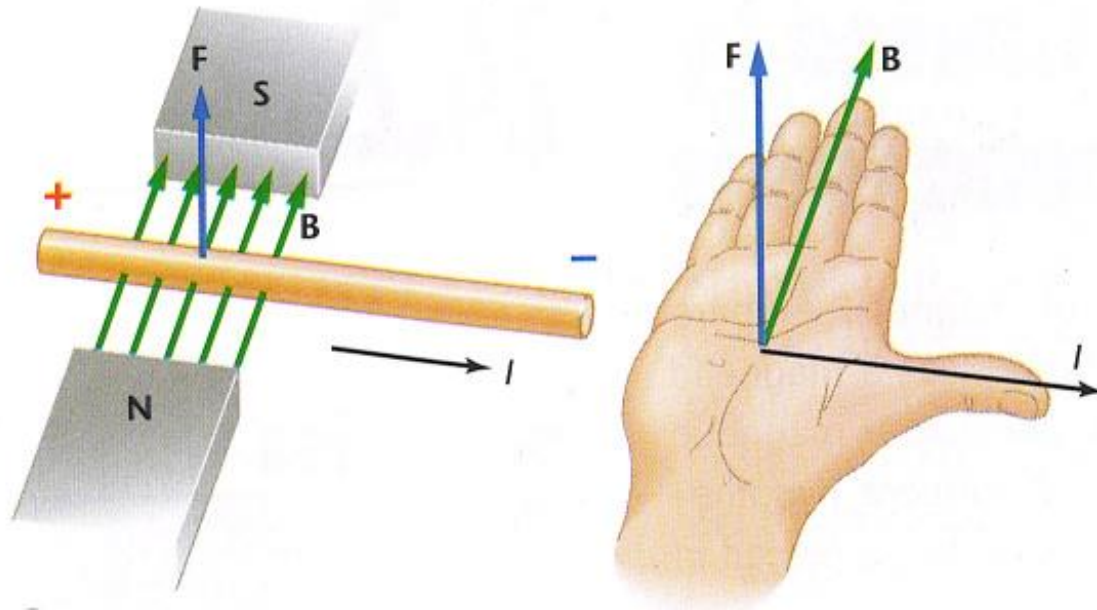
discovered that the **force** on a wire is at **right angles** to the **direction** of the **magnetic field**.

2. **Force** is also at **right angles** to the **direction** of the **current**



B. Use **third right-hand rule** to determine **direction of force**

1. Point fingers of right hand in direction of magnetic field.
2. Point thumb in direction of conventional (+) current
3. Palm of hand points in direction of force acting on the wire

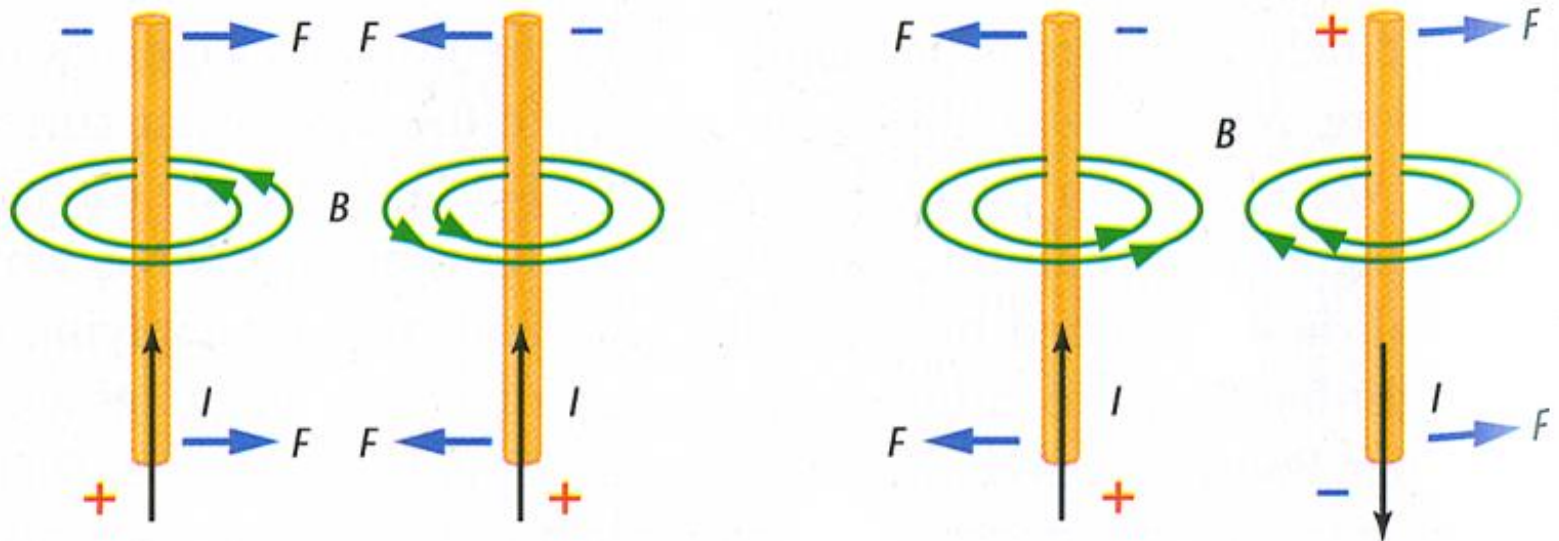


C. Magnitude of force (F) on wire is proportional to 3 factors

1. The strength of field (**B**)
2. The current (**I**) in the wire
3. The length (**L**) of the wire that lies in the magnetic field

Equation:
$$F = BIL$$

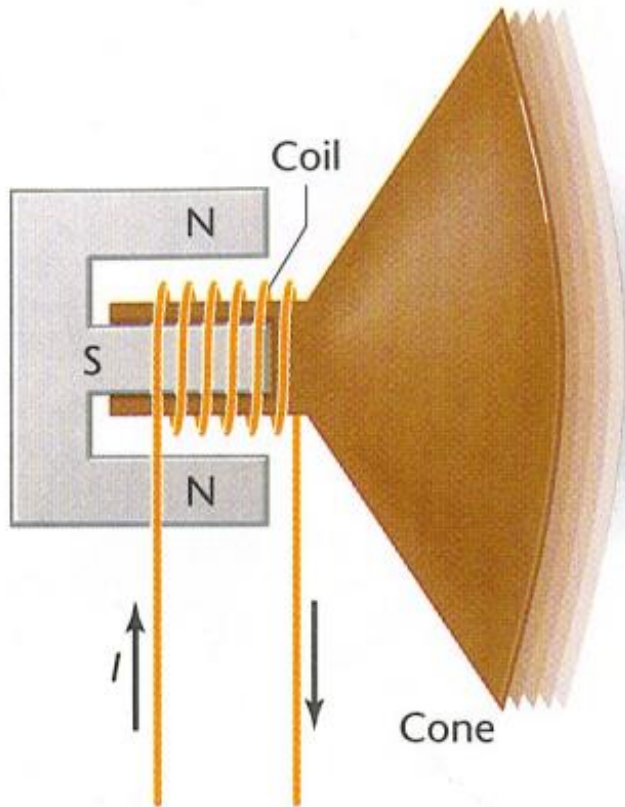
Measured in teslas (T) $1 T = 1 N/A \cdot m$



V. Applications of Magnetic Force

A. Loudspeakers

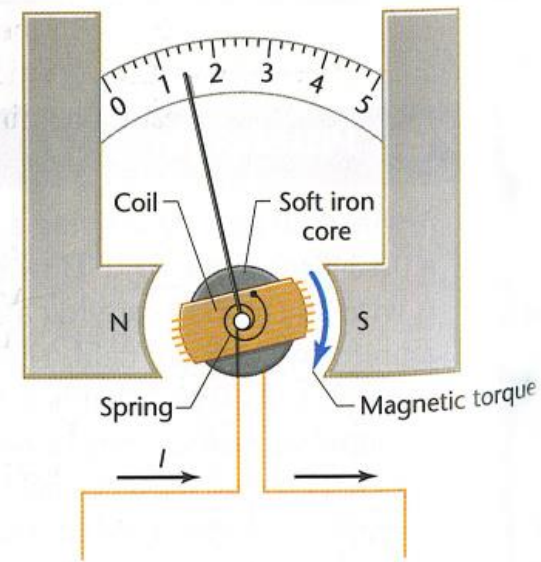
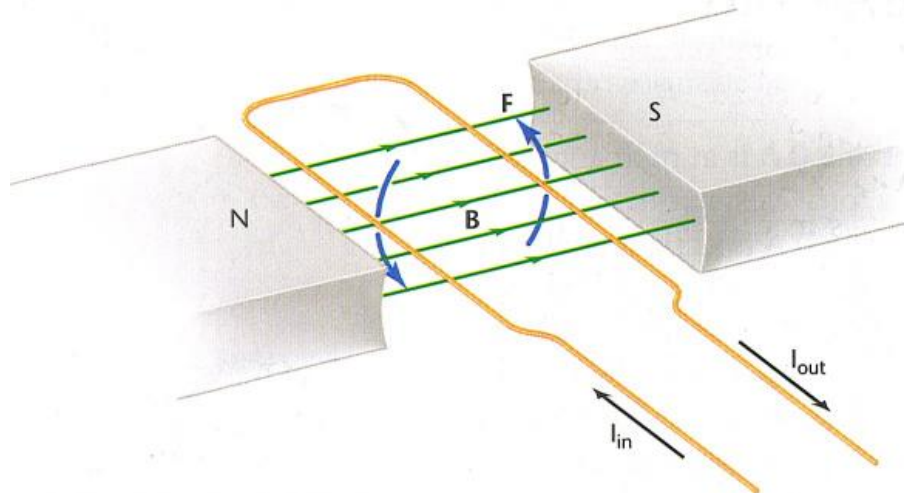
1. Changes **electrical** energy into **sound** energy
2. Uses a coil of fine wire mounted on a paper cone and placed in a magnetic field
3. Amplifier driving loudspeaker sends **current** through the **coil**
4. The **current changes direction** between 20 and 20,000 times each second, depending on the pitch of the tone it represents.



Force, exerted on the coil because it is in a magnetic field, **pushes** the coil either **into** or **out of the field**, depending on the **direction** of the **current**. This **oscillation** of the **coil** causes the **cone to vibrate**, creating **sound waves** in the air.

B. Galvanometer

1. Device used to **measure** very **small currents**
2. Used in **voltmeters** and **ammeters**.
3. A small loop of current carrying wire is placed in a strong magnetic field
4. One **side of loop forced down** and the **other side is forced up** (third right-hand rule)
5. **Magnitude of torque** acting on the loop is **proportional** to the **magnitude of the current**
6. A small spring in the galvanometer exerts a torque that opposes the torque resulting from the current; thus, the amount of rotation is proportional to the current



C. Electric Motor

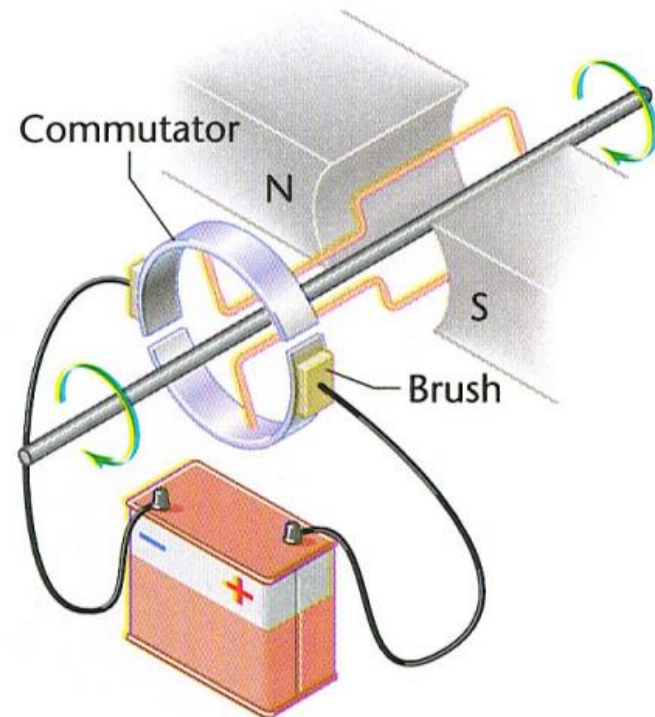
1. Apparatus to **convert electrical energy to kinetic energy**

2. **Must rotate 360°**, therefore the current must **reverse direction** just as the loop reaches its **vertical** position- allowing it to continue rotating.

a. To reverse direction, a split-ring **commutator** is used

b. **Brushes** (pieces of graphite) make contact with the commutator, allowing current to flow into the loop

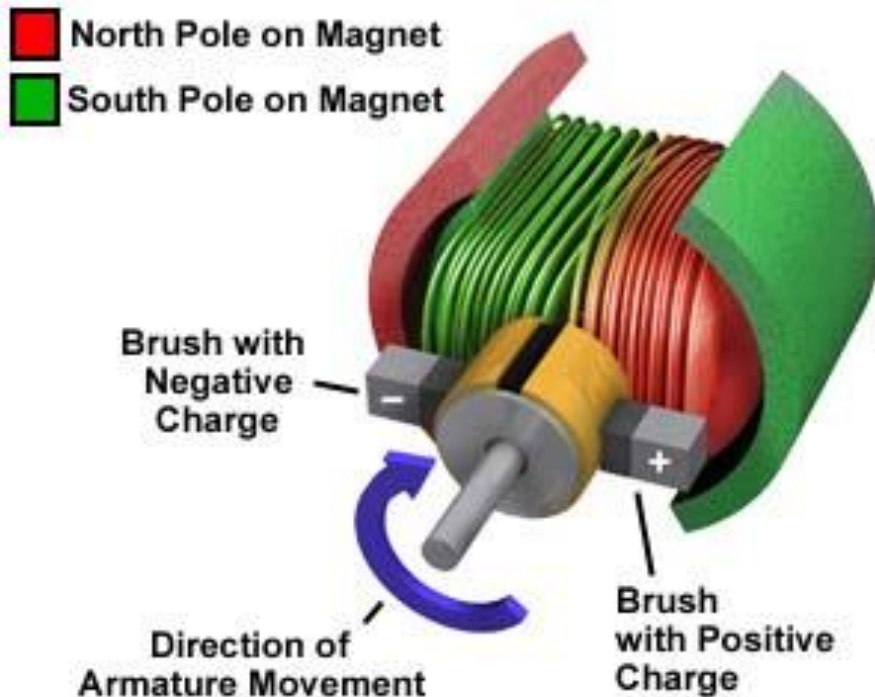
c. The split ring is arranged so that each half of the commutator changes brushes just as loop reaches vertical position.



d. Changing brushes reverses current in the loop- resulting in changing of forces acting on the loop- allowing loop to continue to rotate

e. **armature**- many loops of wire mounted on a shaft in electric motor. Total force proportional to $nBIL$

(n = total turns on armature, B is strength of magnetic field, I is the current, and L is length of wire in each turn that moves through the magnetic field)



D. The Force on a Single Charged Particle

1. Charged particles do not have to be confined to a wire, but can move in any region as long as the air has been removed to prevent collisions with air molecules
2. The picture tube (or cathode ray tube) in a TV uses electrons deflected by magnetic fields to form the pictures to be viewed.
 - a. In the tube, electrons are pulled off of atoms by electric fields at the negative electrode, or cathode.
 - b. Other electric fields gather, accelerate, and focus the electrons into a narrow beam.
 - c. Magnetic fields are used to deflect the beam back and forth and up and down across the screen of the tube.
 - d. The screen is coated with a phosphor and glows when struck by the electrons, producing the picture

