Intro to Magnetism

A little history…

- Until the early 19th century, scientists thought electricity and magnetism were unrelated
- In 1820, Danish science professor Hans Christian Oersted was demonstrating electric currents in front of a class of students
- When electric current was passed in a wire near a magnetic compass, the compass needle moved!

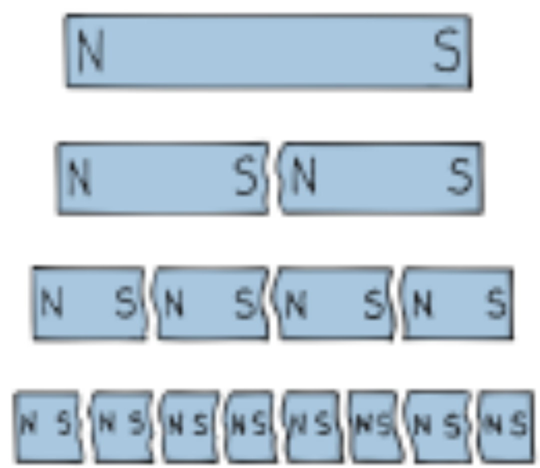
Electricity and Magnetism are related!

Comparing Electricity & Magnetism

- Magnets exert forces on one another
- Similar to electric charges:
  - Can attract and repel without touching
  - Strength of force depends on the distance between the two magnets
- Different from electric charges:
  - Electric charges produce electrical forces
  - Regions called magnetic poles produce magnetic forces

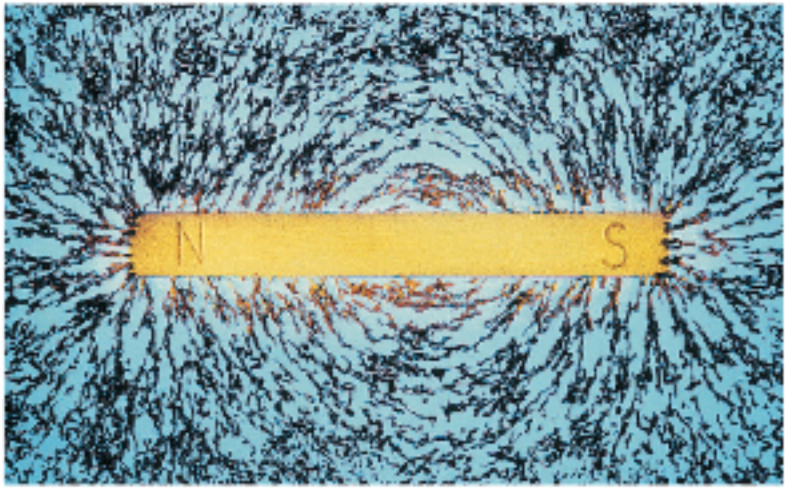
Magnetic Poles

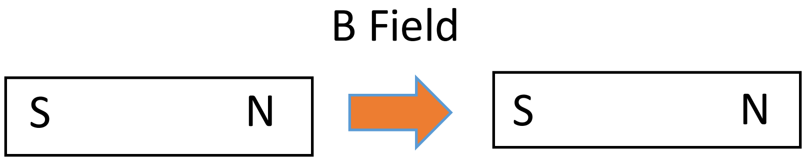
- All magnets have both a north and a south pole
- Like poles repel
- Opposite poles attract
- Magnetic poles always exist in pairs



Magnetic Fields (B fields)

- <u>Magnetic Field (**B**)</u>: The space around a magnet in which a magnetic force is exerted.
  - Measured in units of Tesla – T
  - Magnetic Field is a VECTOR (has magnitude and direction)
- The direction of the magnetic field outside a magnet is **<u>from the north pole to the south pole.</u>**
  - Magnetic field lines point AWAY from north poles and INTO south poles.

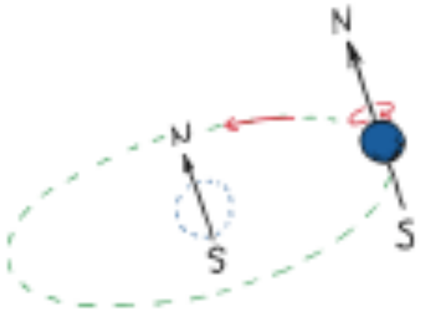




How are Electricity & Magnetism related?

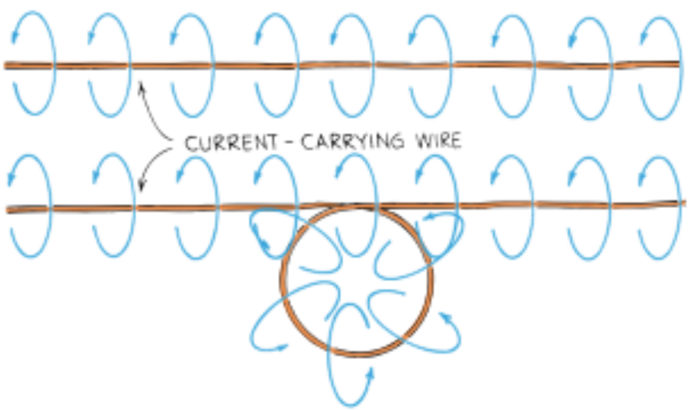
Moving electric charges create magnetic fields.

- Charges in motion have both E (electric) fields and B (magnetic) fields associated with them.
- In a bar magnet, electrons inside are constantly moving.
- Microscopic currents create permanent magnets. The current is caused by the electrons orbiting the nuclei. All of the nuclei need to be aligned to produce a net magnetic field.
- Moving charge (also called current) create magnetic fields!

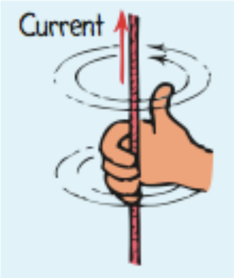


Electromagnets

- If a current carrying wire is bent into a loop, the magnetic field lines become bunched up inside the loop
- A current-carrying coil of wire with many loops is an <u>electromagnet.</u>



Ampere's Law



- We can calculate the magnitude (size) of the magnetic (B) field create by a single current carrying wire using **Ampere's Law**.

$$\boxed{B = \frac{\mu_0 I}{2\pi r}}$$

- B = magnetic field [T]
- μ_0= permeability constant = $4\pi \times 10^{-7}$ [Henrys/m]
- I = current [A]
- r = distance from center of wire [m]

The Right Hand Rule (Part I)

- Ampere’s law helps us find the size (or magnitude) of the magnetic field.
- Since magnetic field is a vector, it also needs to have direction
- We can find the direction of the magnetic field using the **“Right Hand Rule.”**

<u>**Right Hand Rule Instructions:**</u> *Straight Wire*

- To find the direction of the magnetic field in a straight wire, point the thumb of your **right** hand in the direction of current flow.
- Your fingers point in the direction of the magnetic field.

Notation:

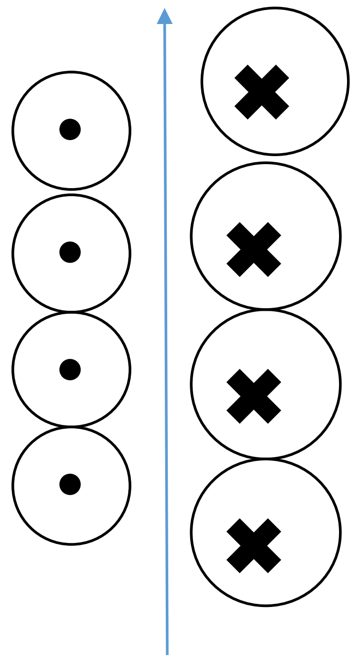
$\odot$ Coming out of the page

$\otimes$ Going into the page

Right Hand Rule Example:

Your thumb follows the current, so you point your thumb up. The fingers on your right hand curl into the page on the right side of the wire and out of the page on the left side of the wire. This is the direction of the magnetic field.

We represent the direction of the magnetic field like this:



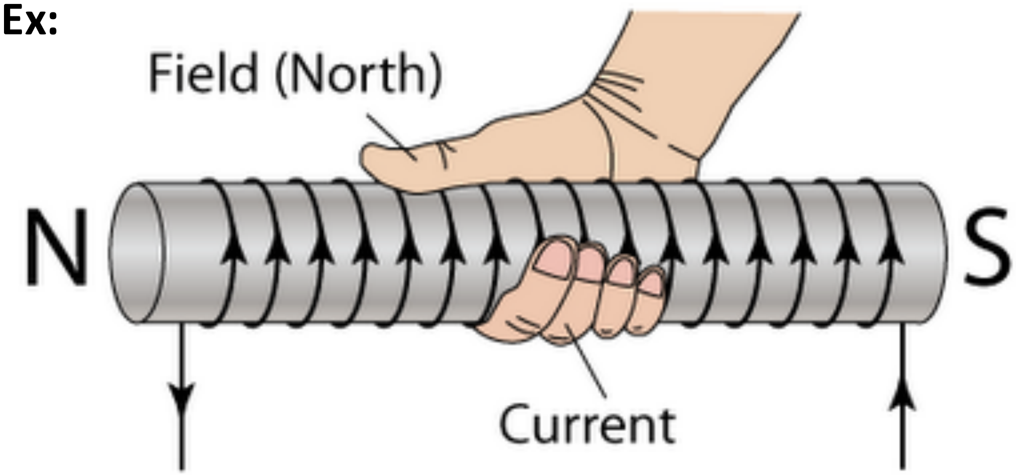
The Right Hand Rule (Part II)

- If we want to find the direction of the magnetic field in a curled wire, we switch the roles of our thumb and fingers.

Right Hand Rule Instructions: *Curled (or coiled) Wire*

- To find the direction of the magnetic field in a coiled wire, point the fingers of your **right** hand in the direction of current flow.
- Your thumb point in the direction of the magnetic field.

Ex:

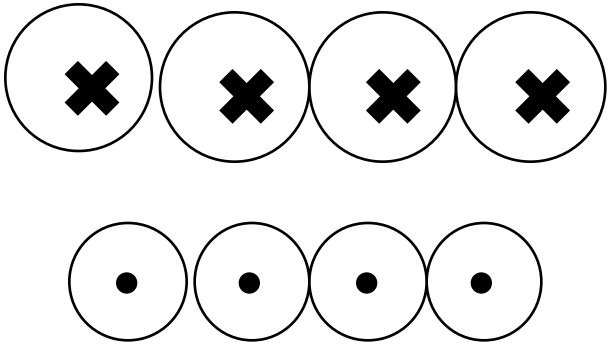


The current is represented by the black arrows. Wrap your fingers in the direction of the arrows, and you find that your thumb points to the left. That is the direction of the magnetic field.

The Right Hand Rule Practice

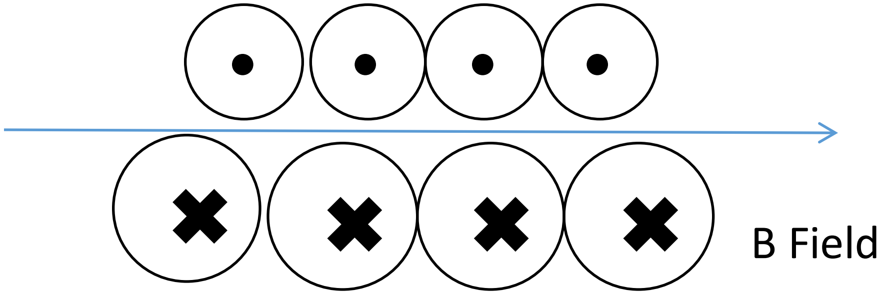
- What is the direction of the magnetic field in this wire?

- What is the direction of the magnetic field in this coil or wire?



ANSWERS

- What is the direction of the magnetic field in this wire?



The magnetic field points INTO the page below the wire and OUT of the page above the wire.

- What is the direction of the magnetic field in this coil of wire?