Magnetism is caused by moving charges.

**Permanent**
- Fridge magnets, N, S
- Hard - hard to become magnetized but keeps magnetic properties for a long time
  - Ex: fridge magnets, N, S
- Soft - easy to become magnetized but keep magnetic properties for a short time
  - Ex: paperclip, nail (iron things)

**Magnetic domains**
- Groups of similar spinning electrons

- Magnetized domains are lined up
- Not magnetized

**Poles**
- North (+)
- South (-)
- Like poles repel
- Opposites attract

**No such thing as a monopole**

**Magnetic fields (B)**
- Space surrounding a magnetic body that influences other magnets, moving charges
- Arrows drawn from north to south

**Electromagnets**
- Current carrying wire

- Moving charges create magnetic fields (B)

**Numerically how big is the B field from a current carrying wire?**

**Amperes’ Law**
- \( B = \frac{\mu_0 I}{2\pi r} \)

- \( \mu_0 = \text{Permeability of Free Space} \)
  - \( \mu_0 = 4\pi \times 10^{-7} \ T/\text{A} \)

- Units of B-field: A/T

- Gauss [G] = 1 T = 10^4 G

**B-field are vectors!!!**

We must use the right hand curl rule to determine the direction of the B field from a current carrying wire.

- Hold on Spencer

- Grab current carrying wire with right hand
- Point thumbs in direction of current
- Fingers curl in direction of B

**Ex: 1**
- A, i
- B
- \( B = \frac{\mu_0 I}{2\pi r} \)

**Ex: 2**
- I
- B
- \( B = B_0 + B_A + B_N \)

**Ex: 3**
- Loop of wire
- Only worry about inside of loop
**\( \mathbf{B} \) FIELDS EXERT FORCES ON MOVING CHARGES**

\[
\mathbf{F} = q \mathbf{v} \times \mathbf{B}
\]

- **\( F \)** - Force exerted \([N]\)
- **\( q \)** - Amount of charge moving \([C]\)
- **\( v \)** - Velocity of charge \([m/s]\)
- **\( \mathbf{B} \)** - Strength of field \([T]\)
- **\( \theta \)** - Angle between \( v \) and \( \mathbf{B} \) \([^\circ]\)

For maximum amount of force, we want the charged particle to travel \( \perp \) to the \( \mathbf{B} \) field.

\[
\sin 90^\circ = 1 \\
\sin 0^\circ = 0 \\
\sin \theta = \sin \theta
\]

If one moving charge experiences a force in a \( \mathbf{B} \) field, then many moving charges will also experience a force in a \( \mathbf{B} \) field.

**CURRENT (I)**

\[
\mathbf{F} = \mathbf{B} \mathbf{I} \mathbf{R} \sin \theta
\]

- **\( F \)** - Force on wire \([N]\)
- **\( I \)** - Current in wire \([A]\)
- **\( R \)** - Length of wire \([\text{m}]\)
- **\( \theta \)** - Angle between \( I \) and \( \mathbf{B} \) \([^\circ]\)

What about the direction of the force?

- We must use the other right-hand rule:

\[\text{RT HAND} \rightarrow \text{charge} \\
\text{LT HAND} \rightarrow \text{current} \]

\[
E_\perp = \frac{m \mathbf{v}^2}{2} - \frac{q \mathbf{B}^2}{2}
\]

\[
E = \frac{1}{2} m \mathbf{v}^2 - \frac{q \mathbf{B}^2}{2}
\]

\[
E = \frac{q \mathbf{v} \cdot \mathbf{B}}{2}
\]

**BUBBLE CHAMBER - MASS SPECTROMETERS**

Charged particles can be separated by mass, speed, and charge.

\[
r = \frac{m \mathbf{v}}{q \mathbf{B}}
\]
FORCE BETWEEN 2 CURRENT CARRYING WIRES

\[ F = BI \ell \]
\[ B = \frac{M_0 I}{2\pi r} \]

\[ F_A = B_B I_A \ell \quad B_B = \frac{M_0 I_B}{2\pi r} \]

\[ F_A = \frac{M_0 I_B I_A \ell}{2\pi r} \]

ATTRACT OR REPEL

\[ \text{ATTRACT OR REPEL} \]
**Oersted - Electrical currents produce magnetic fields**

Faraday & Henry: "Magnetic fields" could produce electric fields (voltage)

Changing magnetic fields = Flux "What the flux?"

**Induced EMF (E or V) → Voltage**

- Close switch (Turn on) → Ammeter jumps
- Leave switch closed → Ammeter back to zero
- Open switch → Ammeter jumps opposite way then back to zero

**Magnetic Flux (Φ) - Strength of the B field through an area**

- \( \Phi = B \cdot A = BA \cos \theta \)
  - Special unit: Weber [Wb]

- \( B \) = Strength of field [T]
- \( A \) = Area of loop [m²] * Inside of loop, always!
- \( \theta \) = Angle between \( B \) & normal line of loop

Max flux

**A change in flux (ΔΦ) results in an induced EMF (E → V)**

1. Change area (ΔA)
2. Change \( B \) strength (ΔΦ)
3. Change \( \theta \) (ΔΔ)

If one or all these things happen, how much EMF (E → V) will be produced?

**Faraday's Law of Induction**

\[ E = N \frac{\Delta \Phi}{\Delta t} \]

- \( E \) = EMF or Voltage induced
- \( N \) = # of loops
- \( \Delta \Phi \) = Change in flux
  - \( \Phi_2 - \Phi_1 = B \cdot A \cdot \cos \theta_2 - B \cdot A \cdot \cos \theta_1 \)
WHAT DIRECTION WILL INDUCED CURRENT FLOW?

LENZ’S LAW – CURRENT WILL BE INDUCED IN THE LOOPS TO MAKE FLUX \( \text{FLOW TO OPPPOSE THE CHANGE IN FLUX} \) (USE RIGHT HAND CURL RULE)

MAKING A "BATTERY" \( \mathcal{E} \) FROM A MOVING ROD

MOTIONAL EMF \( \Rightarrow \) VARIOUS EQUATIONS

IN THE END, WE WILL END UP WITH \( \mathcal{E} = BLv \)

1st DERIVATION OF \( \mathcal{E} = BLv \)

Equilibrium
\[
\mathcal{E} = \mathcal{E}_x = B_x v = B_L v
\]

2nd DERIVATION OF \( \mathcal{E} = BLv \)

\[
\mathcal{E} = \frac{d\Phi}{dt} = \frac{B dA (\cos \theta)}{dt} = \frac{B dV}{dt} = BVL = BLv
\]

NOTE: ADDITIONAL WRENCH

FORCE TO PULL ROD OUT AT A CONSTANT SPEED IS \( F = BIL \)
**Transformers** - is a device to increase (step up) or decrease (step down) AC voltage.

**Step Up Transformer**
- AC Voltage Source
- **Primary Coil**: 6 turns
- **Secondary Coil**: 12 turns

**Step Down Transformer**
- AC Voltage Source
- **Secondary Coil**: 6 turns
- **Primary Coil**: 12 turns

\[
\frac{V_1}{n_1} = \frac{V_2}{n_2}
\]

- \(V_1\) - Voltage of Primary
- \(V_2\) - Induced Voltage of Secondary
- \(n_1\) - # of turns in Primary/Source side
- \(n_2\) - # of turns in Secondary side

You can't get something for nothing → \(N_{\text{in}} = N_{\text{out}}\)

Power Primary = Power Secondary

\[I_1V_1 = I_2V_2\]
MAKE SURE AMPLIFICATION IS FLIPPED TO HIGH

THE WHITE DOT ON THE SENSOR SHOULD HAVE A FIELD COMING OUT OF IT