**ELECTROMAGNETISM**

**Magnetism**
- Magnets are **dipole**
  - Dipole → has two poles (north and south)
  - Like poles repel, opposites attract
  - If you break a magnet in half, you will end up with two dipole magnets.

- **Magnetic Domains**
  - Spinning e\textsuperscript{-} create magnetic fields.
  - Usually e\textsuperscript{-} are paired up and the magnetic fields cancel. These are not magnetic materials (i.e., wood, plastic, etc.)
  - **Ferromagnetic** materials → e\textsuperscript{-} spins don’t completely cancel out (i.e., iron cobalt, nickel).
  - **Magnetic Domain** → a group of atoms whose spins are aligned in the same dir’n.

![Magnetic Domains Diagram](image)

- Some materials can be made into magnets by being in the presence of a magnetic field.
  - **Permanent magnets** → stay magnetized after the field is removed.
  - Magnetism can be removed by heating/cooling or hammering the magnet (domains are shaken out of alignment).

**Magnetic Fields**
- Magnetic force is an action at a distance force.
  - A **magnetic field** (B) surrounds a magnetized material.
  - Magnetic field lines flow from the north to the south pole.
  - Unit of measurement: **Teslas** (T)

![Magnetic Fields Diagram](image)

- Earth’s magnetic field acts like there’s a bar magnet in the middle of the planet.
  - The geographical North pole is a magnetic south pole
  - The geographical South pole is a magnetic north pole
- Magnetic Flux ($\Phi$) measures the strength of the magnetic field.

$$\Phi = AB$$

- $A =$ area
- $B =$ magnetic field

**Magnetism and Electricity**

- 1820 → Hans Oersted discovers that a current-carrying wire made a compass move.
- A long, straight, current-carrying wire has a cylindrical magnetic field.
- Right Hand Rule

**Example 1**: The magnetic field shown below is due to the horizontal, current-carrying wire. Which dir’n does the current flow?

- **Ampere’s Law**
  - Finds the magnetic field generated by a long, straight wire.

$$B = \frac{\mu_o I}{2\pi r}$$
- **B** → Magnetic Field (T)
- **I** → Current (A)
- **μ₀** → Permeability of free space (*a constant*) = $4\pi \times 10^{-7}$ Tm/A
- **r** → distance from the wire (m)

**Example 2:** Find the magnetic field at a distance of 1 m from a long, straight wire carrying a current of 1 A.

- **Solenoid** → a long straight wire bent into a coil of several closely spaced loops.
  - There is a strong, *uniform*, field inside the solenoid.
  - Almost zero magnetic field outside the solenoid.

- When used as an electromagnet, it provides a strong field that you can turn on and off.
- Putting a ferromagnetic rod in the middle increases the B field.
- Uses in medicine: MRI
- **Magnetic field of a solenoid:**

  $$ B = \mu_0 \left( \frac{N}{L} \right) I $$

- **N** = number of loops
- **L** = length of solenoid

**Example 3:** A solenoid is 20.0 cm long, has 200 loops and carries a current of 3.25 A. Find the strength of the magnetic field inside the solenoid.
**Electromagnetic Induction**

- A changing magnetic field induces an electrical current.
- **Faraday’s Induction Law** → Induced EMF is proportional to the area of the loop penetrated perpendicularly by the field.
  
  - EMF → Electromotive force
  - Induced EMF (ε) = voltage
  - Measured in volts (V)
  - ε is proportional to magnetic flux

  \[
  \varepsilon = -\frac{\Delta \Phi}{t}
  \]

- Each coil in a wire will experience an induced EMF
  
  - So as you add coils (N = number of coils)

  \[
  \varepsilon = -N\left(\frac{\Delta \Phi}{\Delta t}\right)
  \]

- Derived mostly from observations, since Faraday had very little formal schooling.

**Example 4:**

A circular flat coil of 200 turns of wire encloses an area of 100 cm\(^2\). The coil is immersed in a uniform perpendicular magnetic field of 0.50 T that penetrates the entire area. If the field is shut off so that it drops to zero in 200 ms, what is the avg induced emf? Given that the coil has a resistance of 25 Ω, what current will be induced in it?

- **Lenz’s Law** → The induced emf will produce a current that always acts to oppose the change that originally created it.

**Motional EMF**

- If you have a moving charge (like through a wire), the magnetic force is found with:

  \[
  F_M = q\nu B
  \]

  - \(F_M\) = magnetic force (in Newtons)
AC/DC

- 1831 → Faraday creates the first electric generator.

- As long as the rotation of the disk is kept steady, a continuous current was supplied to the load.
  ➢ A DC generator
  ➢ Also called a dynamo
- **Direct Current (DC)** → current moves in only one direction and the magnitude of the current remains largely constant.
  ➢ Large electric motors use a DC current
  ➢ Electric railways (subways and trolleys)
  ➢ Batteries
- **Alternating Current (AC)** → A current that reverses direction at regular intervals and varies in magnitude.
  ➢ Terminals in an AC circuit have no fixed polarity. They switch between being + and −.
  ➢ The e flow back and forth through the circuit, essentially oscillating in place at some frequency.
  ➢ AC is the dominant form of current.

**AC/DC War**

- AC was led by Tesla and backed by industrialists.
  ➢ Higher voltage
- DC was led by Edison, his former employer.
  ➢ Lower voltage
- AC ends up being the dominant form of current due to one major factor: POWER LINES.
- A lower current will reduce the amount of power lost.
  ➢ $P = I^2 R$
  ➢ Also $P = IV$, or $I = P/V$
  ➢ As voltage goes up, current goes down, and so does the power lost to heat due to resistance.
- **Transformer** → changes energy in the form of a large current and low voltage into nearly the same amount of energy in the form of a low current at a higher voltage.
  - **Step up transformer** → voltage increased, current decreased.
  - **Step down transformer** → voltage decreased, current increased.
- If the number of loops in the secondary coil is less than the number of loops in the primary, the voltage is stepped down.
  - If the reverse is true, voltage is stepped up.

\[
\frac{V_p}{V_s} = \frac{N_p}{N_s}
\]