Contents of MTE2

- Work of the electric force and potential energy
- Electric Potential and Field
- Capacitors and capacitance
- Current and resistance, Ohm’s law
- DC Circuits and Kirchhoff’s laws
- RC circuits
- Lorentz force and motion of charge in a magnetic field
- Biot and Savart
- No Ampere’s law, No magnetic properties of matter
- Study chapters 27-32 (no 32.6, 32.10, no 32.8 forces between wires)

MTE2 Wed 26, at 5:30-7:00 pm
Ch2103 and SH 180

Alternate Exams will be:
Wed 26
2:30-4:00pm Lab room (Ch 3254)
6:00-7:30pm Lab room (Ch 3254 )

This week Honor Lecture

- Susan Nossal: Climate change

Earth’s A Magnet!

- N geographic pole almost at magnetic S pole
- S geographic pole almost at magnetic N pole

Electric vs Magnetic Field Lines

- Similarities
  - Density gives strength
  - Arrow gives direction
  - Leave +, North
  - Enter -, South

- Differences
  - Start/Stop on electric charge
  - No Magnetic Charge => lines are continuous!

Magnetic Fields

- A vector quantity (B)
- Compass needle traces B field lines and points towards N
- B-field lines start in N and go to S
- They do not start or stop (no magnetic monopoles
- Iron filings show pattern of B-field lines

Electric dipole

- The N pole of a compass needle is attracted toward the geographic N pole (S pole of the B-field)
Charged particle in a B-field: Lorentz force

The magnetic force acts only a moving charged particle

Units: \( N = C \times m/s \times \text{Tesla} \)

\[ F_B = |q|vB \sin \theta \]

- \( F \) is zero when \( v \) and \( B \) are parallel or antiparallel
- \( F \) is a maximum when \( v \) and \( B \) are perpendicular

Effect of uniform magnetic field

- Effect of uniform B-field on charged particle
  - If charged particle is not moving - no effect
  - If particle is moving: force perpendicular to both field and velocity
  - the charge sign must be accounted for

Magnetic Force and Work

Magnetic force perpendicular to the particle displacement

- the magnetic force does not do work!
- B field can alter direction of velocity, but not the speed or the kinetic energy

Quick Quiz

The three charges below have equal charge and speed, but are traveling in different directions in a uniform magnetic field.

Which particle experiences the greatest magnetic force?

A)  B)  C)  D) Same

Cyclotron Motion

- \( F \perp v \) and \( B \)
- particle path is a circle of radius \( R \).
- \( a = v^2/R \) is the centripetal acceleration
- \( R \) depends on \( m, q, v, B \)

In how much time does the particle complete an orbit?

\[ F = qvB \]
\[ F = ma \]

\[ qvB = m \frac{v^2}{R} \]
\[ \omega = \text{angular velocity} = \frac{v}{R} = \frac{qB}{m} \]

\[ \omega = \frac{2\pi}{T}, \quad T = \text{period} = \frac{2\pi m}{qB} \]

Mass spectrometer and v selector
Calculation of Torque
- Square loop has width \( W \) and length \( L \) (into the screen). The torque is given by:
\[
\tau = \frac{1}{2} \omega L = \text{area of loop}
\]
- Note: if loop consists of \( N \) turns, \( \mu = N A I \)

Homopolar motor
- A homopolar motor has a B-field along the axis of rotation and an electric current produced by the battery that moves radially through the magnet.
- The resulting Lorentz force in the tangential direction produces a torque in the magnet, which is free to rotate with the attached screw. The name homopolar refers to the absence of polarity change.
\[
F_{p} = I/L \times B
\]

Torque on a current loop
- Consider current loop in magnetic field perpendicular to the plane of the loop \( \Rightarrow \) Zero net force
- Force on top path cancels force on bottom path \( (F = IBL) \)
- Force on right path cancels force on left path \( (F = IBL) \)

If plane of loop is not \( \perp \) to B-field, there is a torque on the loop (force couple as for electric dipole in E-field)

Potential Energy of Magnetic Dipole
- Work must be done to change the orientation of a dipole (current loop) in the presence of a magnetic field.
- Define a potential energy \( U \) corresponding to this work \((U=0 \text{ when magnetic dipole moment orthogonal to B-field}) = \text{equilibrium position corresponding to max torque})\)
\[
U = -\mu \cdot B
\]
Quick Quiz

Which configuration has the greatest potential energy?

- \( \tau = 0 \)  
  \( U = -\mu B \)

- \( \tau = \mu B \)  
  \( U = 0 \)

- \( \tau = 0 \)  
  \( U = \mu B \)

A) B) C)

Surprise!  Electric current produces magnetic field

- Current (flow of electric charges) in wire produces B-field.
- The magnetic field aligns compass needle
- 2 kinds of magnetism due to permanent magnets and currents or the same?

Current  Magnetic field

1819 Hans Christian Oersted

Magnetic field from a current

Iron filings align with magnetic field lines

Magnetic field loops around the current. (Right hand rule)

Current loop as magnetic dipole

A current loop is an electromagnet: it behaves like a permanent magnet. Two current loops with current in the same direction attract like 2 magnets (since the opposite poles are closer)

Biot-Sarvart Law

For a single charge in motion

For a wire with current

At the center of the loop:

Field from a circular loop

At the center of the loop:

\[
\begin{align*}
\text{For a single charge in motion:} \\
B &= \frac{\mu_0 q v \times u_r}{4\pi r^2} \\
\text{For a wire with current:} \\
B &= \frac{\mu_0 I d\ell}{4\pi R^2} \\
\text{At the center of the loop:} \\
B &= \frac{\mu_0 I}{4\pi R} \int \frac{d\ell}{2R} \\
\mu_0 &= 4\pi \times 10^{-7} \text{Tm} / \text{A} = 1.257 \times 10^{-6} \text{Tm} / \text{A}
\end{align*}
\]
- Happy spring break to all!