E fields-capacitors

Parallel plate capacitors: Positive charges moving horizontally at velocity v, will accelerate vertically down, consistent with Newton's 2nd Law, due to the electric force in the downward direction.

\[ E = \frac{V}{d} \]

\[ q = \frac{CV}{d} \]

\[ x = \frac{vt}{2} \]

\[ s = \frac{d}{2} \]

\[ F = qE = \frac{qCV}{d} \]

\[ m \frac{dv}{dt} = qE \]

\[ v(t) = \frac{qCV}{md} \]

Magnetic Field

Right-Hand-Rule 1:

Direction of the resultant force is determined by using first right hand rule: Point all fingers in B direction, thumb in v direction, then palm will face direction of force.

\[ F = qv \times B \]

\[ F = q(v \sin \theta)B \]

\[ F = q(v \sin \theta)B \]

Note: For magnetic field representation, use

- Field out of page
- Field into page

Magnetic Field

Thumb Rule/Corkscrew rule:

Determine the direction of the resultant force for the following cases:

- i) v and B into page
- ii) v into page, B out of page
- iii) v out of page, B to the right
- iv) Field out of page
- Field into page

Note: For magnetic field representation, use

- Field out of page
- Field into page

Negative charge accelerates downward.
Magnetic-Electric Forces

Charge in Crossed Electric and Magnetic Fields:

Velocity Selector: Adjust E and B field to balance the forces: \( F_E = F_B \)

\[
\begin{align*}
F_B & \uparrow \\
F_E & \downarrow
\end{align*}
\]

If forces are balanced:

\[
qE = qvB
\]

The velocity of the particle is:

\[
v = \frac{E}{B} = \frac{EB}{dB}
\]

If \( v \) is known, select that \( v \) by adjusting \( V \).

Electric Charges

Objectives/Learning outcome:

1. Describe, explain and write mathematical relations to explain forces experienced by current-carrying wires in a magnetic field.
2. Describe, explain and write mathematical relations to explain torques acting on current loops in a magnetic field.
3. Describe, explain and write mathematical relations about a motor.
4. Describe & explain the galvanometer and how to convert it to be used as ammeters and voltmeters.

5. Write mathematical relations to further explain the conversion.
6. Describe and draw the magnetic field lines created by wires carrying current.
7. Describe and explain the magnetic forces experienced by charges moving near a current-carrying wire.
8. Describe and explain the magnetic forces experienced by other current-carrying wire near a current-carrying wire.
9. Write mathematical relations to further explain the forces acting on charges and current-carrying wires near a current-carrying wire.
10. Describe and explain the magnetic field produced by a solenoid.
11. State and use Ampere’s Law for static magnetic fields.
12. Use mathematical relations to solve problems related to magnetic fields and current-carrying wire in magnetic field (motor).

Force on wires

- Magnetic Field: A space where moving electrical charges accelerates in the direction of the magnetic force acting on it
- Magnetic Flux Density (B): The magnetic and direction of a magnetic field can be represented by magnetic flux density (B).
- Magnetic Flux (\( \Phi \)): The magnetic flux, \( \Phi \), through a region is a measure of the number of magnetic field lines passing through the region. The flux through an area, \( A \), is the number of B lines parallel to the normal of the surface, and is given by:
  \[
  \Phi = A \cdot B = AB \cos \theta_{AB}
  \]

Conductors in B field: If consider only a positive charge moving to the right then it feels \( F_E \) upwards. If consider an electron drifting to the left, then \( F_E \) on it is also upwards. For all N charges in the wire of length L, the force is still upwards. Charges moving in the wire is current in that wire. Wire will accelerate upwards.
**Force on wires**

Conductors in B field: Wire will accelerate upwards. Consider charges moving from left end to right. Time to travel the distance L is \( \Delta t \). Since \( F_B = qv_B \sin \theta \) for a charge, then for a stream of charges, \( F_B = \frac{\Delta q}{\Delta t} v_B \Delta t \sin \theta \).

For a charge: \( F_B = qv_B \sin \theta \)  
For a wire: \( F_B = iL \sin \theta \).

The direction is determined by RHR-1.

---

**RHR-1: Thumb Rule/Corkscrew rule**:

Determine the direction of the resultant force for the following cases:

- i) \( i \) and \( B \) into page  
- ii) \( i \) into page, \( B \) out of page  
- iii) \( i \) out of page, \( B \) to the right  
- iv) \( i \) out of page, \( B \) to the right

Note: For magnetic field representation, use

- Field out of page
- Field into page

---

**Determine the direction of the resultant force for the following cases:**

- i) \( i \) and \( B \) into page  
- ii) \( i \) into page, \( B \) out of page  
- iii) \( i \) out of page, \( B \) to the right  
- iv) \( i \) out of page, \( B \) to the right
**Force on wires**

**Loudspeaker:**

A typical operation of a speaker connected to a receiver.

**Torque:**

Determine the direction of rotation for the coil and hence the torque it experienced.

\[ \tau = r x F \]

\[ \tau = rF \sin \theta \]

**Torque:**

When the plane of the coil is perpendicular to B, the force is \( F_B = iLB \). Note that the area of the coil is \( A = Lw \).

Torque for side 1:

\[ \tau_1 = \frac{w}{2}iLB \]

Torque for side 2:

\[ \tau_2 = \frac{w}{2}iLB \]

For both sides, torque is directed into the plane causing clockwise rotation. Then total torque is:

\[ \tau = \tau_1 + \tau_2 \]

If there are \( N \) turns, torque is

\[ \tau_{\text{total}} = NiAB \]

**RHR-1: Thumb Rule/Corkscrew rule:**

Determine the direction of the resultant force for the following cases:

- Zero torque
Force on wires

RHR-1: Thumb Rule/Corkscrew rule:
Determine the direction of the resultant force for the following cases:

Magnetism Lecture Series

Fields and forces on current-carrying conductors

Force on wires

Magnetic field produced by infinitely long wire
Magnetic field density or strength is proportional to the current through the wire and inversely proportional to the distance from the wire.

\[ B \propto \frac{i}{r} \]

\[ B = \frac{\mu_0 i}{l} \]

Where \( \mu_0 = 4\pi \times 10^{-7} \text{Tm/A} \)

Force on wires

Magnetic field produced by infinitely long wire
Magnetic field density or strength is proportional to the current through the wire and inversely proportional to the distance from the wire.

\[ B \propto \frac{i}{r} \]

\[ B = \frac{\mu_0 i}{l} \]

Force on wires

Magnetic field produced by infinitely long wire
Magnetic field density or strength is proportional to the current through the wire and inversely proportional to the distance from the wire.

\[ B \propto \frac{i}{r} \]

\[ B = \frac{\mu_0 i}{l} \]

Force on wires

Magnetic field produced by infinitely long wire
Magnetic field density or strength is proportional to the current through the wire and inversely proportional to the distance from the wire.

\[ B \propto \frac{i}{r} \]

\[ B = \frac{\mu_0 i}{l} \]

Where \( \mu_0 \) is the permeability of free space. \( \mu_0 = 4\pi \times 10^{-7} \text{Tm/A} \)
Force on wires

Force on charges in Magnetic fields produced by current-carrying infinitely long wire

\[ F = q \times B = qv \times \frac{\mu_0 I}{2\pi r} \]

Where \( \mu_0 \) is the permeability of free space. \( \mu_0 = 4\pi \times 10^{-7} \text{Tm/A} \)

A current-carrying infinitely long conductor placed near another current-carrying infinitely long conductor will feel a magnetic force.

Current opposite direction, repulsive force.

Current same direction, attractive force

\[ F = B_i L_i \sin \theta_i \]

Force for 1 meter of wire:

\[ F = -\frac{B_i L_1 \sin \theta_1}{2\pi r} \]

\[ F = \frac{B_i L_2 \sin \theta_2}{2\pi r} \]

\[ F = \frac{B_i L_3 \sin \theta_3}{2\pi r} \]

If \( L_1 = L_2 = L_3 \),

\[ F_{12} = -F_{21}, \quad F_{13} = -F_{31} \]

Magnetic intensity at point \( P \) from current in opposing directions

\[ F = iL \times B = iLB \sin \theta \]
What happens to the coil?

The coil will be attracted to the wire. Since the B field along segment C is weaker, the strength of FA is greater than the strength of FC. Therefore, the coil will be attracted to the wire.

\[
\begin{align*}
F_i &= \frac{\mu_0 I_i}{2\pi r} \\
F_C &= \frac{\mu_0 I_C}{2\pi r} \\
F_B &= -\frac{\mu_0 I_B}{2\pi r}
\end{align*}
\]

Forces between wire loops

Field lines of a single loop can be represented like those of a bar magnet.
Magnetic Forces

When wire loops are wound close to each other, they form a solenoid. Along center or z-axis, the B field of each loop behaves like many bar magnets.

The magnetic field density, B inside a long solenoid is \( B = \mu_0 ni \), where \( n \) is number of turns per unit length, \( n = \frac{N}{L} \).

Assignment

Chap 21:
Conceptual: 14, 15, 16, 18. Submit all.
Problems: 2, 4, 8, 10, 13, 23, 30, 33, 35, 37, 49, 52, 54, 64, 72. Submit underlined problems.

DUE February 24th.

Quiz 4: Thurs Feb 17th. Quiz 5: Thu March 4th
Test 2: Mon Night; 8:45 pm Feb 21st
Test 3: Mon Night; 8:45 pm March 7th