Physics 202, Lecture 11

Today's Topics

- RC circuit (ch. 28.4)
- Magnetic Field (ch. 29.1, 29.2)
- Magnetic Field
- Magnetic Forces
  - Between Bar Magnets
  - On A Charged Particle
  - On Current Carrying Wire
- Earth Magnetic Field
- South Pole or North Pole? (Confusing!)
  - Expected from preview: north and south poles, Tesla, magnetic field lines, magnetic force......

Charging A Capacitor in RC Circuit

- Find I and q when a capacitor is being charged in a RC circuit (see board).

\[ q(t) = \frac{\Delta Q}{C} (1 - e^{-t/\tau}) \]
\[ I(t) = \frac{\Delta E}{R} e^{-t/\tau} \]

Note: \( \tau = RC \) is called time constant

Discharging A Capacitor in RC Circuit

- Find I and q when a capacitor is being discharged in a RC circuit (After class exercise).

\[ q(t) = Q e^{-t/\tau} \]
\[ I(t) = -\frac{Q}{RC} e^{-t/\tau} \]

Note the time constant \( \tau = RC \)
**Demo: Magnetism**

- Bar magnets (Permanent magnetic material)
  - Two type of poles
    - Like poles repel, opposite pole attractive
  - Produce a magnetic field
- Ferromagnetic material (e.g. iron)
  - Does not produce magnetic field by itself.
  - Always attracted by magnets (temporarily magnetized)
- Materials of Weak/Non magnetism
  - (e.g. copper, aluminum, wood, plastics etc.)
  - Does not produce magnetic field by itself.
  - Not (or very weakly) attracted by bar magnets

**Bar Magnets and Compass**

- A magnet always has two opposite magnetic poles. The two poles are conventionally named “north” and “south”
  - Like poles repel, opposite poles attract each other.
  - Both poles attract iron (ferromagnetic material)
  - The two poles are not separable. (i.e. no mono-pole)
- A compass is essentially a bar magnet.
  - Its “north” pole, as conventionally defined, points towards the north direction.

**The Magnetic Field**

- The magnetic field \( \mathbf{B} \) is a field which can exert forces on magnetic objects
  - It is a vector field:
    - Magnitude: Unit Tesla (T)
    - Direction:
      - As pointed by the “north” pole of a compass

\[
1 \text{ T} = 1 \frac{\text{N}}{\text{C} \cdot \text{m/s}} = 1 \frac{\text{N}}{\text{A} \cdot \text{m}}
\]

**Demo: Magnetic Field Lines**

- Tips
  - Outside magnet: N→S
  - Inside magnet: S→N
  - Each line forms a closed loop
Typical Magnetic Field Strength

Table 29.1

<table>
<thead>
<tr>
<th>Source of Field</th>
<th>Field Magnitude (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong superconducting laboratory magnet</td>
<td>30</td>
</tr>
<tr>
<td>Strong conventional laboratory magnet</td>
<td>2</td>
</tr>
<tr>
<td>Medical MRI unit</td>
<td>1.5</td>
</tr>
<tr>
<td>Bar magnet</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Surface of the Sun</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Surface of the Earth</td>
<td>$0.5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Inside human brain (due to nerve impulses)</td>
<td>$10^{-13}$</td>
</tr>
</tbody>
</table>

1 Gauss = $10^{-4}$ Tesla

Magnetic Force

- A moving charged particle in a magnetic field is subject to a magnetic force: $\mathbf{F} = q \mathbf{v} \times \mathbf{B}$
  - direction: “right hand rule”
  - magnitude: $F_B = |q|v_B \sin \theta$.

Exercise: Direction of Magnetic Force

- Indicate the direction of $F_B$ in the following situations:

1. B out of page:
   - (a)
2. B into page:
   - (b)

Quick Quiz 1: Direction of Magnetic Force

- Which fig has the correct direction of $F_B$?
Quick Quiz 2 : Direction of Magnetic Force

- Which fig has the correct direction of $\mathbf{F}_B$?

Properties of Magnetic Force

- Magnetic Force: $\mathbf{F}_B = q \mathbf{v} \times \mathbf{B}$. ($\mathbf{F}_B = |q| \mathbf{v} \mathbf{B} \sin \theta$)
  - $\mathbf{F}_B = 0$ if $\mathbf{v} = 0$
  - $\mathbf{F}_B = 0$ if $\mathbf{v}$ and $\mathbf{B}$ in 0° or 180°
  - $\mathbf{F}_B$ is normal to $\mathbf{v}$
  - $\mathbf{F}_B$ is normal to $\mathbf{B}$
  - Work done by $\mathbf{F}_B$ is always zero!
  - Direction of $\mathbf{F}_B$ are opposite for positive charge and negative charges.

Magnetic Force On Current Carrying Wire(1)

- Magnetic force on a current segment of length $L$ in uniform field $\mathbf{B}$:
  - $\mathbf{F}_B = q \mathbf{v} \times \mathbf{B} = I \mathbf{L} \mathbf{B}$
  - Key steps to derive:
    - Current: moving charges. $I = q \mathbf{v} \mathbf{A}$
    - Magnetic force on charge $q$: $q \mathbf{v} \mathbf{B}$
    - $\mathbf{F}_B = q \mathbf{v} \mathbf{B} (\mathbf{A} \mathbf{L}) = I \mathbf{L} \mathbf{B}$

The Earth Magnetic Field

- The Earth’s Magnetic Field
- North/South? Magnetic Pole
- Geographic North Pole

The Earth Magnetic Field

-南北? 磁北极
- 地磁北極