How Do You Use Magnetic Fields in Your Everyday Life!? 
Lecture 18: FRI 26 FEB
Magnetic fields
Ch.28.1–5

“Aurora Borealis

“I’ll be back....

Physics 2102
Jonathan Dowling

28-1 What Is Physics? 736
28-2 What Produces a Magnetic Field? 736
28-3 The Definition of $B$ 736
28-4 Crossed Fields: Discovery of the Electron 740
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Nicholson 130

Second Exam (Chapters 24–28): 6–7PM THU 05 MAR
Lockett 6
Electric vs. Magnetic Fields

Electric fields are created:
• microscopically, by electric charges (fields) of elementary particles (electrons, protons)
• macroscopically, by adding the field of many elementary charges of the same sign

Magnetic fields are created:
• microscopically, by magnetic “moments” of elementary particles (electrons, protons, neutrons)
• macroscopically, by
  • adding many microscopic magnetic moments (magnetic materials); or by
  • electric charges that move (electric currents)
Magnetic Field Direction

FROM North Poles TO South Poles

Compare to Electric Field Directions
Ritchie’s Rule for Magnets

Opposite Poles Attract

Like Poles Repel
Magnetic vs. Electric Forces

We know that an electric fields exists because it accelerates electric charges, with a force independent of the velocity of the charge, proportional to the electric charge: \( F_E = qE \)

We know that a magnetic field exists because it accelerates electric charges in a direction perpendicular to the velocity of the charge, with a magnitude proportional to the velocity of the charge and to the magnitude of the charge: \( F_B = q \, v \times B \)

Magnetic forces are perpendicular to both the velocity of charges and to the magnetic field (electric forces are parallel to the field).

Since magnetic forces are perpendicular to the velocity, they do no work! \((W=F \cdot r)\)

Speed of particles moving in a magnetic field remains constant in magnitude, ONLY the direction changes.
Kinetic energy is constant! (no work).
Magnetic vs. Electric Forces

Electric Force on Charge Parallel to $E$:

$$\vec{F}_E = q\vec{E}$$

Magnetic Force on Charge Perpendicular to $B$ and $v$.

$$\vec{F}_B = q\vec{v} \times \vec{B}$$
Definition of Magnetic Field

Definition of Electric Field:

\[ \vec{E} = \frac{\vec{F}_E}{q} \]

Definition of Magnetic Field:

\[ |B| = \frac{|\vec{F}_B|}{q|\vec{v}|} \]

Units: \[ B = \left[ \frac{\text{Newton}}{\text{Coulomb} \cdot (\text{meter/sec})} \right] = \left[ \frac{\text{Newton}}{(\text{Coulomb/sec}) \cdot \text{meter}} \right] = \left[ \frac{\text{Newton}}{\text{Ampere} \cdot \text{meter}} \right] = \left[ \frac{\text{N}}{\text{A} \cdot \text{m}} \right] \]
Thompson Experiment

Forces Balance: \( v = \frac{E}{B} \)

Cross-section of a velocity selector

While in the magnetic field an electromagnetic force is felt as \( F_B = qvB \). The right hand rule gives us the direction, with fingers into the page (\( \mathbf{B} \)), thumb to the right (\( \mathbf{I} \)), gives force in direction of the palm being UP.

![Diagram of a velocity selector](image)

As the ions enter the electric field a force \( F_e = qE \) is created based on the charge of the ion and field strength. This force is directed downward as the positive plate repels the positive particle.

In order to pass undeflected through the crossed fields \( F_B = F_e \) or \( qvB = qE \). Factoring the charge gives us \( vB = E \) or solving for \( v \) gives \( v = \frac{E}{B} \). Thus by controlling \( E \) and \( B \) we allow particles of only a specific velocity to pass through.

If the velocity of the particle is too high, then \( F_B > F_e \) and the particle curves up hitting the plate at the end of the selector. If the velocity is too low, \( F_B < F_e \) and the particle curves down hitting the lower portion of the same plate.
\[ E \neq 0, \ B = 0; \quad qE = F_E = ma \]
\[ a = \frac{F_E}{m} = \frac{qE}{m} \]
\[ L = vt; \quad y = \frac{1}{2} at^2; \]

Solve: \[ y = \frac{qEL^2}{2mv^2} \]

III: \[ vB = E \]

I: \[ E = 0, \ B = 0 \]

\[ \frac{m}{q} = \frac{L^2B^2}{2yE} \]

\[ v = \frac{E}{B}; \quad y = \frac{qEL^2}{2mv^2} = \frac{qL^2B^2}{2mE} \]
Magnetic Deflection of a TV Image

MIT Department of Physics Technical Services Group