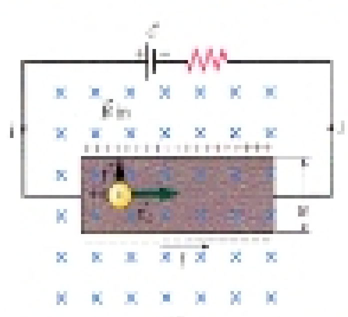
Physics 202, Lecture 13

Today's Topics

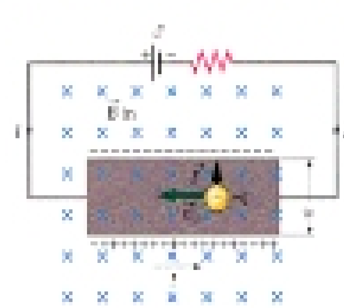
- Magnetic Forces: Hall Effect (Ch. 27.8)
- Sources of the Magnetic Field (Ch. 28)
  - B field of infinite wire
    Force between parallel wires
  - Biot-Savart Law
    Examples: ring, straight wire
  - Ampere's Law:
    - infinite wire, solenoid, toroid

The Hall Effect (1)

Potential difference on current-carrying conductor in B field:



positive charges moving counterclockwise: upward force, upper plate at higher potential



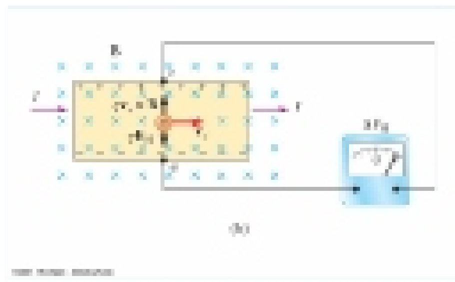
negative charges moving clockwise: upward force
Upper plate at lower potential

Equilibrium between electrostatic & magnetic forces:

$$F_{up} = qv_d B \qquad F_{down} = qE_{ind} = q\frac{V_H}{w} \qquad V_H = v_d Bw = \text{"Hall Voltage"}$$

The Hall Effect (2)

Text: 27.47



$$I = nqv_d A = nqv_d wt \qquad V_H = v_d B w = \frac{IB}{nqt}$$

Hall coefficient: $R_H \equiv \frac{V_H}{IB} = \frac{1}{nqt}$

Hall effect: determine sign,density of charge carriers

(first evidence that electrons are charge carriers in most metals)

Magnetic Fields of Current Distributions

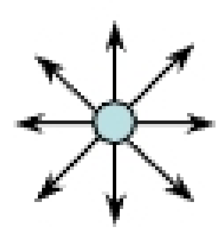
Recall electrostatics: Coulomb's Law)

$$\vec{F} = q\vec{E} \qquad \vec{F} = \frac{kqq'}{r^2}\hat{r}$$ (point charges)

Two ways to calculate E directly:

– Coulomb's Law "Brute force"

$$d\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}\hat{r}$$



– Gauss' Law "High symmetry"

$$\int \vec{E} \bullet d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

$\varepsilon_0 = (4\pi k)^{-1}$

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/(N\ m^2)$: permittivity of free space

Magnetic Fields of Current Distributions

$$\vec{F} = \int I d\vec{l} \times \vec{B} \qquad \vec{F} = k_m \int I d\vec{l} \times \int I' d\vec{l}' \times \frac{\hat{r}}{r^2}$$

(2 circuits)

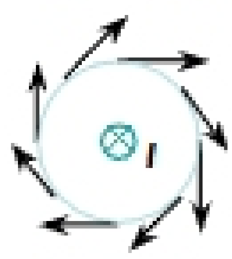
2 ways to calculate B:

– Biot-Savart Law ("Brute force")

$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^2}$$

– Ampere's Law ("high symmetry")

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enclosed}$$



–AMPERIAN LOOP

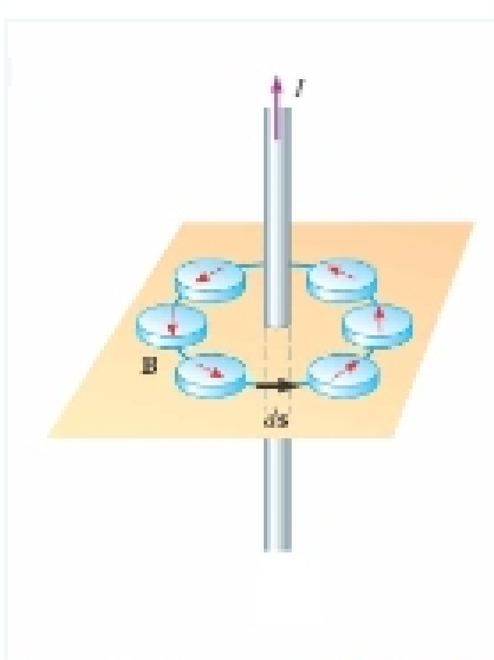
$$\mu_0 = 4\pi k_m$$

$\mu_0 = 4\pi \times 10^{-7}$ T-m/A: permeability of free space

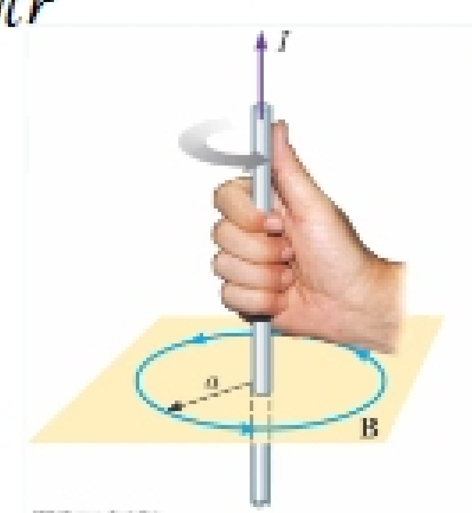
Magnetic Field of Infinite Wire

Result (we'll derive this both ways):

$$\vec{B} = \frac{\mu_0 I}{2\pi r} \hat{\theta}$$



right-hand rule



closed circular loops centered on current