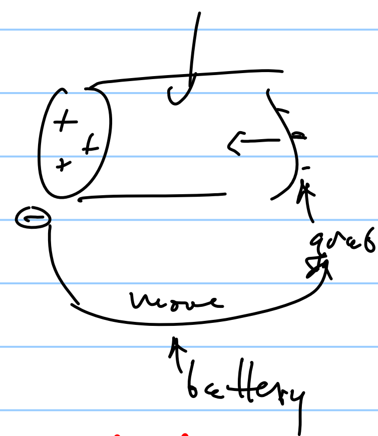
Lecture 30 April 5, 2006

Note Title 4/5/2006

Ch 7.

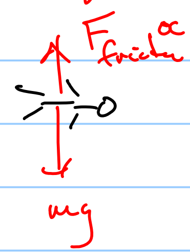
current in wires

lead to E inside conductor



Model motion of charges in conductor

- 1st model skydiver



$v_{terminal\ vel} \propto$

$\sum F = ma = 0$

$mg - Kv_{term} = 0$ $\quad v_{terminal} \propto g$

$F = mg$ $\quad \frac{F}{m} = g$ $\frac{\text{force}}{\text{mass}}$

Charge in a conductor

$q \leftrightarrow E$

$E = \frac{\text{force}}{\text{charge}}$ or electromotive force

$\vec F = q\vec E + q\vec v \times \vec B$

$q\vec v \times \vec B$: always small so neglect this term

Ohmic materials $v \propto E$ but $J = \rho v \Rightarrow J \propto E$

$\boxed{\vec J = \sigma \vec E}$ OHMS LAW no a general law but specific to certain materials

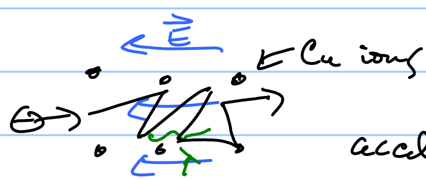
Microscopic models

(1) inside copper electrons are free to move

$F = ma = qE$ $\quad a = \frac{qE}{m} \Rightarrow$ velocity should increase with position along wire

OHMS Law $\rho v = J = \sigma E$ $\quad v \propto E$ but this model says v is not constant (increases)

(2)



electron hits lattice & then has to accel again.

λ distance between collisions $\qquad \frac{1}{2}at^2 = \lambda \qquad t = \sqrt{\frac{2\lambda}{a}}$

given λ can find time between collisions

$$v_{ave} = \frac{\overset{0}{v_i} + \overset{at_f}{v_f}}{2} = \frac{1}{2} a \sqrt{\frac{2\lambda}{a}} = \sqrt{\frac{\lambda a}{2}}$$

but $a = \frac{qE}{m} \Rightarrow v_{av} \propto \sqrt{E}$ not Ohm's Law

(3) Charges move very fast $\qquad k_B T = \frac{1}{2} m_e v_e^2 \qquad v_e \simeq .01\, c$

thermal $\qquad$ speed of light

$$v_{av} = \frac{\overset{0}{v_{in}} + v_{fin}}{2} \Rightarrow t_{bet.\,coll} = \frac{\lambda}{v_{thermal}}$$

$$v_{av} = \frac{1}{2}at = \frac{a\lambda}{2 v_{thermal}} \qquad \text{but } a = \frac{qE}{m}$$

$v_{av} \propto E \qquad$ Ohm's Law ✓

Ohm's Fails
- at low temp
- at high Electric fields

Uniform σ in Ohm's law $\qquad \vec{J} = \sigma \vec{E}$

magnetostatics

$$\vec{\nabla} \cdot \vec{E} = \vec{\nabla} \cdot \frac{\vec{J}}{\sigma} = 0 \qquad E = -\vec{\nabla} V$$

E in a ohmic conductor obeys

Laplaces eqn $\nabla^2 V = 0$