

Physics 202, Lecture 9

- **Current and Resistance (Ch 25)**
 - DC currents
 - Ohm's Law: Resistors and Resistance
 - Conductivity and Resistivity

Next lecture: DC circuits

Reminder: HW #4 due tomorrow, 11 PM

Charge Motion in a Conductor

Electrons in a conductor have random motion ($v_{\text{ave}}=0$)

In an **external electric field** (e.g. as supplied by a source of potential difference such as a battery), electrons accelerate, produces **current**:

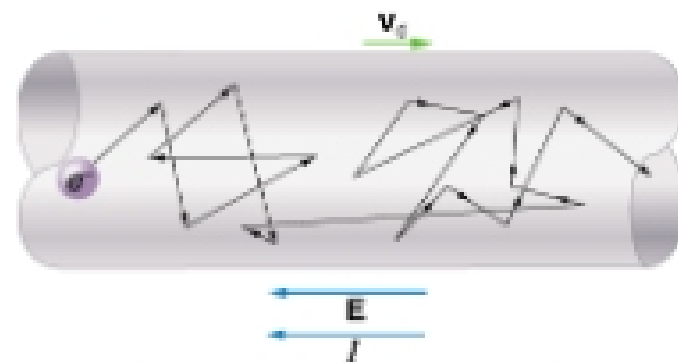
Average current:

$$I = \frac{\Delta Q}{\Delta t}$$

Instantaneous current:

$$I = \frac{dQ}{dt}$$

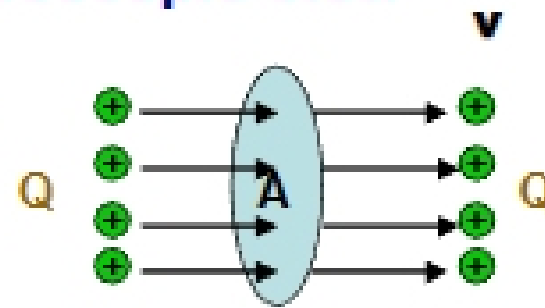
direct current (DC): I constant



Text: 25.1

Current: Macroscopic View

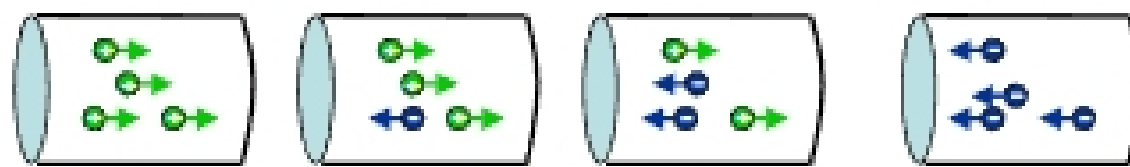
Current: rate at which charge flows through surface:



Unit: 1 Ampere = 1 C/s

Current is directional: Follows positive charge (convention)

+q moving in +x direction \leftrightarrow -q in moving -x direction

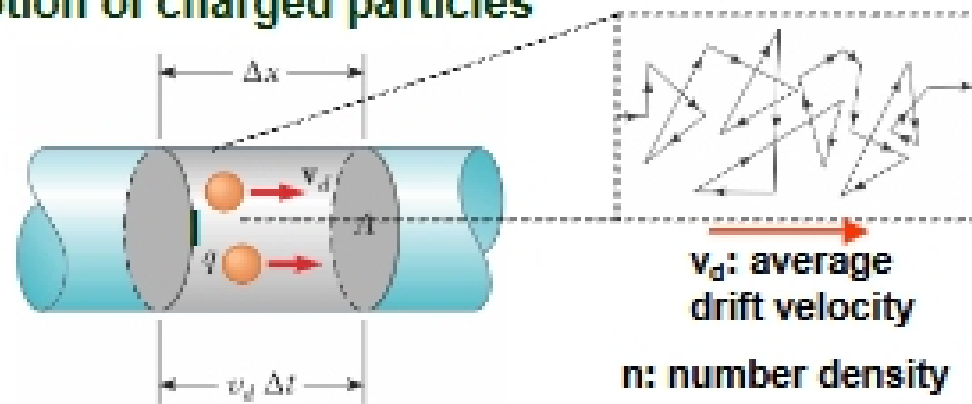


Charge conservation \rightarrow Current conservation



Current: Microscopic View

Current: motion of charged particles



$$I_{average} = \frac{\Delta Q}{\Delta t} = nq v_d A = I$$

Current density:
(vector!)

$$J = \frac{I}{A} = nq v_d$$

$$\int \vec{J} \cdot d\vec{A} = I$$

Drift velocity of conduction electrons

In external electric field:

acceleration $a = qE/m$

velocity $v = v_0 + qEt/m$

v_0 = velocity after last collision

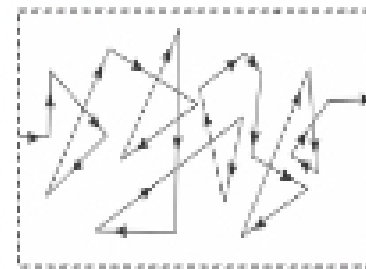
t = time since last collision

Lots of particles: average over all particle velocities

$$v_{\text{ave}} = (v_0)_{\text{ave}} + qEt_{\text{ave}}/m = qE\tau/m$$

v_d = Drift velocity = $qE\tau/m$

τ = ave. time since last collision



Ohm's Law: Resistance

I = current = nqv_dA

v_d = Drift velocity = $qE\tau/m$

$$I = nq \left(\frac{qE\tau}{m} \right) A = \left(\frac{nq^2\tau A}{m L} \right) V \Rightarrow V = IR \quad R = \left(\frac{nq^2\tau A}{m L} \right)^{-1}$$

Voltage proportional to current! This is **Ohm's law**.

Text: 25.6

$$\vec{J} = nq\vec{v}_d = \left(\frac{nq^2\tau}{m} \right) \vec{E} = \sigma \vec{E} = \frac{1}{\rho} \vec{E}$$

↑ conductivity
 ← resistivity