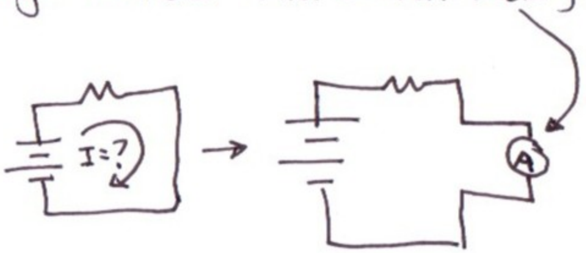
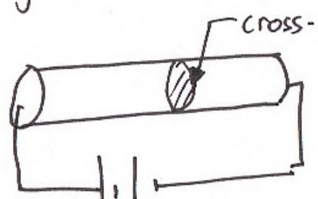
28-5 Ammeters & Voltmeters

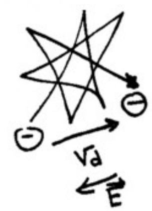
To measure current, you must interrupt the circuit & force current to flow through "ammeter" (i.e. current meter):



Drift velocity

Apply a voltage across a piece of wire:





$\Delta V_{AB} = -\int \vec{E} \cdot d\vec{l} \Rightarrow \vec{E} \neq 0$ inside the metal wire

(it's no longer in static equilibrium)

Book $\rightarrow$ $I = n A q v_d$

$\frac{\#\text{ of carriers}}{\text{volume}} \times \text{cross-sectional area} = \frac{\#\text{ of charge carriers}}{\text{length of wire}}$

$n(Cu) = 8.47_{28}$ electrons/m^3

$\Rightarrow$ in a typical circuit, $v_d \sim 0.01$ mm/s ! (compare to $v_{random} \sim 1_5$ m/s)

Electrical impulses are carried by $\vec{E}$, at speeds near the speed of light.

Drude model of microscopic conduction

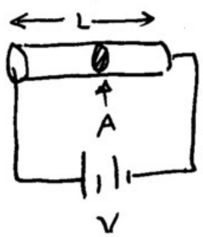
- Each time electron suffers collision, assume velocity is randomized
- $\tau \equiv$ average time since last collision

$\Rightarrow$ average velocity $= v_d = a\tau$, where $a = \frac{F}{m_e} = \frac{-eE}{m_e}$ (charge of electron: $-e$; m_e: mass of electron)

$\Rightarrow v_d = \frac{-eE\tau}{m_e}$

$I = nAqv_d = nA(-e)v_d \Leftrightarrow v_d = -\frac{I}{nAe}$

$\Rightarrow \frac{-eE\tau}{m_e} = \frac{-I}{nAe} \Leftrightarrow I = \frac{ne^2E\tau}{m_e}A$



Inside the wire, E is uniform $\Rightarrow V = EL \Leftrightarrow E = \frac{V}{L}$

$\Rightarrow I = \frac{ne^2\tau}{m_e} V \frac{A}{L}$

$V = IR \Leftrightarrow R = \frac{V}{I}$

$R = \frac{m_e}{ne^2\tau}\frac{L}{A}$

$\Updownarrow$

$R = \rho\frac{L}{A}$

* **Drude model: $\rho = \frac{m_e}{ne^2\tau}$** *

28-6 Circuits with capacitors