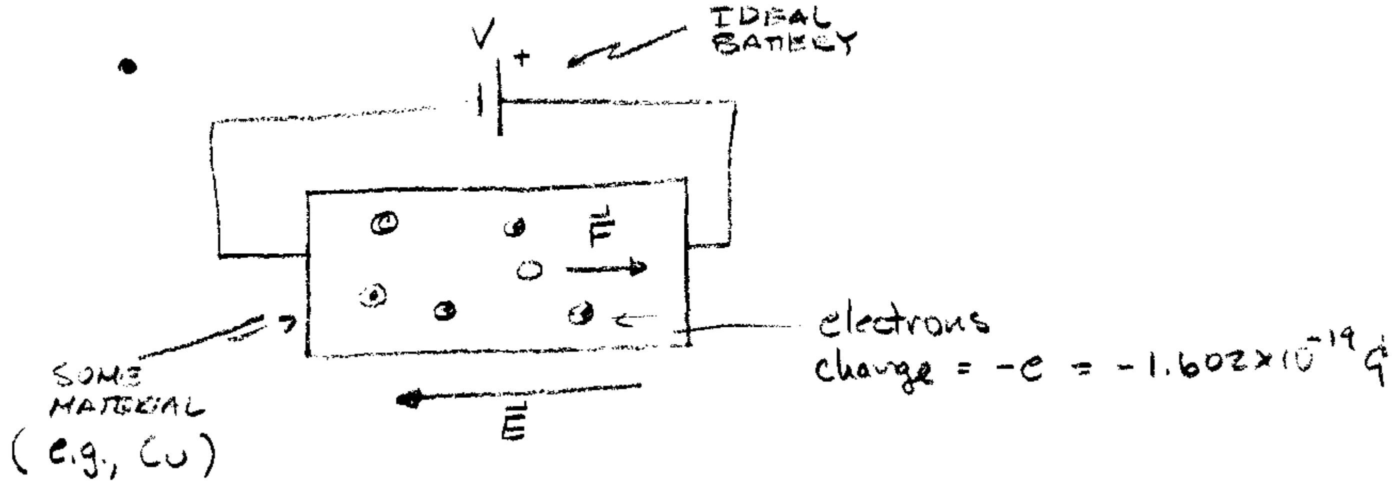
# I. ELECTRIC CURRENT

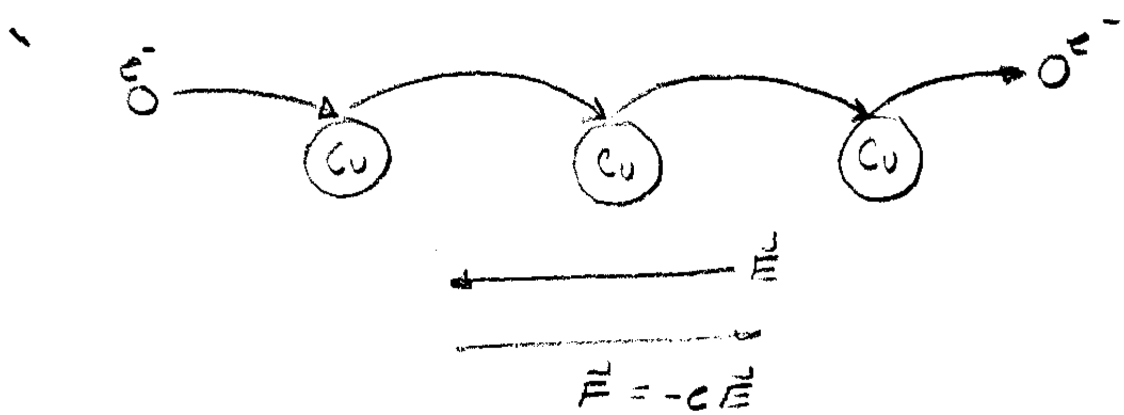
- 


ELECTRONS EXPERIENCE A FORCE

$$\vec{F} = q\vec{E}$$
$$= -e\vec{E}$$

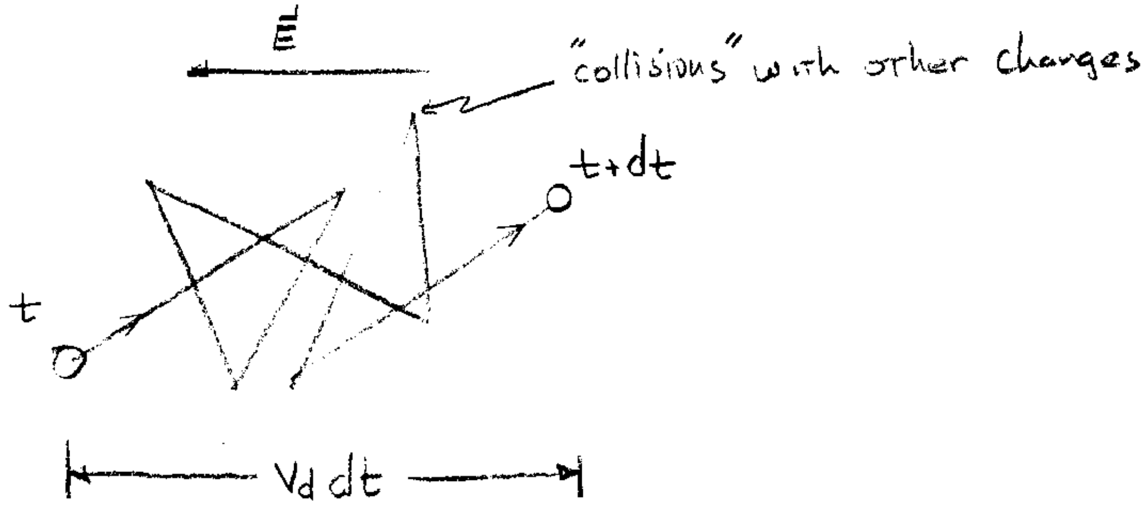
AND WANT TO MOVE TO HIGHER POTENTIAL

- BASIC ATOMIC MODEL I



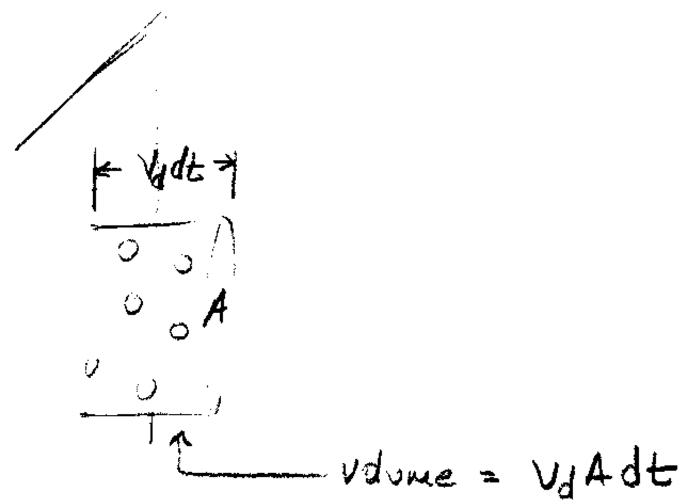

$\vec{E}$ just needs to be large enough to overcome binding force of $e^-$ to Cu atom. For conductors, this is rather easy. For insulators, This is much harder.

- BASIC ATOMIC MODEL II




$V_d$ = Drift Velocity

= average velocity of typical charge carrier in the material under influence of external field.




$$dq = q_0 \eta V_d A\,dt$$

$$= \left(\text{charge per particle}\right)\left(\frac{\text{particles}}{\text{unit volume}}\right)\left(\text{volume}\right)$$

- Current is the amount of charge crossing some region per unit time. (The region could be area, as we are considering, or it could be something like a line, as in the case of surface current.)

$$\boxed{I \equiv \frac{dq}{dt}}$$

1 Ampere (a.k.a. "Amp") = $1\,C/s$

$I = \frac{dq}{dt} = \text{const.} \Rightarrow$ constant current.

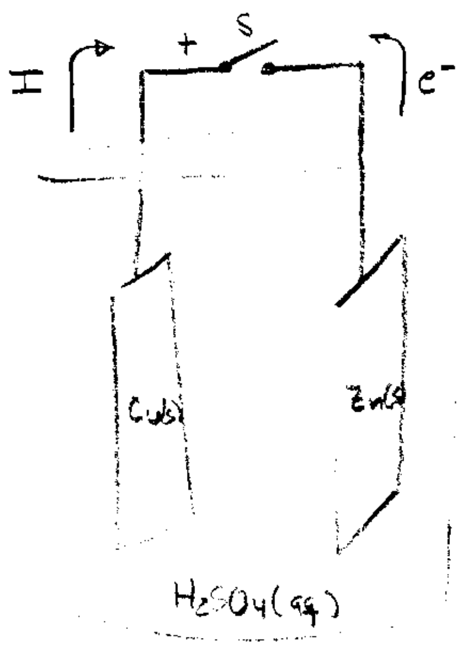
$I = \frac{dq}{dt} \neq \text{const.} \Rightarrow$ varying current (e.g., vary the applied potential.)

- By <u>convention</u>, the direction of current is the direction which positive charge carriers would move under the influence of the potential (or electric field).

- The charge carriers in a system can be positive, negative, or both at the same time.

# II. Real Batteries

- Ex: Cu-Zn




- $H_2SO_4(aq) + Zn(s) \rightarrow 2H^+ + SO_4^{2-} + Zn^{2+} + 2e^-$

  $H_2SO_4(aq) + Cu(s) \rightarrow 2H^+ + SO_4^{2-} + Cu^{2+} + 2e^-$

- Get some

  $H_2SO_4(aq) + Zn(s) \rightarrow ZnSO_4\downarrow + H_2\uparrow$

  $H_2SO_4(aq) + Zn(s) \rightarrow CuSO_4\downarrow + H_2\uparrow$

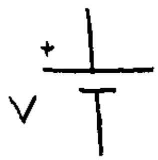
- But also Cu electronegativity > Zn so $Cu^{2+}$ tries to snatch-up some of the $e^-$ left-behind by the Zn.

Closing (making contact) switch S allows this to occur, so there's a flow of $e^-$ from Zn to Cu electrodes

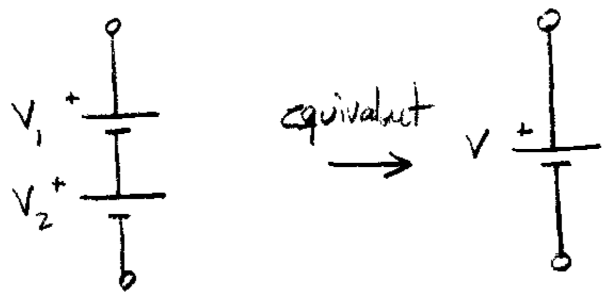
- Reality is:
  - all reactants are finite quantity $\Rightarrow$ battery eventually dies.
  - Process slows-down as precipitants remove material from reaction $\Rightarrow$ less current flows even though potential is the same $\Rightarrow$ battery <u>resistance</u> increases
- Rate of charge delivery is limited by reaction rates and electrolyte diffusion $\Rightarrow$ amount of charge delivered per unit time is limited.

# III. BATTERIES IN SERIES AND PARALLEL

## (A) UNIVERSAL SCHEMATIC SYMBOL FOR BATTERY

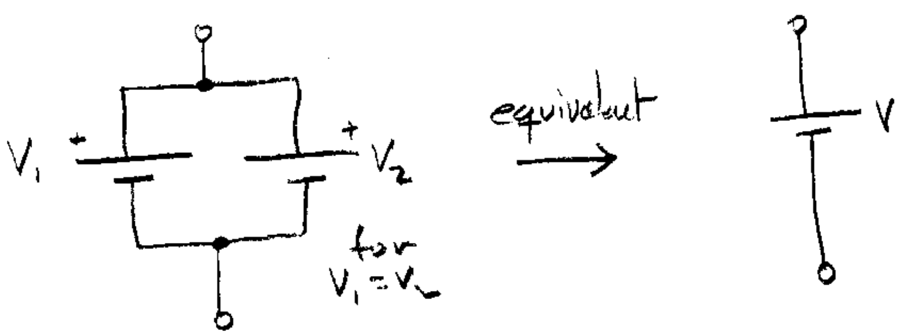



## (B) SERIES




- $V = V_1 + V_2$
- Reaction rates can't exceed that of the "slowest" battery — current is limited to that of "slowest" battery.

## (C) PARALLEL

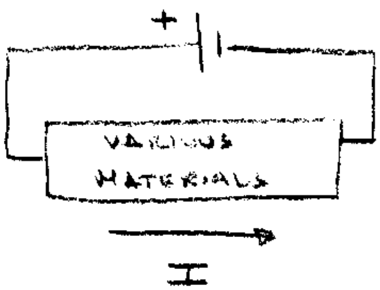


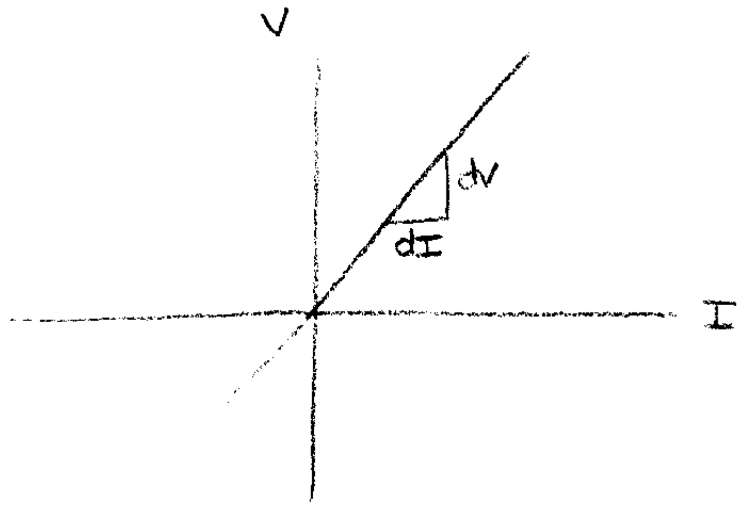

- $V = V_1 = V_2$
- Reaction rates are the sum of the two battery rates ⇒ same voltage, but can deliver more charge per unit time.

(WILL HANDLE $V_1 \neq V_2$ later).

# IV. Resistance

## (A) Ohm's "Law"




DISCOVERS $V = I\left(\frac{dV}{dI}\right)$

$$\boxed{V = IR}$$ Ohm's Law

WHERE $R = \frac{dV}{dI}$ Defn. of Ohmic Resistance.

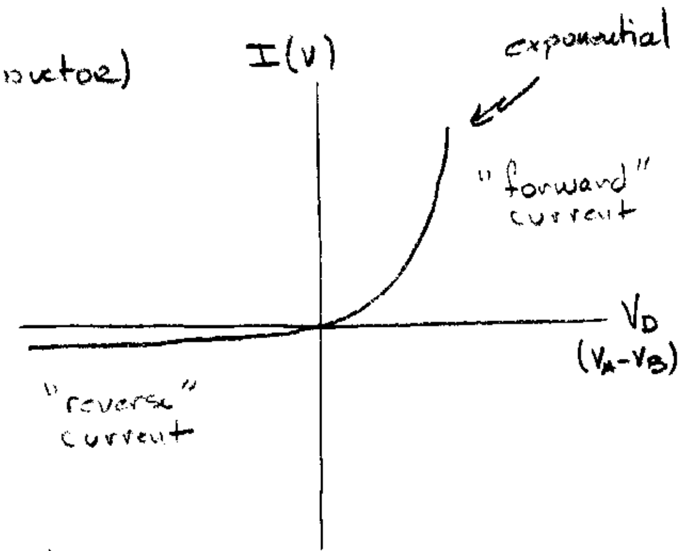
$$[\text{Resistance}] = \left[\frac{\text{Energy}\cdot\text{Time}}{\text{Charge}^2}\right]$$

A STANDARD UNIT : $1 \text{ Ohm} = \frac{1 \text{ Volt}}{\text{Amp}}$

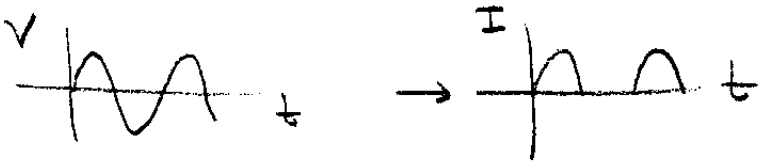
## (B) Nonohmic Devices

### (1) Junction Diode (Semiconductor)


Mostly only allows charge to flow one way

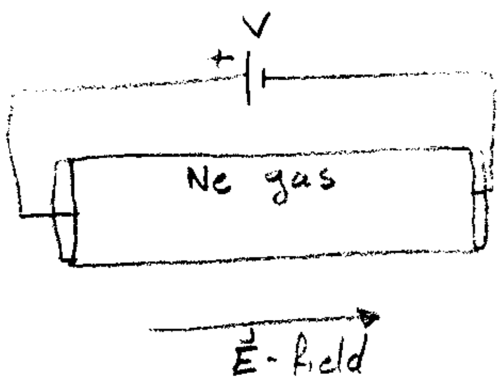


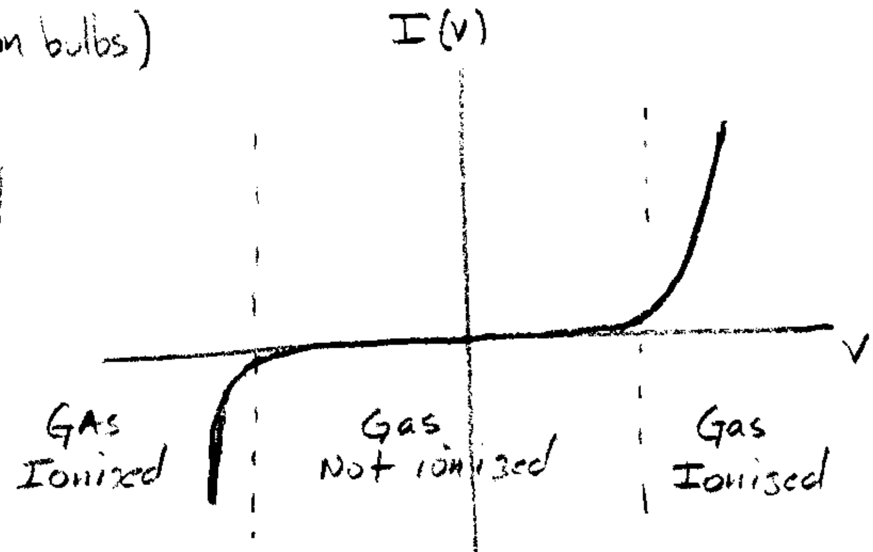

Typical application: "Rectifier"




Convert A.C. to D.C.

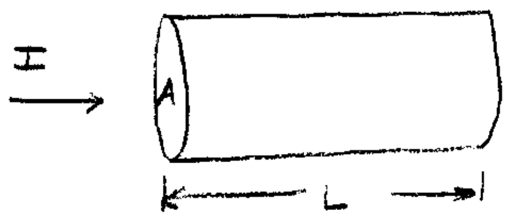
### (2) Gases (e.g., neon bulbs)




## (C) Schematic Symbol for Resistor

## (D) Resistivity



$R \sim L$ (Longer path = more collisions = Greater resistance to flow of charge)

$R \sim \frac{1}{A}$ (Larger area = more charge carriers can move = less resistance to flow of charge)

ignorance-factor

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

$\rho \equiv$ resistivity

$$\equiv \frac{RA}{L}$$

Unit of Resistivity

$$\rho \equiv \frac{RA}{L} \Rightarrow \Omega \cdot m$$

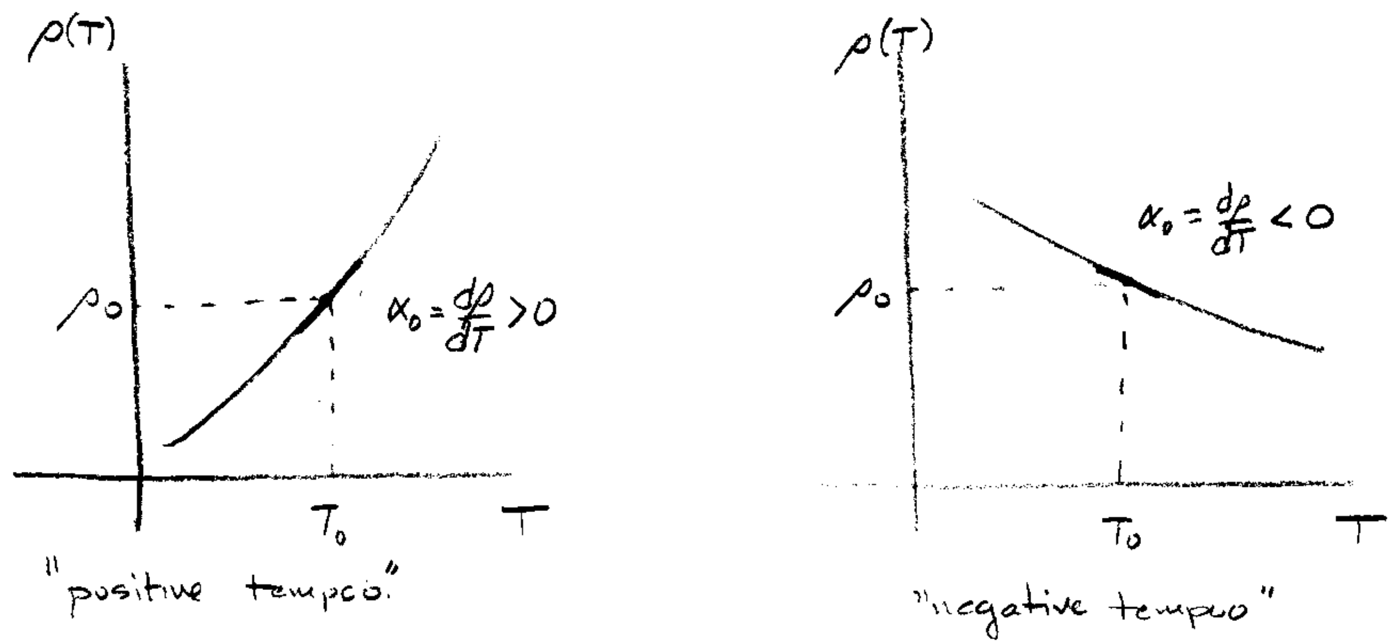
- Some typical values

$\rho_{conductors} \sim 10^{-8}\,\Omega \cdot m$

$\rho_{\substack{carbon \\ resistors}} \sim 10^{-5}\,\Omega \cdot m$ ← $\rho_{blood} \sim 1.5\,\Omega \cdot m$

$\rho_{insulators} \sim 10^{7} - 10^{14}\,\Omega \cdot m$

## (E) RESISTANCE CHANGES WITH TEMPERATURE ("TEMPCO")




$$\rho \simeq \rho_0 \left(1 + \frac{d\rho}{dT} \Delta T\right)$$

$$\frac{d\rho}{dT} \equiv \alpha_0$$

$$\rho \simeq \rho_0 \left(1 + \alpha_0 \Delta T\right)$$

- EX APPLICATION: ELECTRONIC THERMOMETERS