Announcement: Test graded by Thursday

Average for multiple choice 7.5/15: exam will be graded by Thursday

Office Hours: TR 10:30-11:30 am

Physical Science Building

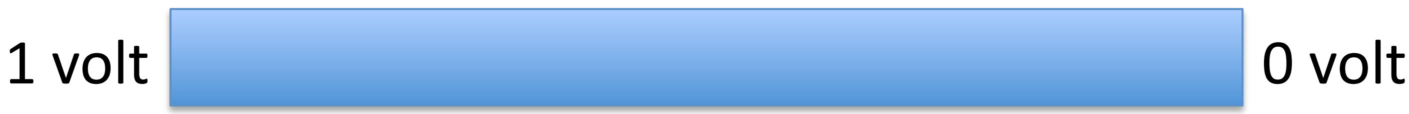
Enter through the garage door behind the Harris engineering building

Current: charge per unit time

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

1 Amp = 1 C/sec

What is the speed of electrons?



Potential energy: 1 electron volt

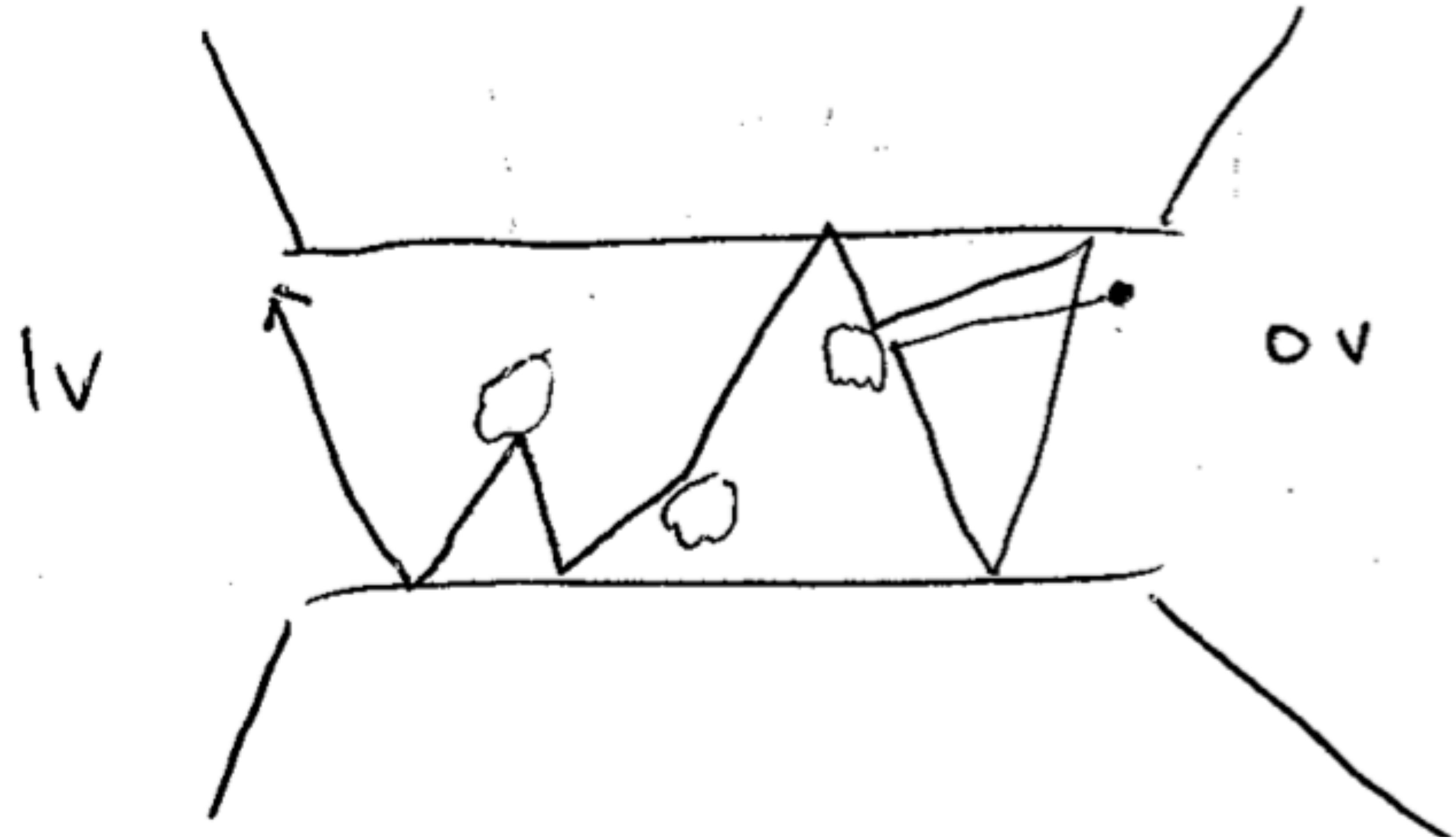
$$U = \frac{1}{2} m v^2$$

$$1.6 \times 10^{-19} J = \frac{1}{2} \times 9.109 \times 10^{31} kg \times v^2$$

$$v = \sqrt{\frac{3.2 \times 10^{-19}}{9.109 \times 10^{-31}}} m / s = 0.35 \times 10^6 m / s$$

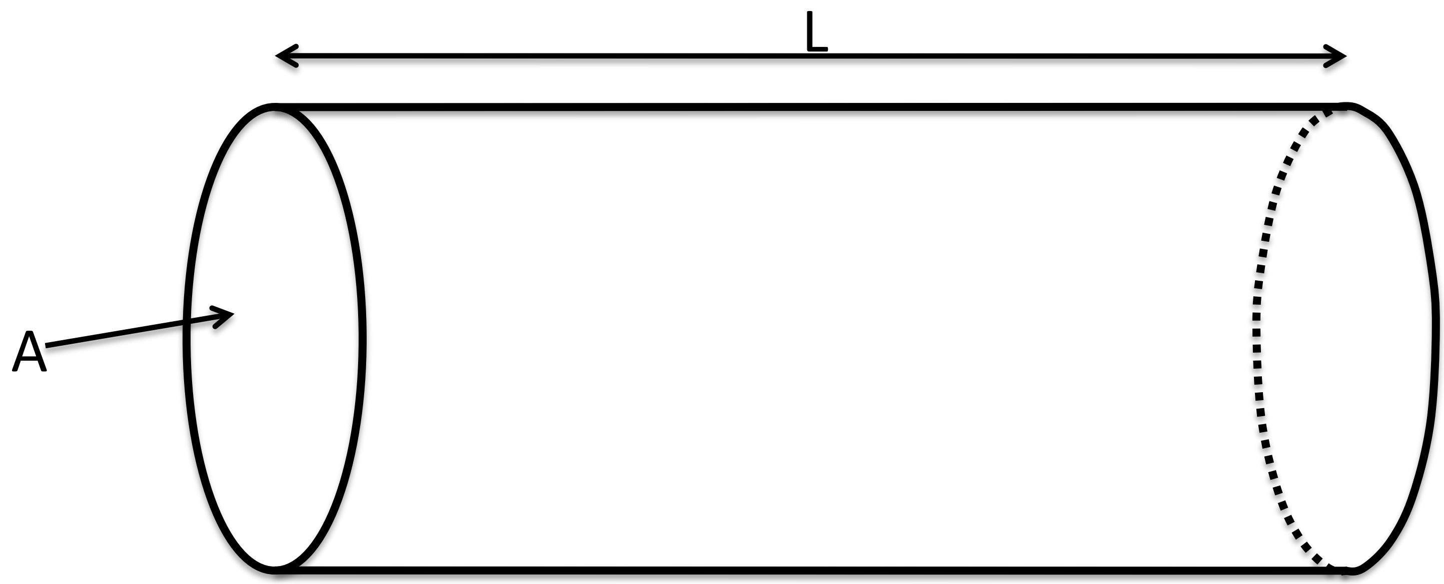
But in reality, charge carriers diffuse at mm/sec, why?

Carrier velocity small because of scattering



v_d : “Drift velocity”

Current

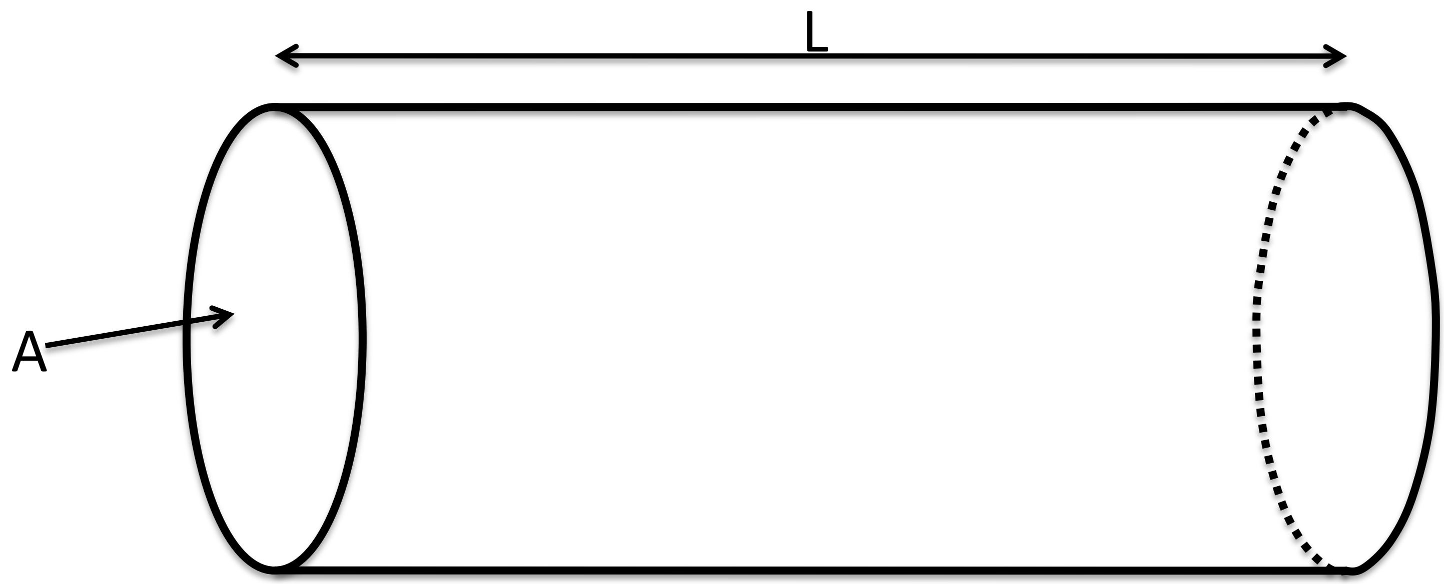


n: volume density of electrons

$$Q = neAL$$

$$I = \frac{dQ}{dt} = neA\frac{dL}{dt} = neAv_d$$

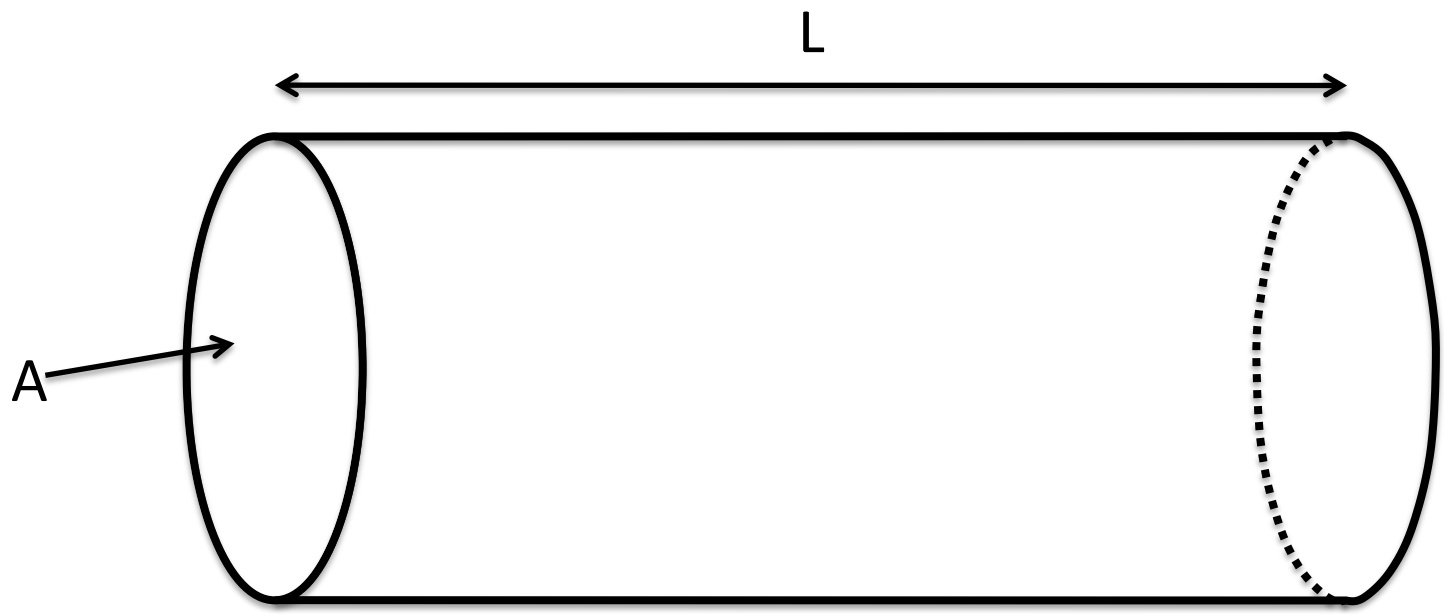
Current Density



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

Ohm's Law $\vec{J} = \sigma \vec{E}$ σ: conductivity

Ohm's Law



Ohm's Law $\vec{J} = \sigma \vec{E}$

$$\frac{1}{\sigma}\vec{J} = \vec{E}$$

$$\frac{L}{\sigma}J = LE$$

$$\frac{L}{\sigma}\frac{I}{A} = LE = V$$

$$\frac{L}{\sigma A}I = V$$

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

$$RI = V$$

Conductivity, Resistance and Resistivity

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

Resistance : Ω

$$\rho = \frac{1}{\sigma}$$

Resistivity : Ω m

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

Resistivity

Silver: 1.59×10^{-8} Ωm
Copper: 1.7×10^{-8} Ωm
Gold: 2.44×10^{-8} Ωm

Glass: 10^{10} ~10^{14}Ωm

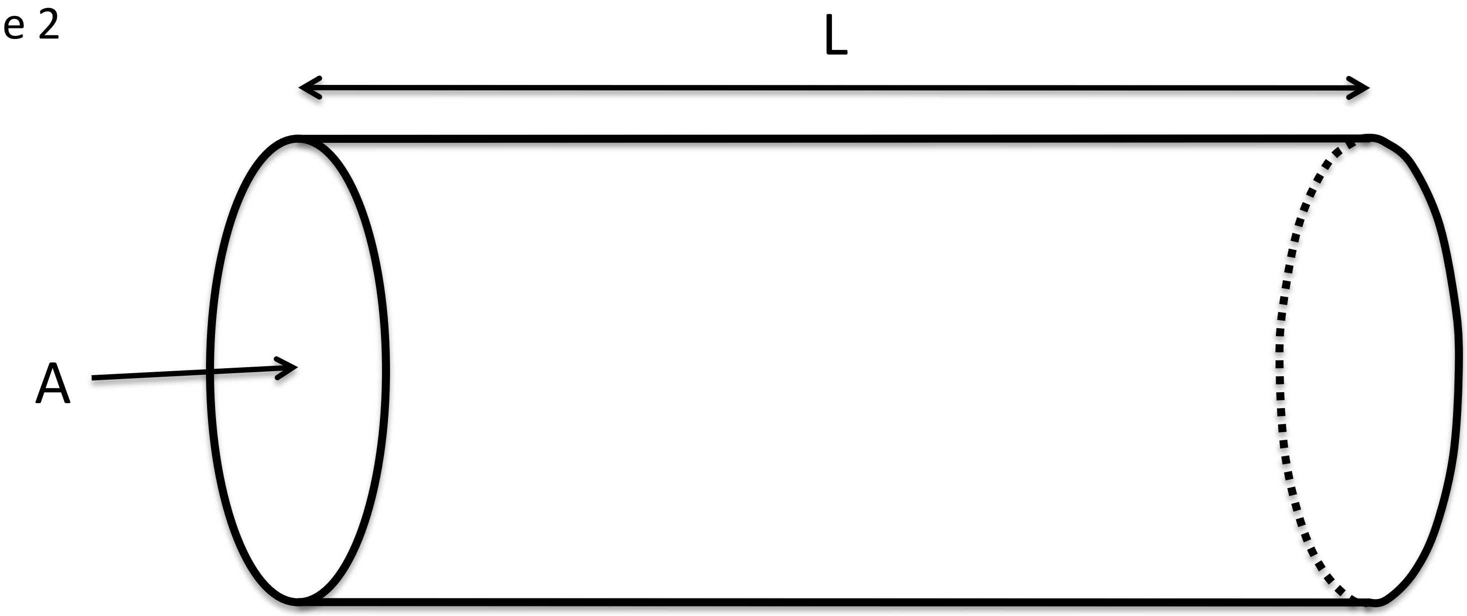
Example

A= 1 cm², L= 4 m, Resistivity: Copper: $1.7\times10^{-8}\ \Omega m$

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

$$R = \frac{1.7\times10^{-8}\,\Omega m \times 4m}{0.0001m^2} = 6.8\times10^{-4}\,\Omega$$

Example 2



A= 1 cm², L= 4 m, Resistivity: Copper: $1.7\times10^{-8}\ \Omega m$

$$R = \frac{1.7\times10^{-8}\,\Omega m\times 4m}{0.0001m^2} = 6.8\times10^{-4}\,\Omega$$

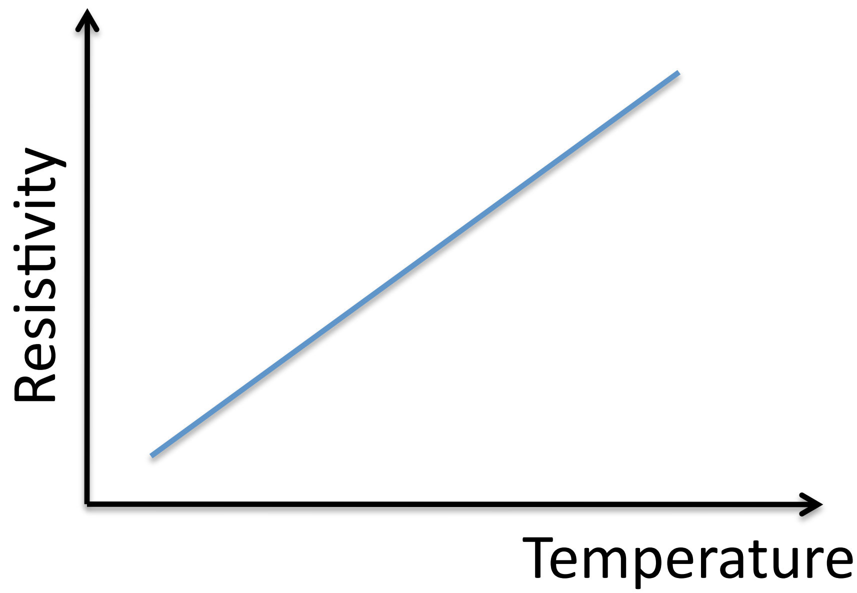
If you have 1 μV along the wire, how much current will pass through the wire?

$$V = IR$$

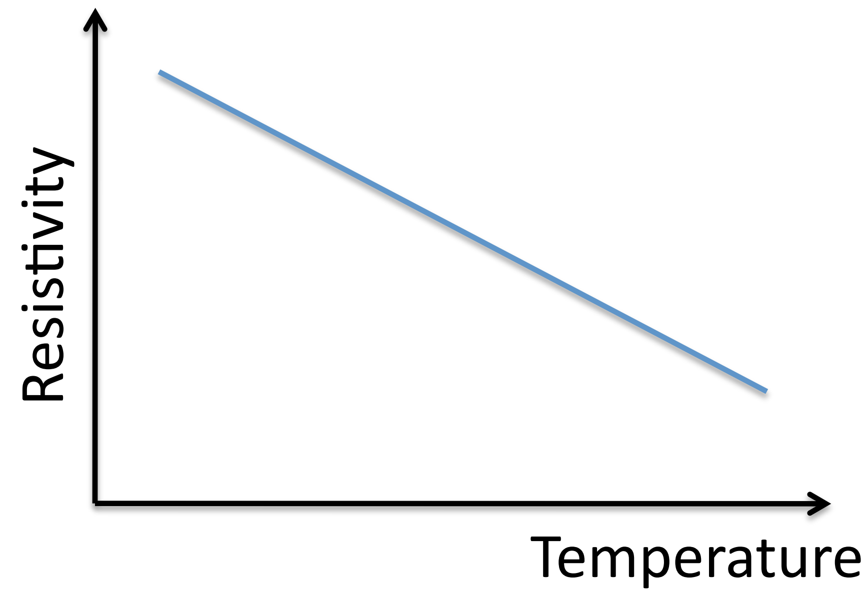
$$1\times10^{-6}V = I\times6.8\times10^{-4}\,\Omega$$

$$I = 0.147\times10^{-2}A$$

Temperature dependence of resistivity

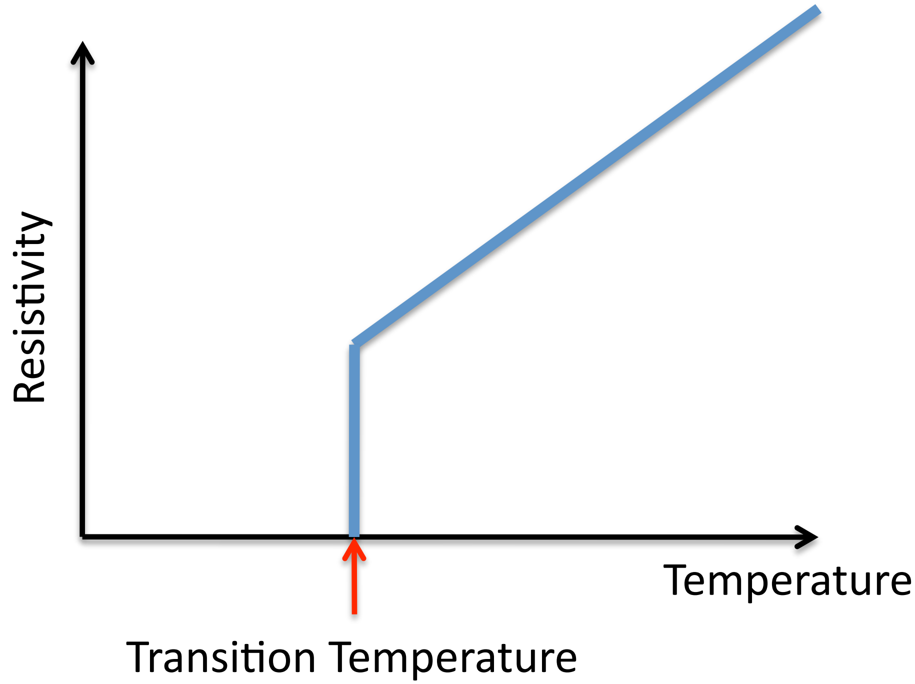


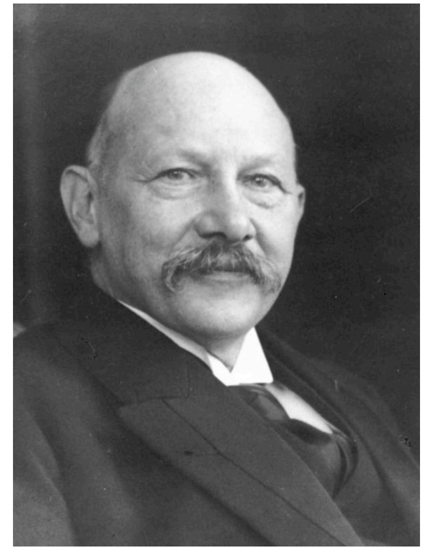
Metals



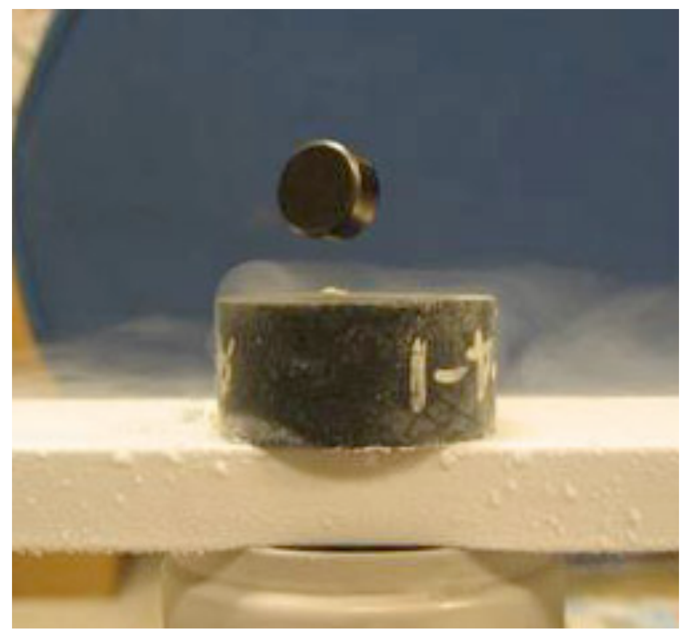
Semiconductors

Superconductivity





Onnes, 1911: in Mercury

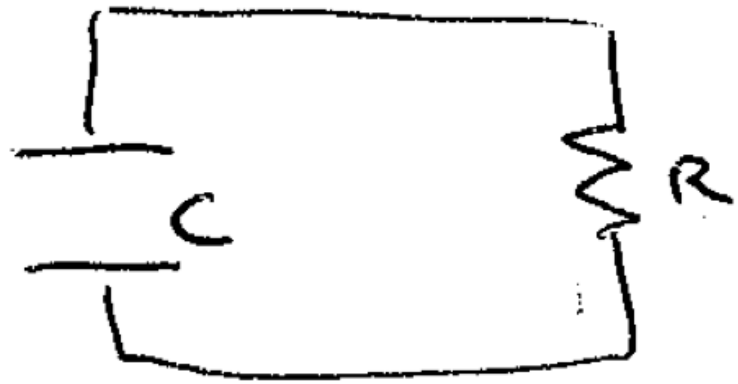


• zero resistivity

• perfect resistance to any magnetic field

Tc =138 K $HgBa_2Ca_2Cu_3O_8$

RC circuit

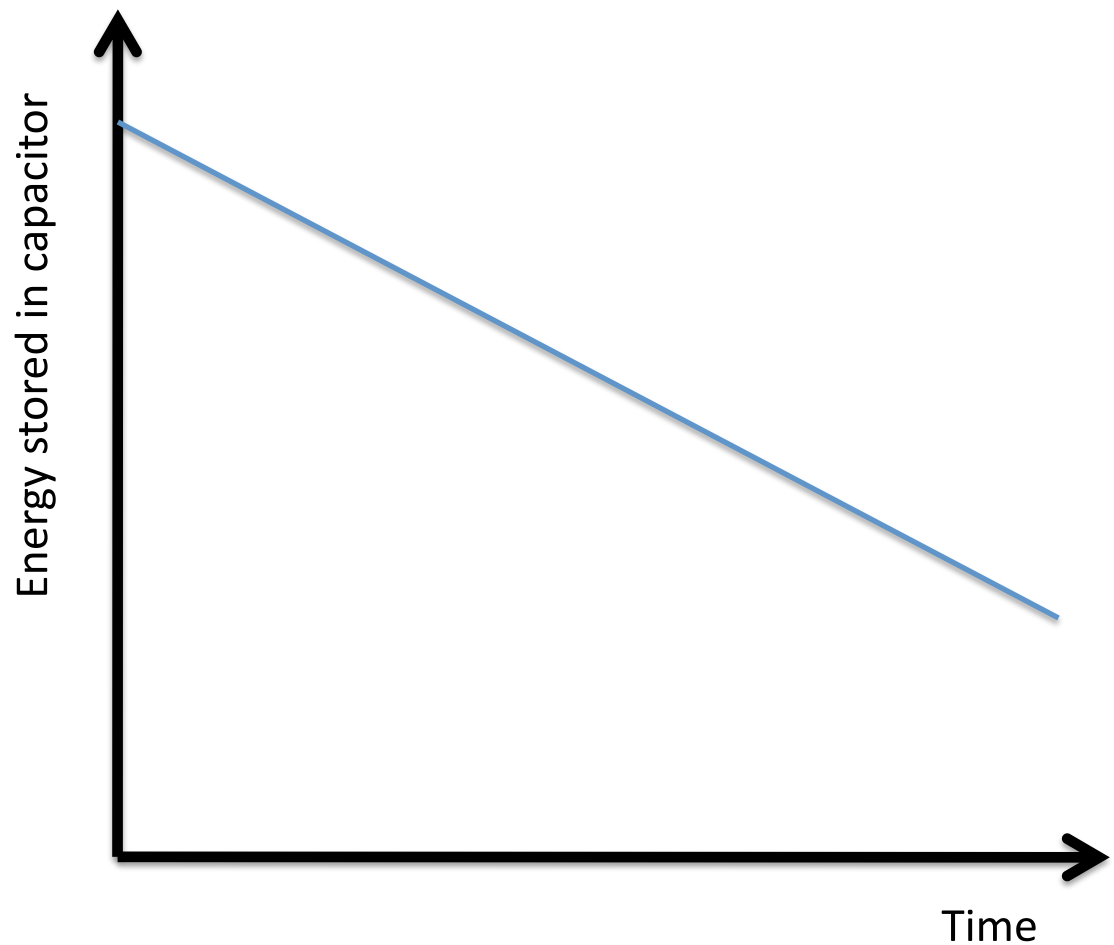


C = 100 μF

Initially, voltage across the capacitor is 10 volts and it discharges

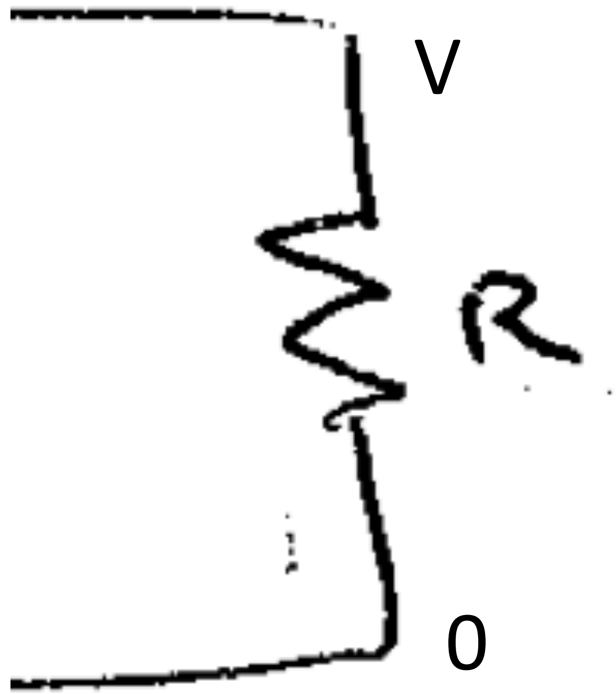
Initial energy stored is $\frac{1}{2}CV^2$

Board calculation

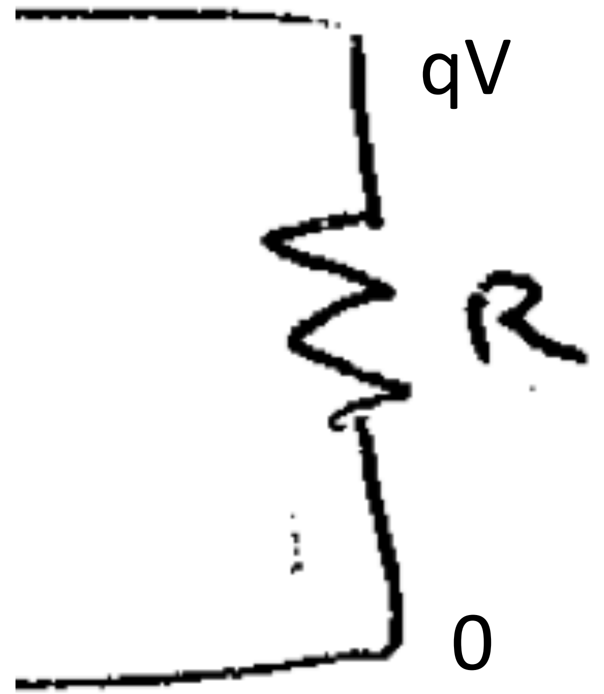


Power: rate of energy dissipated in circuit

Potential drop across the resistor



Potential energy drop across the resistor

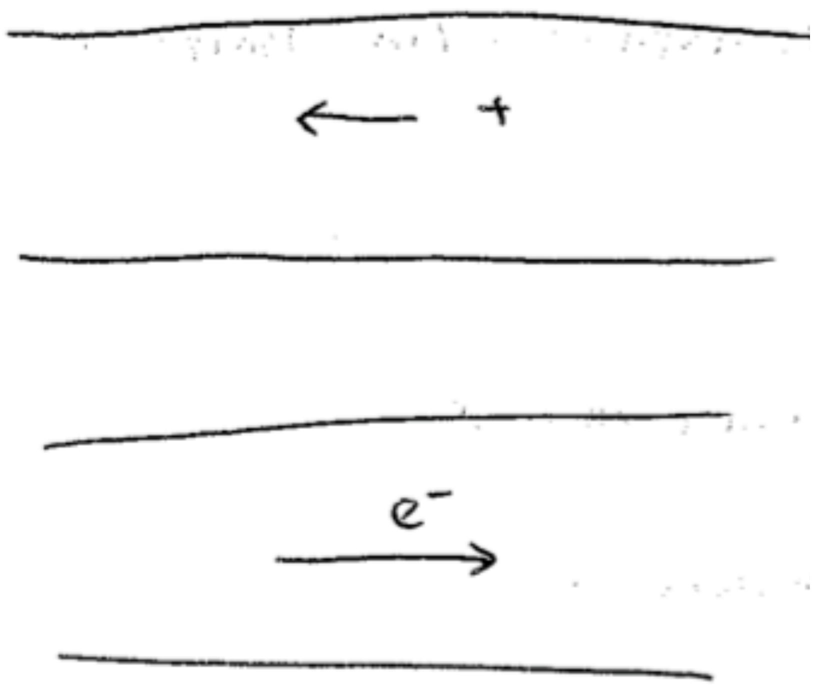


If voltage is held constant, rate of energy dissipation is

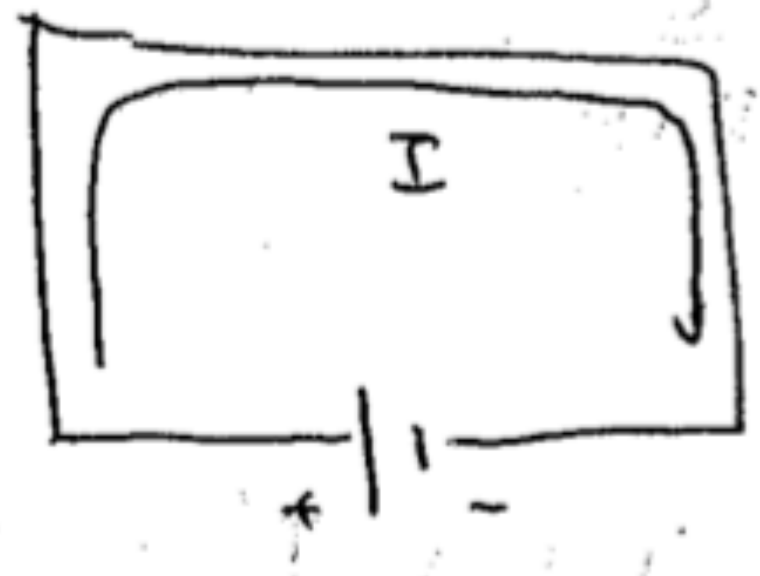
$$\frac{d(qV)}{dt} = V\frac{dq}{dt} = IV = P$$

P: power [J/s], Watt

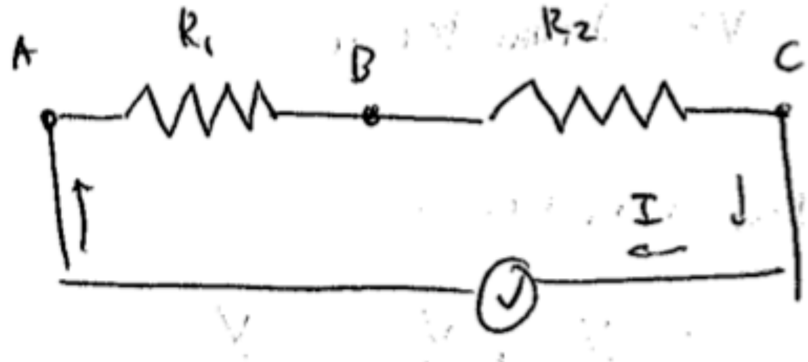
Direction of current



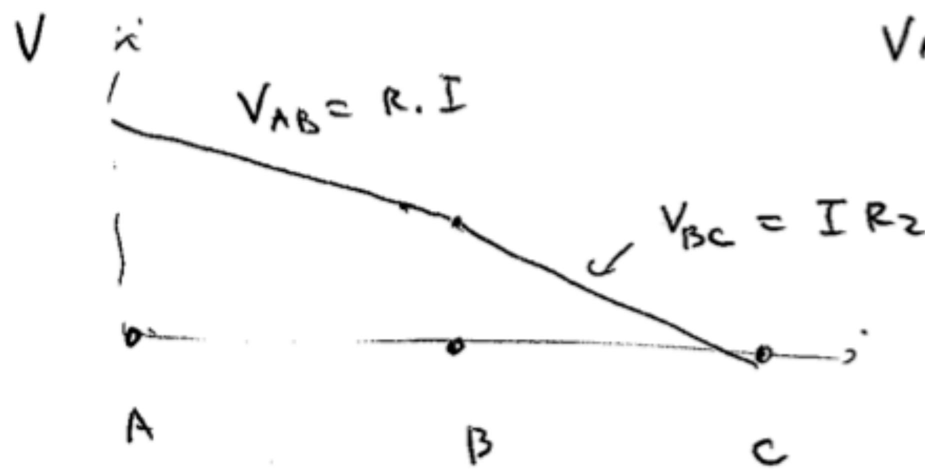
Convention assumes positive charges



Resistors in series



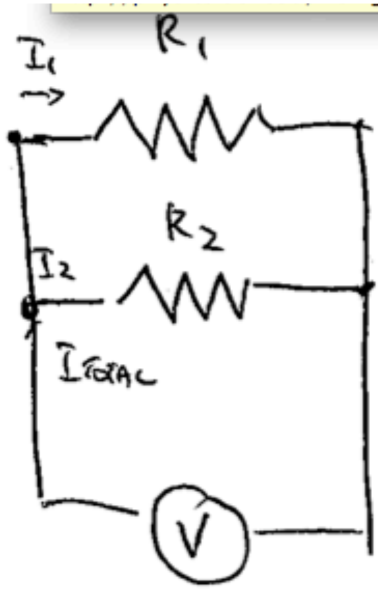
~~IR~~ $I R_{TOTAL} = V$



$V_{AB} + V_{BC} = V = I(R_1 + R_2)$

$R_{TOTAL} = R_1 + R_2$

Resistors in parallel



$$V = I_1 R_1$$

$$V = I_2 R_2$$

$$V = I_{TOTAL} R_{TOTAL}$$

$$I_{TOTAL} = I_1 + I_2$$

$$= \frac{V}{R_1} + \frac{V}{R_2} = \frac{V}{R_{TOTAL}}$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$