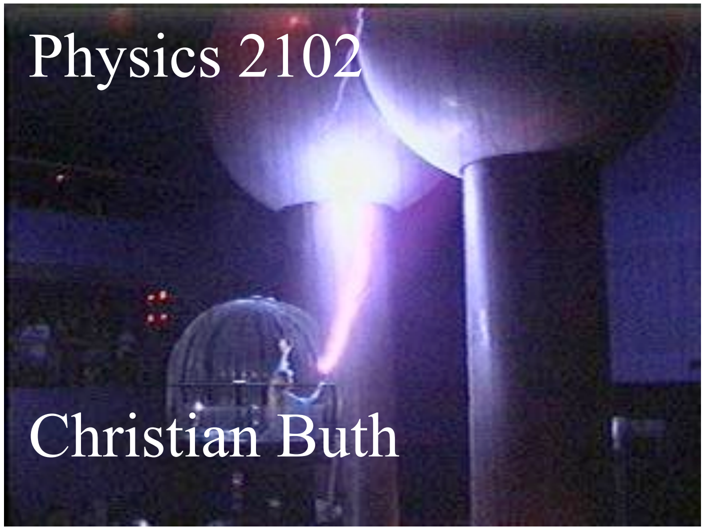
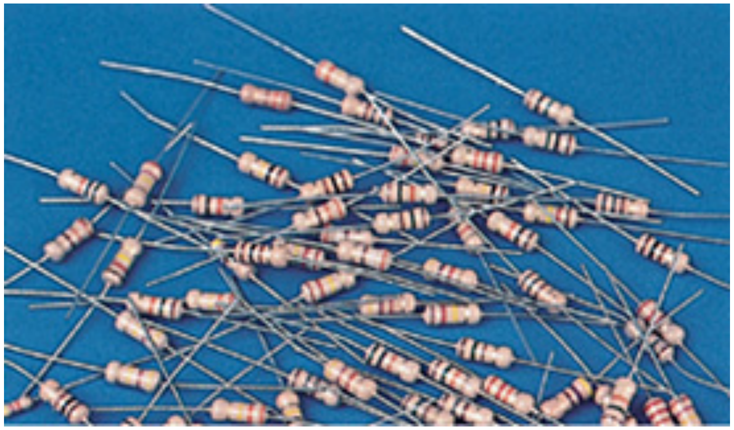
Resistance
Is
Futile!



Physics 2102
Lecture 14
Current and Resistance 2

Georg Simon Ohm
(1789-1854)

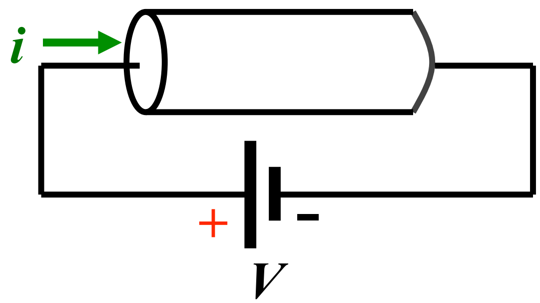


Version: 02/13/2009

Review

- Capacitor with a dielectric: **capacitance increases** $C' = \kappa C$
- Dielectric consists of molecules which **align** in field; yields **surface charges** which reduce the field between the plates
- Battery creates **potential difference** which leads to a **current** in a closed circuit
- **Current arrow** is drawn in direction in which **positive** charge carriers would move
- **Drift speed**: v_d speed at which electrons move to establish a current

Resistance



• The resistance is related to the potential we need to apply to a device to drive a given current **through** it

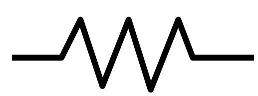
• The larger the resistance, the larger the potential we need to drive the same current

$$R \equiv \frac{V}{i}$$

Georg Simon Ohm (1789-1854)

$$[R] = \frac{\text{Volt}}{\text{Ampere}} \equiv \text{Ohm (abbr. } \Omega)$$

"a professor who preaches such heresies is unworthy to teach science." Prussian minister of education 1830

Devices specifically designed to have a constant value of *R* are called **resistors**, and symbolized by 

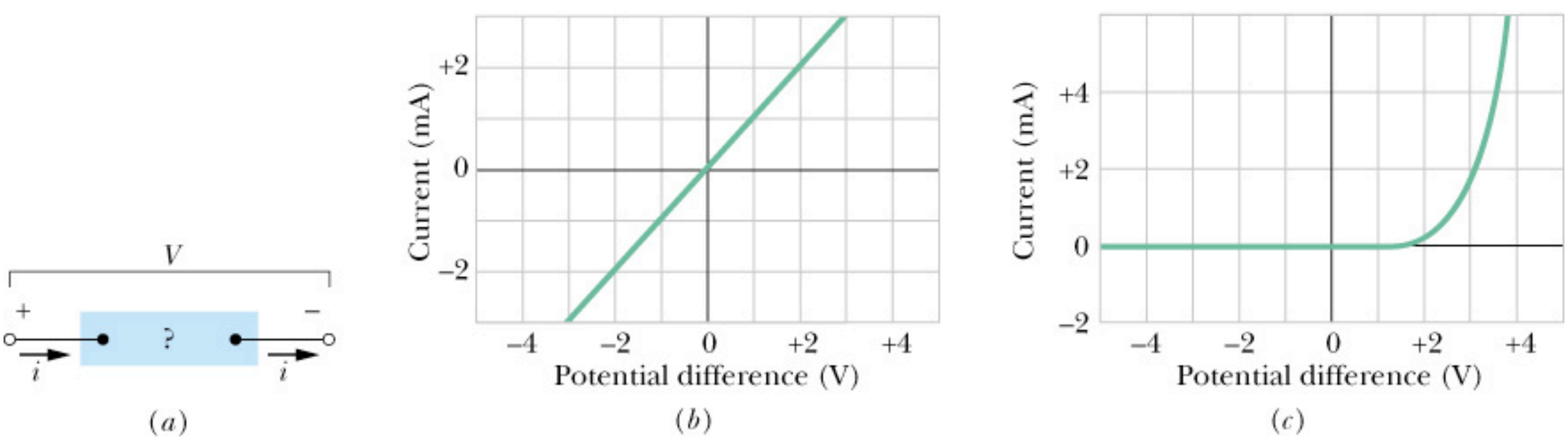
Example

A human being can be electrocuted if a current as small as 50 mA passes near the heart. An electrician working with sweaty hands makes good contact with the two conductors he is holding. If his resistance is 1500 Ω, what might the fatal voltage be?

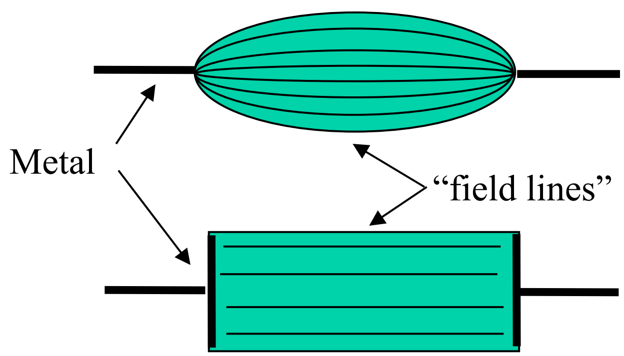
(Ans: 75 V)

Ohm's Law

- A **resistor** is a conductor whose resistance does **not** change with the voltage
- Plots (b), (c) is called ***I – V* curve**
- Conductor with linear *I – V* curve is said to be **Ohmic** Fig. (b)
- Conductor (semiconductor diode) in Fig. (c) is **non-Ohmic**



Resistivity and resistance



- Two devices could have the same resistance R
- Yet obvious that inside different things go on

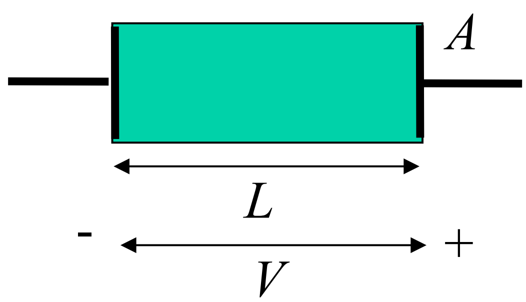
Resistivity: $\rho = \dfrac{E}{J}$ or, as vectors, $\vec{E} = \rho\,\vec{J}$

Resistance: $R = V/I$

Conductivity : $\sigma = \dfrac{1}{\rho}$

- **Resistivity** is associated with a **material**
- **Resistance** with respect to a **device** constructed with the material

Resistance of a Rod



$$E = \frac{V}{L}, \qquad J = \frac{i}{A}$$

$$\rho = \frac{V/L}{i/A} = R\frac{A}{L}$$

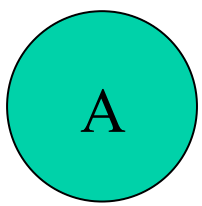
$$\boxed{R = \rho\frac{L}{A}}$$

Makes sense! Longer → More resistance

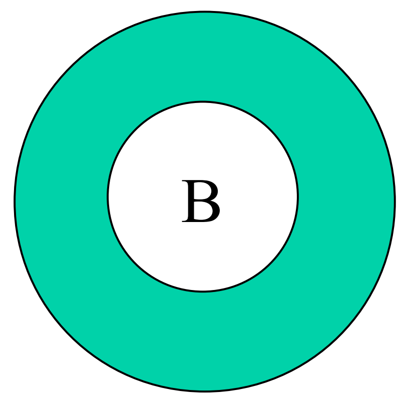
For a given material: Thicker → Less resistance

Example

Two conductors are made of the same material and have the same length. Conductor *A* is a solid wire of diameter 1.0 mm. Conductor *B* is a hollow tube of outside diameter 2.0 mm and inside diameter 1.0 mm. What is the resistance ratio R_A/R_B, measured between their ends?



$$R=\rho L/A$$



$$A_A=\pi\, r^2$$

$$A_B=\pi\, ((2r)^2-r^2)=3\pi r^2$$

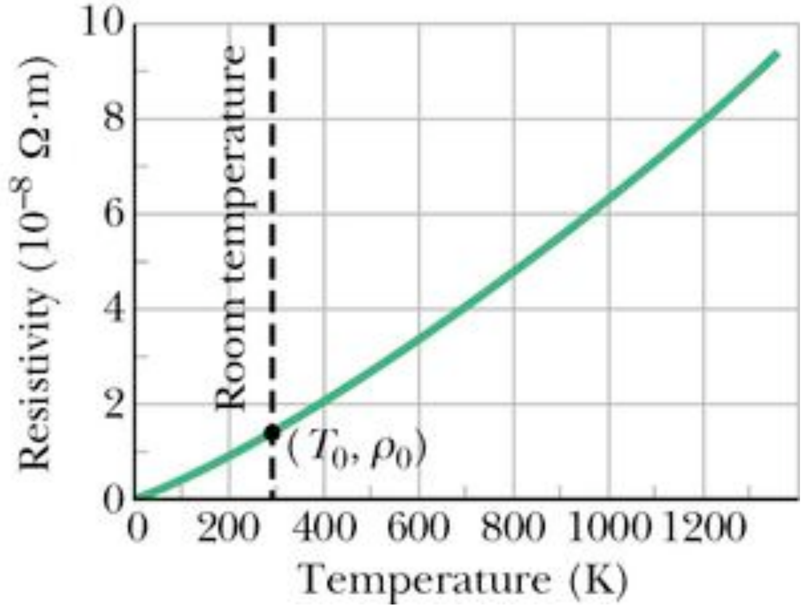
$$R_A/R_B= A_B/A_A= 3$$

Resistivity and Temperature

- Resistivity depends on temperature **almost** linearly:

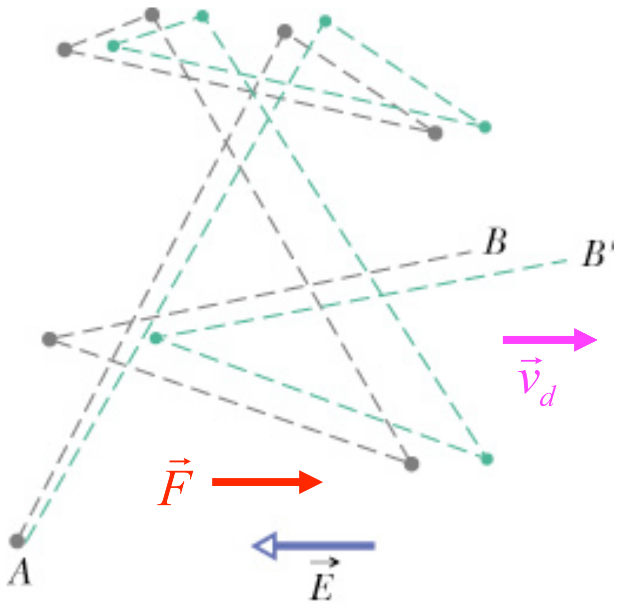
$$\rho = \rho_0 (1+\alpha (T-T_0))$$

- **Reference temperature** T_0
- **Temperature coefficient** of resistivity α
- Resistivity at T_0 is ρ_0



- Temperature difference => Celsius and Kelvin may be used
- At what T is the resistance of copper twice its value at 20.0°C?
- Does this hold for copper conductors of all shapes and sizes?

Microscopic View of Ohm's Law



- **Conduction process** at atomic level
- Conduction electrons move in **random directions** with effective speed $v_{\text{eff}} = 1.6 \times 10^6$ m/s
- **Collisions** of conduction electrons with stationary ionic lattice
- An electric field imposes a small **drift speed** v_d

Microscopic Resistivity

- **Time** between collisions τ
- Force from electric field $F = eE$
yielding **acceleration** $a = F/m = eE/m$
- Drift speed $v_{\mathrm{d}} = a\tau = eE\tau/m = J/(ne)$
- This gives $E = \dfrac{m}{ne^2\tau} J$
- With $E = \rho J$ the resistivity is $\rho = \dfrac{m}{ne^2\tau}$
- This is a statement of Ohm's law (the resistance of the conductor does not depend on the voltage and thus E)

Summary

• A **resistor** is a conductor whose resistance does **not** change with the voltage

$$R \equiv \frac{V}{i} \qquad R = \rho \frac{L}{A}$$

• A linear $I - V$ curve is said to be **Ohmic** otherwise non-Ohmic

• **Resistivity** is associated with a **material**, **resistance** with respect to a **device** constructed with the material

• Conductivity : $\sigma = \dfrac{1}{\rho}$

• Resistivity depends on temperature: $\rho = \rho_0 (1+\alpha (T\text{-}T_0))$

• Reason for resistance: conduction electrons **collide** with stationary ionic lattice