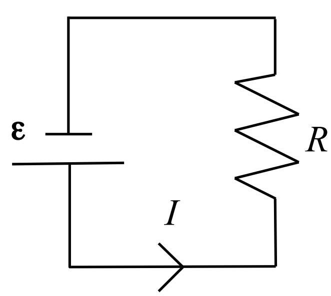
Lecture 4

Physics 1502: Lecture 9
Today's Agenda

- **Announcements:**
  - **Lectures posted on:** **www.phys.uconn.edu/~rcote/**
  - **HW assignments, solutions etc.**

- **Homework #3:**
  - **On Masterphysics : due Friday at 8:00 AM**
  - **Go to masteringphysics.com**

Electric Current



$\varepsilon = R\,I$

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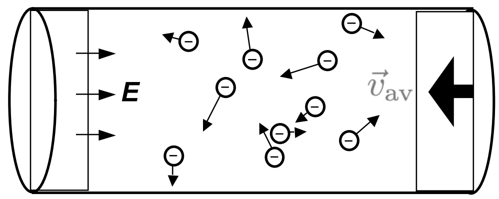
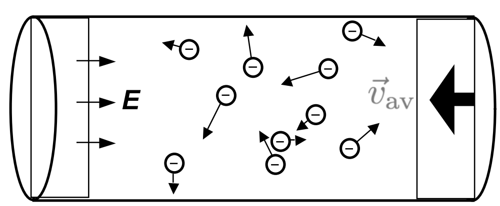
Current Idea



- Current is the flow of charged particles through a path, at circuit.
- Along a simple path current is conserved, cannot create or destroy the charged particles
- Closely analogous to fluid flow through a pipe.
  - Charged particles = particles of fluid
  - Circuit = pipes
  - Resistance = friction of fluid against pipe walls, with itself.

Current & Resistance

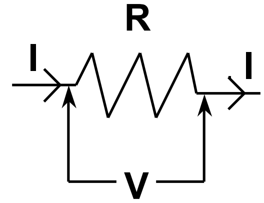


- **Current**
  - — Definition: $I_{avg} = \Delta Q / \Delta t$ or $I = \partial Q / \partial t$
  - — and $I_{avg} = \Delta Q/\Delta t = n\, A\, v_d\, q$
- **Resistance and Ohm's law**

  Resistance is defined to be the ratio of the applied voltage to the current passing through.

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

UNIT: OHM = Ω



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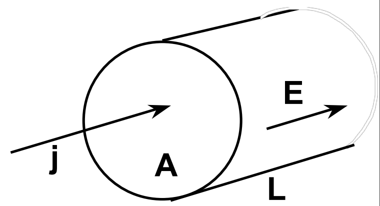
Resistivity & Resistance

- **Property of bulk matter related to resistance of a sample is the resistivity ρ defined as:**

$$\rho \equiv \frac{E}{j}$$



where E = electric field and

j = current density in conductor = *I/A*.

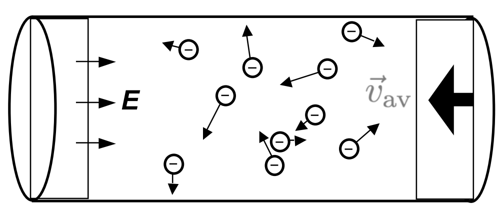
- **From the potential** $V = EL$

$$\Rightarrow V = EL = \rho j L = \rho \frac{I}{A} L = I\left(\frac{\rho L}{A}\right)$$

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

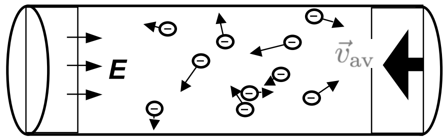
- **Depends only on geometry and material**
  - **Longer ⇒ harder to flow**
  - **Wider ⇒ easier to flow**

A more detailed model



- $I_{avg} = \Delta Q/\Delta t = n\, A\, v_d\, q$
- Difficult to know v_d directly.
- Can calculate it.

A more detailed model



- $I_{avg} = \Delta Q/\Delta t = n\, A\, v_d\, q$
- The force on a charged particle is,

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

- If we start from v=0 (on average) after a collision then we reach a speed,

$$\vec{v}_{avg} = \vec{v}_d = \frac{q\vec{E}}{m_e}\tau$$

τ : average collision-free time

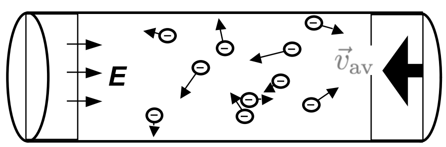
- Substituting gives, (note *j* = *I/A*)

$$\rho \equiv \frac{E}{j} \qquad \vec{j} = \frac{n_0 q^2 \vec{E}}{m_e}\tau$$

or

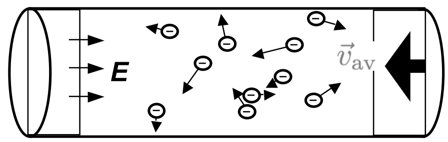
$$\sigma \equiv \frac{1}{\rho} = \frac{n_0 q^2 \tau}{m_e}$$

A more detailed model



- This formula is still true for most materials even for the most detailed quantum mechanical treatment.
- In quantum mechanics the electron can be described as a wave. Because of this the electron will not scatter off of atoms that are perfectly in place in a crystal.
- Electrons will scatter off of
    1. Vibrating atoms (proportional to temperature)
    2. Other electrons (proportional to temperature squared)
    3. Defects in the crystal (independent of temperature)

Lecture 9, ACT 1



I am operating a circuit with a power supply and a resistor. I crank up the power supply to increase the current. Which of the following properties increases,

A) n   B) q   C) E   D) τ

Conductivity versus Temperature

- **In lab you measure the resistance of a light bulb filament versus temperature.**
- **You find R∝T.**
- **This is generally (but not always) true for metals around room temperature.**
- **For insulators R∝1/T.**
- **At very low temperatures atom vibrations stop. Then what does R vs T look like??**
- **This was a major area of research 100 years ago – and still is today.**

Lecture 4

Resistivities and Temperature Coefficients of Resistivity for Various Materials

Material	Resistivity[a] ($\Omega \cdot m$)	Temperature Coefficient[b] $\alpha[(°C)^{-1}]$
Silver	1.59×10^{-8}	3.8×10^{-3}
Copper	1.7×10^{-8}	3.9×10^{-3}
Gold	2.44×10^{-8}	3.4×10^{-3}
Aluminum	2.82×10^{-8}	3.9×10^{-3}
Tungsten	5.6×10^{-8}	4.5×10^{-3}
Iron	10×10^{-8}	5.0×10^{-3}
Platinum	11×10^{-8}	3.92×10^{-3}
Lead	22×10^{-8}	3.9×10^{-3}
Nichrome[c]	1.50×10^{-6}	0.4×10^{-3}
Carbon	3.5×10^{-5}	-0.5×10^{-3}
Germanium	0.46	-48×10^{-3}
Silicon	640	-75×10^{-3}
Glass	10^{10} to 10^{14}	
Hard rubber	$\sim 10^{13}$	
Sulfur	10^{15}	
Quartz (fused)	75×10^{16}	

[a] All values at 20°C.
[b] See Section 27.4.
[c] A nickel–chromium alloy commonly used in heating elements.

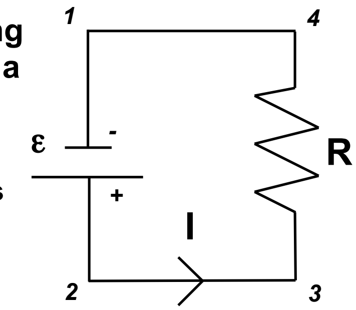
Color Coding for Resistors

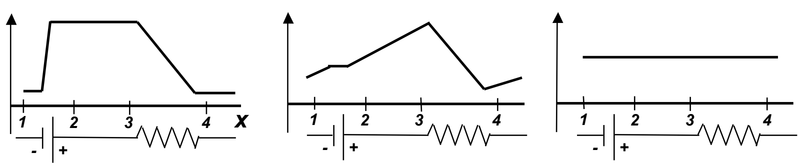
Color	Number	Multiplier	Tolerance
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5%
Silver		10^{-2}	10%
Colorless			20%

Lecture 9, ACT 2

Consider a circuit consisting of a single loop containing a battery and a resistor.

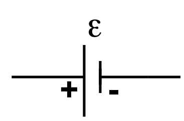
Which of the graphs represents the current I around the loop?





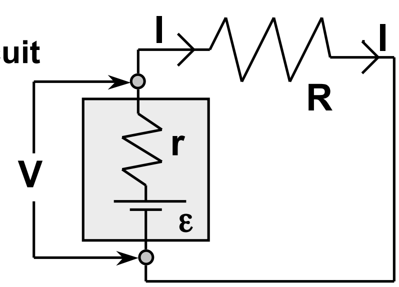
Electromotive force

- **Provides a constant potential difference between 2 points**
  - ε: "electromotive force" (emf)



- **May have an internal resistance**
  - Not "ideal" (or perfect: small loss of V)
  - Parameterized with "internal resistance" r in series with ε
- **Potential change in a circuit**

$$\varepsilon - Ir - IR = 0$$



Power

- **Battery:**

  Stores energy chemically. When attached to a circuit, the energy is transferred to the motion of electrons. This happens at a constant **potential**.

  » Battery **delivers** energy to a circuit.

  » Other elements, like resistors, dissipate energy. (light, heat, etc.)

- **Total energy delivered not always useful.**
  - How much energy does it take to light your house … well for how long?
  - Remember definition of Power (Phys. 1501).

Power

- **Recall that**

$$P = \frac{dW}{dt} \quad \text{where} \quad W = qV$$

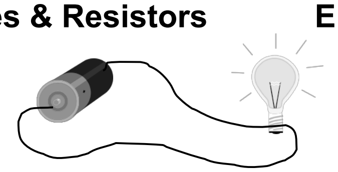
- **In a circuit, where the potential remains constant.**
  - Only q varies with time

$$dW = V\,dq + q\,dV$$

$$P = \frac{dW}{dt} = V\frac{dq}{dt} = VI$$

Power

Batteries & Resistors **Energy expended**



chemical
to electrical
to heat

Rate is: $\frac{\text{energy}}{\text{time}} = \text{power}\left(\frac{J}{s}\right)$

What's happening?

Charges per time

Assert: $\boxed{P = VI}$

Energy "drop" per charge

For Resistors: $\boxed{P = (IR)I = I^2R}$ or $\frac{V^2}{R}$

Units okay? $\frac{\text{Joule}}{\text{Coulomb}} \times \frac{\text{Coulomb}}{\text{second}} = \frac{J}{s} = Watt$ ☑

Power

- **What does power mean?**
  - Power delivered by a battery is the amount of work per time that can be done. i.e. drive an electric motor etc.
  - Power dissipated by a resistor, is amount of energy per time that goes into heat, light, etc.
- **A light bulb is basically a resistor that heats up. The brightness (intensity) of the bulb is basically the power dissipated in the resistor.**
  - A 200 W bulb is brighter than a 75 W bulb, all other things equal.

Lecture 9, Act 3

- You buy two light bulbs at the hardware store, a 200 W bulb and a 100 W bulb. Which bulb has the larger resistance?

A) 200 W bulb B) 100 W bulb C) Same