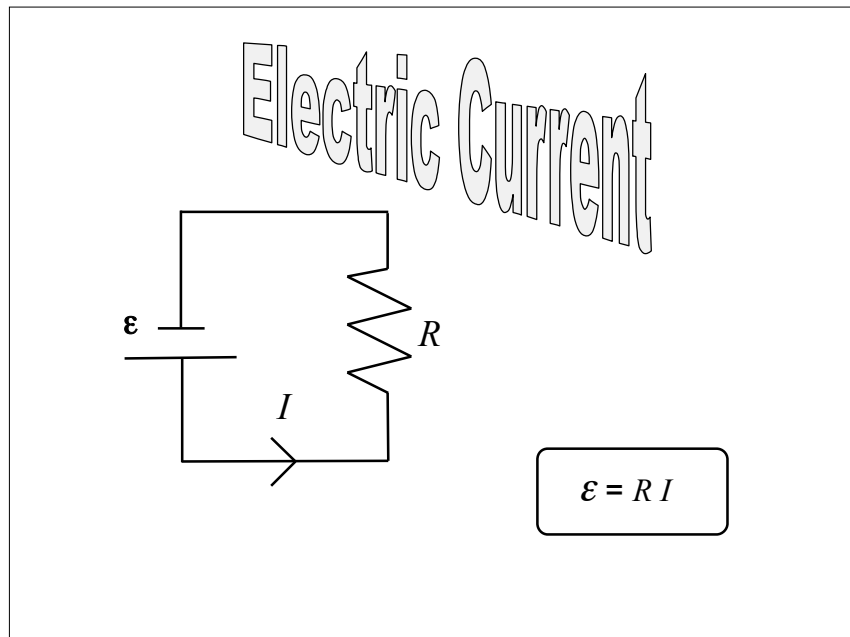


Lecture 4

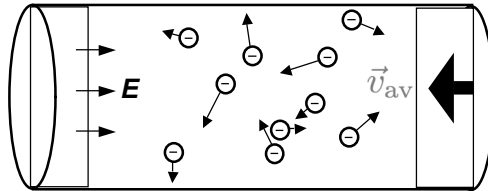
Physics 1402: Lecture 9 Today's Agenda

- **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



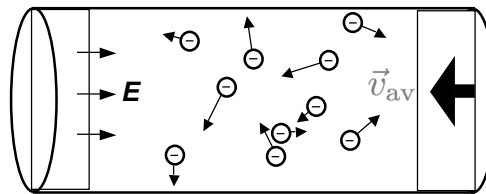
Lecture 4

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



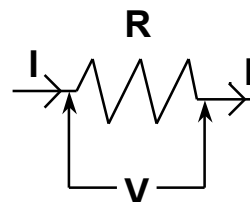
- **Current**
 - Definition: $I_{avg} = \Delta Q / \Delta t$ or $I = dQ / dt$
 - and $I_{avg} = \Delta Q / \Delta t = n A v_d q$

- **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



Lecture 4

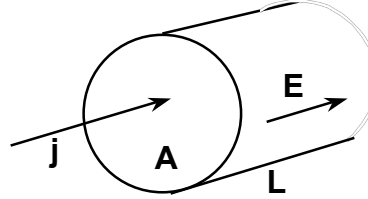
Resistivity & Resistance

- 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 $V = EL$

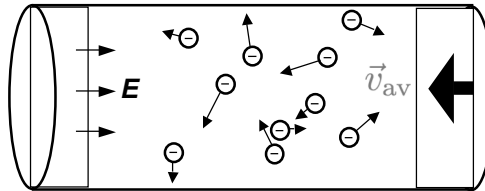
$$\Rightarrow V = EL = \rho jL = \rho \frac{I}{A} L = I \left(\frac{\rho L}{A} \right)$$

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

- Depends only on geometry and material

- Longer \Rightarrow harder to flow
- Wider \Rightarrow easier to flow

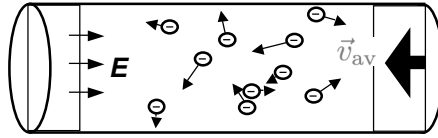
A more detailed model



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

Lecture 4

A more detailed model



- $I_{\text{avg}} = \Delta Q / \Delta t = n A v_d q$

- The force on a charged particle is,

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

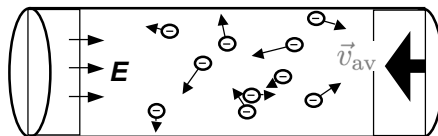
- If we start from $v=0$ (on average) after a collision then we reach a speed,

$$\vec{v}_{\text{avg}} = \vec{v}_d = \frac{q\vec{E}}{m_e} \tau \quad \tau : \text{average collision-free time}$$

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

$$\rho \equiv \frac{E}{j} \quad \vec{j} = \frac{n_0 q^2 \vec{E}}{m_e} \tau \quad \text{or} \quad \sigma \equiv \frac{1}{\rho} = \frac{n_0 q^2 \tau}{m_e}$$

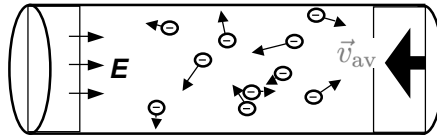
A more detailed model



- 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 4

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 $R \propto T$.
- This is generally (but not always) true for metals around room temperature.
- For insulators $R \propto 1/T$.
- 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 $\alpha[(^{\circ}C)^{-1}]$
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.

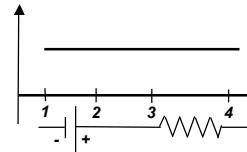
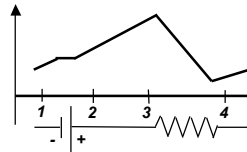
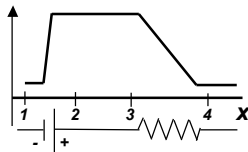
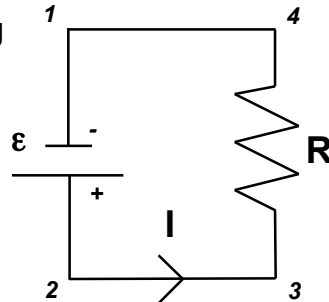
Color Coding for Resistors			
Color	Number	Multiplier	Tolerance
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5%
Silver		10^{-2}	10%
Colorless			20%

Lecture 4

Lecture 9, ACT 2

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

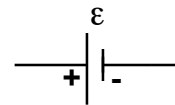
Which of the graphs represents the current I around the loop?



Electromotive force

- Provides a constant potential difference between 2 points

– ϵ : “electromotive force” (emf)



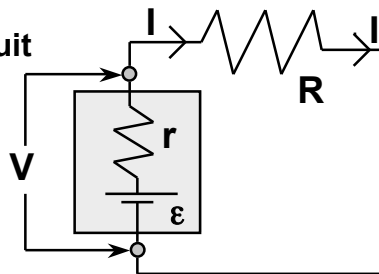
- May have an internal resistance

– Not “ideal” (or perfect: small loss of V)

– Parameterized with “internal resistance” r in series with ϵ

- Potential change in a circuit

$$\epsilon - Ir - IR = 0$$



Lecture 4

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. 1401).

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

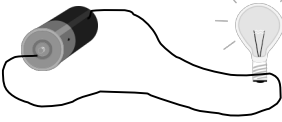
$$dW = Vdq + qdV$$

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

Lecture 4

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: $P = VI$

Energy "drop" per charge

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

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

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 4

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