Physics 202, Lecture 8

Today's Topics

- More on Exam 1: logistics and mini-review
- Current And Resistance (Ch. 27)
  - Current: Macroscopic and Microscopic
  - Resistance: Macroscopic and Microscopic
  - Electrical Power

Reminder: Homework #3 due Friday, 9/28, 10 PM.

Exam 1

- **Logistics. Exam time: Monday Oct 1 at 5:30-7:00pm**

Rooms: 2650 and 3650 Humanities

2650: Sections 304,305,310,312,323,324,327
3650: Sections 301,302,303,307,321,325,326,328,329,330

- **Bring: your calculator, your formula sheet**
- **Alternate exam times:**
  Only open to those with evening course conflicts who have provided prior notification!!

  Those in this category should have received email from me today regarding alternate exam schedule (if not, contact me and/or your TA ASAP -- by Friday at latest)

Exam 1: Electrostatics Topics

Most important topic: calculating electric fields and potentials for discrete and continuous charge distributions.

3 methods:

1. Direct calculation of E field: integrate to get V.
2. Gauss's Law: obtain E (special cases), integrate to get V.
3. Calculate electric potential V: take derivatives to get E.

Point charges -- straightforward.
Continuous distributions -- harder in general.

You will not be asked to do any problem where a nontrivial surface or volume integral is required.

Ex: 1., 3. uniformly charged ring and finite line charge (on-axis)
2. Gauss's Law (uniform sphere, infinite cylinder/line, infinite plane)

Exam 1: Electrostatics Topics, Mechanics

More topics (not exhaustive):

- ❑ Coulomb Forces, Potential Energy
- ❑ Motion of charged particles in electric fields
- ❑ Electric field lines and equipotentials
- ❑ Conductors in electrostatic equilibrium
- ❑ Capacitance, Capacitors in circuits (example)

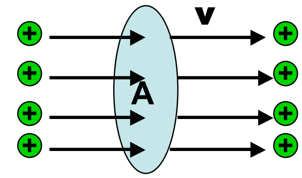
Mechanics -- not the main focus, but you should know:

- ❑ Kinematics of uniformly accelerated particles
- ❑ Newton's Laws: statics and dynamics
- ❑ Anything on homework is fair game for this midterm or the final exam (e.g. circular orbits, springs)

Math -- you will not be expected to do nontrivial integrals.
You should be able to do integrals which require simple substitutions.

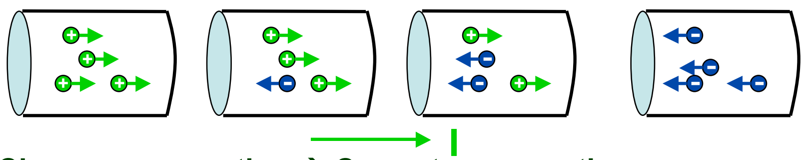
Current: Macroscopic View

- Rate at which charge flows through surface: $I = \dfrac{dQ}{dt}$

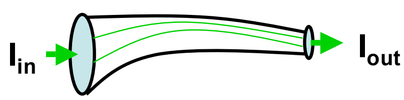


- Unit:1 Ampere = 1 C/s
- Current is directional: Follows positive charge

+q moving in +x direction ←→ –q in moving –x direction



- Charge conservation → Current conservation

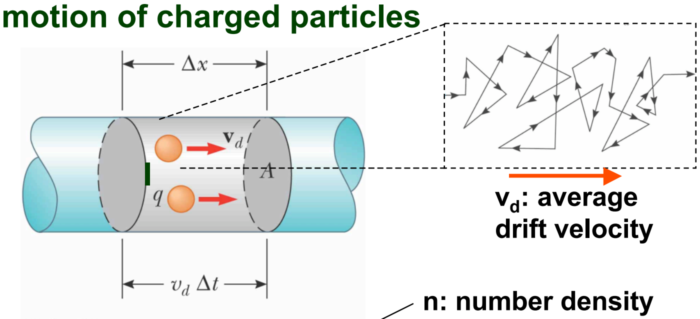


$I_{in} = I_{out}$

Examples: Ch. 27 #5

Current: Microscopic View

- Current: motion of charged particles



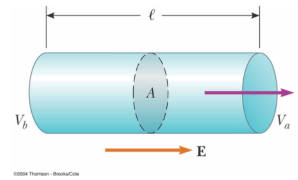
n: number density

- Show that: $I_{average} = \dfrac{\Delta Q}{\Delta t} = nqv_d A = I$
- Current density: $J = \dfrac{I}{A} = nqv_d$ note: $v_d \propto E$ (why?)

current density is really a vector: $\int \vec{J} \cdot d\vec{A} = I$

Conductivity, Resistivity, Resistance

- Ohm's Law (microscopic): **J=σE**
  - σ = conductivity
  - ρ=1/σ = resistivity



- Ohm's Law (macroscopic): ΔV=IR
- Resistance R (unit: Ohm Ω = Volt/Ampere)
- Exercise: relate R to ρ

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

Resistance

Length & Cross-section (shape)

Resistivity (intrinsic)

Resistors

Resistivity For Various Materials

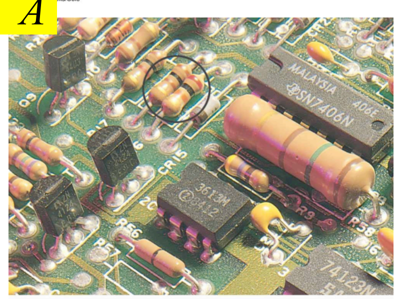
Resistivities and Temperature Coefficients of Resistivity for Various Materials

Material	Resistivity[a] (Ω · m)	Temperature Coefficient[b] α[(°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}	

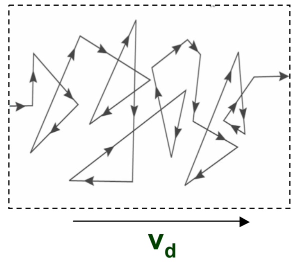
[a] All values at 20°C.
[b] See Section 27.4.
[c] A nickel–chromium alloy commonly used in heating elements.

Resistors

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



Classical Model For Electrical Conduction



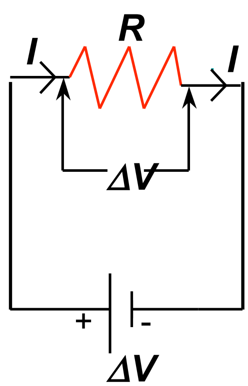
- Free electrons inside conductor:
  - density: n_e
  - average time between collisions: Collision time τ
- Exercise: Show that average drift speed due to E (board) $v_d = \tau eE/m_e$)
- $J=n_e e v_d = (n_e e^2\tau)/m_e E$

resistivity $\rho = m_e/(n_e e^2\tau)$

Electrical Power

- Electrical Power

$$P = \frac{dU}{dt} = \frac{d(Q\Delta V)}{dt} = I\Delta V$$

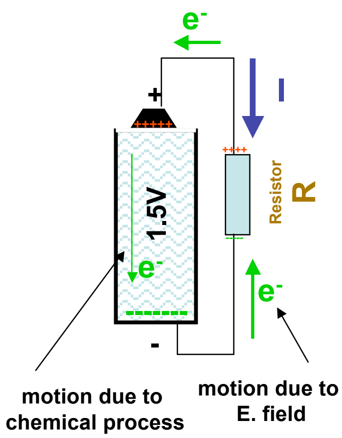


- For resistors:

$$P = I^2 R = \frac{(\Delta V)^2}{R}$$

Example: Battery Connected To A Resistor

- Show the energy flow of this battery-resistor set-up



- Chemical Process → $\Delta V = 1.5V$
- ΔV on Resistor → Current $I = \Delta V/R$

Charge flow through the resistor in Δt:
$Q = I\Delta t = \Delta V/R \Delta t$

Electrical potential energy released:
$U = Q\Delta V = \Delta V/R \Delta t \, \Delta V = (\Delta V)^2/R \Delta t$

Power: $P = U/dt = (\Delta V)^2/R$

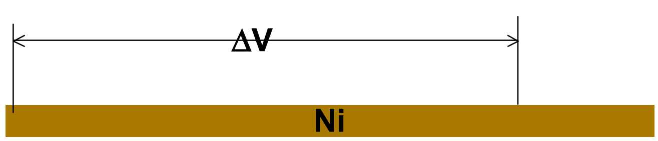
collisions

Energy Flow: Chemical → Electrical U → K_E → thermal/light

Question 1:
Consumption of Electric Power On Resistors

- A voltage is applied to a wire of length L . When L increases, Does power consumed increase or decrease?

Increases
→ Decreases
Same



Question 2:
Consumption of Electric Power On Resistors

- When a current passes through serially connected wire segments made of copper and nichrome, which metal: copper or nichrome, consume more energy?

($\rho_{Cu} \sim 10^{-8}\ \Omega m$, $\rho_{Ni} \sim 10^{-6}\ \Omega m$, All segments have about the same length and diameter.)

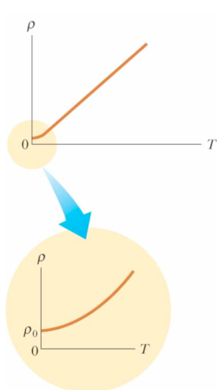
Copper

➔ Nichrome

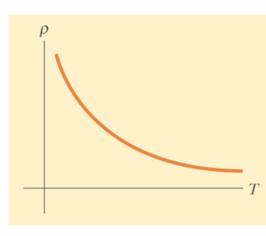
Same

Resistance And Temperature

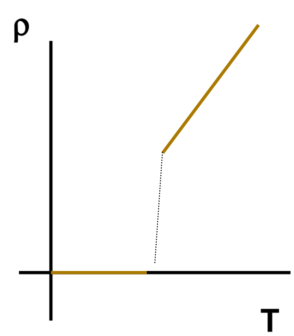
- Resistivity is usually temperature dependent.



Normal Metal



Semiconductor



Superconductor

Superconductivity

- **Superconductors: temperature $T<T_C$, resistivity $\rho=0$**
  - **Superconductivity is a quantum phenomenon.**
  - **Superconductors have special electric and magnetic features**

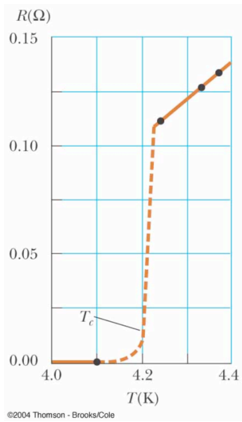


Table 27.3

Critical Temperatures for Various Superconductors

Material	T_c(K)
$HgBa_2Ca_2Cu_3O_8$	134
Tl–Ba–Ca–Cu–O	125
Bi–Sr–Ca–Cu–O	105
$YBa_2Cu_3O_7$	92
Nb_3Ge	23.2
Nb_3Sn	18.05
Nb	9.46
Pb	7.18
Hg	4.15
Sn	3.72
Al	1.19
Zn	0.88