Physics 3: ELECTRICITY AND MAGNETISM

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- No of credits: 3 (45 hours)

Textbook: Halliday/Resnick/Walker (2011) entitled Principles of Physics, 9th edition, John Willey & Sons, Inc.

Course Requirements

- Attendance + Discussion + Homework: 15%
- Assignment: 15%
- Mid-term exam: 30%
- Final: 40%

Preparation for each class

- Read text ahead of time
- Finish homework

Questions, Discussion

- Monday's and Friday's afternoon: see the secretary of the department (room A1.413) for appointments

Overview

✓ The physics of electromagnetism is the combination of electric and magnetic phenomena

✓ The basis of electronic devices: computers, TV, radio, telecommunications, lamps,...

✓ The basis of the nature phenomena: lightning, auroras and rainbows

Tel Aviv Univ.

Brief Contents
Part A: Electricity

✓Midterm exam after Lecture 10

Part B: Electromagnetism

✓Assignment given in Lecture 16
✓Final exam

Part A Electricity

Chapter 1 Electric Fields
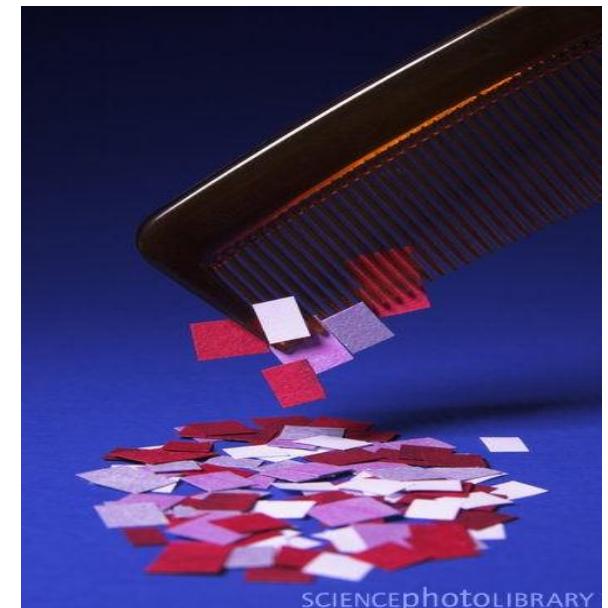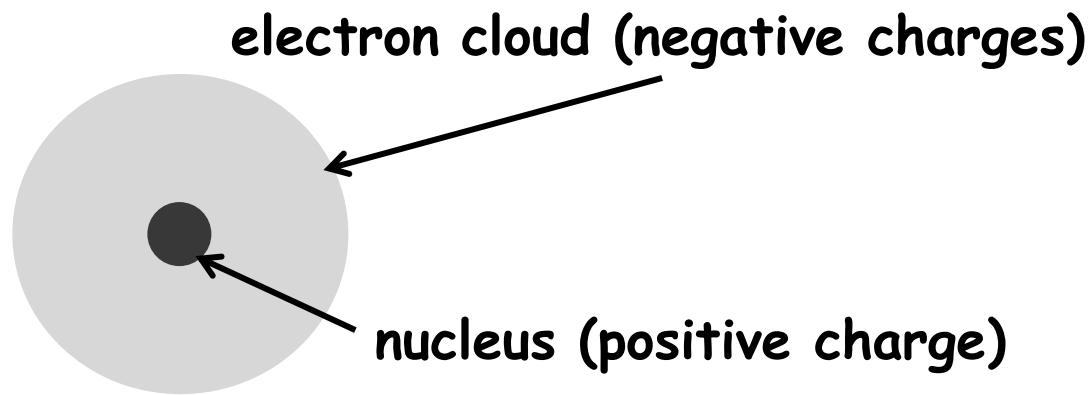
1.1. Properties of Electric Charges:

1.1.1. Electric charge:

<u>Experiment:</u> Rubbing a plastic comb with wool (dry weather), small pieces of paper can stick to the comb.

<u>Question:</u> **Why?**

electron cloud (negative charges)

nucleus (positive charge)
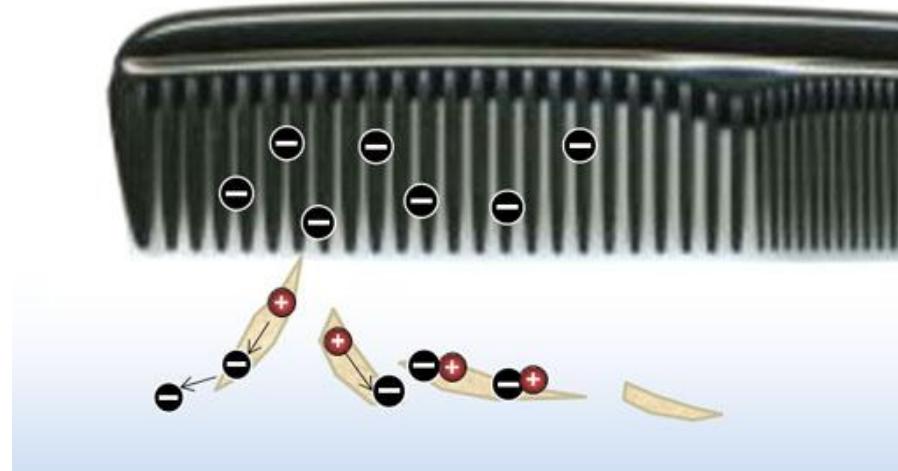
<u>Answer:</u>
- The outer electrons of the atoms in the wool are held more loosely than the outer electrons of the atoms in the plastic comb
- Some electrons from the wool get rubbed off and they stick to atoms in the plastic comb that now has an excess of negative electric charge

• When the negatively charged comb is brought near the neutral pieces of paper, the electrons on the surface of the pieces of paper are repelled, leaving the surface of papers a positive charge

• The negative charge of the comb then attracts the positive charge of the papers


chemistryland.com
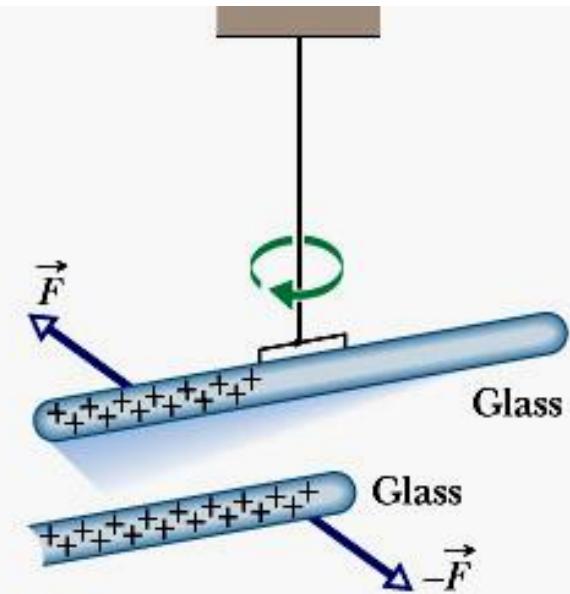
• Every object contains a vast amount of electric charge, which is an intrinsic property of the fundamental particles making up the objects

• Two types of charge: positive and negative:
  - Electrically neutral obj.: a balance of charge, no net charge
 - Charged objects: a charge imbalance or a net charge

1.1.2. Properties:
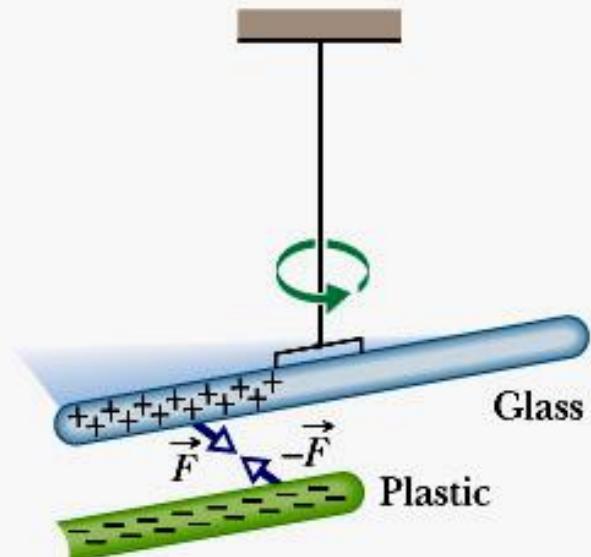
Experiments: Bringing two charged rods of the same sign and opposite signs in close proximity.

> ⊕ Charges with the same electrical sign repel each other, and charge with opposite signs attract each other

• The "*positive*" and "*negative*" labels signs were given by Benjamin Franklin in 1752.

(a) **repulsion**

(b) **attraction**

(a) Charge is quantized:
Any positive or negative charge q can be written as:

$$q = ne, n = \pm 1, \pm 2, \pm 3, \ldots$$
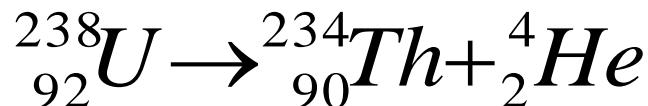
$$e = 1.602 \times 10^{-19} \text{ C}$$

- SI unit of charge: **C** (Coulomb), derived from **A** (ampere) **1 C = (1 A)(1 s)** (see next chapters)

| Particle	Symbol	Charge
Electron	e or e⁻	-e
Proton	p	+e
Neutron	n	0
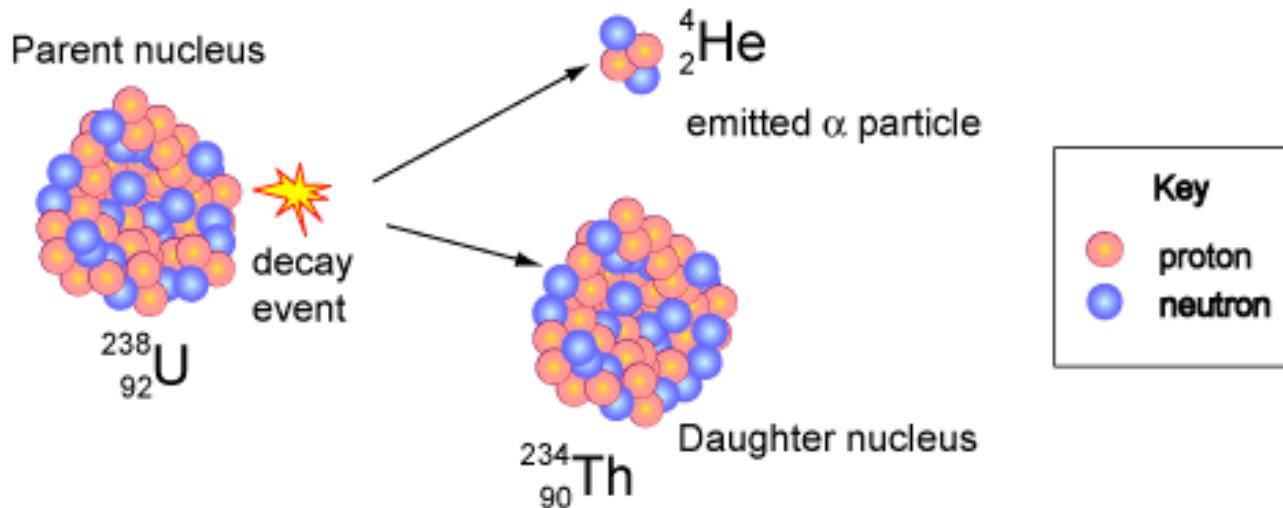
(b) Charge is conserved: The net charge of any isolated system is conserved

- **Example 1: Decay of $^{238}_{92}U$**

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$$
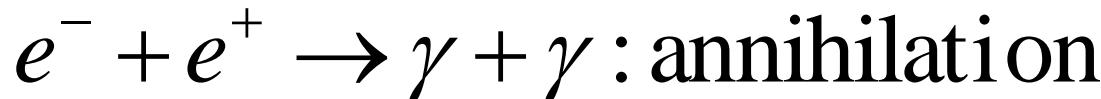
The total charge is +92e that is conserved
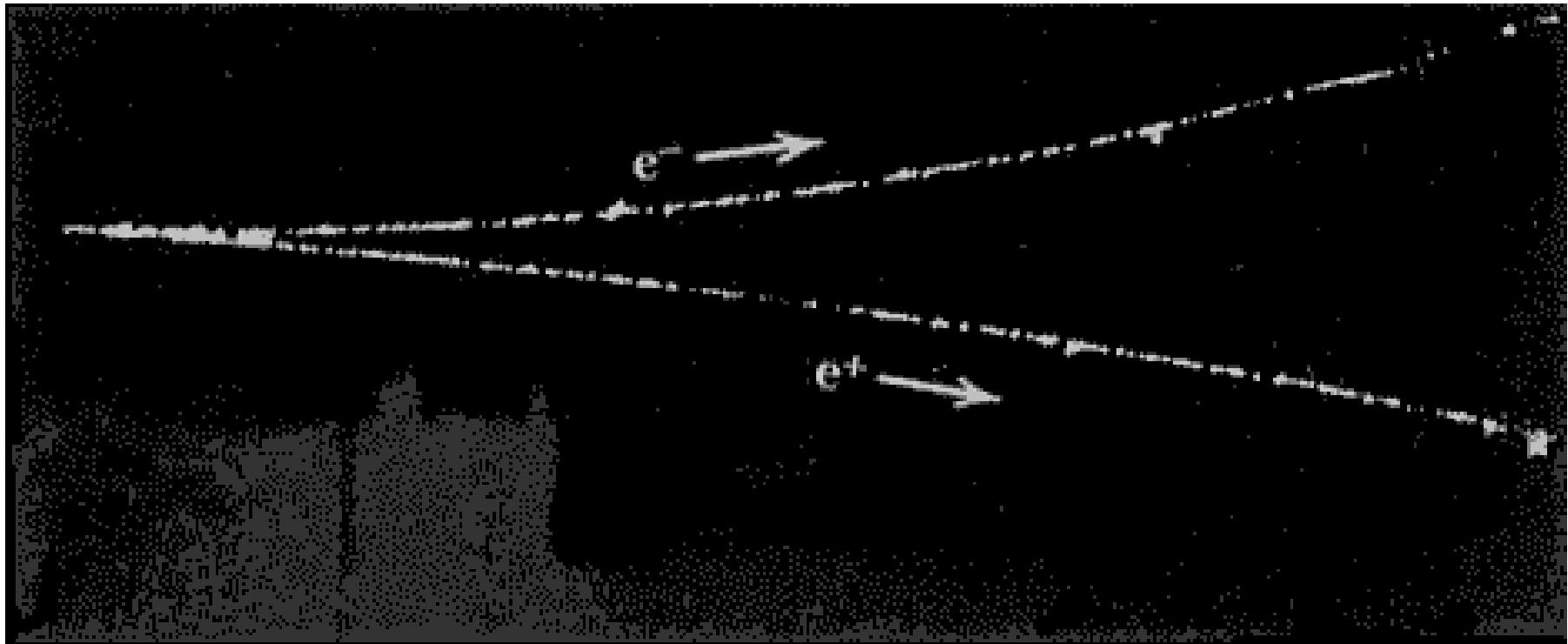
Alpha Decay of a Uranium-238 nucleus

Parent nucleus

$^{4}_{2}He$

emitted α particle

decay event

$^{238}_{92}U$

Daughter nucleus

$^{234}_{90}Th$

Key

proton

neutron

- **Example 2: Annihilation of electron e⁻ and positron e⁺ or pair production**

$$e^- + e^+ \rightarrow \gamma + \gamma : \text{annihilation}$$

$$\gamma \rightarrow e^- + e^+ : \text{pair production}$$
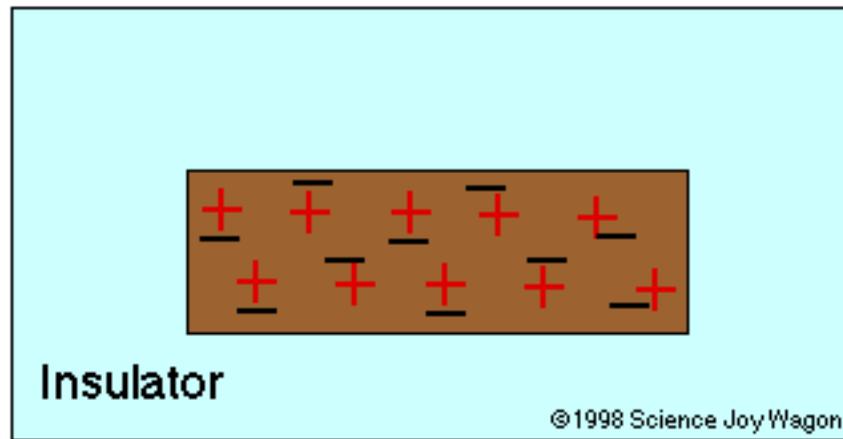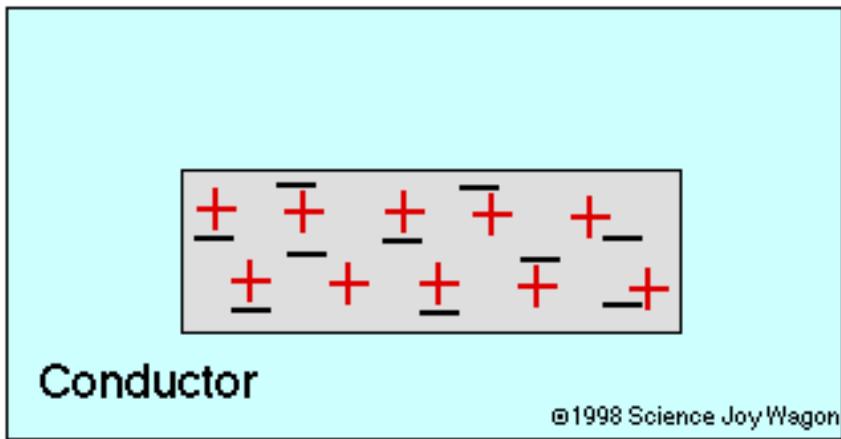
# Trails of bubbles left in a bubble chamber by an electron and a positron
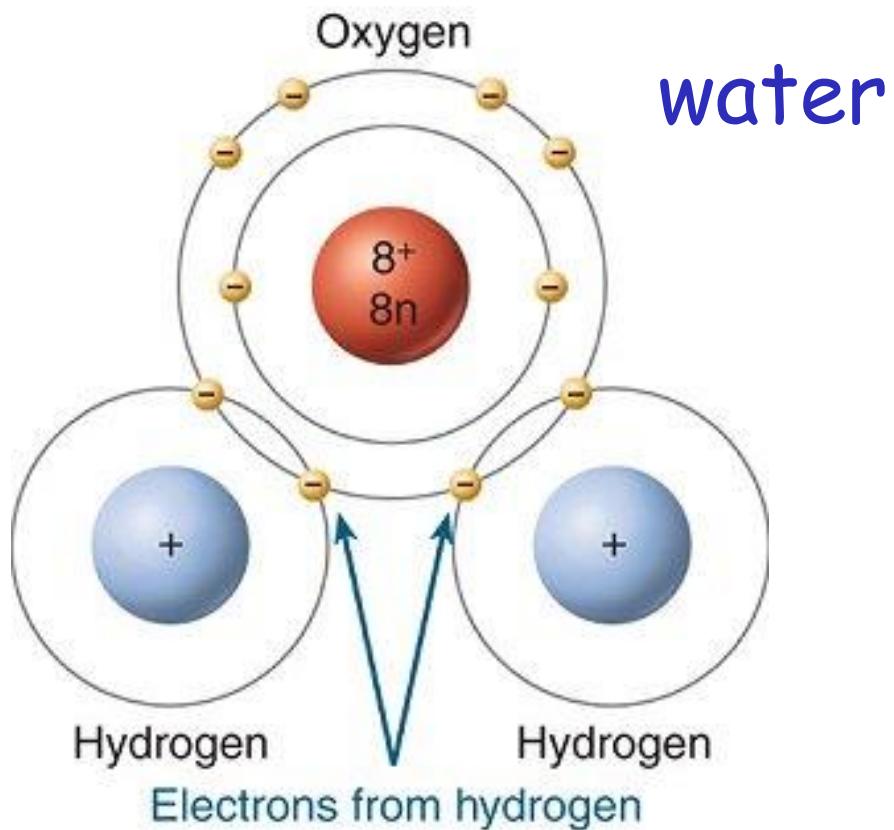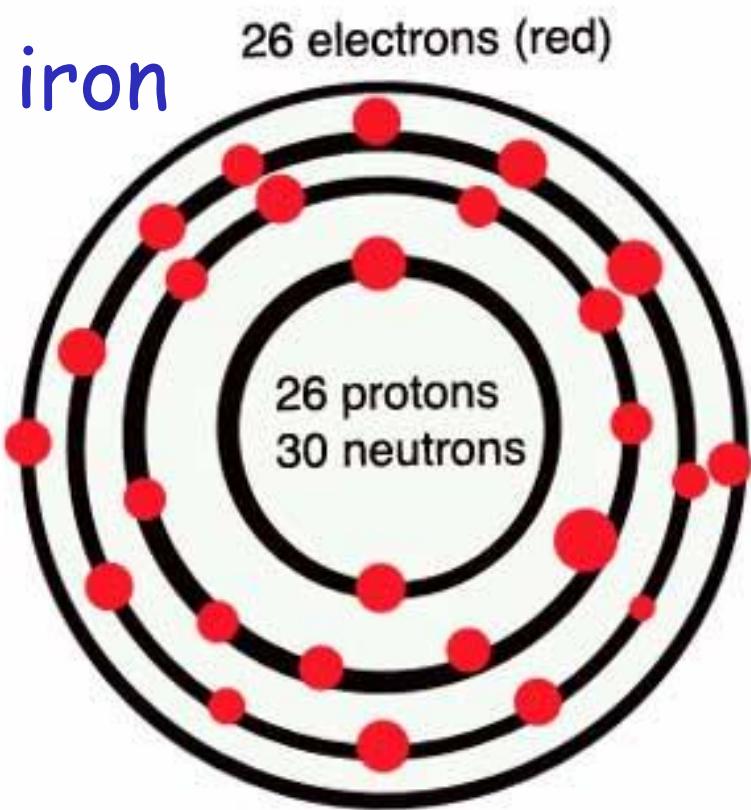
1.2. Conductors and Insulators:

- **Conductors:** materials in which charge can move rather freely, e.g., metals (iron, copper,…), human body, tap water,…
- **Insulators (nonconductors):** materials in which charge cannot move freely, e.g., plastic, glass, rubber, pure water,…
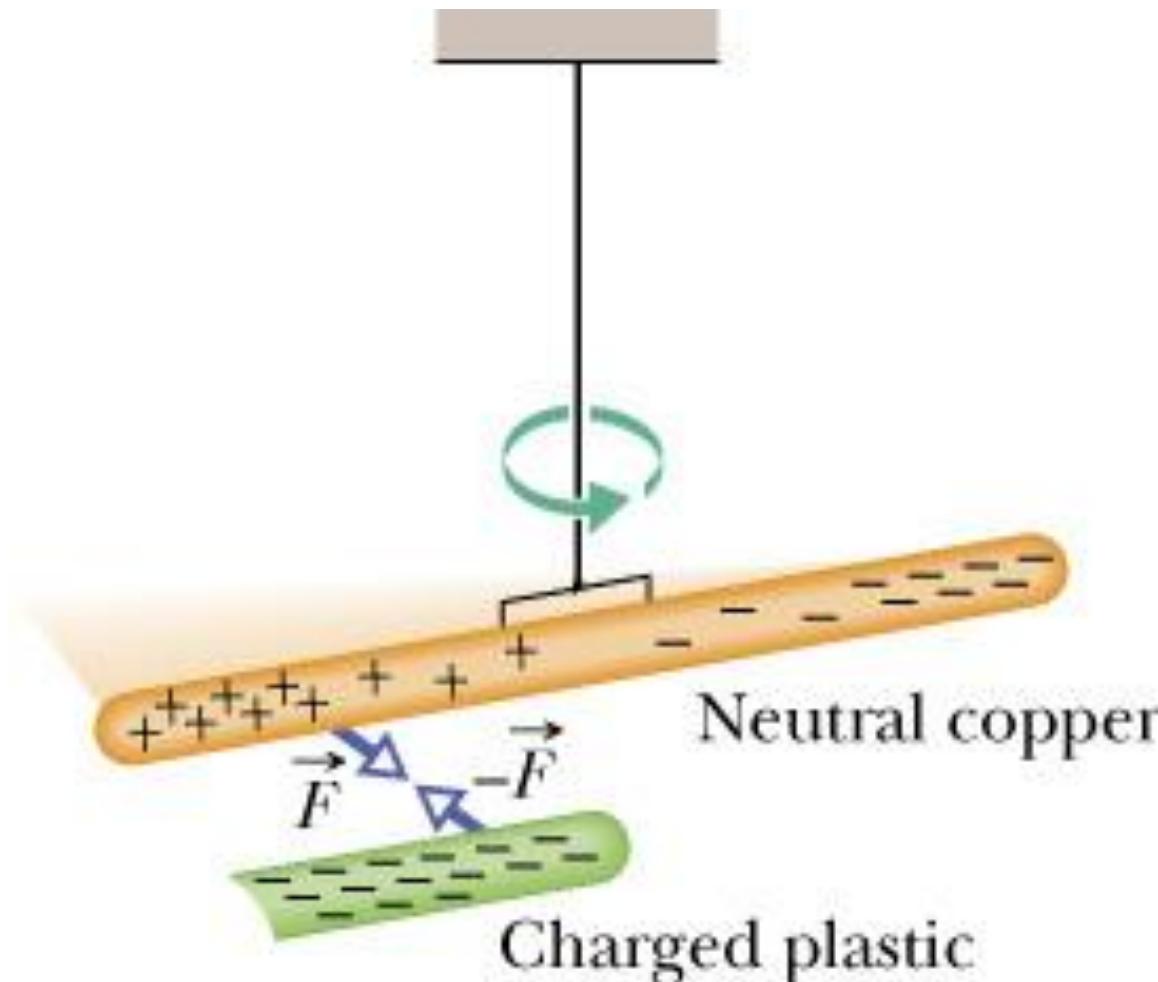

- **Semi-conductors:** materials with electric conductivity intermediate in magnitude between conductors and insulators, e.g., silicon, germanium,…(computer chips)
- **Superconductors:** perfect conductors, allowing charge to move without any hindrance
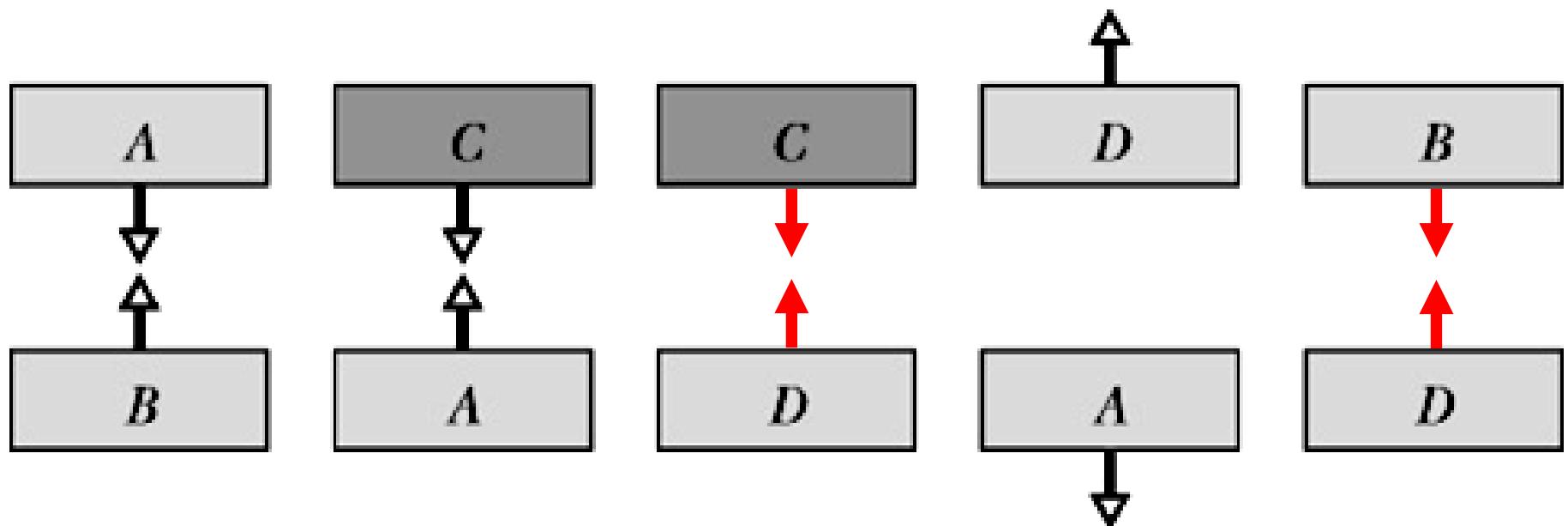
- **The electrical conductivities of conductors and insulators are different due to the structure and nature of atoms**

iron

26 electrons (red)

26 protons
30 neutrons

water

Oxygen

8^+
$8n$

Hydrogen

Hydrogen

Electrons from hydrogen

- mobile electrons in conductors are called "*conduction electrons*"
- When a charged object is brought close to a neutral object, charges are induced on the surface of the neutral object and are called "*induced charges*"

Neutral copper
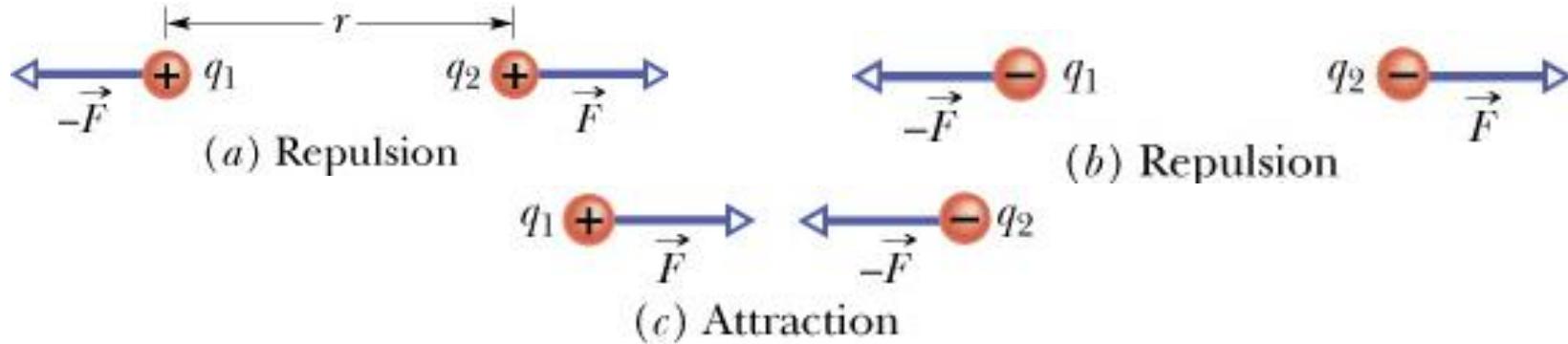
Charged plastic

Checkpoint 1 (page 564): The figure shows five pairs of plates: A, B, and D are charged plastic plates and C is an electrically neutral copper plate. The electrostatic (electric) forces between the pairs of plates are shown for three of the pairs. For the remaining two pairs, do the plates repel or attract each other?

- A and D repel each other, so they have the same sign: B and D attract each other
- C is neutral: C and D attract each other

1.3. Coulomb's Law:

● **The electrostatic force between q_1 and q_2:**

(a) Repulsion (b) Repulsion

(c) Attraction

$$F = k \frac{|q_1||q_2|}{r^2}$$

$k = \dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \ N.m^2/C^2$: electrostatic constant

$\varepsilon_0 = 8.85 \times 10^{-12} C^2/N/m^2$: permittivity constant

1.4. The Principle of Superposition:
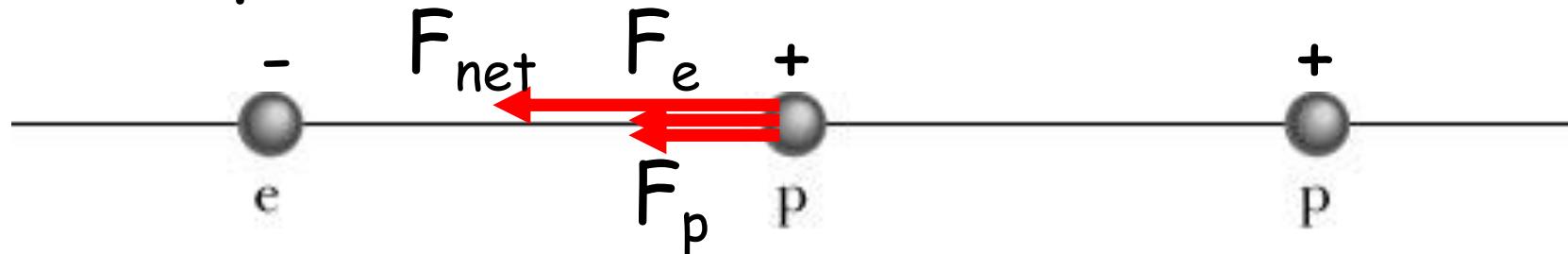
1.4.1. The principle:

● n charged particles:

$$\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + ... + \vec{F}_{1n}$$

Checkpoint 2 (page 566):
The figure shows two protons (p) and one electron (e) on an axis. What is the direction of (a) the electrostatic force on the central p due to the e-, (b) the electrostatic force on the central p due to the other p, and (c) the net force on the central p?
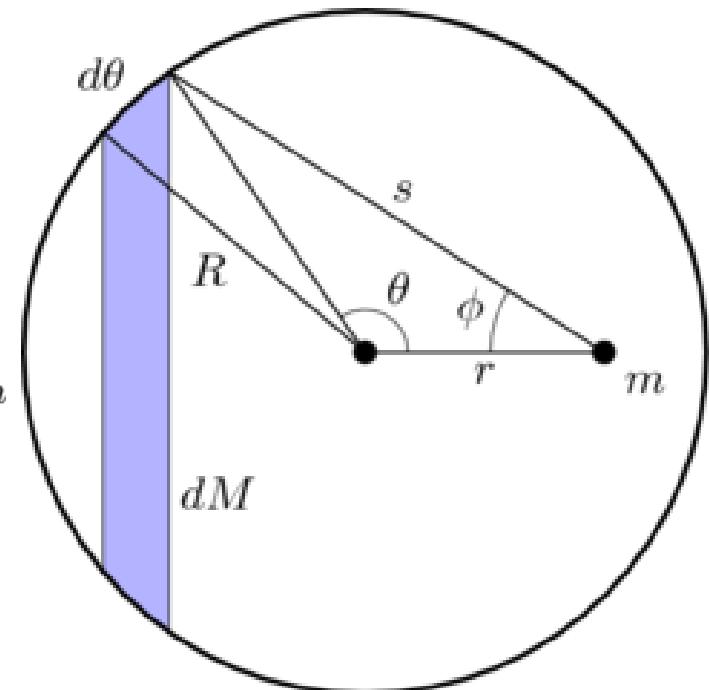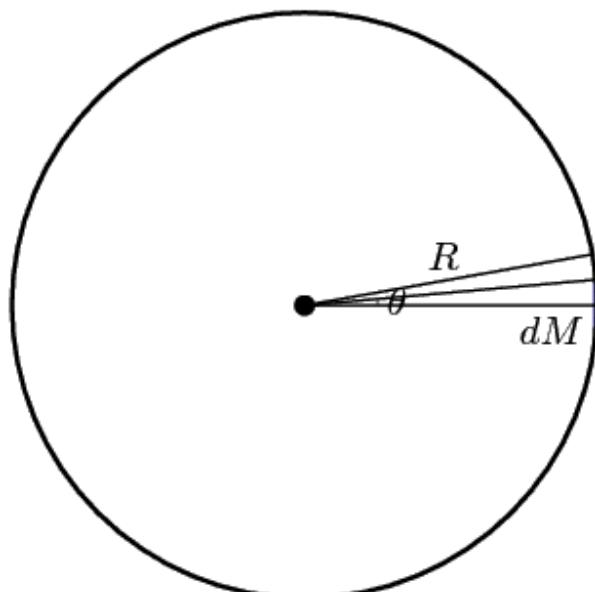
1.4.2. Spherical Conductors:

The shell theorem:

- A shell of uniform charge attracts or repel a charged particle that is outside the shell as if all the shell's charge were concentrated at its center

- If a charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell

➢ **Recall the shell theorem for gravity (any phenomenon with an inverse square law)**

Homework:

- Prove the shell theorem for the electrostatic force
- 3, 6, 9, 10, 16, 23, 33, 35 (page 575-577)