PHYS11 CH:18 The Force That Moves Everything

Electric Charge and Conservation

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Outline

1. Introduction
2. Electrical Charges, Conservation of Charge, and Transfer of Charge
3. Worked Example
4. Practice Application
5. Summary

Why Does Hair Stand on End?

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What invisible force makes strands of hair repel each other?

The Invisible World

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Electric forces keep them apart.

Learning Objectives

By the end of this lesson, you will be able to:

- **18.1:** Describe positive and negative electric charges

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- **18.1:** Use conservation of charge to calculate charge transfers
- **18.1:** Characterize conductors vs insulators
- **18.1:** Describe electric polarization and charging by induction

18.1 Two Types of Charge

Nature's Binary Code

Electric charge is a property of matter that causes objects to attract or repel each other.

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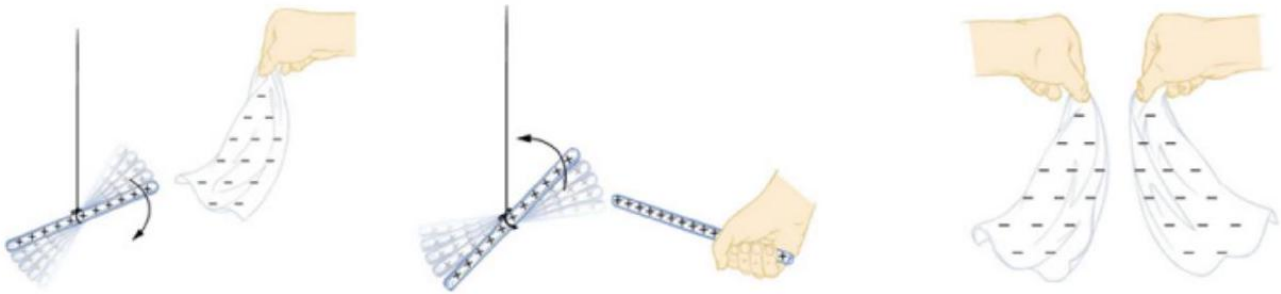
The Mental Model

Charge is nature's binary system: positive or negative. No neutral charge exists.

18.1 Experimental Evidence



(a) (b) (c)

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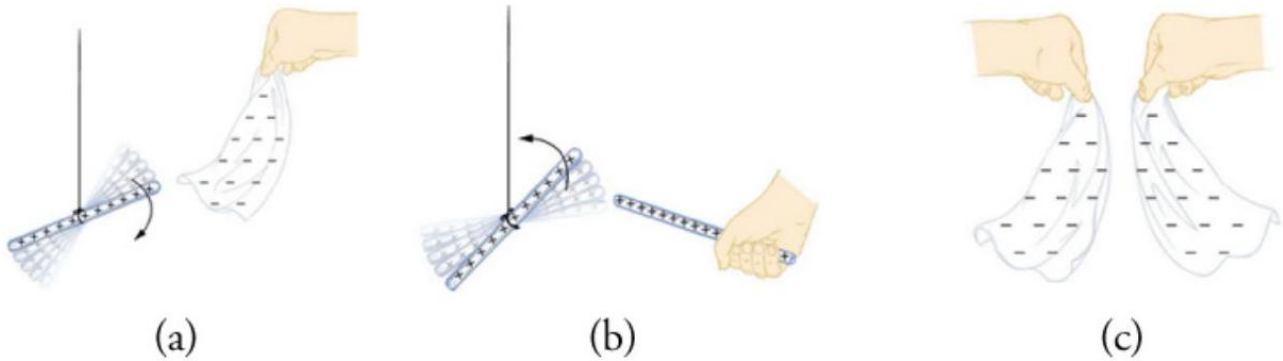

Pattern: Glass rods repel each other. Silk cloths repel each other. Glass attracts silk.

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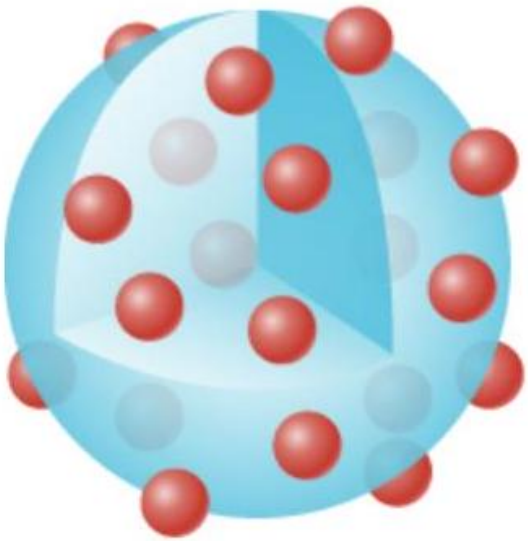
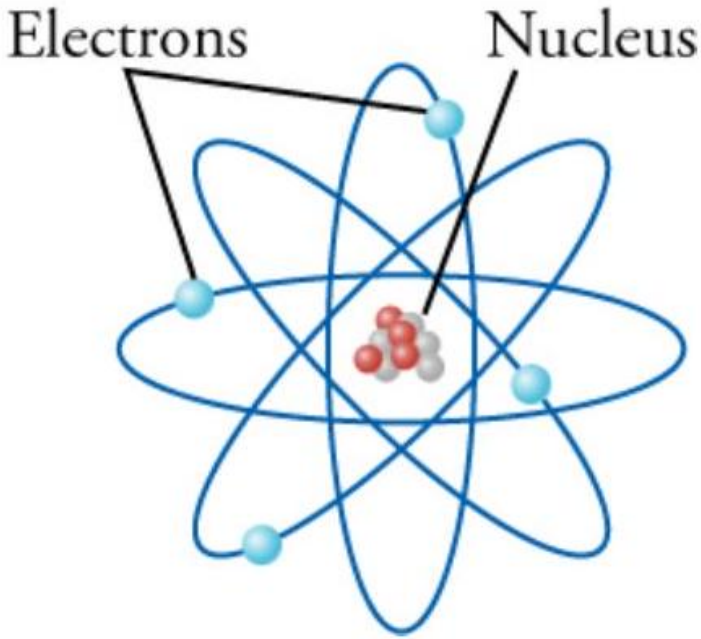
Universal Law: The Electron

The electron carries the fundamental unit of *negative* electric charge.

18.1 Inside the Atom





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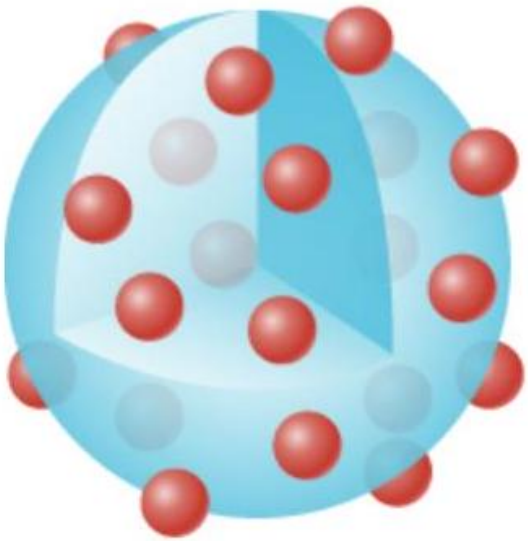

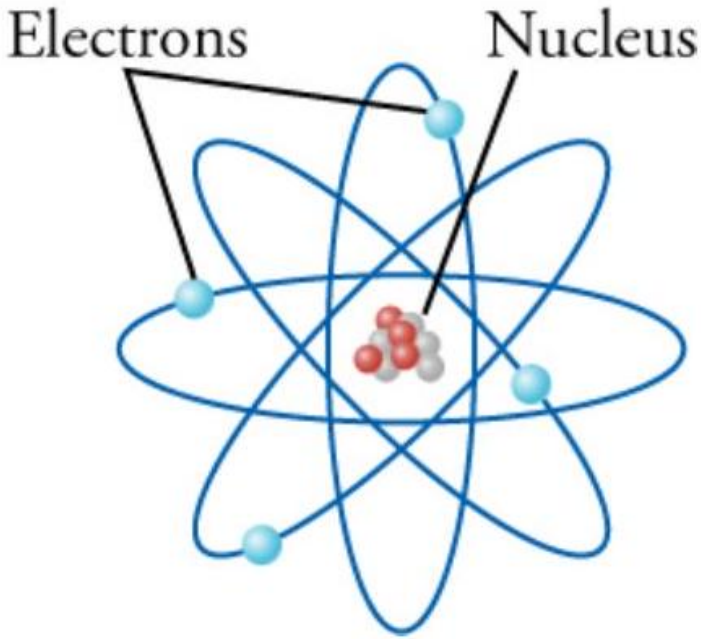

Rutherford's model: electrons orbit a tiny, dense nucleus of protons.

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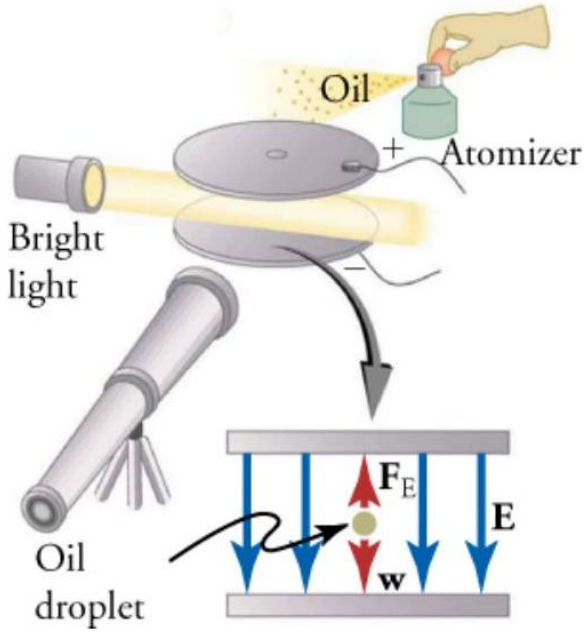
The Paradox

Civilian: "Why is charge so tiny?"
Physicist: "It takes 6.25×10^{18} protons to make just 1 coulomb!"

18.1 Measuring the Electron Charge



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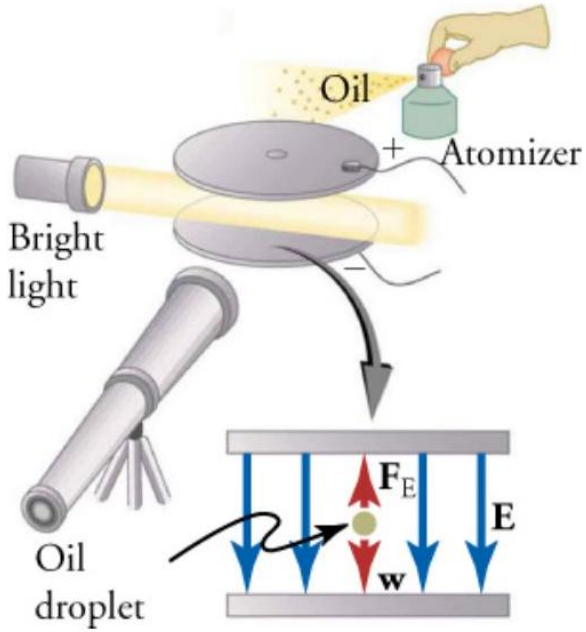

Millikan Oil-Drop Experiment (1909):

- Spray oil droplets between charged plates
- Balance electric force against gravity
- Measure charge on individual drops

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Meaning: You can have 5 electrons or 5 million, but never 5.5 electrons.

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What this means:

- Total charge before interaction = total charge after
- Charge can move, but net charge stays constant
- Most fundamental conservation law in physics

18.1 Conductors vs Insulators

Conductors

Materials that allow charge to move freely

Examples:

- Metals (copper, silver, aluminum)
- Electrons loosely bound

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The Mental Model

Conductor = highway for electrons. Insulator = roadblock.

18.1 The Conductivity Spectrum

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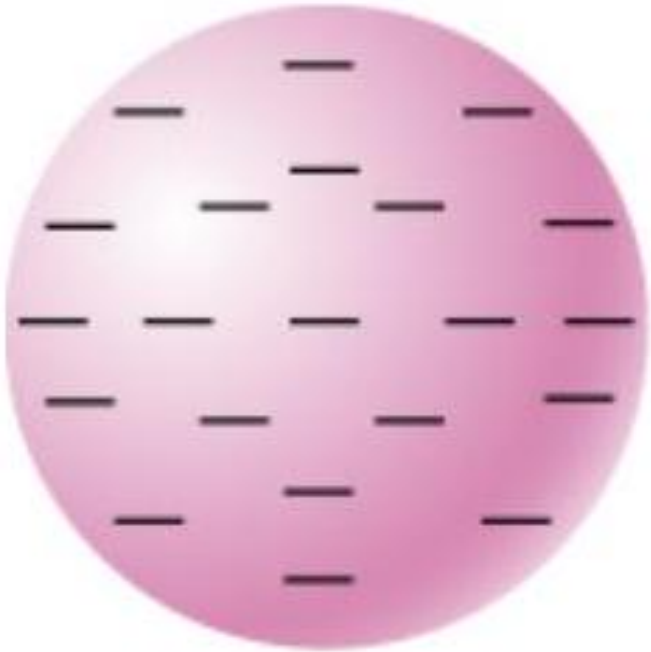
Semiconductors: Between conductors and insulators (silicon, germanium)

18.1 Charge Distribution



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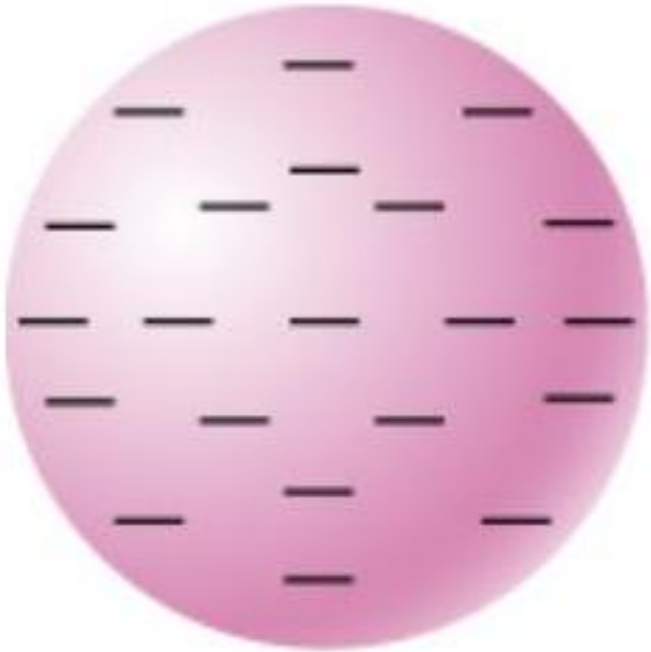

Conductor: Charge spreads to outer surface (repulsion wins).
Insulator: Charge stays in place (can't move).

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Real-World: Static Shock

Rubbing increases contact between materials, transferring more electrons.

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Charges redistribute to equalize - like water finding same level.

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- Excess positive charge on body
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- Spread to extremities (hair)
- Hair strands repel $\rightarrow$ stand on end!

The Mental Model

Like dominos - push on one end, disturbance travels to other end.

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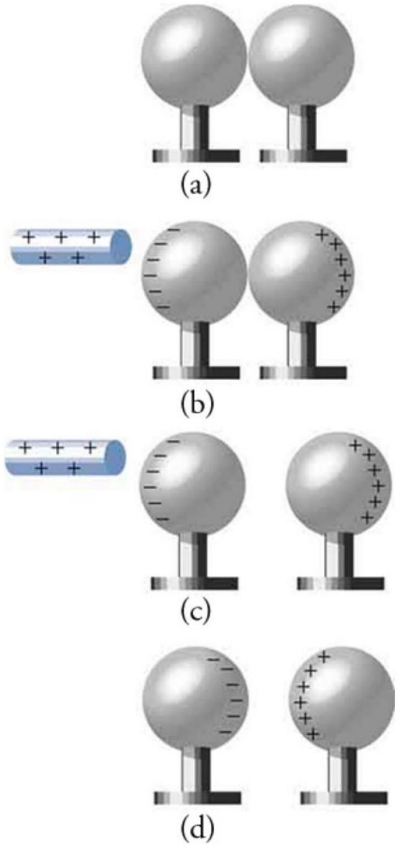

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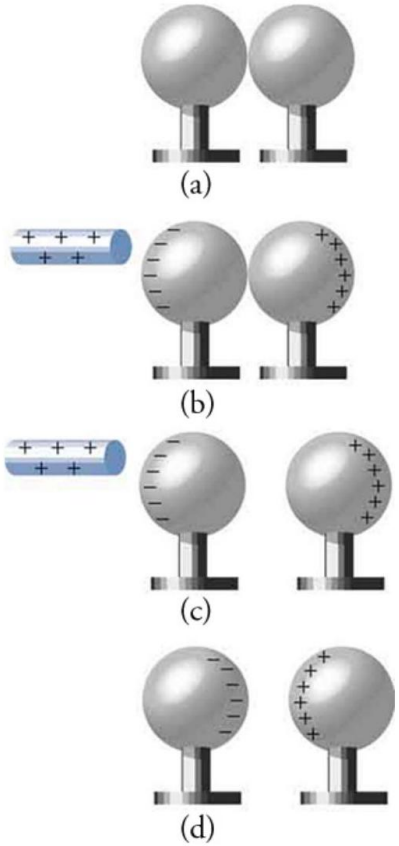

Induction: Creating charge separation by approaching a charged object (no touching!)

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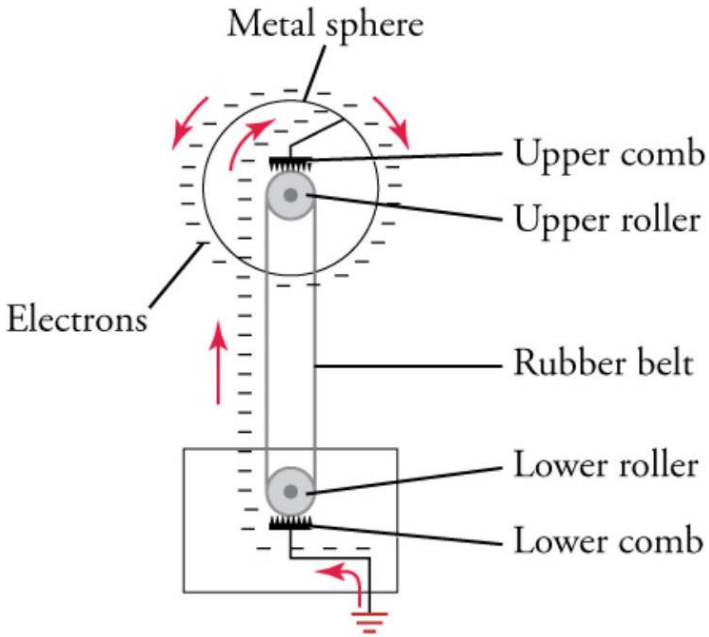

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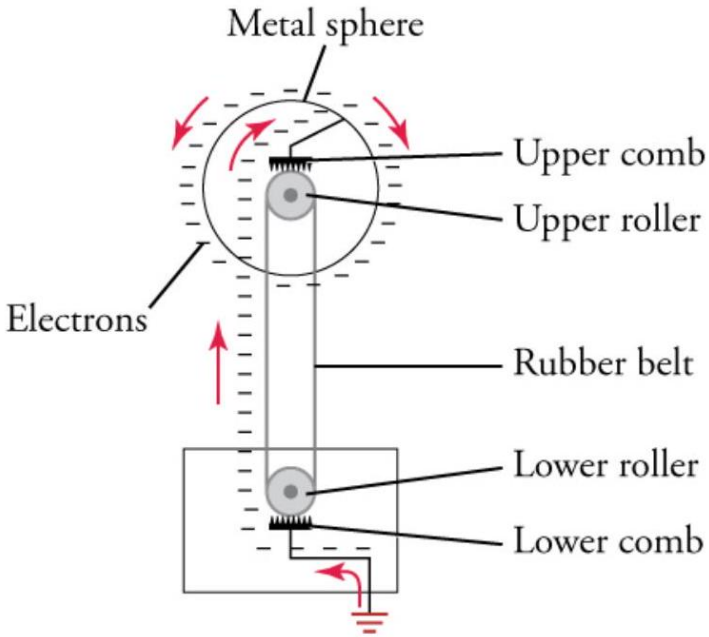

How it works:

- Belt transfers electrons to metal globe
- Electrons spread over outer surface (repulsion)
- Can accumulate millions of volts!

18.1 Hair-Raising Physics

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Why does hair stand up?

- Each hair strand gets excess charge (same sign)
- Like charges repel
- Strands push away from each other as far as possible

Attempt: Conservation Challenge

The Challenge (3 min, silent)

Two metal spheres initially have charges of $+4$ C and $+8$ C. After touching each other, one sphere has $+10$ C.

Given:

- Blue sphere initial: $q_1 = +4$ C
- Red sphere initial: $q_2 = +8$ C
- Blue sphere final: $q_1' = +10$ C

Find: Final charge on red sphere q_2'

Can you use conservation of charge? Work silently.

Compare: Conservation Strategy

Turn and talk (2 min):

1. What law did you use?
2. What is the total initial charge?
3. How did you find the final charge on the red sphere?

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Reveal: Conservation in Action

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Law: $q_{\text{initial}} = q_{\text{final}}$

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Step 1: Find total initial charge

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Step 3: Solve for q_2'

$$+12\ \text{C} = +10\ \text{C} + q_2'$$

$$\boxed{q_2' = +2\ \text{C}}$$

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$$+12\ \text{C} = +10\ \text{C} + q_2'$$

$$\boxed{q_2' = +2\ \text{C}}$$

Check: $12 = 10 + 2$ ✓Charge is conserved!

Attempt: Counting Electrons

The Challenge (3 min, silent)

An ink droplet in a printer has net charge $q = -1.0 \times 10^{-10}$ C after passing through an electron beam.

Given:

- Droplet charge: $q = -1.0 \times 10^{-10}$ C
- Electron charge: $e = -1.602 \times 10^{-19}$ C

Find: Number of electrons captured by droplet

How many electrons does it take? Work silently.

Compare: Quantization Strategy

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Check: About 600 million electrons - seems large but atoms have 10^{16} atoms!

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4. Conservation: $q_{\text{initial}} = q_{\text{final}}$ (never violated)
5. Conductors let charge move; insulators don't
6. Transfer methods: contact, conduction, induction

Key Equations

$$e = 1.602 \times 10^{-19}\ \text{C} \quad \text{(fundamental charge)} \tag{1}$$

$$Q = ne \quad \text{(charge quantization)} \tag{2}$$

$$q_{\text{initial}} = q_{\text{final}} \quad \text{(conservation of charge)} \tag{3}$$

Homework

Complete the assigned problems

posted on the LMS