

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?

What if everything you touch
is held together by invisible forces?

The Invisible World

What if everything you touch
is held together by invisible forces?

The atoms in your fingertips never actually touch the atoms in this desk...

What if everything you touch
is held together by invisible forces?

The atoms in your fingertips never actually touch the atoms in this desk...

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:** Describe positive and negative electric charges
- **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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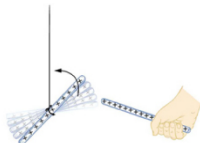
The Mental Model

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

18.1 Experimental Evidence



(a)

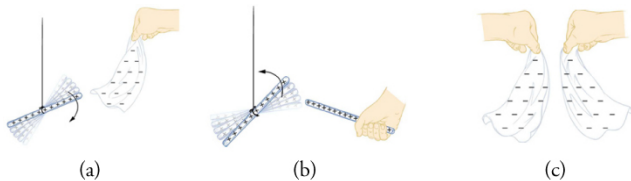


(b)



(c)

18.1 Experimental Evidence



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

18.1 The Discovery of the Electron

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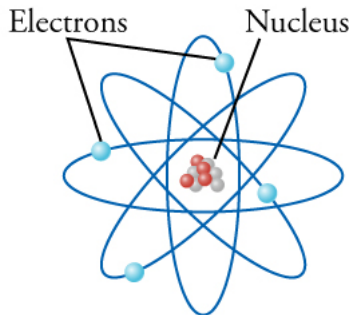
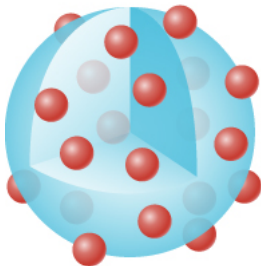
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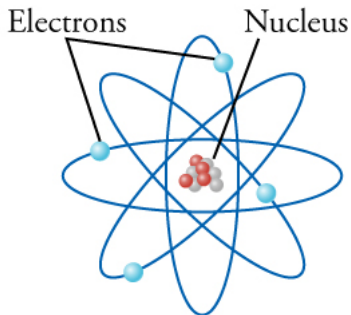
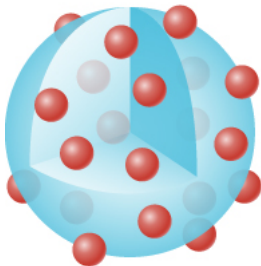
Universal Law: The Electron

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.

18.1 The Fundamental Unit of Charge

Nature's Quantum

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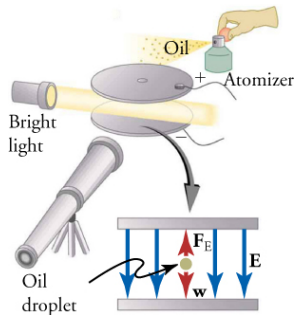
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The Paradox

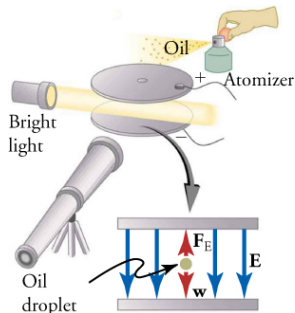
Civilian: "Why is charge so tiny?"

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

18.1 Charge Quantization

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

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Electric charge cannot be created or destroyed.

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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- Rubber, plastic, glass, wood
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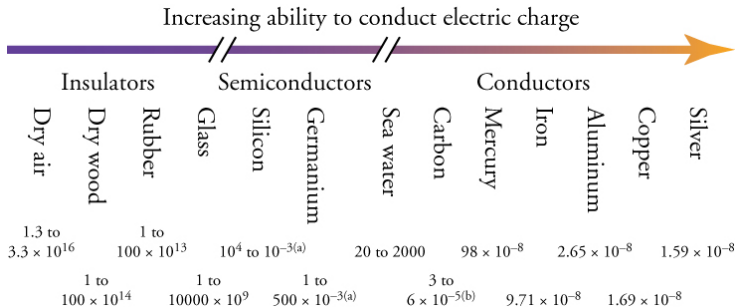
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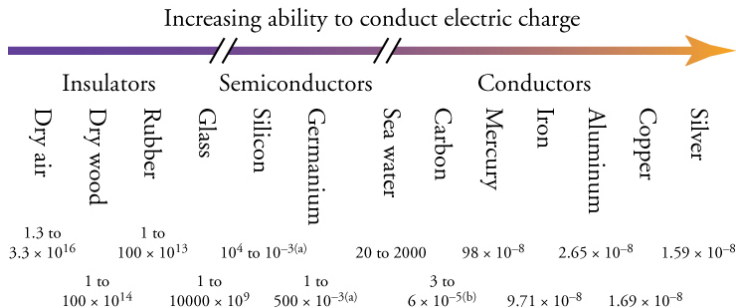
The Mental Model

Conductor = highway for electrons. Insulator = roadblock.

18.1 The Conductivity Spectrum

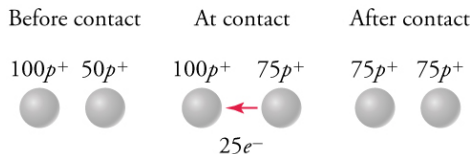
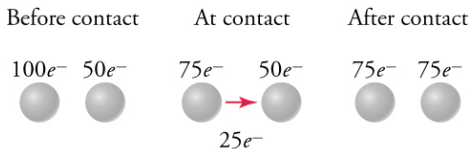


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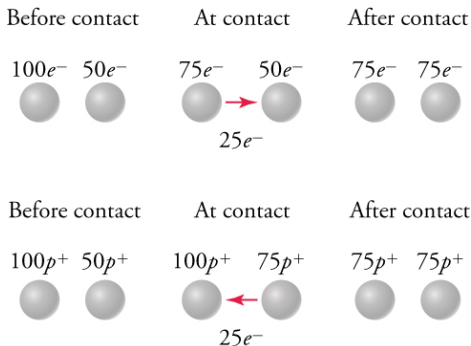


Semiconductors: Between conductors and insulators (silicon, germanium)

18.1 Charge Distribution



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Conductor: Charge spreads to outer surface (repulsion wins).

Insulator: Charge stays in place (can't move).

18.1 Transferring Charge: Contact

Charging by contact: Surfaces touch and share electrons

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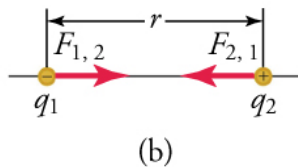
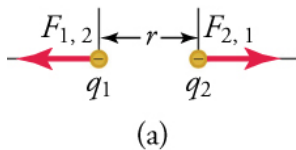
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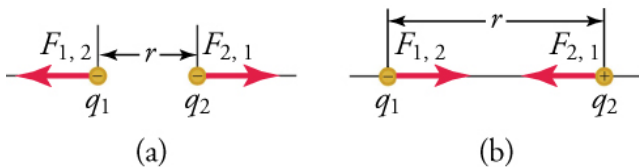
Real-World: Static Shock

Rubbing increases contact between materials, transferring more electrons.

18.1 Transferring Charge: Conduction

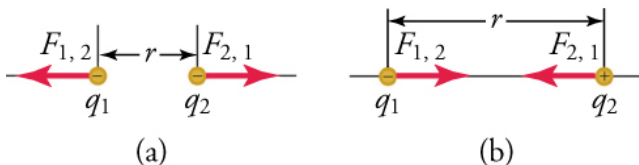


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Charging by conduction: Touching charged object to neutral object

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Charging by conduction: Touching charged object to neutral object
Charges redistribute to equalize - like water finding same level.

18.1 Polarization

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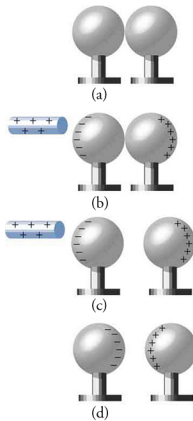
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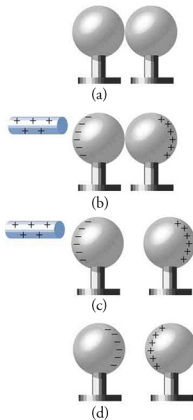
The Mental Model

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

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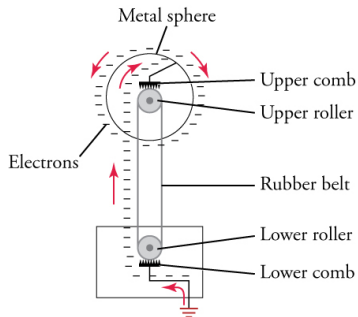


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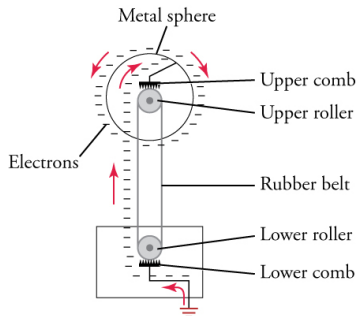


Induction: Creating charge separation by approaching a charged object (no touching!)

18.1 Van de Graaff Generator



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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 $+4\text{ C}$ and $+8\text{ C}$. After touching each other, one sphere has $+10\text{ C}$.

Given:

- Blue sphere initial: $q_1 = +4\text{ C}$
- Red sphere initial: $q_2 = +8\text{ C}$
- Blue sphere final: $q'_1 = +10\text{ C}$

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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$$q_{\text{final}} = +10 \text{ C} + q'_2$$

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Step 3: Solve for q'_2

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

Attempt: Counting Electrons

The Challenge (3 min, silent)

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

Given:

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

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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- 5 Conductors let charge move; insulators don't
- 6 Transfer methods: contact, conduction, induction

Key Equations

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

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

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

Complete the assigned problems
posted on the LMS