Department of biology

((Biophysics))

1 Stage

LEC 2

Electric Charge

By

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Electric Charge

1) Discoveries of Static Electricity

The phenomenon of **static electricity** has fascinated people for centuries, and its effects are both common in everyday life and significant in scientific understanding.

Everyday Observations:

1. **Static in Clothing:**
   - Clothes stick together when removed from a dryer, especially certain fabrics like wool or synthetics.
   - The clinging occurs due to the transfer of electric charges between the clothes during tumbling.
2. **Combing Hair:**
   - On a dry day, combing hair may result in hair sticking to the comb or being attracted to it.
   - Bringing the charged comb near a thin stream of water causes the stream to bend toward the comb without physical contact (Figure 1).

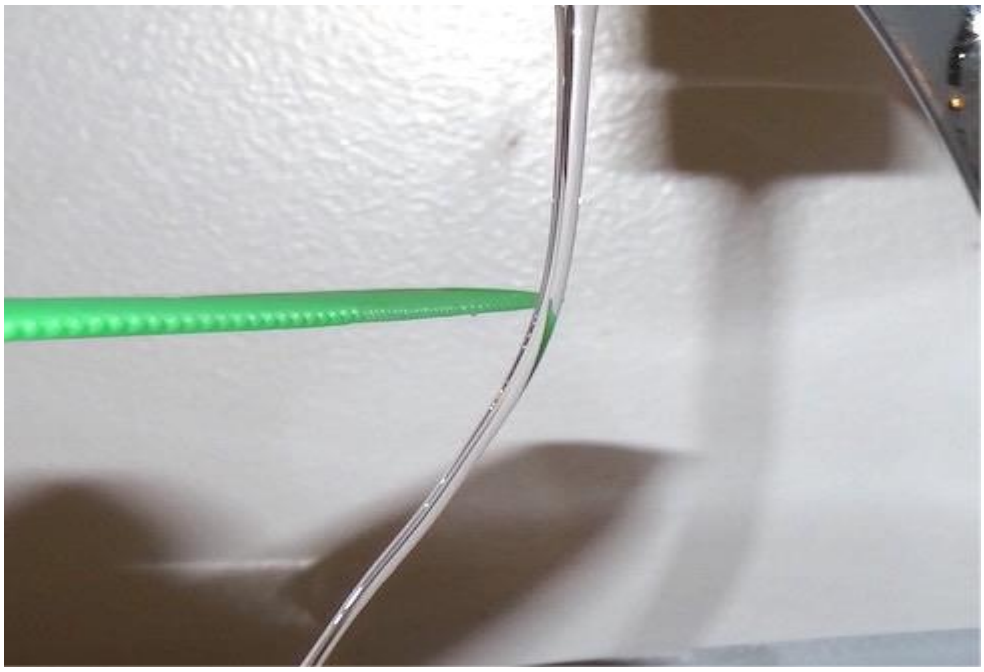


Figure (1) An electrically charged comb attracts a stream of water from a distance. Note that the water is not touching the comb.

3. **Cling Wrap and Balloons:**
    - Plastic wrap clings to surfaces due to charge buildup.
    - A balloon rubbed on a wall adheres because of static charge interaction.
4. **Shocks from Conductors:**
    - After walking on a carpet, touching a metal doorknob may result in a shock due to the discharge of accumulated static charge.

Historical Discoveries:

Thales of Miletus (624–546 BCE):

- Thales was one of the earliest recorded observers of static electricity.
- He discovered that rubbing amber (fossilized resin) with fur caused the two to attract each other. Figure (2)
- His experiments showed that this attraction extended to other nonmetallic objects nearby.

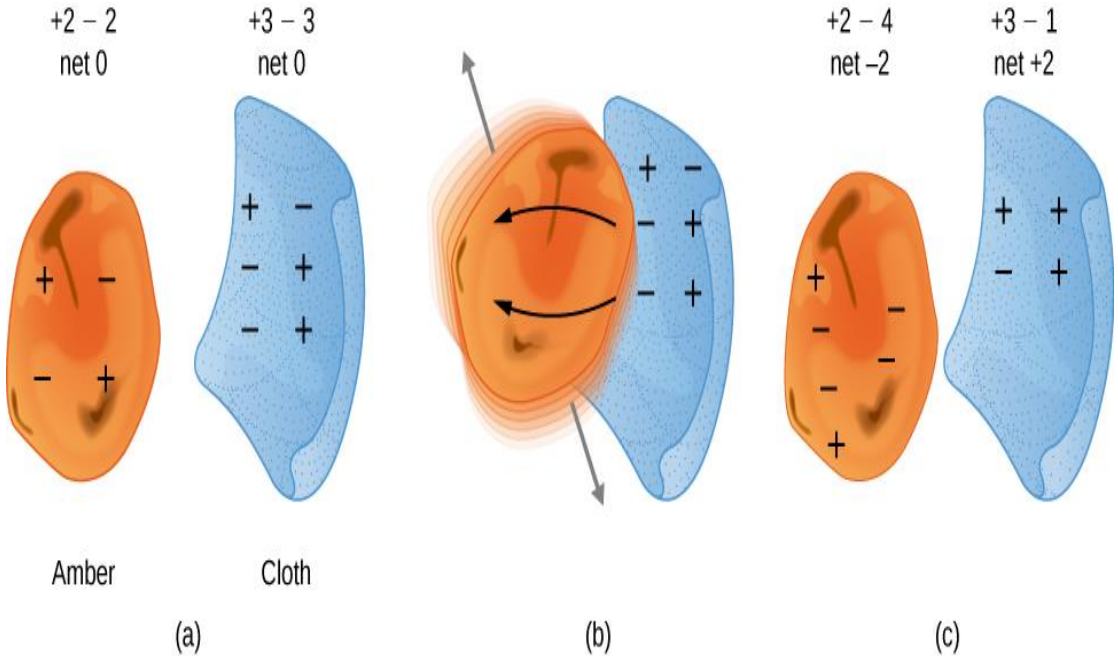


Figure (2): When materials are rubbed together, charges can be separated, particularly if one material has a greater affinity for electrons than another. (a) Both the amber and cloth are originally neutral, with equal positive and negative charges. Only a tiny fraction of the charges are involved, and only a few of them are shown here. (b) When rubbed together, some negative charge is transferred to the amber, leaving the cloth with a net positive charge. (c) When separated, the amber and cloth now have net charges, but the absolute value of the net positive and negative charges will be equal

Scientific Significance:

- These observations led to the discovery of the **electric force** and the broader study of **electrostatics**, forming the foundation for understanding charge interactions.
- Figure 3 demonstrates how a charged comb can attract lightweight materials like paper strips, further illustrating the electric force's influence over distance.

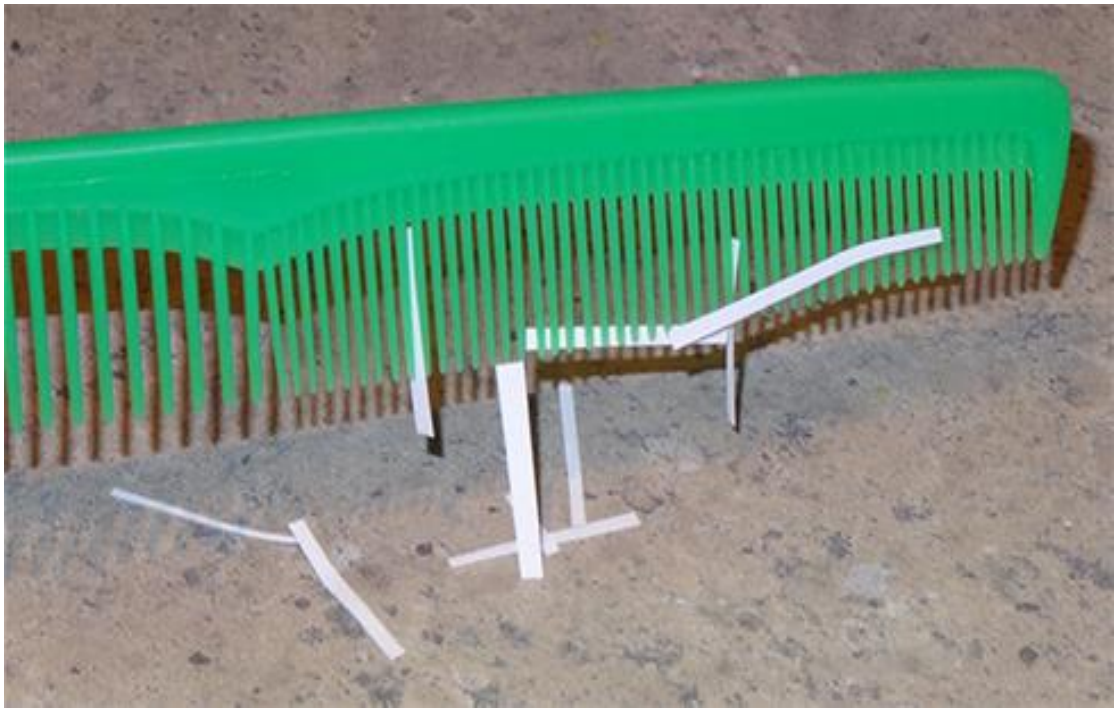


Figure (3): After being used to comb hair, this comb attracts small strips of paper from a distance, without physical contact. Investigation of this behavior helped lead to the concept of the electric force.

Key Concept:

Static electricity arises from the **transfer of electrons** between materials, creating an imbalance of electric charges. This imbalance results in attraction, repulsion, or discharge, depending on the materials and conditions.

The discovery of static electricity led to the identification of two types of electric charge: positive and negative. The electric force between these charges behaves in a very specific way:

1. **Attraction and Repulsion**: The force between two charges depends on their type. If the charges are of the same type (both positive or both negative), the force is **repulsive**. If the charges are of opposite types (one positive and one negative), the force is **attractive**. This is the basis for electrostatic attraction and repulsion.
2. **Coulomb's Law**: The force between two charges also depends on the distance between them. Specifically, the magnitude of the electric force decreases as the **square of the distance** between the two charges increases. This is a very rapid decrease—doubling the distance reduces the force to one-fourth of its original value.

2) <u>Here are some key observations about electric forces:</u>

1. The force can act **without physical contact** between objects.
2. It can be **attractive** or **repulsive** based on the types of charges.
3. Not all objects experience this force—only those with charge are affected.
4. The force decreases as the **inverse square** of the distance between the objects increases.
5. The surrounding environment of the charged objects can also affect the force, though this will be explored in more detail later.

3) properties of electric charge

The **properties of electric charge** reveal several fundamental principles that govern the behavior of charge in our universe. Here are the key properties:

1. **Quantization of Charge**: Electric charge comes in discrete amounts. The smallest possible unit of charge is represented by the **elementary charge** ee, which is 1.602×10^{-19} . This is the charge of a single electron (negative) or proton (positive). No object can have a charge smaller than this, and the charge on any object must be an integer multiple of this value. The charge on macroscopic objects arises from the addition or removal of electrons, resulting in a net charge that is a multiple of the elementary charge.
2. **Magnitude Independence**: The magnitude of the elementary charge is the same for both positive and negative charges. The smallest possible **positive charge** is $+1.602\times10^{-19}$, and the smallest possible **negative charge** is -1.602×10^{-19} . These values are exactly equal, which reflects the symmetry in nature's treatment of positive and negative charges.
3. **Conservation of Charge**: Charge is **conserved**, meaning it cannot be created or destroyed. It can only be transferred between objects. When we say charges "cancel," we mean that the forces from equal and opposite charges can balance out in a way that the net force on another object is zero. However, the charges themselves do not disappear. The total amount of charge in the universe remains constant.

Charge conservation is true even in a **closed system**. For example, if negative charge were to disappear from one place (like your lab bench) and appear somewhere else (like the Moon), the total charge in the universe would still remain unchanged. In practice, charge flow into or out of a system will be measurable if there is a change in the system's total charge.

4) sources of charges

The sources of charges in bodies are rooted in the **atomic structure of matter**. Here's how charges arise in bodies:

1. Electrons and Protons:

- **Electrons**: Negatively charged particles that orbit the nucleus of an atom.
- **Protons**: Positively charged particles located in the nucleus.
- The charges of electrons and protons are equal in magnitude but opposite in sign. In a **neutral atom**, the number of electrons equals the number of protons, resulting in no net charge.

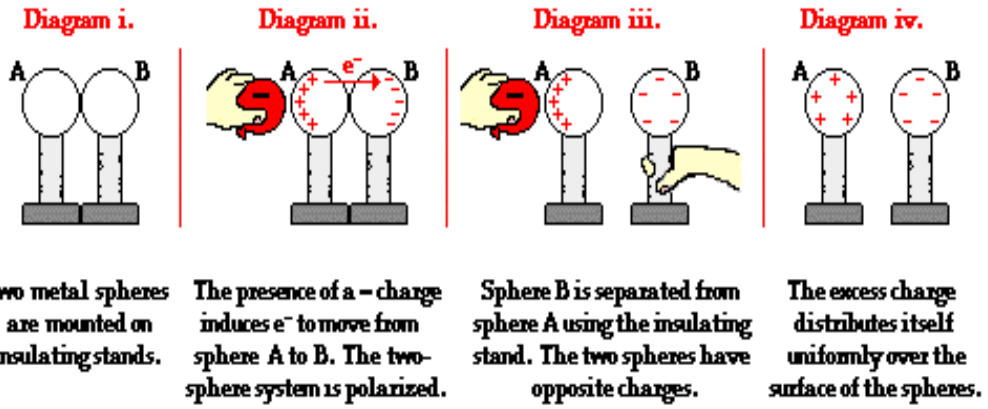
2. Ionization:

Atoms or molecules can gain or lose electrons:

- **Loss of Electrons**: Results in a **positive ion** (cation) because the atom has more protons than electrons.
- **Gain of Electrons**: Results in a **negative ion** (anion) because the atom has more electrons than protons.

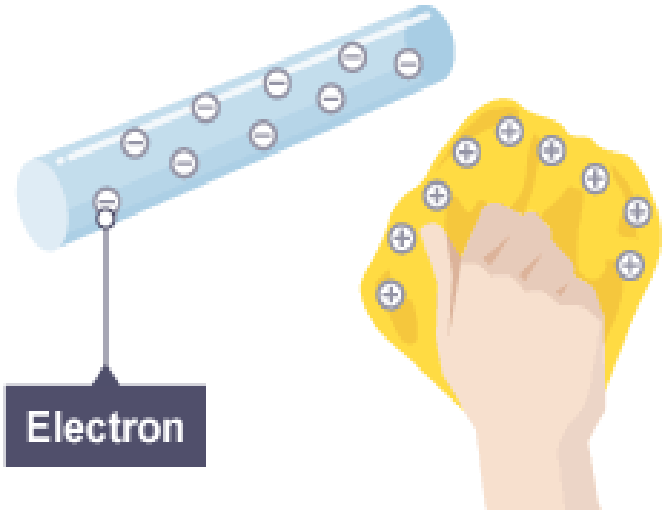
3. Charge Separation:

- When two materials come into contact and are then separated, electrons may transfer from one material to another due to differences in **electron affinity**.
  - The material gaining electrons becomes negatively charged.
  - The material losing electrons becomes positively charged.



4. Friction:

- Friction between two surfaces can cause the transfer of electrons:
  - For example, rubbing fur on amber (as observed by the Greeks) results in the amber becoming negatively charged and the fur positively charged.
- This is due to the **triboelectric effect**, where certain materials are more likely to gain or lose electrons when in contact.

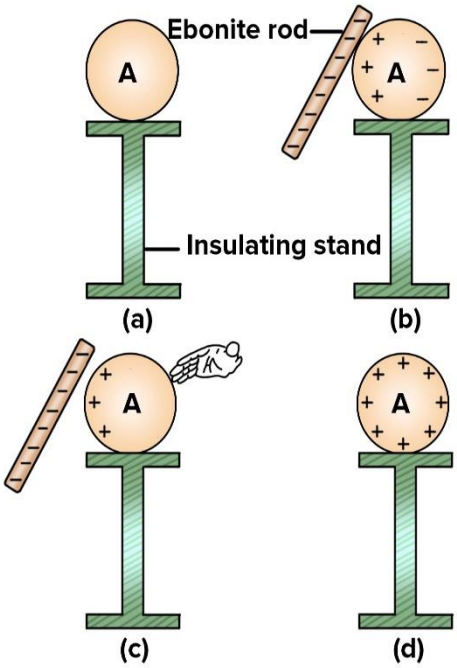


5. Chemical Reactions:

- In chemical reactions, atoms rearrange, often resulting in the transfer of electrons.
- For example, in a **battery**, chemical reactions create a flow of electrons, generating a charge difference between the terminals..

6. Induction:

- A charge can be induced in a body without direct contact:
  - If a charged object is brought near a neutral conductor, the charges in the conductor rearrange. This separation creates areas of positive and negative charge within the conductor.



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1. Which of the following phenomena demonstrates static electricity?

A. Water boiling B. A comb attracting a stream of water
C. A metal rod conducting heat D. Dissolving salt in water

2. What causes the sticking of clothes together after they are removed from a dryer?

A. Friction between clothes, transferring electrons B. Magnetic forces
C. Chemical reactions between fabrics D. Heat generated by the dryer

3. Who is credited with one of the earliest recorded observations of static electricity?

A. James Clerk Maxwell B. Thales of Miletus
C. Benjamin Franklin D. Alessandro Volta

4. What happens when amber is rubbed with fur, according to Thales?

A. Amber becomes magnetic. B. Amber and fur repel each other.
C. Amber and fur attract each other. D. Amber discharges electricity.

5. Which property of electric charge is described as the smallest unit of charge being 1.602×10−191.602 \times 10^{-19} C?

A. Conservation of charge B. Quantization of charge
C. Symmetry of charge D. Coulomb's law

6. According to Coulomb's law, how does the electric force between two charges vary with distance?

A. Inversely with the square of the distance B. Proportionally with the distance
C. Proportionally with the square of the distance D. Inversely with the distance

7. What type of ion is formed when an atom loses electrons?

A. Neutral atom B. Cation (positive ion)
C. Anion (negative ion) D. Molecule

8. What is the process called when a charge is created in a body without physical contact?

A. Friction B. Induction
C. Ionization D. Triboelectric effect

9. Which material property explains why rubbing different materials causes charge transfer?

A. Heat capacity B. Electron affinity
C. Magnetic susceptibility D. Atomic mass

10. Which of the following statements is true about the conservation of charge?

A. Charge can be created or destroyed in a closed system.
B. Charge can be transferred but not created or destroyed.
C. Positive charges can disappear entirely in chemical reactions.
D. The total charge in the universe changes with time.