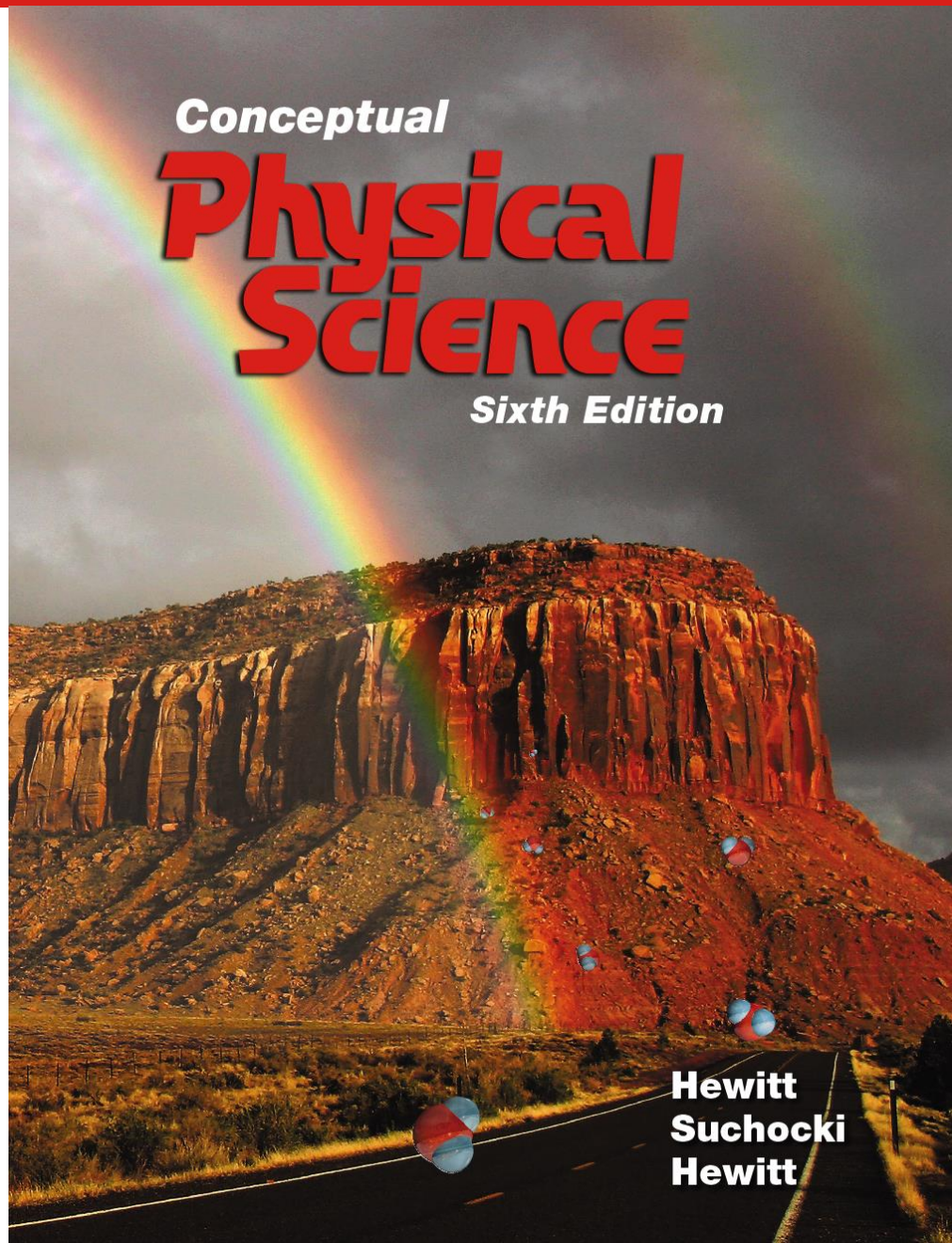
Chapter 9: Static and Current Electricity



This lecture will help you understand:

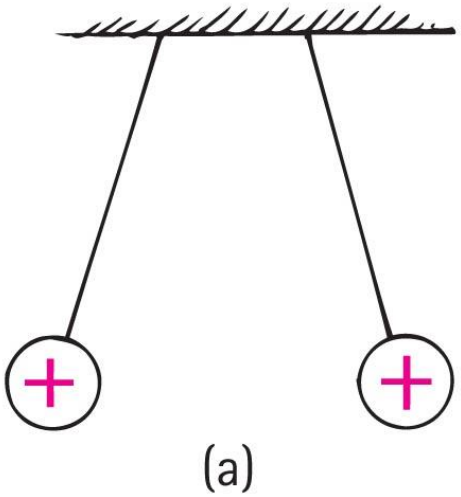
- Electric Charge
- Coulomb's Law
- Electric Field
- Electric Current
- Electrical Resistance

Electric Force and Charge

- Electric force:
  - a fundamental force of nature can attract some objects and repel others
- Electric charge:
  - fundamental quantity underlying electric force and all electric phenomena
  - comes in two kinds:
    - positive such as protons
    - negative such as electrons

Electric Force and Charge

- Fundamental rule for electricity:
  - Like charges repel; unlike charges attract.



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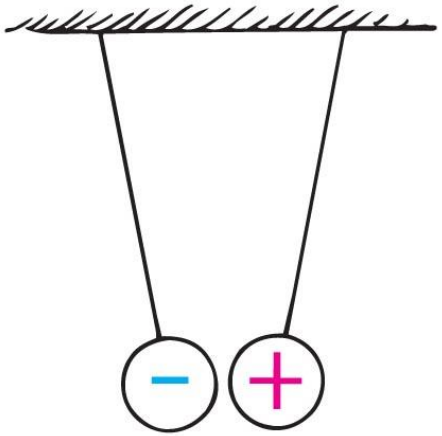

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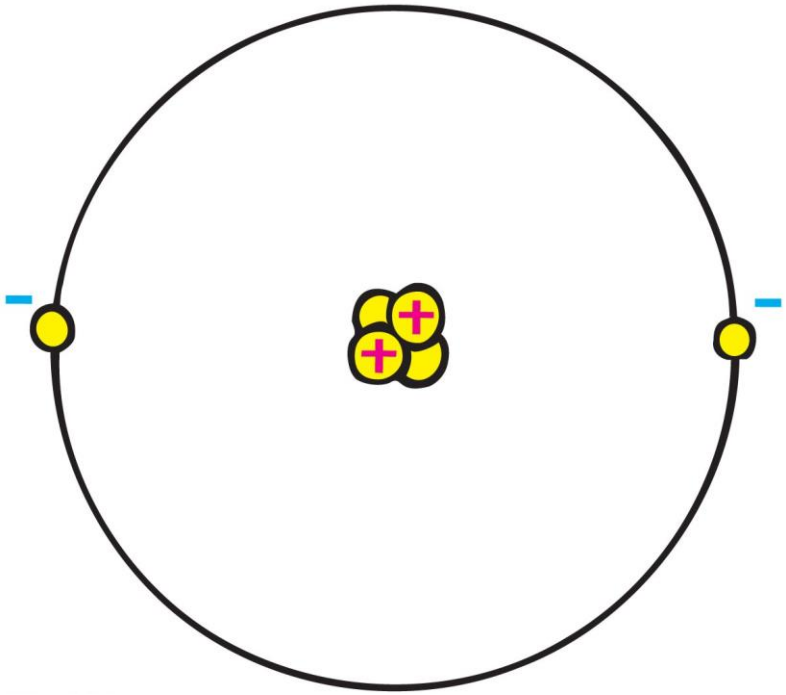
Electric Force and Charge

- Protons
  - positive electric charges
  - repel positives, but attract negatives
- Electrons
  - negative electric charges
  - repel negatives, but attract positives
- Neutrons
  - neutral electric charge



Electric Force and Charge

- Atom is normally electrically neutral
- Same number of electrons outside nucleus as protons in the nucleus
- Outer electrons in metals
  - loosely bound
  - can move freely
  - can flow
  - can join with other atoms

Electric Force and Charge

- Atom losing 1 or more electrons ⇒ positive ion
- Atom gaining 1 or more electrons ⇒ negative ion
- Amount of work varies in pulling electrons from atoms of different substances
  - very little for metals and other good *conductors*
  - more work for rubber and other good *insulators*

Conductors and Insulators

- **Electric Conductors**
  - Materials that allow easy flow of charged particles.
    - outermost electrons of atoms attracted loosely and are easily dislodged—as in metals.
    - innermost electrons strongly attracted to nucleus
- **Electric Insulators**
  - Materials having tightly bound electrons.

Electric Charge

- Conservation of Charge
  - In any charging process, no electrons are created or destroyed.
  - Electrons are simply transferred from one material to another.

Electric Charge
CHECK YOUR NEIGHBOR

When you brush Fido's fur and scrape electrons from it, the charge of Fido's fur is

A. positive.
B. negative.
C. both A and B.
D. neither A nor B.

Electric Charge
CHECK YOUR ANSWER

When you brush Fido's fur and scrape electrons from it, the charge of Fido's fur is

A. positive.

B. negative.

C. both A and B.

D. neither A nor B.

Explanation:

And if electrons were scraped off the brush onto Fido's fur, the fur would have a negative charge.

Coulomb's Law

- Coulomb's Law
  - For a pair of charged objects much smaller than the distance between them, force between them varies directly as
    - the product of their charges
    - and inversely as the square of the separation distance

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

Coulomb's Law

- Unit of charge is measured in coulombs, C.
  - The charge of an electron is the fundamental charge

$$= 1.6 \times 10^{-19}\ \text{C}.$$

- k is the proportionality constant $9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2$ that converts units to force in Coulomb's law
  - like signs of charge—force is repulsion
  - unlike signs of charge—force is attraction

Coulomb's Law

- Differences and similarities between gravitational and electrical forces:
  - Gravity only attracts. Electricity can both attract and repel.
  - Both forces can act between things that are not in contact with each other.
  - Both forces act in a straight-line direction between masses or charges.
  - A force field surrounds both: Gravitational field for mass and electric field for charge.

$$F \sim \frac{q_1 q_2}{d^2}$$

$$F \sim \frac{m_1 m_2}{d^2}$$

$$\frac{F}{\left(\frac{q_1 q_2}{d^2}\right)} = k$$

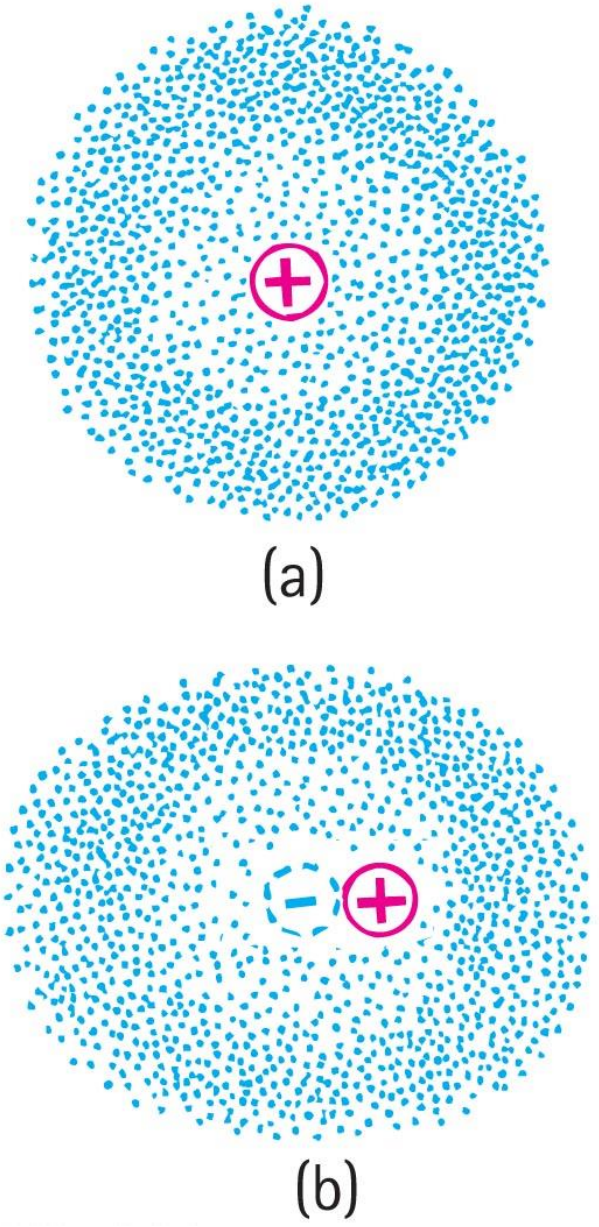
$$\frac{F}{\left(\frac{m_1 m_2}{d^2}\right)} = G$$

$$F = G\frac{m_1 m_2}{d^2}$$

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

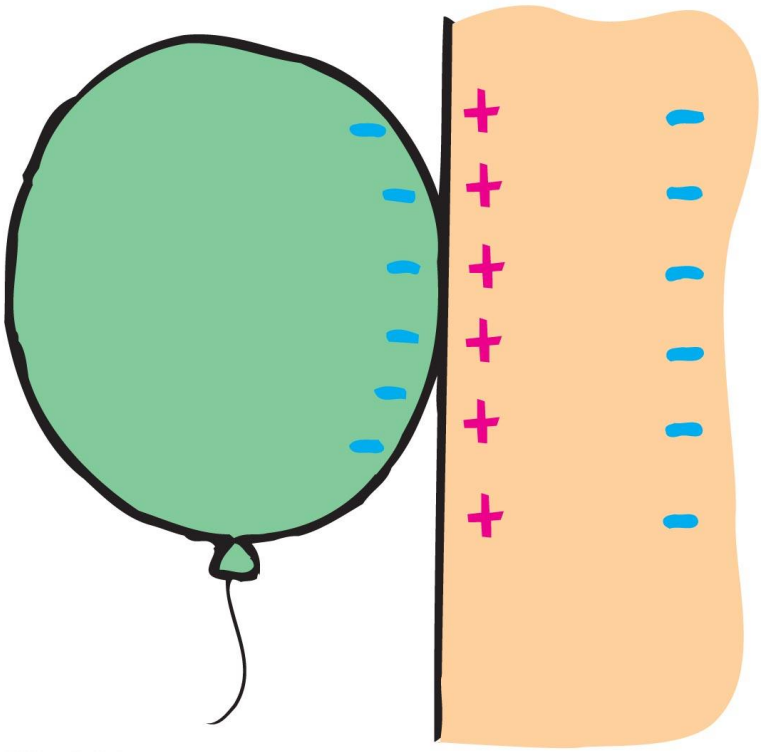
Coulomb's Law

- Charge Polarization
  - Molecules in solids can't move from their relatively stationary positions, but their "centers of charge" can move.
  - This distortion of charge in the atom or molecule is *electric polarization*.



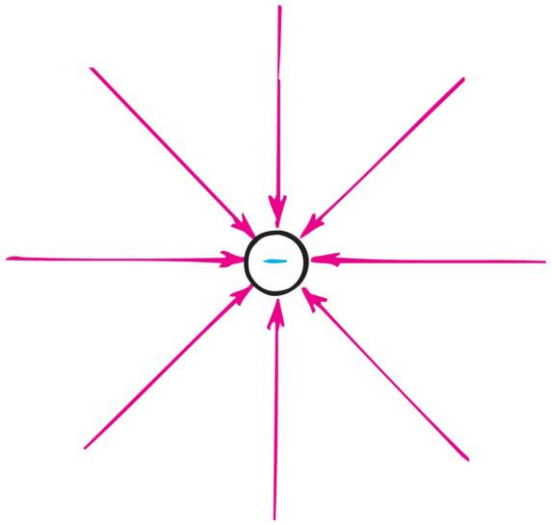
Polarization

- Charge polarization
  - Why a charged rubber balloon sticks to a wall.
    - The charged balloon induces polarization of molecules or atoms in the wall. Negative charges on balloon pull positive sides of molecules near it. Hence a slightly positive induced surface charge on the wall.
    - The balloon sticks.



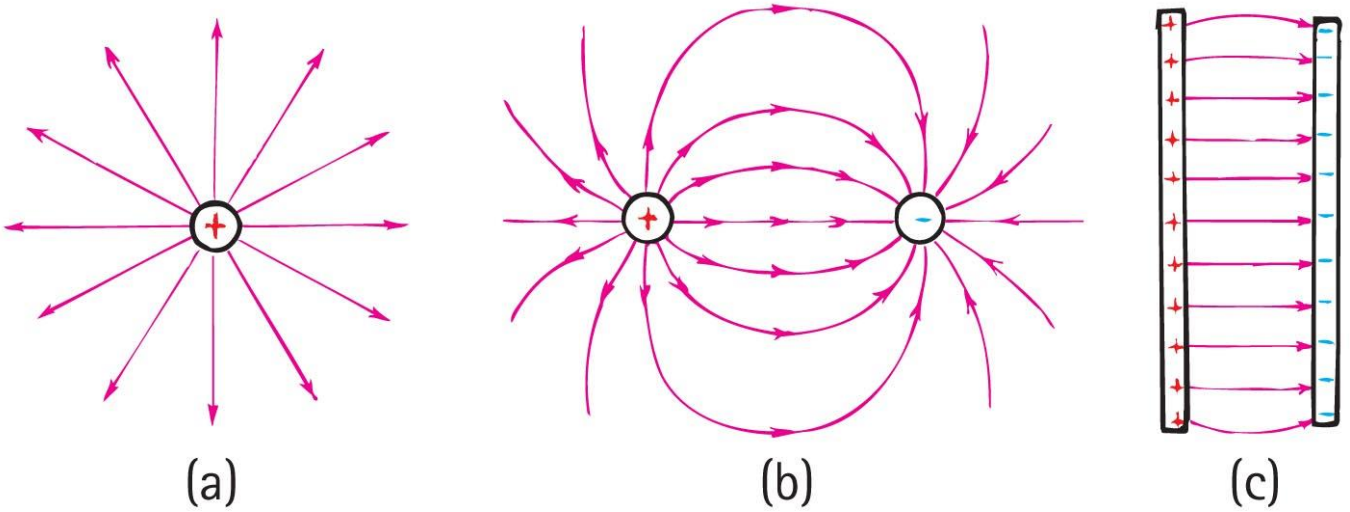
Electric Field

- Electric field:
  - occupies the space that surrounds any charged object
  - is a vector quantity (having magnitude and direction)
  - magnitude of field at any point is force per unit charge
  - obeys the inverse-square law for a point source



Electric Field

- Field lines:
  - used to visualize electric field
  - show direction of electric field—away from positive and toward negative
  - show intensity of electric field:
    - bunched together ⇒ field is strongest
    - lines farther apart ⇒ field is weaker



Electric Current

- Electric current:
  - is the flow of electric charge
  - in metal—conduction electrons
  - in fluids—positive and negative ions
  - measured in amperes
- One **ampere** is the rate of flow of 1 coulomb of charge per second or billion billion electrons per second.
- Actual speed of el6.25ectrons is slow through a wire, but electric signal travels near the speed of light.

Electric Current
CHECK YOUR NEIGHBOR

Which of these statements is true?

A. Electric current is a flow of electric charge.

B. Electric current is stored in batteries.

C. Both are true.

D. Neither are true.

Electric Current
CHECK YOUR ANSWER

Which of these statements is true?

A. Electric current is a flow of electric charge.

B. Electric current is stored in batteries.

C. Both are true.

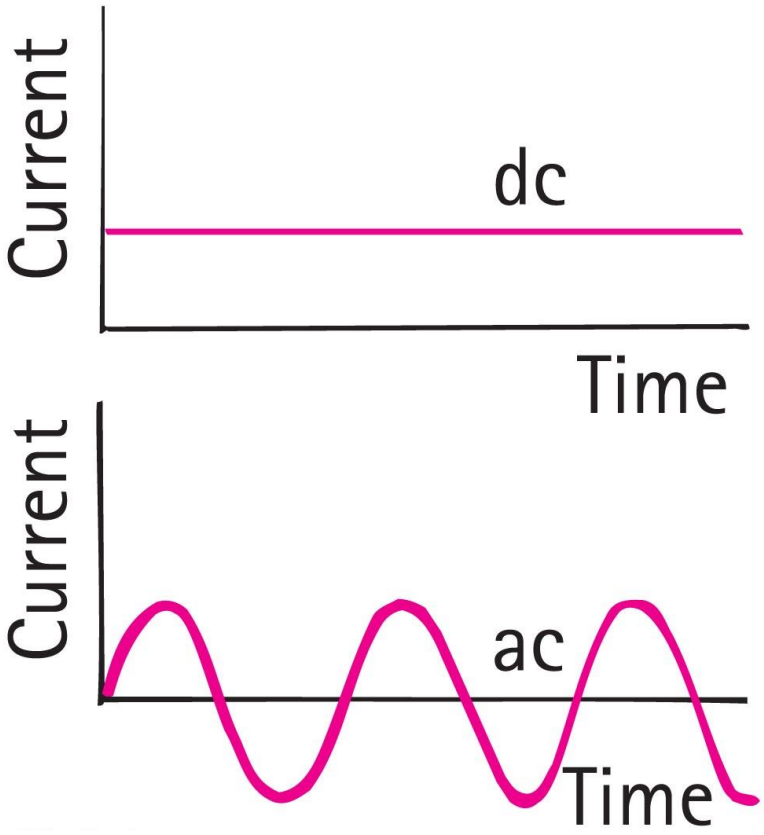
D. Neither are true.

Explanation:

Voltage, not current, is stored in batteries. The voltage will produce a current in a connecting circuit. The battery moves electrons already in the wire, not necessarily those in the battery.

Electric Current

- Electric current may be
  - DC—direct current
    charges flow in one direction
  - AC—alternating current
    charges alternate in direction
- Accomplished in a generator or alternator by periodically switching the sign at the terminals



Electrical Resistance

- Electrical resistance:
  - describes how well a circuit component resists the passage of electric current
  - defined as the ratio of energy-source voltage to the current moving through the energy receiver
  - measured in ohms after 19th century German physicist Georg Simon Ohm

Electrical Resistance

- Factors affecting electrical resistance:
  - thin wires resist electrical current more than thicker wires
  - long wires offer more electrical resistance
  - materials of wire:
    - copper has a low electrical resistance, so it is used to make connecting wires
    - rubber has an enormous resistance, so it is used in electrical insulators
  - temperature:
    - higher temperature (greater jostling of atoms), greater resistance

Electrical Conductors

- **Semiconductors**
  - materials that are neither good conductors nor good insulators, whose resistance can be varied
- **Superconductors**
  - certain metals that acquire infinite conductivity (zero resistance) at temperatures near absolute zero

Electric Current

- Sustained electric current requires suitable voltage source
  - works by pulling negative charges apart from positive ones (available at the terminals of a battery or generator)
  - energy per charge at terminals provides the difference in potential (voltage) to provide "electrical pressure" to move electrons through a circuit