ELECTROSTATICS

Electrostatics

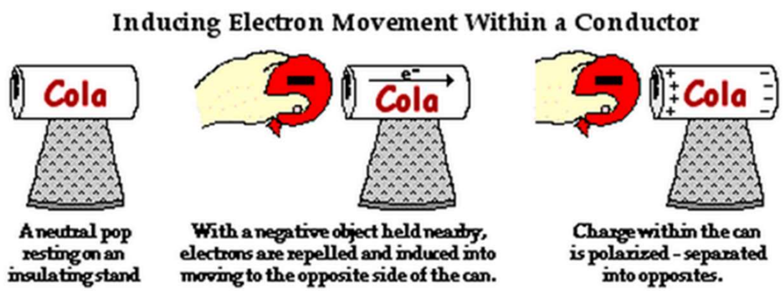
- **Electrostatics** → the study of charges at rest.
  - Static electricity
- 3 types of subatomic particles:

Proton (p^+)	Neutron (n^o)	Electron (e^-)
In nucleus	In nucleus	Outside nucleus
Tightly bound	Tightly bound	Weakly bound
Positive charge	No charge	Negative charge
Massive	Massive	Not very massive

- In the majority of cases, only the negative charges (e^-) will be mobile.
- **Neutral** objects → have equal amounts of + and − charges.
  - No net electrical force

Electric Force

- Action at a distance force
  - Aka a field force
- ***Opposite charges attract, like charges repel***.
  - **Attractive forces**→ at least one object must be charged if attraction is present.
  - **Repulsive forces** → both objects must be charged if there is repulsion.
- **Polarization** → the process of separating opposite charges in an object.
  - I.e., creating + and – poles

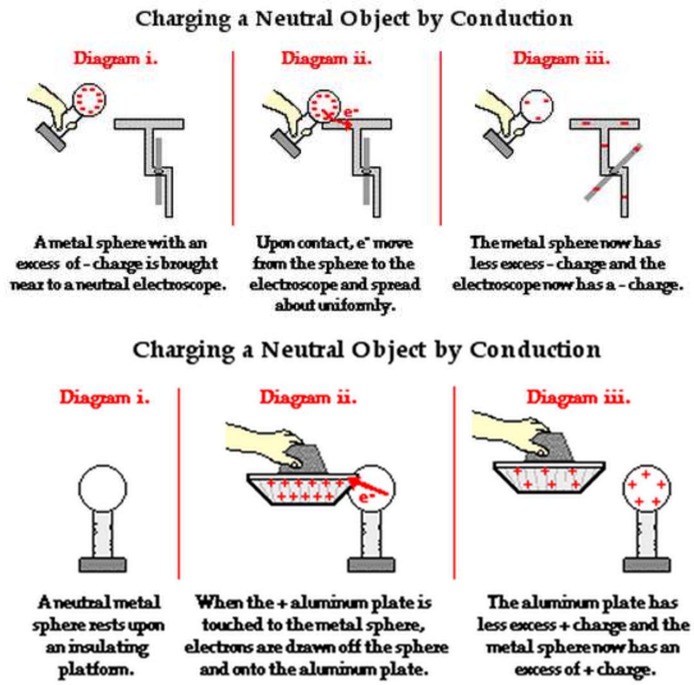


- **Law of Conservation of Charge** → the total charge within a system *must* be conserved.
  - Charges can't magically appear or disappear.
  - Protons and electrons must be accounted for.

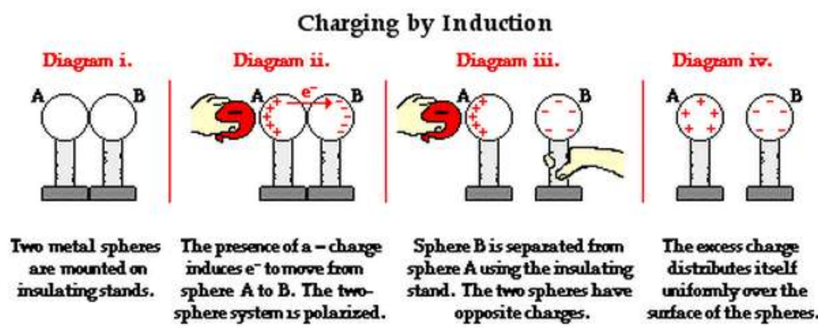
Charging

- **Charging by friction** → when two objects rub together, it's possible for electrons to transfer between them.
  - **Insulators**→ hold on to e^- tightly.
  - **Conductors** → hold on to e^- loosely. Allow charges to flow freely.

- **Charging by conduction →** transferring charge by physically touching two differently charged objects.
  - ➢ If you touch a charged object to a neutral object, the charge will spread over both objects uniformly, leaving both charged.
  - ➢ A positively charged object brought into contact with a neutral object will steal e^-.
  - ➢ ***Only e^- are transferred***.



- **Charging by induction →** Charging an object without actually touching it.
  - ➢ Involves using polarization to charge the object.



- **Ground →** a large object that serves as an infinite source or sink of e^-.
  - ➢ Ex: the Earth. Grounding something allows for charges to flow in/out of the Earth itself to prevent charge buildup.

<u>**Coulomb's Law**</u>

- 1785 → Charles Augustin de Coulomb found that electrical force is similar to gravitational force.
  - ➢ Both follow an ***inverse square law***.

- **Coulomb's Law**

$$F_E = \frac{kq_1q_2}{r^2}$$

Variable	Meaning	Units
F_E	Electric force	Newtons (N)
k	Coulomb's constant	Newton meters squared per Coulomb square (Nm^2/C^2)
q_1 and q_2	Charges	Coulombs (C)

➢ Coulomb's constant: $k = 9 \times 10^9 \ Nm^2/C^2$

Particle	Charge (C)	Mass (kg)
Electron	-1.6×10^{-19}	9.11×10^{-31}
Proton	1.6×10^{-19}	1.67×10^{-27}
Neutron	0	1.67×10^{-27}

Example Problem 1

A Hydrogen atom consists of an electron moving about a proton at an avg distance of 0.53×10^{-10} m. Find the electric and gravitational forces acting between the two particles.

Electric Field

- **Electric** field → An area surrounding a charge in which an object will experience an electric force.
  ➢ The amount of force and the size of the electric field depend on the source charge.

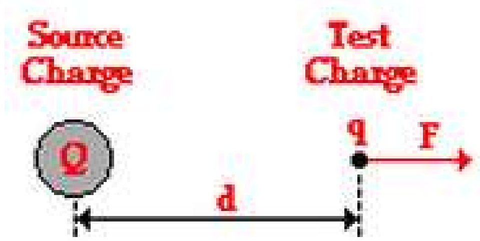
$$E = \frac{F_E}{q}$$

Variable	Meaning	Units
F_E	Electric force	Newtons (N)
E	Electric field	Newtons per coulomb (N/C)
q	Test charge	Coulombs (C)

Example Problem 2

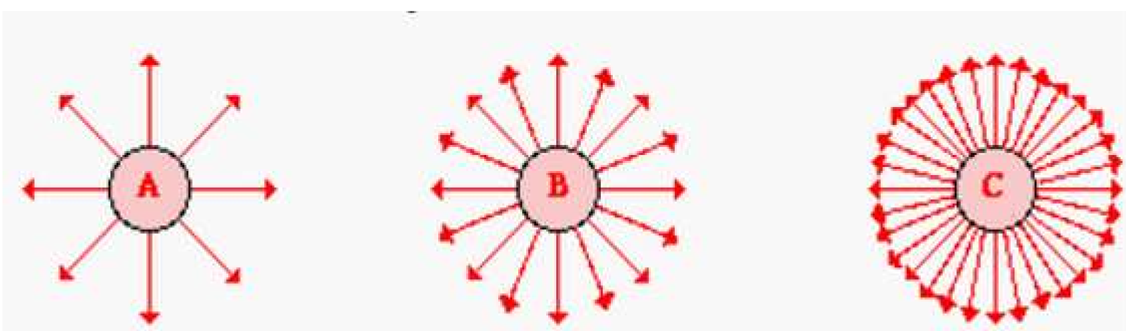
A positive test charge of 5.0×10^{-6} C is in an electric field that exerts a force of 2.0×10^{-4} N on it. What is the magnitude of the electric field at the location of the test charge?

- The test charge is charge used to *test* the strength of an electric field.
- The source charge is the source of the field.

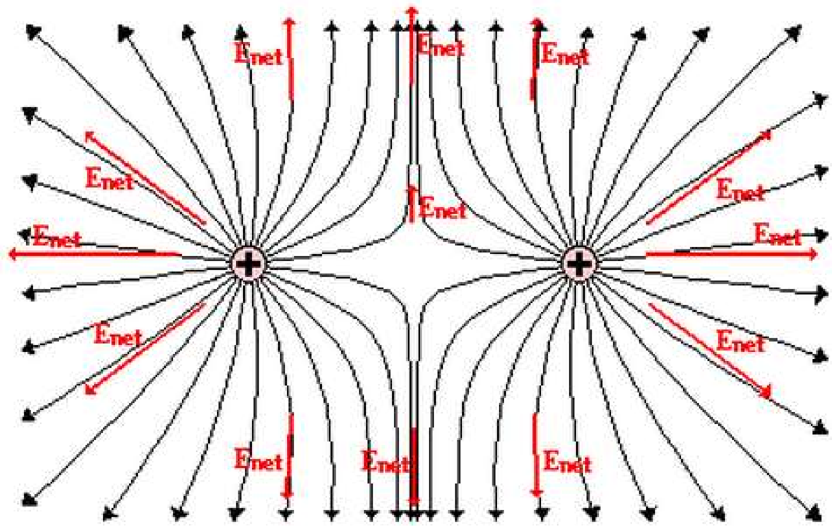


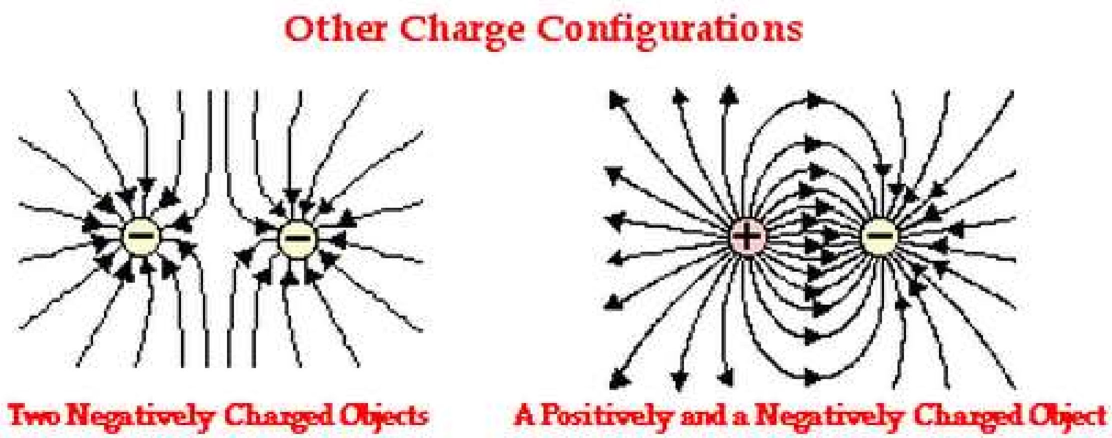
- The direction of the electric field depends on whether the source is positively or negatively charged.
  - The ***positive*** direction is the direction that a positive test charge would be pushed or pulled.
  - Electric field lines always point away from positive source charges (**source)** and into negative charges (**sinks**).
  - Electric field lines *do not* cross.
  - Density of the field lines indicate strength of the field.

Conceptual Example 1

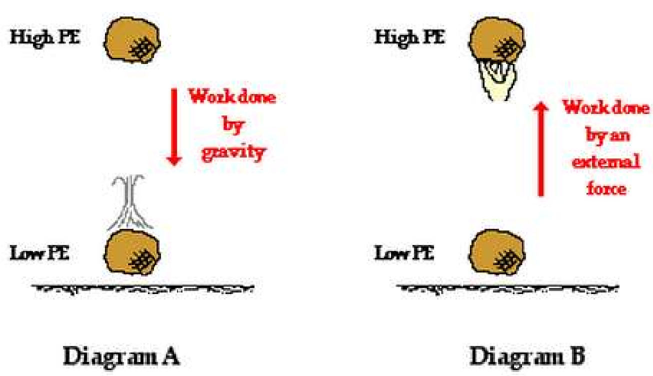


Which of the objects above has the greatest charge? Is it positive or negative?

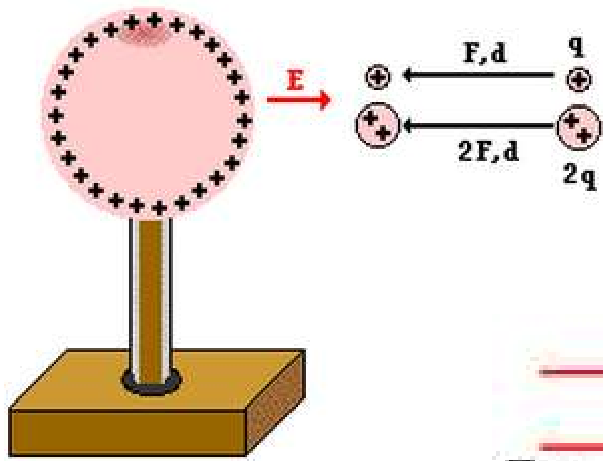


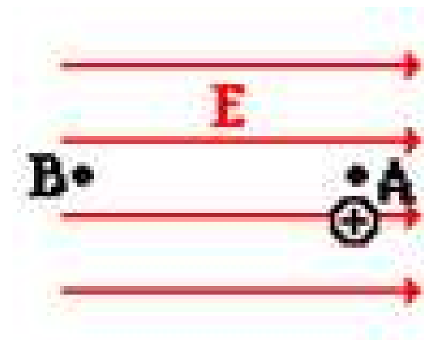


Electric Potential Difference



- **Electric potential difference** → the change in electric potential energy
  - Also called: **electric potential, potential difference, voltage**
  - *Not* the same thing as electric potential energy.
- **Electric potential energy** → Depends on the amount of charge and the distance from the source charge.





- Doing work against an electric field increases the amount of electric potential energy.
  - Also increases the electric potential.

$$\Delta V = \frac{W}{Q} = \frac{\Delta E}{Q}$$

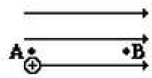
Variable	Meaning	Units
ΔV	Electric potential	Volts (V)
W	Work	Joules (J)
Q	Charge	Coulombs (C)
ΔE	Change in electric potential energy	Joules (J)

- 1 V = 1 J/C
- ***Only differences in potential energy are important.***
  - ***Work done against the electric field increases PE, work done by the electric field decrease PE.***
  - ***The work done moving an charge from point A to B is independent of the path taken.***

Example Problem 3

A small sphere carrying a + charge of 10 micro-Coulombs is moved against an E field through a potential difference of 12.0 V. How much work was done by the applied force in raising the potential of the sphere?

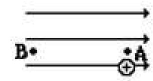
Conceptual Example 2



Work done on charge? Yes or No

Electric PE is greatest at: A B

Electric potential is greatest at: A B



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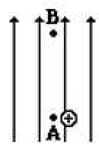

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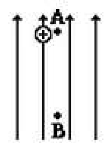

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Looking Ahead to Circuit Electricity

- **Internal circuit**→ Where energy is supplied to a charge.
  - Ex: battery
  - It's where electric potential is increased
- **External circuit** → the charge moving through the wires.
- **Electric pressure** → Charges naturally move from high potential to low potential.
  - Similar to a water slide.