ELECTROSTATICS

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

<table>
<thead>
<tr>
<th>Proton (p⁺)</th>
<th>Neutron (n⁰)</th>
<th>Electron (e⁻)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In nucleus</td>
<td>In nucleus</td>
<td>Outside nucleus</td>
</tr>
<tr>
<td>Tightly bound</td>
<td>Tightly bound</td>
<td>Weakly bound</td>
</tr>
<tr>
<td>Positive charge</td>
<td>No charge</td>
<td>Negative charge</td>
</tr>
<tr>
<td>Massive</td>
<td>Massive</td>
<td>Not very massive</td>
</tr>
</tbody>
</table>

- 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.

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

\[ F_E = \frac{k q_1 q_2}{r^2} \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Meaning</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_E )</td>
<td>Electric force</td>
<td>Newtons (N)</td>
</tr>
<tr>
<td>( k )</td>
<td>Coulomb’s constant</td>
<td>Newton meters squared per Coulomb square (Nm(^2)/C(^2))</td>
</tr>
<tr>
<td>( q_1 ) and ( q_2 )</td>
<td>Charges</td>
<td>Coulombs (C)</td>
</tr>
</tbody>
</table>

- Coulomb’s constant: \( k = 9 \times 10^9 \) Nm\(^2\)/C\(^2\)

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge (C)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>(-1.6 \times 10^{-19})</td>
<td>(9.11 \times 10^{-31})</td>
</tr>
<tr>
<td>Proton</td>
<td>(1.6 \times 10^{-19})</td>
<td>(1.67 \times 10^{-27})</td>
</tr>
<tr>
<td>Neutron</td>
<td>0</td>
<td>(1.67 \times 10^{-27})</td>
</tr>
</tbody>
</table>

**Example Problem 1**

A Hydrogen atom consists of an electron moving about a proton at an avg distance of \(0.53 \times 10^{-10}\) 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.

\[ E = \frac{F_E}{q} \]

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<td>Electric force</td>
<td>Newtons (N)</td>
</tr>
<tr>
<td>( E )</td>
<td>Electric field</td>
<td>Newtons per coulomb (N/C)</td>
</tr>
<tr>
<td>( q )</td>
<td>Test charge</td>
<td>Coulombs (C)</td>
</tr>
</tbody>
</table>
Example Problem 2

A positive test charge of $5.0 \times 10^{-6} \text{ C}$ is in an electric field that exerts a force of $2.0 \times 10^{-4} \text{ N}$ 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

Diagram A

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

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

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<tbody>
<tr>
<td>$\Delta V$</td>
<td>Electric potential</td>
<td>Volts (V)</td>
</tr>
<tr>
<td>$W$</td>
<td>Work</td>
<td>Joules (J)</td>
</tr>
<tr>
<td>$Q$</td>
<td>Charge</td>
<td>Coulombs (C)</td>
</tr>
<tr>
<td>$\Delta E$</td>
<td>Change in electric potential energy</td>
<td>Joules (J)</td>
</tr>
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- $1 \text{ V} = 1 \text{ J/C}$
- 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?
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.