Electric Charges And Fields

Electric charge

- It is the additional property of protons and electrons which gives rise to electric force between them.
- There are two kinds of charges positive charge and negative charge.

Properties of electric charge

- Electric charge is a scalar quantity.
- Like charges repel each other whereas unlike charges attract each other.

Conductors

- The substances which allow electricity to pass through them easily are called conductors for example metals are good conductors of electricity.

Insulators

- The substances which do not allow electricity to pass through them easily are called insulators for example the non-metals such as porcelain, wood, nylon, etc. are examples of insulator.

Gold-leaf electroscope

- A simple apparatus used to detect charge on a body is the gold-leaf electroscope.
- It can only measure the magnitude of the charge on a body cannot mesure its polarity.

Charging by induction

- This is a process of charging an uncharged body with the help of a charged body without any actual contact.
- A charge of opposite sign develops on uncharged body when a charged body is braught near to the uncharged body.

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Basic Properties of Electric Charges

- The total electric charge on an object is equal to the algebraic sum of all the electric charges distributed on the different parts of the object

- The total charge of an isolated system remains constant with time.

- All observable charges are always some integral multiple of elementary charge, *e* (= ± 1.6 × 10^{-19} C)

Coulomb's Law

- Two point charges attract or repel each other with a force which is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.

- F=Kq1q2r2,K=14πε0=9×109 Nm2C-2

Principle of Superposition

- It is based on the property that the forces with which two charges attract or repel each other are not affected by the presence of a third (or more) additional charge(s).

- The total force on a given charge due to number of charges is equal to the vector sum of the individual forces exerted on the given charge by all the other charges.

Electric Field

- It is the space around a charge, in which any other charge experiences an electrostatic force.

Electric Field Intensity

- The electric field intensity at a point due to a source charge is defined as the force experienced per unit positive test charge placed at that point without disturbing the source charge.

- Electric field due to a point charge at distance r from it is E= q4πε0r2
- Electric field due to a number of charges is found by adding the individual electric fields vectorially.

Electric Field Lines

- An electric line of force is the path along which a unit positive charge would move, if it is free to do so.

- Properties of electric field lines

  - They are continuous curves without any breaks
  - They cannot cross each other.
  - They cannot form closed loops.

Continuous Charge Distribution

- **Linear charge density –** When charge is distributed along a line then charge density is given by λ.

$\lambda = \frac{q}{L}$

- **Surface charge density-**When charge is distributed along a surface, the charge density is given by σ.

$\sigma = \frac{q}{A}$

- **Volume charge density-**When charge is distributed along a volume, the charge density is given by δ.

$\delta = \frac{q}{V}$

Electric Dipole

- System of two equal and opposite charges separated by a certain small distance.

Electric Dipole Moment

- It is a vector quantity, with magnitude equal to the product of either of the charges and the length of the electric dipole and direction from the negative charge to the positive charge.

$\vec{p} = q(\overrightarrow{2a})$

Electric Field on Axial Line of an Electric Dipole

E=→2 p4πε0r3

Electric Field for Points on the Equatorial Plane

E=→- p4πε0r3

Dipole in a Uniform External Field

In a uniform electric field *E*, a dipole experiences a torque *t*, due to two equal and unlike parallel forces acting on dipole

τ = Force × Perpendicular distance between the two forces
τ = $pE \sin\theta$
$\therefore \vec{\tau} = \vec{p} \times \vec{E}$

Electric flux

- It is the total number of electric field lines of force crossing the unit surface area in a direction normal to the surface.

- The flux Φ of an electric field *E*, through a small area element *ds* is given by $\phi = \int_s \vec{E} \cdot \vec{ds} = \int_s \vec{E}_n \, ds$

Gauss's law

- It states that the total electric flux through a closed surface enclosing a charge *q* is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed.

$$\phi = \frac{q}{\varepsilon_0}$$

$$\phi = \oint_s \vec{E} \cdot \vec{ds}$$

Applications of Gauss's Law

- Electric field intensity due to an infinitely long straight wire of linear charge density *λ* at a point which is at a perpendicular distance *r* from the wire is given by
 λ2πε0r n^, where n^ is the radial unit vector in the plane normal to the wire passing

- Electric field intensity due to a uniformly charged infinite plane sheet of surface charge density *s* is given by σ2ε0n^ , where n^ is a unit vector normal to the plane, acting outward on either side.

- Electric field intensity due to a total charge q distributed along its surface is given by
 q4πεr2 (r≥R), 0 (r<R)

 Here, *r* is the distance of the point from the centre of the shell and *R* is the radius of the shell.

- Mechanical force per unit area of a charged conductor, f=12εE2.
- Energy density per unit volume of a charged conductor, dudv=12εE2.