Chapter Overview

Quantum of charge: $e = 1.6\times10^{-19}$ C.

1. Sharing of charge between two spherical conductors of radii R_1 and R_2 having total charge Q, when braught to contact and then separated: $Q_1' = \frac{R_1 Q}{R_1+R_2}$ and $Q_2' = \frac{R_2 Q}{R_1+R_2}$.

2. Coulomb's Law:

(1) Magnitiue of Coulomb's force:

$$F = \frac{q_1q_2}{4\pi\varepsilon_0 r^2} \text{ (vacuum)}; \quad F = \frac{q_1q_2}{4\pi\varepsilon_0\varepsilon_r r^2} \text{ (in medium of d.e.c. } \varepsilon_r)$$

(2) Vector form: $\vec{F}_{12} = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}\hat{r}_{12}$, $\vec{F}_{21} = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}\hat{r}_{21}$ hence $\vec{F}_{21} = -\vec{F}_{21}$

(3) In terms of position vector of the charges:

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2(\vec{r}_1-\vec{r}_2)}{|\vec{r}_1-\vec{r}_2|^3}, \quad \vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2(\vec{r}_2-\vec{r}_1)}{|\vec{r}_2-\vec{r}_1|^3}$$

3. Relative permitivitty or dielectric constant: $\varepsilon_r = \frac{F_0}{F_m} = \frac{\varepsilon}{\varepsilon_0}$.

4. Electric Field: $\vec{E} = \lim_{\Delta q\to 0}\frac{\Delta\vec{F}}{\Delta q}$. **Unit:** NC^{-1} or Vm^{-1}. **Dimension:** [$MLA^{-1}T^{-3}$].

5. Intensity of Electric Field

A. Calculated by using Coulomb's law:

(i) Due to a point charge: $\vec{E} = -\frac{q}{4\pi\varepsilon_0 r^2}\hat{r}$.

(ii) Due to a uniformly charged ring of radius on the axis: $E = \frac{qx}{4\pi\varepsilon_0(R^2+x^2)^{3/2}}$.

(iii) Due to a finite line of charge: $E_x = \frac{\lambda}{4\pi\varepsilon_0 x}(\sin\theta_1+\sin\theta_2)$, $E_y = \frac{\lambda}{4\pi\varepsilon_0 x}(\cos\theta_1-\cos\theta_2)$

(θ_1 and θ_2 are respectively, negative and positive angles made by the ends of the line at the point by the ends of the line charge.)

B. Calculated by applying Gauss's theorem:

(i) Infinite line of charge: $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{r}$

(ii) Infinite sheet of charge: $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

(iii) Outside a charged conductor: $\vec{E} = \frac{\sigma}{\varepsilon_o}\hat{n}$

(iv) Between oppositely charged sheets or conducting planes: $\vec{E} = \frac{\sigma}{\varepsilon_o}\hat{n}$

(v) Charged hollow sphere: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ (outside), $E = 0$ (inside).

(vi) Charged solid sphere: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ (outside), $\vec{E} = \frac{Q\vec{r}}{4\pi\varepsilon_0 R^3}$ (inside).

C. Due to an electric dipole:

(a) At an axial point : $\vec{E} = \dfrac{2\vec{p}\,r}{4\pi\varepsilon_0\left(r^2 - l^2\right)^2}$.

(b) At an equatorial point: $\vec{E} = -\dfrac{\vec{p}}{4\pi\varepsilon_0 r^3}$.

6. Superposition principle in electrostatics:

The net force on q_0 is the vector sum of all the forces, $\vec{F} = \dfrac{q_0}{4\pi\varepsilon_0}\sum_{i=1}^{n}\dfrac{q_i}{r_{0i}^2}\hat{r}_{0i}$.

If q_i is the i^{th} charged particle in the distribution of charges, then intensity of field at the point P will be given as, $\vec{E} = \dfrac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\dfrac{q_i}{r_i^2}\hat{r}_i$. $\Rightarrow \vec{E} = \sum_{i=1}^{n}\vec{E}_i$.

If charge is distributed continuously then net field at point $E = \int dE$.

7. Specific charge on a particle: $\dfrac{q}{m}$.

8. Acceleration of a charged particle in a field: $a = \dfrac{qE}{m}$.

9. Equation of trajectory of a charged particle in a uniform electric field when initial velocity v is along x axis and electric field is long y axis: $y = \dfrac{qE}{2m}x^2$

10. Electric dipole moment: $\vec{p} = q\vec{L}$. **Unit:** Cm, **Dimension:** [ATL].

11. Torque on an electric dipole in a uniform electric field: $\vec{\tau} = \vec{P}\times\vec{E}$ or $\tau = PE\sin\theta$.

12. Electric flux: $d\phi = \vec{E}\cdot d\vec{s}$; total flux $\phi = \oint_{surface}\vec{E}\cdot d\vec{s}$.

Unit: N m^2/C or volt-m. **Dimensions:** [$ML^3T^{-3}A^{-1}$].

13. Gauss's theorem: $\phi = \dfrac{q}{\varepsilon_0}$.