ELECTROSTATICS - 1

Charge

Quantization of charge

$Q = \pm ne$ Q=Total charge

n=1,2,3....

e=1.6 x 10^{-19}C

Additivity of charge

$Q' = Q_1 + Q_2$

Redistribution of charge

$Q' = \frac{Q_1 + Q_2}{2}$

Q'=Charge on each shell after redistribution

Charge Density

Linear Charge density, $\lambda = \frac{Q}{L}$ Unit= $\frac{C}{m}$

Surface Charge density, $\sigma = \frac{Q}{S}$ Unit= $\frac{C}{m^2}$

Volume Charge density, $\rho = \frac{Q}{V}$ Unit= $\frac{C}{m^3}$

Q=Total charge V=Volume

L=Length S=Area

?

If a charge on the body is 1 nC, then how many electrons are present on the body?

a) 1.6 × 10^{19} b) 6.25 × 10^{9}

c) 6.25 × 10^{27} d) 6.25 × 10^{28}

Coulomb's Law

$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$

ε_0=Permitivity of free space

$[\varepsilon_0] = \frac{[Q_1][Q_2]}{[r^2][F]} = \frac{[AT][AT]}{[L^2][MLT^{-2}]} = M^{-1}L^{-3}T^4A^2$

$F_{med} = \frac{F_{air}}{k}$

k=dielectric constant of the medium

Superposition

Direction:

a) Like- Towards the point at which force has to be evaluated (repulsion)

b) Unlike- Away from the point at which force has to be evaluated (attraction)

- General rule: $F_{Net} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$
- When θ=60°: $F_{net} = \sqrt{3}F$
- When θ=90°: $F_{net} = \sqrt{2}F$
- When θ=120°: $F_{net} = F$

Equillibrium of Charges

Calculation of Charge

$\frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^2$ q in equillibrium

$q = -\left(\frac{r_1}{r_1 + r_2}\right)^2 Q_2$ Q_1 in equillibrium

$q = -\left(\frac{r_2}{r_1 + r_2}\right)^2 Q_1$ Q_2 in equillibrium

?

A charge is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to

a) -Q/2 c) +Q/4

b) -Q/4 d) +Q/2

Charge on pendulum

$\tan\theta = \frac{qE}{mg}$

$\sin\theta = \frac{r}{2l}$

r=2l sin θ

if θ is very small

tanθ≈Sinθ

$\frac{r}{2l} = \frac{qE}{mg}$

$\frac{r}{2l} = \frac{kq^2/r^2}{mg}$, $r^3 \propto q^2$

Density of ball "ρ"

if θ does not change on submerging in liquid

Dielectric constant of liquid,

$K = \frac{\rho}{\rho - \sigma}$

density of liquid=σ

Electric Field

Electric field at a point, due to point charge $E = \frac{Kq}{r^2}$

$K = \frac{1}{4\pi\varepsilon_0}$

$E \propto \frac{1}{r^2}$

Superposition

General rule: $E_{Net} = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$

- $E_{Net} = E_1 + E_2$
- $E_{Net} = |E_1 - E_2|$
- $E_{Net} = \sqrt{E_1^2 + E_2^2 + E_1E_2}$; If, $E_1 = E_2 = E$ Then, $E_{net} = \sqrt{3}E$
- $E_{Net} = \sqrt{E_1^2 + E_2^2}$; If, $E_1 = E_2 = E$ Then, $E_{net} = \sqrt{2}E$
- $E_{Net} = \sqrt{E_1^2 + E_2^2 - E_1E_2}$; If, $E_1 = E_2 = E$ Then, $E_{net} = E$

Direction

1) Positive charge:-Towards the point at which electric field has to be evaluated

2) Negative charge:-Away from the point at which electric field has to be evaluated

Neutral Point

Like Charges

$x_1 = \frac{\sqrt{Q_1}\,r}{\sqrt{Q_1} + \sqrt{Q_2}}$

$x_2 = \frac{\sqrt{Q_2}\,r}{\sqrt{Q_1} + \sqrt{Q_2}}$

Unlike Charges

Outside closer to smaller charge

$|Q_1| < |Q_2|$

$x = \frac{\sqrt{Q_1}\,r}{\sqrt{Q_1} - \sqrt{Q_2}}$

Distance from Q_1=x+r

?

Two point charges +8q and -2q are located at x = 0 and x = L respectively. The location of a point on the x axis at which the net electric field due to these two point charges is zero is:

a) 8L

b) 4L

c) 2L

d) L/4

Charged particle released in an electric field

1) Force, F=qE

2) Acceleration, $a = \frac{qE}{m}$

3) Velocity, $V = \frac{qE}{m}t$

4) Velocity, $V = \sqrt{\frac{2qE}{m}x}$

5) Kinetic energy, $K.E = \frac{q^2E^2t^2}{2m}$

accelerated in the direction of electric field

accelerated opposite to the direction of electric field

$V = \sqrt{V_x^2 + V_y^2}$

$V_y = \frac{qEt}{m}$

$\sqrt{U^2 + \left(\frac{qE}{m}t\right)^2}$

accelerated in the direction of field and perpendicular to initial velocity

$\frac{M_p}{M_e} = 1837$, $\frac{e}{m} = 1.7 \times 10^{11}$

$\frac{1}{2}at^2 = h = \text{Constant}$

$\frac{1}{2}\frac{qE}{m}t^2 = h$

$t^2 \propto m$

$\frac{t_p}{t_e} = \left[\frac{m_p}{m_e}\right]^{1/2}$

$\Rightarrow t_p > t_e$

Time period of Charged Pendulum in an electric filed

$T = 2\pi\sqrt{\frac{l}{\left(g - \frac{QE}{m}\right)}}$ Time period will increase

$T = 2\pi\sqrt{\frac{l}{\left(g + \frac{QE}{m}\right)}}$ Time period will decrease

$T = 2\pi\sqrt{\frac{l}{\sqrt{g^2 + \left(\frac{QE}{m}\right)^2}}}$ Time period will decrease

Electric field inside a dielectric medium

$E_{net} = \frac{E}{k} \Rightarrow K$

$E_{net} = E - E_{induced}$, $E_{induced} = E - E_{net} = E\left(1 - \frac{1}{k}\right)$

Properties of field lines

1) Start from positive charge and end on negative charge

2) Never intersect each other. If they intersect there will be 2 directions for electric field which is not possible

3) Always perpendicular to Conducting surface

4) E α Electric field line density

5) Never form closed loops (Conservative force)

6) q α no. of field lines

$|q_1| > |q_2|$

?

Electric lines of force about negative point charge are:

a) circular, anticlockwise

b) circular, clockwise

c) radial, inward

d) radial, outward

Electric flux

Flux is proportional to total no. of field lines passing through an area

$\Phi = \int E.ds\cos\theta$

$\Phi = \int \vec{E}.\vec{ds}$

Gauss Law:- $\Phi = \frac{q}{\varepsilon_0} = \oint E.ds\cos\theta$

Zero flux:- $\Phi = \frac{q_{net}}{\varepsilon_0} = 0$, where $q_{net} = 0$

Electric flux for Cube

1) No charge inside the cube

$\Phi = \frac{q}{\varepsilon_0} = 0$

2) Charge placed at the center

$\Phi_{total} = \frac{q}{\varepsilon_0}$

$\Phi_{one\ side} = \frac{q}{6\varepsilon_0}$

3) Charge placed at the face

$\Phi_{cube} = \frac{q}{2\varepsilon_0}$

4) Charge placed at the corner

$\Phi_{cube} = \frac{Q}{8\varepsilon_0}$

$\Phi_{one\ face} = \frac{Q}{8\varepsilon_0} \times \frac{1}{3} = \frac{Q}{24\varepsilon_0}$

5) Charge placed at the edge

$\Phi_{cube} = \frac{Q}{4\varepsilon_0}$

$\Phi_{face} = \frac{Q}{\varepsilon_0} \times \frac{1}{4} = \frac{Q}{16\varepsilon_0}$

6) Flux through curved surface

$\Phi_{effective} = \Phi_{curve} + 2\Phi_{cross\ section}$

Application of Gauss's Theorem

1) Point charge $E = \frac{Kq}{r^2}$

2) Metal sphere/Hollow sphere

$E_{surface} = \frac{KQ}{R^2}$

$E_{outside} = \frac{KQ}{r^2}$

$E_{inside} = 0$

3) Non-Conducting sphere

$E_{inside} = \frac{KQr}{R^3}$

$E_{surface} = \frac{KQ}{R^2}$

$E_{outside} = \frac{KQ}{r^2}$

4) Conducting sheet

$E = \frac{\sigma}{\varepsilon_0}$

5) Non-conducting sheet

$E = \frac{\sigma}{2\varepsilon_0}$

Q_{outer} Q_{inner} Q_{plate}

$Q_{inner} = Q_{plate} - Q_{outer}$

7) Electric field due to a finite linear charge distribution

$E = \frac{2k\lambda}{r}\sin(\theta/2)$

8) Electric field due to a infinite linear charge distribution

$E = \frac{2k\lambda}{r}$

9) Electric field due to circular arc at its center

$E_0 = \frac{2k\lambda}{r}\sin(\theta/2)$

eg: For a semicircle θ=180°

$E_0 = \frac{2k\lambda}{r}\sin(180°/2) = \frac{2k\lambda}{r}$

10) Electric field at the center of a circular ring

$E_0 = 0$

11) Electric field due to a circular ring of charge

$E = \frac{1}{4\pi\varepsilon_0}\frac{qx}{(x^2 + r^2)^{3/2}}$

(For large distance)

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$

E_{max} at $x = \frac{r}{\sqrt{2}}$

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