ELECTROSTATICS - 1

PHYSICS WALLAH

Charge

Quantization of charge

$Q=\pm ne$ Q=Total charge

n=1,2,3....

$e=1.6\times10^{-19}C$

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

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

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

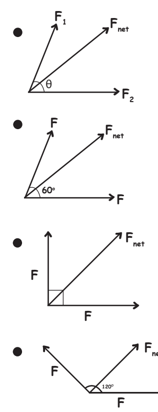
k=dielectric constant of the medium

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: $F_{Net}=\sqrt{F_1^2+F_2^2+2F_1F_2\cos\theta}$

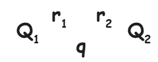
When $\theta=60°$: $F_{net}=\sqrt{3}F$

When $\theta=90°$: $F_{net}=\sqrt{2}F$

When $\theta=120°$: $F_{net}=F$

Equillibrium of Charges

Calculation of Charge



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

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

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

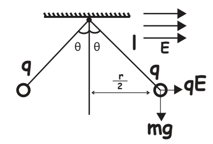
?

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

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

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

Charge on pendulum



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

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

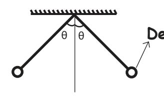
$r=2l\sin\theta$

if θ is very small

$\tan\theta\approx\sin\theta$

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

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



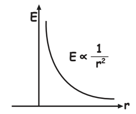
Density of ball "ρ"

if θ does not change on submerging in liquid Dielectric constant of liquid,

density of liquid= σ

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

Electric Field



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

$E\propto\frac{1}{r^2}$ $K=\frac{1}{4\pi\varepsilon_0}$

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, $E_{net}=E$

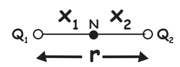
Direction

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

$|Q_2|<|Q_1|$

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

Distance from Q_1=x+r

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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, $a=\frac{qE}{m}$

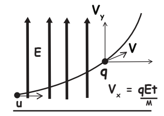
3) Velocity, $V=\frac{qE}{m}t$

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



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

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

accelerated in the direction of field and perpendicular to initial velocity

$\frac{M_p}{M_e}=1837$, $\frac{e}{m}=1.7\times10^{11}$

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

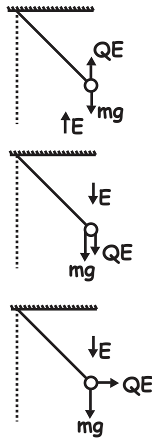
$\frac{1}{2}\frac{qE}{m}t^2=h$

$t^2\propto m$

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

$\Rightarrow t_p>t_e$

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

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

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

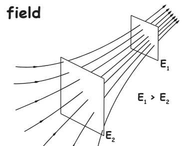
Properties of field lines

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 $|q_2|>|q_1|$

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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

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

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

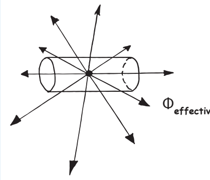
5) Charge placed at the edge

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

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

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

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

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

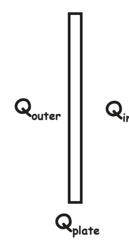
$E_{outside}=\frac{KQ}{r^2}$

4) Conducting sheet

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

5) Non-conducting sheet

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



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

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 $x=\frac{r}{\sqrt{2}}$