Ch-01

Electric Charges & Fields

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PHYSICSWALLAH LAKSHYA BATCH 2020-21

Formula Sheet
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WINNER

ELECTRIC CHARGES AND FIELDS CH-1

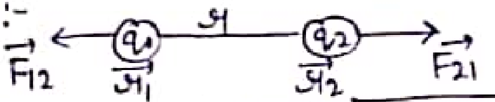
Charge :- intrinsic property of a matter due to which it experience electric and magnetic effects. [symbol-Q , unit - coulomb 'C', Dimension - [AT]]

Properties of charges :- (1) Quantisation - $\boxed{Q = \pm ne}$

(2) Conservation of charge -

then $\boxed{q_1+q_2+q_3=q_4+q_5+q_6}$

Coullomb's Law :-



$\vec{F}_{12} = -\vec{F}_{21}$ $|\vec{F}_{12}| = |\vec{F}_{21}| = F$

$\boxed{F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}}$

where $K = 9\times10^9\,Nm^2/C^2$

$\boxed{\vec{F}_{21} = \frac{Kq_1q_2(\vec{r}_2-\vec{r}_1)}{|\vec{r}_2-\vec{r}_1|^3}}$ $\boxed{\vec{F}_{12} = \frac{Kq_1q_2(\vec{r}_1-\vec{r}_2)}{|\vec{r}_1-\vec{r}_2|^3}}$

$\boxed{F = \frac{Kq_1q_2}{r^2}}$ $\boxed{F \rightarrow Max \ \frac{dF}{dq}=0}$

q_1, q_2 with sign

Principle of superposition:-

$\boxed{F_{net} \text{ on } q_n = \vec{F}_{n1} + \vec{F}_{n2} + \vec{F}_{n3} + \cdots + \vec{F}_{n(n-1)}}$

Third charge in equilibrium type -

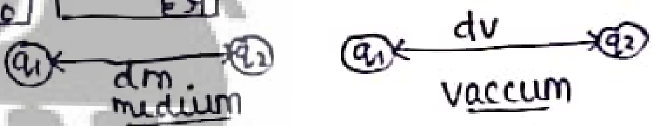
* If q_1 and q_2 → opposite sign. 3rd charge will be kept outside & near to smaller charge & $x = \left(\frac{\sqrt{q_1}}{\sqrt{q_2}-\sqrt{q_1}}\right)L$, where q_1 → smaller

x - distance from q_1

* If q_1 and q_2 are of same sign third charge will be kept b/w the charges and near to smaller charge & then $\boxed{x = \left(\frac{\sqrt{q_1}}{\sqrt{q_1}+\sqrt{q_2}}\right)L}$ where q_1 - smaller charge and x is distance from q_1.

Relative permittivity :- $\boxed{\epsilon_r = \frac{\epsilon_m}{\epsilon_0}}$ $\boxed{F_m = \frac{F_0}{\epsilon_r}}$, $\epsilon_0 = 8.85\times10^{-12}\,C^2/Nm^2$

Equivalent distance in vaccum :-



$\boxed{dV = \sqrt{\epsilon_r}\,dm}$

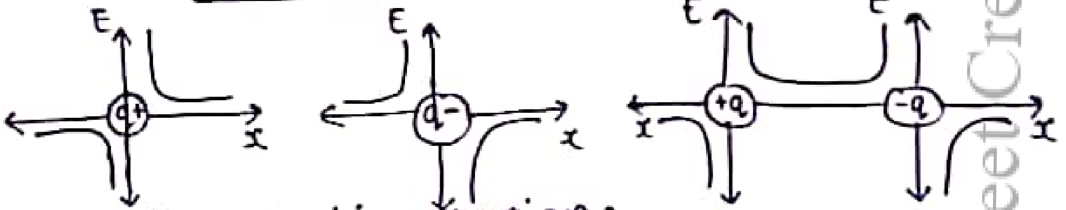
Electric field :- $\boxed{E_P = \frac{KQ}{r^2}}$ $\boxed{\vec{E}_P = \frac{KQ\cdot\vec{r}}{|\vec{r}|^3}}$

[valid for point charges only]

For system of charges :- $\boxed{\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3}$

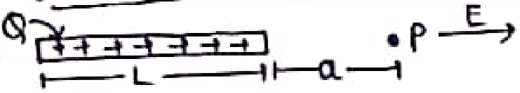
Graph E v/s x :-

E $\xrightarrow{(+)ve}$ E $\xleftarrow{(-)ve}$



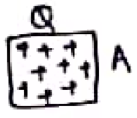
Electric field due to charge distribution :-

(1)



$\boxed{E = \frac{KQ}{a(a+L)}}$ $\boxed{\lambda = Q/L}$ λ - Linear charge density.

(2)



(2-D)

$\boxed{\sigma = \frac{Q}{A}}$ σ → surface charge density

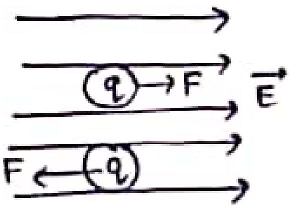
(3)

(3-D)

$\boxed{\rho = \frac{Q}{V}}$ ρ → volume charge density

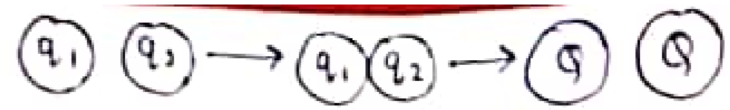
Force on charge placed in an $\vec{E}$ field :-

$\boxed{F = qE}$ → with sign

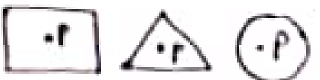


identical spheres are touched:-

$\boxed{Q = \frac{q_1+q_2}{2}}$

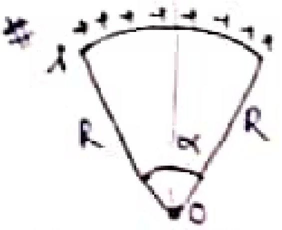


Electric field due to closed system:-



$\boxed{E_P = 0}$

#



$\boxed{E_O = \frac{2K\lambda}{R}\sin\frac{\alpha}{2}}$

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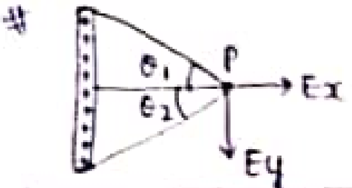


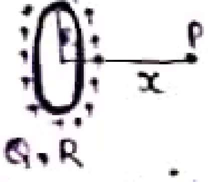
$\boxed{E_x = \frac{K\lambda}{d}(\sin\theta_2+\sin\theta_1)}$

$\boxed{E_y = \frac{K\lambda}{d}(\cos\theta_1-\cos\theta_2)}$

$\boxed{E_P = \frac{\lambda}{2\pi\varepsilon_0 d}}$

$\boxed{E_P = \frac{\sqrt{2}K\lambda}{d}}$

$\vec{E}$ field due to uniformly charge ring:-



$\boxed{E_P = \frac{KQx}{(R^2+x^2)^{3/2}}\hat{i}}$

$\boxed{E_P = \frac{KQ}{x^2}}$
For $x >>>> R$

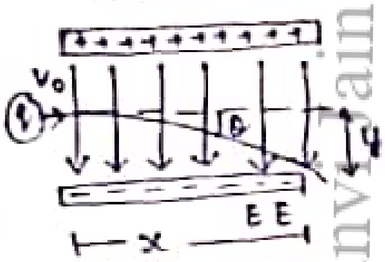
$\boxed{E=0 \text{ at } x=0}$
for centre

$\boxed{E_{max\ Ring} = \frac{2KQ}{3\sqrt{3}R^2}}$

$\boxed{\text{at } x = \pm\frac{R}{\sqrt{2}}}$

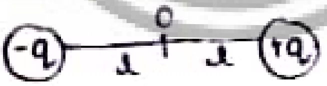
Motion in 2D:-

consider ⇒ x direction motion | y-directⁿ motion
and solve



Electric field lines:-
(1) originate from (+)charge and terminate on (-)ve charge.
(2) doesn't form closed loops. (3) don't terminate in free space.
(4) $\boxed{\text{Relative no of field lines} \propto \text{Magnitude of charge}}$ (5) $\boxed{\text{relative closeness of field lines} \propto \text{Magnitude of field}}$
(6) E = 0 inside a conductor

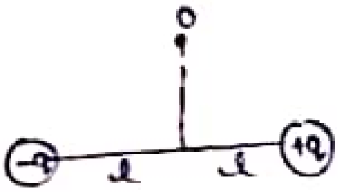
Dipole moment:-



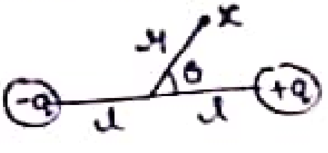
$\boxed{\vec{p} = q \times 2l}$ directⁿ of $\vec{p}$ is (-)ve to (+)ve

Electric field due to dipole-

$\boxed{E_{net\ axial} = \frac{2k\vec{p}}{r^3}}$



$\boxed{E_O \text{ or } E_\perp = \frac{-K\vec{p}}{r^3}}$

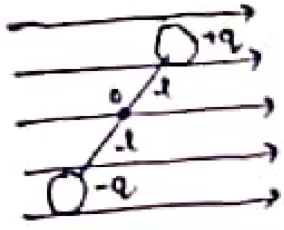


$\boxed{E_x = \frac{kp}{r^3}\sqrt{3\cos^2\theta+1}}$
general point

Torque on dipole placed in an $\vec{E}$ field:-

$\vec{\tau} = \vec{p} \times \vec{E} = pE\sin\theta$

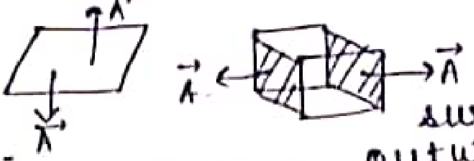
[Electric field tries to align dipole along its own direction.]



Time period of SHM of dipole in an $\vec{E}$ field:-

$\boxed{T = 2\pi\sqrt{\frac{ml}{2qE}}}$

Area Vector:-



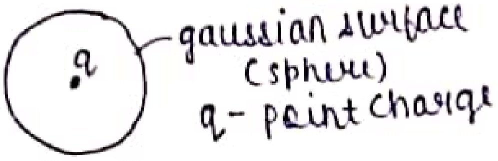
Area Vector is ⊥ to plane. Both direction for open surfaces (2D) and normally outward for closed surfaces (3D)

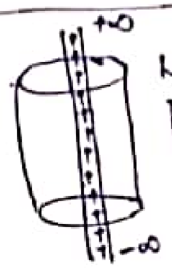
Electric flux (ϕ):-

For uniform $\vec{E}$ field – $\boxed{\phi = \vec{E}\cdot\vec{A}}$ For non-uniform $\vec{E}$ field – $\boxed{\phi = \int d\phi = \int \vec{E}\cdot d\vec{A}}$

Gauss's Law:-

$$\boxed{\underset{\text{closed surfaces}}{\phi_{net}} = \frac{Q_{in}}{\varepsilon_0} \text{ (with sign)}}$$





Linear charge $\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$

$\boxed{\phi = \frac{Q_{in}}{\varepsilon_0}}$

Sphere

Hemisphere $\boxed{\phi = \frac{Q}{2\varepsilon_0}}$

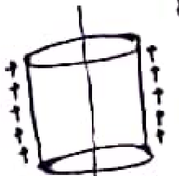
$\vec{E}$ field due to long cylindrical wire:-

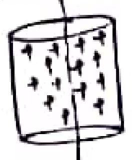
inside - $\boxed{E=0}$ – for conducting solid, Hollow and Dielectric hollow cylinder

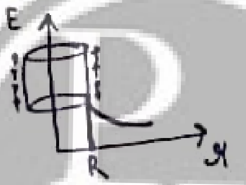
$\boxed{E = \frac{\rho r}{2\varepsilon_0}}$ – for Dielectric solid

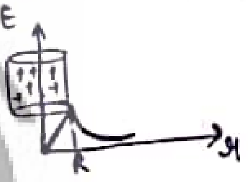
outside - $\boxed{E = \frac{\sigma R}{r\varepsilon_0}}$ – for conducting solid, Hollow and Dielectric hollow cylinder

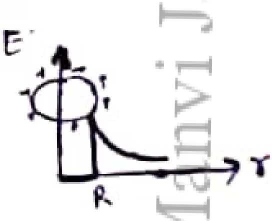
$\boxed{E = \frac{\rho R^2}{2\varepsilon_0 r}}$ – for Dielectric solid











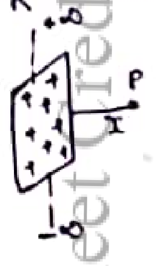
$\vec{E}$ field due to spheres:-

outside - ($r>R$): Any sphere consider Q at centre $\boxed{E = \frac{KQ}{r^2}}$

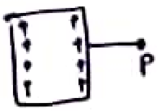
inside - ($r<R$):- Any sphere except solid Dielectric $\boxed{E=0}$

$\boxed{E = \frac{KQr}{R^3}}$ for non conducting solid sphere

Electric field due to sheet (Infinite charged):- $\boxed{E_P = \frac{\sigma}{2\varepsilon_0}}$

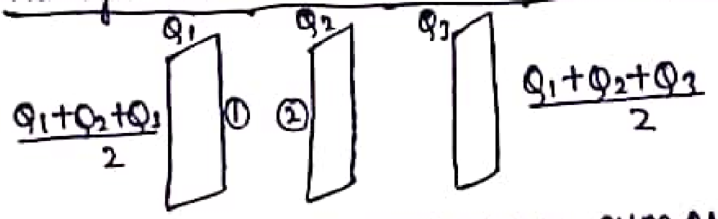


Electric field due to charged plate:- $\boxed{E_P = \frac{\sigma}{\varepsilon_0}}$



E=0 inside the material of conductor.

Charge distribution on surfaces of plates:-



surface (1) $= \frac{Q_1-Q_2-Q_3}{2}$

surface (2) $= -\left(\frac{Q_1-Q_2-Q_3}{2}\right)$

on outward surfaces = $\frac{\text{sum of charges on plates}}{2}$

inward surfaces have equal and opp. charges