Electrostatics

Unit 1: Electric Field
Day 1

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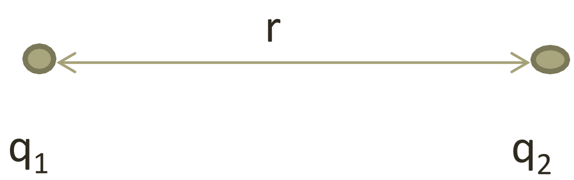
Coulomb's Law



The magnitude of the electrostatic force between two point electric charges are directly proportional to the product of the magnitudes of each charge and inversely proportional to the square of the distance between charges

$F \infty q_1q_2/r^2$

$F = k'. q_1q_2/r^2$

$K = 1/4\pi\epsilon_0$

$F = 1/4\pi\epsilon_0 \frac{q_1q_2}{r^2}$

$\varepsilon\ is\ permitivity\ of\ the\ medium$

Unit and Dimension for permittivity

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

$\varepsilon_0 = 1/4\pi \; q_1 q_2 / Fr^2$

Unit for permittivity $= C^2/Nm^2$

$= C^2N^{-1}m^{-2}$

Dimension for permittivity $= [IT][IT]/[MLT^{-2}][L^2]$

$= [I^2T^2]/[ML^3T^{-2}]$

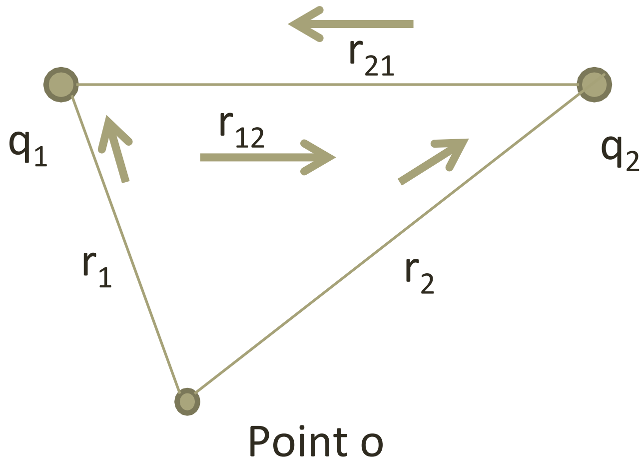
$= M^{-1}L^{-3}T^4I^2$

For Air Medium

$\varepsilon_0 = 8.854 \ast 10^{-12}$ $C^2N^{-1}m^{-2}$

$1/4\pi\epsilon_0 = 9 * 10^9 \, Nm^2C^{-2}$

Couloumb's Law in Vector form



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

Force exerted on q_1 charge due to q_2

$\vec{F}_{12} = 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{12}^{\ 2}} \ r_{12}\,\hat{}$

$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2$

$\vec{r}_{12} = r_{12} \, . \, r_{12}\,\hat{}$

$r_{12}\,\hat{} = \vec{r}_{12} / r_{12}$

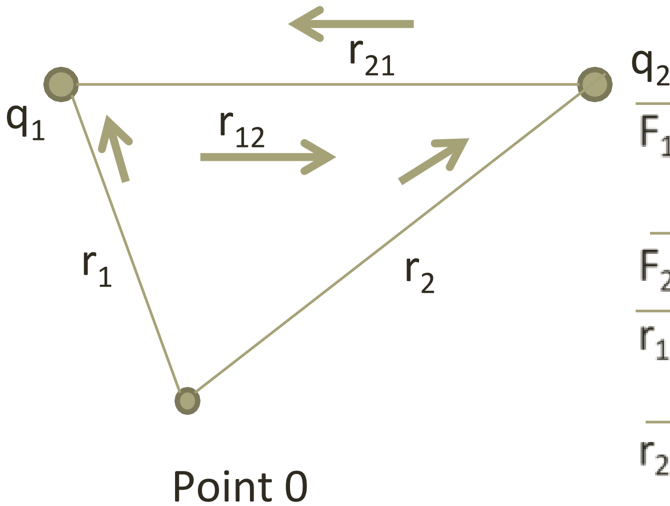
$\vec{F}_{12} = 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{12}^{\ 2}} \ \vec{r}_{12} / r_{12}$

$\vec{F}_{12} = 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{12}^{\ 3}} \ \vec{r}_{12}$

Similarly Force exerted on q_2 Charge due to q_1

$\vec{F}_{21} = 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{21}^{\ 3}} \ \vec{r}_{21}$

Coulomb’s law Satisfies Newton’s Law



Relative force between two identical electric charges are equal and opposite

$$\vec{F}_{12} = 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{12}^{\ 3}} \ \vec{r}_{12}$$

$$\vec{F}_{21} = 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{21}^{\ 3}} \ \vec{r}_{21}$$

$$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2$$

$$\vec{r}_{21} = \vec{r}_2 - \vec{r}_1$$

$$= -(\vec{r}_1 - \vec{r}_2)$$

$$= -\vec{r}_{12}$$

$$|\ r_{12}\ | = |\ r_{21}\ |$$

$$\vec{F}_{21} = -\ 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{21}^{\ 3}} \ \vec{r}_{12}$$

$$\vec{F}_{21} = -\ 1/4\pi\epsilon_0 \frac{q_1 q_2}{r_{12}^{\ 3}} \ \vec{r}_{12}$$

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

Unit Charge

CGS Unit:

$F = q_1 q_2 / r^2$

If f = 1 dyne and r = 1 cm
$r^2 = 1$
$r = \pm 1$

If in air medium or zero medium two equal point charges are exerting 1 dyne force relative force when kept at 1 cm distance, then each equal charges are called as unit charge in C.G.S unit.(Stat Coluomb)

SI Unit:

$F = 1/4\pi\epsilon_0 \frac{q_1 q_2}{r^2}$
Now as we know $1/4\pi\epsilon_0 = 9*10^9\ Nm^2C^{-2}$
If $F = 9*10^9$ N and r = 1m

If in air medium or zero medium two equal point charges are exerting 1 N force relative force when kept at 1 m distance, then each equal charges are called as unit charge in S.I unit.(Coulomb)

Dielectric Constant

Ratio between permittivity of any medium and permittivity of zero medium known as Dielectric Constant.

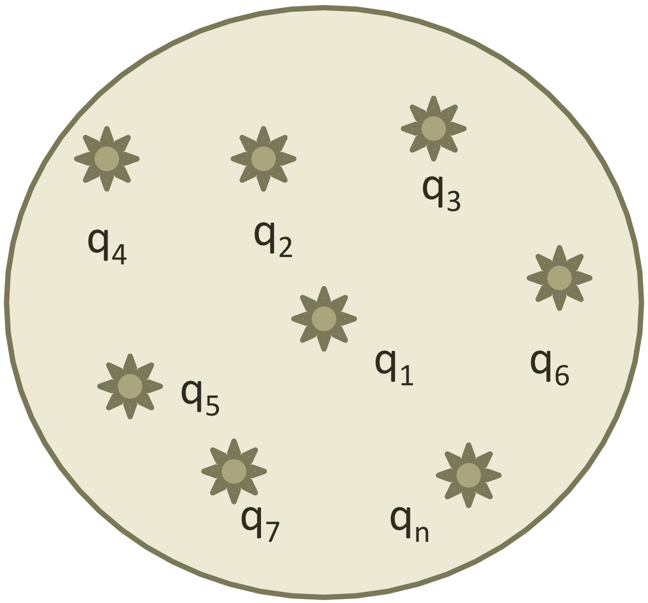
$\varepsilon = k\varepsilon_0$

k = $\varepsilon / \varepsilon_0$

k is known as dielectric constant

Superposition Principle

The force on any charge due to number of other charges is the vector sum of all the forces on that charge due to other charges.



$F_1 = F_{21} + F_{31} + F_{41} + F_{51} + \ldots.. + F_{n1}$

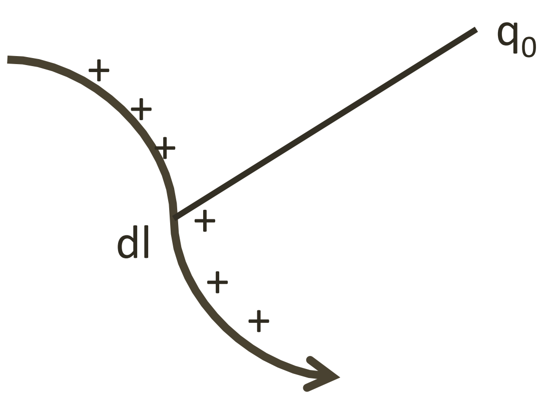
$\vec{F1} = 1/4\pi\varepsilon_0[(q_1q_2/r_{12}^3)\vec{r}_{12} + (q_1q_2/r_{13}^3)\vec{r}_{13} + \ldots.. + (q_1q_2/r_{12}^3)\vec{r}_{1n}]$

$F_i = F_{1i} + F_{2i} + F_{3i} + \ldots\ldots + F_{ni}$

$$\vec{F}_i = \sum_{j=1\ i\neq j}^{n} \frac{q_i q_j}{r_{ij}^{3}} \vec{r}_{ij}$$

Continuous Charge Distribution

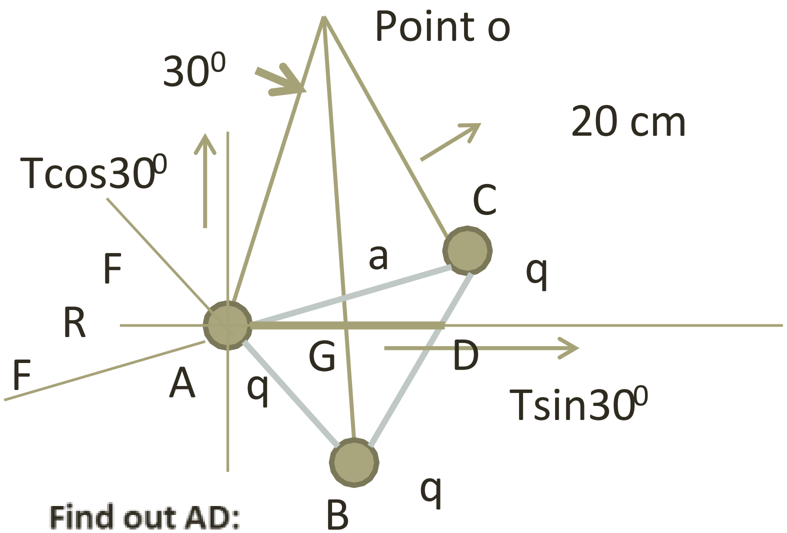
Line Charge



Line charge density = charge/Length

Problems

Three balls with 0.1g mass being hanged from a particular point with three 20cm length of ropes in such a way that each ball will create 30 deg angle with vertical. Find out How much charge we should give to each ball.[You can consider each ball is having the same amount of charge]



Find out AD:

BD = CD = a/2

AD = $(a^2 - a^2/4)^{1/2}$

$= \frac{\sqrt{3}}{2} a$

AG = 2/3 AD

$= a/\sqrt{3}$

$T\cos 30^0 = mg$

$T\sin 30^0 = R$

$\sin 30^0 = AG/OA$

$½ = a/\sqrt{3}/20$

$a = 10\sqrt{3}$

$Ø = 120^0$

$R^2 = F^2 + F^2 + 2.F.F\cos Ø$

$= F^2$

$= q^2/a^2$

$R/mg = \tan 30^0$

$q^2/a^2mg = 1/\sqrt{3}$

Find q

END