3. Point charges 1mC and -2mC are located at (3, 2, -1) and (-1, -1, 4), respectively. Calculate the electric force on 10nC charge located at (0, 3, 1) and electric field intensity at that point.

Solution

Here $1mC = 1\times10^{-3}\,C$

$1nC = 1\times10^{-9}\,C$

$q_1 = 10^{-3}C \; ; q_2 = -2\times10^{-3}C$

$\vec{r}_1 = 3\hat{i}+2\hat{j}-\hat{k}$ $\qquad \vec{r}_2 = -\hat{i}-\hat{j}+4\hat{k}$

$\vec{r} = 0\hat{i}+3\hat{j}+\hat{k}$

$$\vec{E} = \frac{q_1}{4\pi\epsilon_0}\frac{(\vec{r}-\vec{r}_1)}{|(\vec{r}-\vec{r}_1)|^3} + \frac{q_2}{4\pi\epsilon_0}\frac{(\vec{r}-\vec{r}_2)}{|\vec{r}-\vec{r}_2|^3}$$

$\vec{r}-\vec{r}_1 = 3\hat{j}+\hat{k}-3\hat{i}-2\hat{j}+\hat{k} = -3\hat{i}+\hat{j}+2\hat{k}$

$|\vec{r}-\vec{r}_1| = \sqrt{(-3)^2+(1)^2+(2)^2} = \sqrt{9+1+4} = \sqrt{14}$

$\vec{r}-\vec{r}_2 = 3\hat{j}+\hat{k} - (-\hat{i}-\hat{j}+4\hat{k})$

$= 3\hat{j}+\hat{k}+\hat{i}+\hat{j}-4\hat{k} = \hat{i}+4\hat{j}-3\hat{k}$

$|\vec{r}-\vec{r}_2| = \sqrt{(1)^2+(4)^2+(-3)^2} = \sqrt{1+16+9} = \sqrt{26}$

$$\vec{E} = \frac{10^{-3}}{4\pi\epsilon_0}\frac{(-3\hat{i}+\hat{j}+2\hat{k})}{(14)^{3/2}} + \frac{-2\times10^{-3}}{4\pi\epsilon_0}\frac{(\hat{i}+4\hat{j}-3\hat{k})}{(26)^{3/2}}$$

$$\Rightarrow \vec{E} = \frac{9\times10^{+9}\times10^{-3}}{(14)^{3/2}}(-3\hat{i}+\hat{j}+2\hat{k}) - \frac{2\times10^{-3}\times9\times10^{+9}}{(26)^{3/2}}(\hat{i}+4\hat{j}-3\hat{k})$$

$$\Rightarrow \vec{E} = (-650.7\,\hat{i} - 381.7\,\hat{j} + 750.6\,\hat{k})\times10^{3}\ V/m$$

$$\Rightarrow \vec{E} = (-650.7\,\hat{i} - 381.7\,\hat{j} + 750.6\,\hat{k})\ KV/m$$

$$\vec{F} = q\vec{E}$$

$$q = 10\times10^{-9}\ C$$

$$\therefore \vec{F} = (-650.7\,\hat{i} - 381.7\,\hat{j} + 750.6\,\hat{k})\times10^{3}\times10\times10^{-9}\ N$$

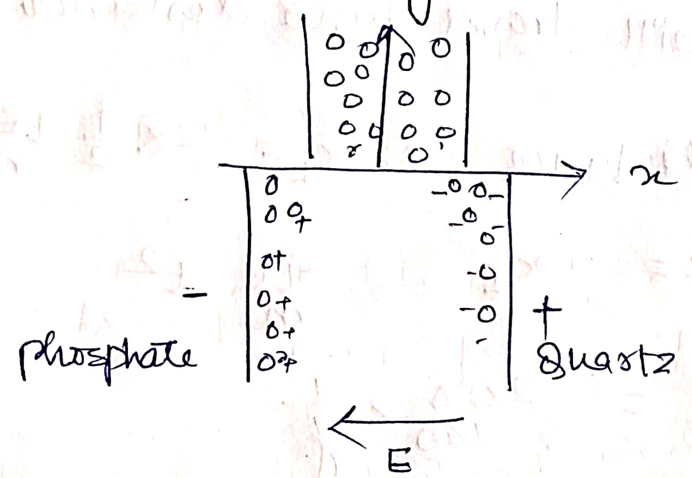
$$= (-650.7\,\hat{i} - 381.7\,\hat{j} + 750.6\,\hat{k})\times10^{-5}\ N$$

$$= (-6.507\,\hat{i} - 3.817\,\hat{j} + 7.506\,\hat{k})\ mN$$

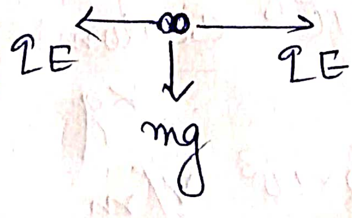
Problem: Mixture consisting of small particles quartz and phosphate rock, is separated into components by applying a uniform electric field. Assuming zero initial velocity and displacement, determine separation between the particles after falling 80cm.

Take $E = 500\ kV/m$ and $q/m = 9\ \mu C/kg$ for both positive and negative charged particles

Solution.



Ignoring Coulomb force between particles.
Electrostatic force is acting horizontally
Gravitational force acting vertically downward.



Given Initial velocity is zero
$u = 0$

Vertical motion : $S = ut + \frac{1}{2}at^2$

$$\frac{80}{100}\ m = \frac{1}{2} g t^2 \qquad [u = 0]$$

$$\Rightarrow t^2 = \frac{2 \times 80}{100} \times \frac{1}{g}$$

Horizontal motion for one particle

$S = ut + \frac{1}{2}at^2$

Force on charged particle $F = qE$

acceleration $= F/m$

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

$\therefore \quad x_1 = \frac{1}{2}\frac{qE}{m}t^2$

Another particle will travel same distance x_1

$\therefore$ total distance $2 \times x_1 = 2 \times \frac{1}{2}\frac{qE}{m}t^2$

$x = 2x_1 = \frac{qE}{m}t^2$

$t^2 = \frac{2 \times 80}{100} \times \frac{1}{g}$

$\Rightarrow x = \frac{q}{m}E \quad \frac{2 \times 80}{100} \times \frac{1}{g}$

$g = 9.8\ m/s^2$

$q/m = 9 \times 10^{-6}\ \frac{\text{Coulomb}}{\text{kg}}$

$E = 500 \times 10^3\ V/m$

$\therefore \quad x = 9 \times 10^{-6} \times 500 \times 10^3 \times \frac{2 \times 80}{100} \times \frac{1}{9.8}$

$= \frac{9 \times 5 \times 16 \times 10^{-2}}{9.8} = 0.73469\ m$

$= 73.47\ cm$