Ans. to the Q. No-1

Given,

Mass of the block $m = 10g$
$= 0.01 kg$

charge on the block $q = +8.00 \times 10^{-5} C$

Electric field $\vec{E} = (3000\hat{i} - 600\hat{j})$ N/C

Time $t = 3s$ [for d]

(a) Electrostatic force on the block,

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

$$= (8 \times 10^{-5})(3000\hat{i} - 600\hat{j})$$

$$= 0.24\hat{i} - 0.048\hat{j}$$

Magnitude of the force,

$$|\vec{F}| = \sqrt{(0.24)^2 + (-0.048)^2}$$

$$= 0.2447 N$$

(b) Direction of the force is given by,

$$\theta = \tan^{-1}\left(\frac{-0.048}{0.24}\right)$$

$$= -11.31^\circ$$

(the negative sign implies the direction is with respect to negative x axis)

Direction relative to the positive direction of the x-axis is,

$$\theta = 180^\circ - 11.31^\circ$$

$$= 168.69^\circ \text{ w.r.t. positive } x\text{-axis.}$$

(e) The displacement of the block from rest position at origin is,

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

We know,

$$F = ma$$

$$F = qE$$

$$\therefore ma = qE$$

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

$$a_x = \frac{(8.00\times10^{-5})\times 3000\hat{i}}{0.01}$$

$$= 24\hat{i}\ m/s^2$$

$$a_y = \frac{(8.00\times10^{-5})\times(-600\hat{j})}{0.01}$$

$$= -4.8\hat{j}\ m/s^2$$

$$S_x = u_x t + \frac{1}{2}a_x t^2$$

$$= \frac{24\hat{i}\times 3^2}{2} \quad [u_x = 0]$$

$$= 108\ m$$

$[u_x = 0]$ $[u_y = 0]$

$$S_y = u_y t + \frac{1}{2}a_y t^2$$

$$= \frac{-4.8\times 3^2}{2}$$

$$= -21.6\ m$$

$\therefore$ ~~$s = s_x \hat{i} + s_y \hat{j}$~~

~~$= 108\hat{i} - 21.6\hat{j}$~~

(d) From c,

$$a_y = -4.8\hat{j} \ m/s^2$$

$$\therefore s_y = u_y t + \frac{1}{2} a_y t^2$$

$$= \frac{-4.8 \times 3^2}{2} \quad [u_y = 0]$$

$$= -21.6 m$$

$$\therefore s = s_x \hat{i} + s_y \hat{j}$$

$$= 108\hat{i} - 21.6\hat{j} \ m$$

X co-ordinate of the displacement

$$s_x = 108 m$$

Y " of the "

$$s_y = -21.6 m$$

Ans. to. the. Q.No-2

Given.

radius of the shell, $a = 2.00cm$

inner " " " " , $b = 2.00a$"

outer " " " " , $c = 2.40a$"

$$q_1 = +5fC$$
$$= +5 \times 10^{-15} C$$
$$q_2 = -q_1$$
$$= -5 \times 10^{-15} C.$$

The field is uniform on the surface, so $\int \vec{E} \cdot d\vec{A} = 4\pi r^2 E$, where r is the radius of Gaussian surface.

For $r < a$ the charge enclosed by the Gaussian surface is $q(\frac{r}{a})^3$.

Gauss Law yields:

$$4\pi r^2 E = \frac{q}{\epsilon_0} \times \left(\frac{r}{a}\right)^3$$

$$\Rightarrow E = \frac{qr}{4\pi\epsilon_0 a^3}$$

(a) Electric field, $E = \dfrac{q r}{4\pi\epsilon_0 a^3}$ [Uniform charge, field at $r \le a$]

For, $r = 0$, $E = \dfrac{q}{4\pi\epsilon_0 a^3} \times 0$

$= 0 \ N/C$

(b) For $r = a/2.00$,

$$E = \frac{q\left(\frac{a}{2}\right)}{4\pi\epsilon_0 a^3}$$

$$= \frac{K q}{2 \times a^2} \quad \left[K = \frac{1}{4\pi\epsilon_0} = 9\times10^9 \ N.m^2/C^2\right]$$

$$= \frac{9\times10^9 \times 5\times10^{-15}}{2\times(2.00\times10^{-2})^2}$$

$$= 5.62 \times 10^{-2} \ N/C$$

(c) For $r = a$,

$$E = \frac{qa}{4\pi\epsilon_0 a^3}$$

$$= \frac{kq}{a^2}$$

$$= \frac{9\times10^9 \times 5\times10^{-15}}{(2\times10^{-2})^2}$$

$$= 0.112 \text{ N/C}$$

(d) For $r = 1.50a$,

$$E = \frac{1}{4\pi\epsilon_0} \times \frac{q}{r^2}$$ [spherical, field at $r > a$]

$$= \frac{kq}{r^2}$$

$$= \frac{9\times10^9 \times 5\times10^{-15}}{(1.50\times2\times10^{-2})^2}$$

$$= 0.05 \text{ N/C}$$

(e) In the region $b<r<c$, since the shell is conducting and the charge q doesn't lie inside the shell ($q=0$), that's why electric field is zero.

$\therefore$ For $r = 2.300\,a$, $E = 0$.

(f) For $r = 3.500\,a$ $[r>c]$, the charge enclosed by Gaussian surface is zero because q_1 lies inside the shell, q_2 lies outside.

$$\therefore \quad E = 0.$$

(g) if q_{inner} is the charge on the inner surface of the shell

$$q_{sphere} + q_{inner} = 0$$

$$\Rightarrow -q_{sphere} = q_{inner}$$

$$\Rightarrow q_{inner} = -5.00 \times 10^{-15}\,C$$

(h) Let,

q_{out} = charge on the outer surface of the shell

q_{inner} = " " " inner " "

$-q$ = net charge on the shell

$$q_{inner} + q_{out} = -q$$

$$\Rightarrow q_{out} = -q - q_{inner}$$

$$= -5\times10^{-15} - (-5\times10^{-15})$$

$$= 0$$

Ans. to the Q. No - 3

Given,

$x = \pm 3m$

$y_i = 4m$

$y_f = 0$

$q' = -15 \times 10^{-6} C$

$q_1 = q_2 = 50 \times 10^{-6} C = q$

$k_0 = 1.2 J$

$$K_0 + U_0 = K_f + U_f$$

where (letting $x = \pm 3m$ and $q_1 = q_2 = 50 \times 10^{-6} C = q$)

$$U_i = \frac{qq'}{4\pi\epsilon_0\sqrt{x^2+y^2}} + \frac{qq'}{4\pi\epsilon_0\sqrt{x^2+y^2}}$$

$$= \frac{2qq'}{4\pi\epsilon_0\sqrt{x^2+y^2}}$$

$$= \frac{2kqq'}{\sqrt{x^2+y^2}}$$

(a) solving K_f (with $y_i = 1m$)

$$K_f = K_0 + U_0 - U_f$$

$$= 1.2 + \frac{2kqq'}{\sqrt{x^2 + y_i^2}} - \frac{2kqq'}{|x|}$$

$$= 1.2 + 2kqq'\left(\frac{1}{\sqrt{x^2+y_i^2}} - \frac{1}{|x|}\right)$$

$$= 1.2 + 2 \times 9 \times 10^9 \times (-15 \times 10^{-6}) \times (50 \times 10^{-6}) \times \left(\frac{1}{\sqrt{3^2+4^2}} - \frac{1}{3}\right)$$

$$= 3J$$

(b) When Particle momentarily stop,

$$K_f = 0$$

$$K_i + U_i = K_f + U_f$$

$$\Rightarrow 1.2 + \frac{k \times 2qq'}{\sqrt{x^2+y_i^2}} = 0 + \frac{k \times 2qq'}{\sqrt{x^2+y_f^2}}$$

$$\Rightarrow 1.2 + \frac{9 \times 10^9 \times 2 \times 50 \times 10^{-6} \times (-15 \times 10^{-6})}{\sqrt{3^2+4^2}} = \frac{2qq' \times k}{\sqrt{x^2+y_f^2}}$$

$$\Rightarrow 1.2 - 2.7 = \frac{2qq' \times k}{\sqrt{x^2+y_f^2}}$$

$$\Rightarrow -1.5 = \frac{2qq' \times K}{\sqrt{x^2 + y_f^2}}$$

$$\Rightarrow \sqrt{3^2 + y_f^2} = \frac{2 \times 50 \times 10^{-6} \times (-15 \times 10^{-6}) \times 9 \times 10^{9}}{-1.5}$$

$$\Rightarrow \sqrt{3^2 + y_f^2} = 9$$

$$\Rightarrow 3^2 + y_f^2 = 81$$

$$\Rightarrow y_f^2 = 72$$

$$\Rightarrow y_f = \pm 8.5 m$$

At -8.5 m, the particle momentarily stop.