Phy112 - Assignment - 03

Section - 04

ID: 191077

Md. Shaftkat Hasan

## Ans. To The Q. No. (3.1)

a) Here,

$\sigma_1 = 4\ \mu C/m^2 = 4 \times 10^{-6}\ C/m^2$

$R_1 = 0.2\ mm = 0.2 \times 10^{-3}\ m$

$R_2 = 1.4\ mm = 1.4 \times 10^{-3}\ m$

$Q_1 + Q_2 = 0$

$\Rightarrow \sigma_1 A_1 = -\sigma_2 A_2$

$\Rightarrow \sigma_1 \pi R_1 = -\sigma_2 \pi R_2$

$\Rightarrow \sigma = -\dfrac{\sigma_1 R_1}{R_2}$

$= \dfrac{-4 \times 10^{-6} \times 0.2 \times 10^{-3}}{1.4 \times 10^{-3}}$

$= -5.7143 \times 10^{-7}\ C/m^2$

(Ans)

b) We knew,

$$\oint \vec{E}\, d\vec{A} = \frac{q_{enc}}{\epsilon_0}$$

$$\Rightarrow EA = \frac{q_{enc}}{\epsilon_0}$$

$$\Rightarrow E = \frac{\sigma_1 R_1}{r\, \epsilon_0}$$

Here,
$r = 0.6399$ mm
$= 0.6399 \times 10^{-3}$ m

$$= \frac{4\times10^{-6}\times 0.2\times10^{-3}}{0.6399999\times10^{-3}\times 8.854\times10^{-12}}$$

$$= 141177.3487 \text{ N/C}$$

(Ans)

c) $$\Delta V = \left| -\int_{R_1}^{R_2} \vec{E}\, d\vec{r} \right|$$

$$= \left| -\frac{\sigma_1 R_1}{\epsilon_0} \int_{R_1}^{R_2} \frac{1}{r}\, dr \right|$$

$$= \left| -\frac{\sigma_1 R_1}{\epsilon_0} \left[\ln r\right]_{R_2}^{R_1} \right|$$

$$= \left| -\frac{\sigma_1 R_1}{\epsilon_0} \ln\left(\frac{R_2}{R_1}\right) \right|$$

$$= \left| -\frac{4\times10^{-6}\times 0.2\times10^{-3}}{8.854\times10^{-12}} \ln\left(\frac{1.4}{0.2}\right) \right|$$

$$= 175.8220 \text{ Volts}$$

(Ans)

d) We knew,

$$C = \frac{Q}{\Delta V} = \frac{\sigma_1 2\pi r l}{\frac{\sigma_1 r}{\epsilon_0} \ln\left(\frac{R_2}{R_1}\right)}$$

$$= \frac{2\pi L \epsilon_0}{\ln\left(\frac{R_2}{R_1}\right)}$$

Here,
$L = 15 cm$
$= 15 \times 10^{-2} m$

$$= \frac{2\pi \times 15 \times 10^{-2} \times 8.854 \times 10^{-12}}{\ln\left(\frac{1.4}{0.2}\right)}$$

$$= 4.2883 \times 10^{-12} \text{ farads}$$

(Ans)

## Ans. To The Q. No. (3.2)

a) Here,

$q = 18\mu C = 18 \times 10^{-6} c$

$r_1 = 8 m$

$\therefore E = \frac{kq}{r_1^2} = \frac{8.987 \times 10^9 \times 18 \times 10^{-6}}{(8)^2}$

$= 2527.59375 N/C$

b) Inside the walls of a ~~ho~~ hollow conducting sphere, $\vec{E} = 0$

Here, $q_{enc} = 0 c$ (Ans)

c) Outside the walls of a hollow conducting sphere $\vec{E} \neq 0$

Here, $r_2 = 20 m$, $q_{ence} = q = 18 \times 10^{-6} c$ (Ans)

$E = \frac{k q_{enc}}{r_2^2} = \frac{8.987 \times 10^9 \times 18 \times 10^{-6}}{20^2}$

$= 404.415 N/C$ (Ans)

d) $\Phi_{r_2} = \frac{q_{enc}}{\epsilon_0}$

$= \frac{18 \times 10^{-6}}{8.854 \times 10^{-12}} = 2032979.444 Nm^2/c$

(Ans)

e) Potential at

$r = d = 40\,m$

$$V_d = \frac{kq}{d} = \frac{8.987\times10^9 \times 18\times10^{-6}}{40}$$

$= 4044.15$ volts

(Ans)

Potential at $r = c = 24\,m$

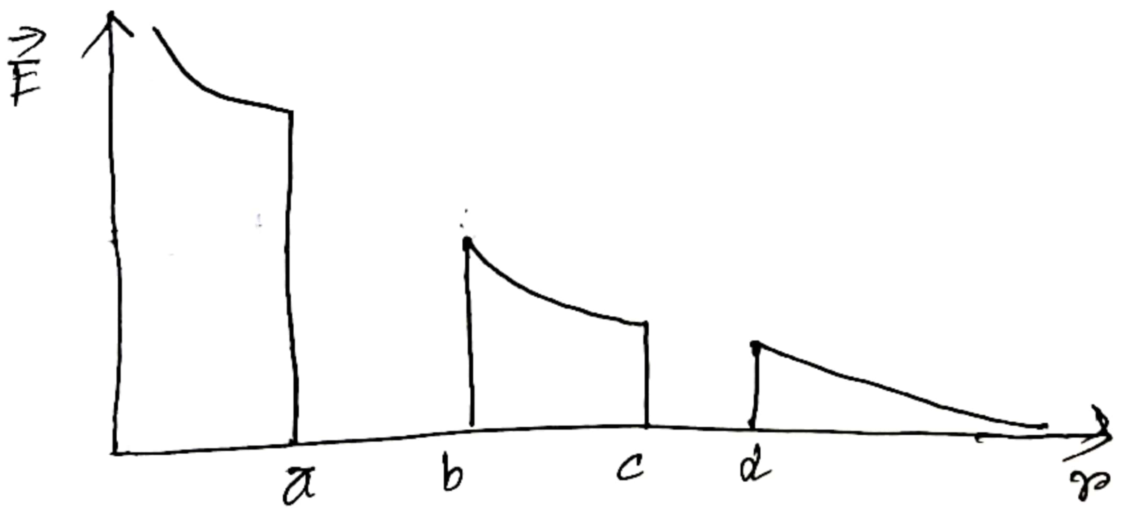
$$V_c = \frac{kq}{d} = \frac{8.987\times10^9 \times 18\times10^{-6}}{40}$$

$= 4044.15\ V$ (Ans)

Potential at $r = \frac{c+d}{2} = \frac{40+24}{2} = 32\,m$

$V = 4044.15$ volts Ans

f)

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g) At different points,

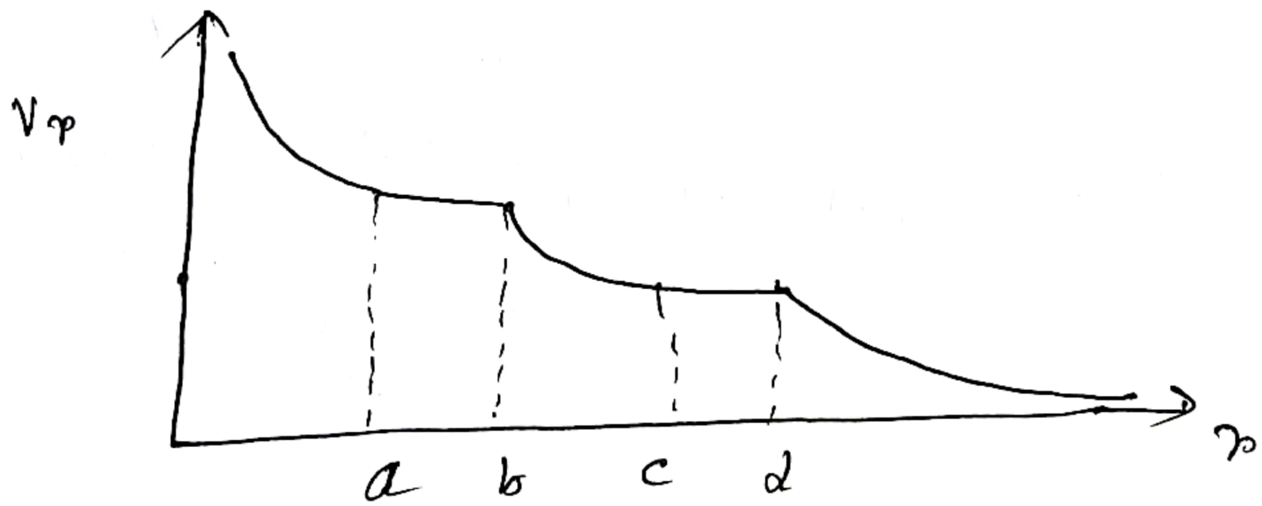
$$V_r = \frac{kq}{r} \quad \text{at } r > d$$

$$V_r = \frac{kq}{d} \quad \text{at } c < r < d$$

$$V_r = \frac{kq}{r} \quad \text{at } b < r < c$$

$$V_r = \frac{kq}{b} \quad \text{at } a < r < b$$

$$V_r = \frac{kq}{r} \quad \text{at } r < a$$



Ans. To The Q. No. (3.3)

a) Here,

$q_1 = 3e$ , $q_2 = 2e$, $q_3 = -5e$

$r = 3\ nm = 3 \times 10^{-9}\ m$

for $q_3$ and $q_1$,

$\vec{P}_1 = q_1 \times r\,(-\hat{j})$

$= 3 \times 1.6 \times 10^{-19} \times 3 \times 10^{-9}\,(-\hat{j})$

$= -1.44 \times 10^{-27}\,\hat{j}$

for $q_3$ and $q_2$,

$r = \sqrt{(3)^2 + (3)^2} = 4.24 \times 10^{-9}\ m$

$\theta = 45°$

$\vec{P}_2 = q_2 \times r\,(\cos\theta\,\hat{i} - \sin\theta\,\hat{j})$

$= 2 \times 1.6 \times 10^{-19} \times 4.24 \times 10^{-9}\,(\cos 45°\,\hat{i} - \sin 45\,\hat{j})$

$= 9.59 \times 10^{-28}\,\hat{i} - 9.59 \times 10^{-28}\,\hat{j}$

$\vec{P}_{net} = 9.59 \times 10^{-28}\,\hat{i} - 2.399 \times 10^{-27}$

(Ans)

b) $r_{q_2P} = 3 \times 10^{-9}$ m

$r_{q_3P} = 3 \times 10^{-9}$ m

$r_{q_1P} = \sqrt{(3)^2 + (3)^2}$ nm $= 4.24 \times 10^{-9}$ m

$$V_P = \frac{kq_1}{r_{q_1P}} + \frac{kq_2}{r_{q_2P}} + \frac{kq_3}{r_{q_3P}}$$

$$= k\left(\frac{-3 \times 1.6 \times 10^{-19}}{4.24 \times 10^{-9}} + \frac{-2 \times 1.6 \times 10^{-19}}{3 \times 10^{-9}} + \frac{5 \times 1.6 \times 10^{-19}}{3 \times 10^{-9}}\right)$$

$= 0.422$ volts (Ans)

c) $\because P(x, y) \equiv (-1.5, -3)$

Here,

$m = 1$ N/C m$^2$ , $n = 1$ N/C m

$V(x, y) = 3xy(mx + n)$

$\therefore V_P = 3 \times (-1.5) \times 10^{-9} \times -3 \times 10^{-9} (-1.5 \times 10^{-9} + 1)$

$= 1.34 \times 10^{-17}$ V

(Ans)

d) $V_{P,net} = (0.422 + 1.34 \times 10^{-17})$ V

$= 0.422$ V

(Ans)

Potential energy of a proton,

$U = Vq$ | Here, $q = 1.6 \times 10^{-19}$ C

$= 0.422 \times 1.6 \times 10^{-19}$

$= 6.7 \times 10^{-20}$ J

(Ans)

e) $\vec{E}_{q_2P} = \frac{k q_2}{(r_{q_2P})^2} \hat{j}$

$= \frac{8.987 \times 10^9 \times 2 \times 1.6 \times 10^{-19}}{(3 \times 10^{-9})^2} \hat{j}$

$= 319537777.8 \hat{j}$

$\vec{E}_{q_3P} = \frac{k q_3}{(r_{q_3P})^2} (\hat{i})$

$= \frac{8.987 \times 10^9 \times (-5) \times 1.6 \times 10^{-19}}{(3 \times 10^{-9})^2} \hat{i}$

~~$= -7.988 \times 10^{-}$~~

$= -798844444.4 \hat{i}$

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$$\vec{E}_{q_1P} = \frac{kq_1}{(r_{q_1P})^2}(\sin 45\,\hat{i} + \cos 45\,\hat{j})$$

$$= \frac{8.987\times10^9 \times 3\times1.6\times10^{-19}}{(4.2\times10^{-9})^2}(0.707\hat{i}+0.707\hat{j})$$

$$= 169646021.7\,\hat{i} + 169646021.7\,\hat{j}$$

$$\vec{E}_{net} = \vec{E}_{q_1P} + \vec{E}_{q_2P} + \vec{F}_{q_3P}$$

$$= -629198422.7\hat{i} + 489183799.5\hat{j}$$

(Ans)

f) (i) $\vec{F} = \vec{E}q$

$$= (-629198422.7\hat{i} + 489183799.5\hat{j}) \times 1.6\times10^{-19}$$

$$= -1\times10^{-10}\,\hat{i} + 7.827\times10^{-11}\,\hat{j}$$

(Ans)

(ii) $$|\vec{F}| = \sqrt{(-1\times10^{-10})^2 + (7.827\times10^{-11})^2}$$

$$= 1.27\times10^{-10}\ \text{N}$$

$$\therefore a = \frac{|F|}{m_p} = \frac{1.27\times10^{-10}}{1.67\times10^{-27}}$$

$$= 7.6\times10^{16}\ \text{ms}^{-2}$$

(Ans)

g) $\tan(90-\phi) = \tan\frac{\pi}{4} = 1$

$$\frac{y}{x} = 1$$

$$y = x$$

$$y = x = 1.5 \text{ nm}$$

$S_1 \equiv (1.5, 1.5)$ , $S_2 \equiv (-1.5, 1.5)$

$$V_{S1} = 3 \times 1.5 \times 10^{-9} \times 1.5 \times 10^{-9} (1 \times 1.5 \times 10^{-9} + 1)$$

$$= 6.75 \times 10^{-18} \text{ V} \quad \text{(Ans)}$$

$$V_{S2} = 3 \times (-1.5) \times 10^{-9} \times 1.5 \times 10^{-9} (1 \times 1.5 \times 10^{-9} + 1)$$

$$= -6.75 \times 10^{-18} \text{ V} \quad \text{(Ans)}$$

h) at $S_1$,

$$r_{q_1 S_1} = 1.5 \text{ nm}$$

$$r_{q_3 S_1} = 1.5 + 3 = 4.5 \text{ nm}$$

$$r_{q_2 S_1} = \sqrt{(1.5)^2 + 3^2} = 3.354 \text{ nm}$$

$$V_{S_1} = \frac{kq_1}{r_{q_1 S_1}} + \frac{kq_2}{r_{q_2 S_1}} + \frac{kq_3}{r_{q_3 S_1}}$$

$$= k\left(\frac{3 \times +1.6 \times 10^{-19}}{1.5 \times 10^{-9}} + \frac{2 \times -1.6 \times 10^{-19}}{3.354 \times 10^{-9}} + \frac{-5 \times -1.6 \times 10^{-19}}{4.5 \times 10^{-9}}\right)$$

$$= -2.136 \text{ V} \quad \text{(Ans)}$$

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At $S_2$,

$r_{q_2S_2} = 1.5\ nm$

$r_{q_1S_2} = \sqrt{3^2 + (1.5)^2} = 3.354\ nm$

$r_{q_3S_2} = \sqrt{3^2 + (3+1.5)^2} = 5.4\ nm$

$$V_{S_2} = k\left(\frac{3\times -1.6\times10^{-19}}{3.354\times10^{-9}} + \frac{2\times(-1.6)\times10^{-19}}{1.5\times10^{-9}} + \frac{-5\times-1.6\times10^{-19}}{5.4\times10^{-9}}\right)$$

$= -1.872\ V$ (Ans)

(i) $V_{net,S_1} = (6.75\times10^{-18} - 2.136)\ V$

$= -2.136\ V$

(Ans)

$V_{net,S_2} = (-6.75\times10^{-18} - 1.872)V$

$= -1.872\ V$

(Ans)

j) $r_{s_1 s_2} = 3\ nm$

$$V_{s_2'} = \frac{KP}{r_{s_1 s_2}}$$

$$= \frac{8.987 \times 10^9 \times 1.6 \times 10^{-19}}{3 \times 10^{-9}}$$

$$= 0.429\ V$$

$$V_{net, s_2'} = V_{net, s_2} + V_{s_2'}$$

$$= (0.479 - 1.872)\ V$$

$$= -1.3927\ V$$

Potential Energy,

$$U = V_{net, s_2} \times P$$

$$= -1.3927 \times 1.6 \times 10^{-19}$$

$$= -2.23 \times 10^{-19}\ J$$

(Ans)