[redacted]

phy112 Assignment 3.1

~~For~~ innere cylindere: $\sigma_1 = 18\times10^{-6}\,C/m^2$

$R_1 = 0.4\times10^{-3}\,m$

~~for~~ ~~otut~~ outere cylindere:

$\sigma_2 = ?$

$R_2 = 1.5\times10^{-3}\,m$

(a) $\sigma(2\pi R_1 L) = -\sigma_2(2\pi R_2 L)$

$\Rightarrow \sigma(R_1) = -\sigma_2(R_2)$

$\Rightarrow \sigma_2 = \dfrac{-\sigma_1 R_1}{R_2} = \dfrac{-18\times10^{-6}\times0.4\times10^{-3}}{1.5\times10^{-3}}$

$= -4.8\times10^{-6}$

(b) curved surface

$\int E\,dA\cos0^\circ + \int EA\cos90^\circ + \int EA\cos90^\circ =$

$\sigma_1 \dfrac{(2\pi R_1 l)}{\varepsilon_0}$

uppere circle

lowere circle

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$$E\int dA = \frac{\sigma \times 2\pi R_1 l}{\varepsilon_0}$$

$$E(2\pi r l) = \frac{\sigma \times 2\pi R_1 l}{\varepsilon_0}$$

$$E = \frac{\sigma_1 R_1}{r \varepsilon_0}$$

$$= \frac{18\times10^{-6} \times 0.4\times10^{-3}}{0.76\times10^{-3} \times 8.854\times10^{-12}}$$

$$= 1069989.181$$

(c)

$$V = \int_{R_1}^{R_2} -E\,dr = \int_{R_1}^{R_2} \frac{\sigma_1 R_1}{\varepsilon_0} \ln\left(R_2/R_1\right)$$

$$V = \frac{\sigma_1 R_1}{\varepsilon_0}\int_{R_1}^{R_2} \frac{dr}{r} = \frac{\sigma_1 R_1}{\varepsilon_0} \ln\left(R_2/R_1\right)$$

$$\therefore V = \frac{18\times10^{-6} \times 0.4\times10^{-3}}{8.854\times10^{-12}} \ln\left(\frac{1.5\times10^{-3}}{0.4\times10^{-3}}\right)$$

$$= 1074.8399 \text{ volts}$$

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(d) Capatitance 'c' is given by
$(L = 0.14m)$

$$C = \frac{q}{V} = \frac{\sigma_1 (2\pi R_1 L)}{1074.8399}$$

$$= \frac{18\times10^{-6} \times 2\times 3.1416\times 0.4\times10^{-3} \times 0.14}{1074.8399}$$

$$= \cancel{5.8092}$$

$$= 5.892\times10^{-12}$$

3.2

q = 5μC charge at the origin

(a) Electric field at $r_1 = 7m$

$$EA = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E(4\pi r_1^2) = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r_1^2}$$

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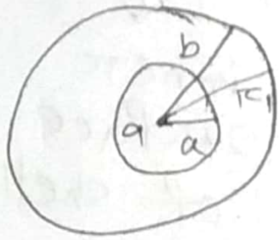
$$E = \frac{1}{4\pi\varepsilon_0} \frac{5\times10^{-6}}{7^2}$$ $[1\mu C = 10^{-6} C]$

$$= \frac{1}{4\times3.1416\times8.854\times10^{-12}} \times \frac{5\times10^{-6}}{49}$$

$= 917.114$

(b)




$a = 1m$

$b = 4m$

net charge

$q_{net} = 0$

so, inner surface with have $-q$ charge

outer " " " $+q$ "

Net charge enclosed by sphere of $r_1$ readius $q_{enc} = q - q$

$= 0$

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(c).

$c = 21\,m$

$d = 35\,m$

$r_2 = 17.5\,m$

Net chareged enclosed by $r_2$

$q_{enc} = q - q + q$

at the center

inner surface of shell A

outer surface of shell A

$\Rightarrow q_{enc} = q = 5 \times 10^{-6}$

Electric field at $r_2$

$$EA = \frac{q_{enc}}{\varepsilon_0}$$

$$\Rightarrow E\, 4\pi r_2^2 = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r_2^2}$$

$$= \frac{1}{4 \times 3.1416 \times 8.854 \times 10^{-12}} \times \frac{5 \times 10^{-6}}{(17.5)^2}$$

$$= 146.738$$

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(d) we know,

flux formula is $= q/\varepsilon_0$

$$= \frac{5\times10^{-6}}{8.854\times10^{-12}}$$

$$= 564716.5123$$

(e) Potential at $r = d$, $V(d) = \frac{kq}{d}$

$$= \frac{k\times5\times10^{-6}}{35}$$

$$= \frac{9\times10^{9}\times5\times10^{-6}}{35}$$

$$= 1285.714\,V$$

Potential at $r = c$, $V(c) = V(d)$

$r = \frac{c+d}{2}$, $V\left(\frac{c+d}{2}\right) = V(d)$

For, sphere $V_{inside} = V_{sphere}$

since d is the outermost radius

$$V(c) = V\left(\frac{c+d}{2}\right) = V(d) = 1285.714\,V$$

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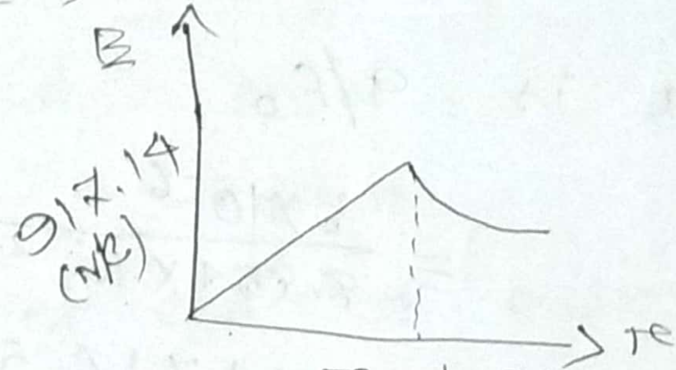
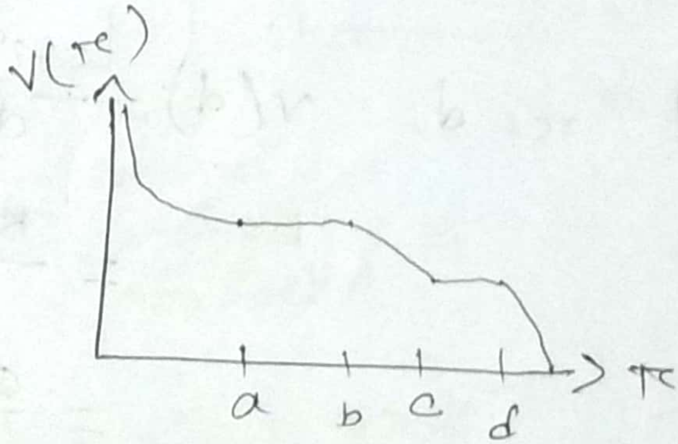
(f)




$r = d = 35$

(g)




For plotting potential of r, we always take the largest value of r because we always assume $V(\infty) = 0$

$$V(r) = \begin{cases} \frac{kq}{r} ; & r > d \\ \frac{kq}{d} ; & c < r < d \\ \frac{kq}{r} ; & b < r < c \\ \frac{kq}{b} ; & a < r < b \\ \frac{kq}{r} ; & r < a \end{cases}$$

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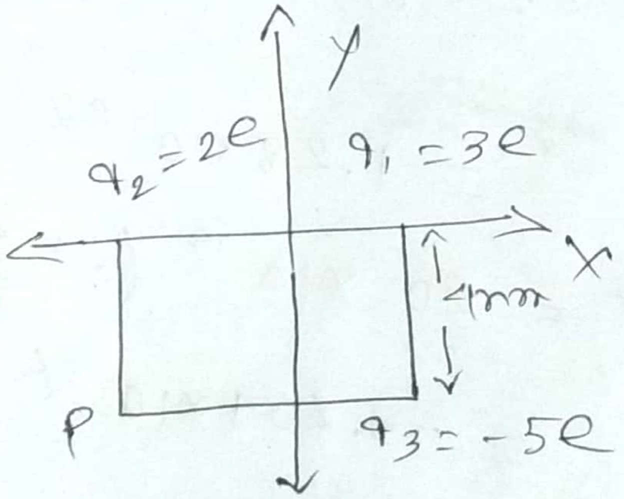
3.3




ⓐ Dipole moment.

$\vec{P} = \sum q_i \vec{r_i}$

$= q_1 \vec{r_1} + q_2 \vec{r_2} + q_3 \vec{r_3}$

$= (3e \times 2\hat{x}) + (2e \times -2\hat{x}) + (-5e)(2\hat{x} - 4\hat{y})$

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x component $= -8\times10^{-9}(-1.60\times10^{-19})$

$= 1.28\times10^{-27}$

y-component $= 20\times10^{-9}(-1.602\times10^{-19})$

$= -3.204\times10^{-27}$

(b) Electric Potential at 'P'

$$V = \sum \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_i}{r_{ip}}$$

$r_{1p} = 4\sqrt{2}\,nm$

$r_{2p} = 4\,nm$

$r_{3p} = 4\,nm$

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_{1p}} + \frac{q_2}{r_{2p}} + \frac{q_3}{r_{3p}}\right]$$

$$= \frac{1}{4\times3.1416\times8.854\times10^{-12}}\left[\frac{3\times(-1.60\times10^{-19})}{4\sqrt{2}} + \frac{2\times(-1.60\times10^{-19})}{4} - \frac{5\times(-1.60\times10^{-19})}{4}\right] \times10^{9}$$

$= 3.158\times10^{-10}\times10^{9}$

$= .3158$

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Part · II

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

$m = 1\,N/C\,m^2$, $n = 1\,N/C\,m$, $x = 2\times10^{-9}\,m$, $y = 4\times10^{-9}\,m$

ⓒ Potential at Point 'P' due to $v(-2,-4)$

$v(-2,-4) = 3\times(-2\times10^{-9})\times(-4\times10^{-9})\left[-2\times10^{-9}+1\right]$

$= 2.399\times10^{-17}$

ⓓ Total potential $= V + v(-2,-4)$

$= .3158 + (2.399\times10^{-17})$

$= .3158$

If a proton is placed at P, then potential energy

$U = V_P \times e_P$

$= .3158 \times (1.602\times10^{-19})$

$= 5.05\times10^{-20}$

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(e) Electric field due to dipole.

$$E_1 = \frac{Kq_1}{(4\sqrt{2})^2}\left(-\sin 45^\circ \hat{i} - \cos 45^\circ \hat{j}\right)$$

$$= \frac{(8.987\times10^9)\times(3\times(-1.602\times10^{-19}))}{(4\sqrt{2}\times10^{-9})^2} \times \left(-\frac{\hat{i}}{\sqrt{2}} - \frac{\hat{j}}{\sqrt{2}}\right)$$

$$= -134973506.2\left(-\frac{\hat{i}}{\sqrt{2}} - \frac{\hat{j}}{\sqrt{2}}\right)$$

$$= 95440681.5\,\hat{i} + 95440681.51\,\hat{j}$$

$$E_2 = \frac{Kq_2}{(4\times10^{-9})^2}(-\hat{j})$$

$$= \frac{9\times10^9\times2\times(-1.602\times10^{-19})}{(4\times10^{-9})^2}(-\hat{j})$$

$$= 180225000\,\hat{j}$$

$$E_3 = \frac{kq_3}{(4\times10^{-9})^2}(-\hat{i})$$

$$= \frac{9\times10^9\times5\times1.602\times10^{-19}}{(4\times10^{-9})^2}(-\hat{i})$$

$$= -450562500\,\hat{i}$$

Electric field ~~ϕ~~ due to continuous charge.

$$\vec{E}_4 = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j}$$

$V = 3xy(x+1)$
$= 3x^2y + 3xy$

$$= -(6xy+3y)\hat{i} - (3x^2+3x)\hat{j}$$

$$= ~~-(6x\cdot2-4~~$$

$$= ~~-(6~~$$

$$= (-6\times2\times-4+3\times-4)\hat{i} - (3(-2)^2+3(-2))\hat{j}$$

$$= -60\hat{i} - 18\hat{j}$$

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value of $E_4$ is very small compared to $E_1, E_2, E_3$

x-component of $E = (9.5441\times10^7 - 4.499\times10^8)\hat{i}$

$= -354459000\hat{i}$

$\approx -3.544 \times 10^8 \hat{i}$

y-component of $E = (9.5441\times10^7 + 180225000)\hat{j}$

$= 275666000$

$= 2.75\times 10^8 \hat{j}$

(f)

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

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

$= (1.602\times10^{-19})(-3.5447\times10^8\hat{i} + 2.75\times10^8\hat{j})$

$= -5.67\times10^{-11}\hat{i} + 4.4055\times10^{-11}\hat{j}$

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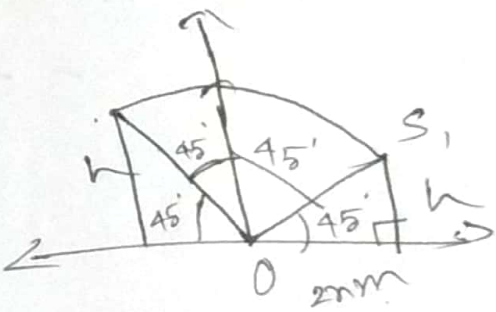
(ii) $a = \frac{|F|}{m} = \frac{\sqrt{(-5.67\times10^{-11})^2 + (4.4\times10^{-11})^2}}{1.67\times10^{-27}}$

$= 4.29 \times 10^{16}$

Part - III

$\tan 45° = \frac{\text{height}}{\text{base}}$




$\Rightarrow 1 = \frac{h}{(2\times10^{-9})}$

$\therefore h = 2\times10^{-9}$ m or 2nm

so, $S_1 = (2, 2)$ and $S_2 = (-2, 2)$ in nm

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(g) $V(x,y) = 3xy(x+1)$

at $S_1$

$V(2,2) = 3(2\times10^{-9})(2\times10^{-9})(2\times10^{-9}+1)$

$= 1.2\times10^{-17}$

$V(-2,2) = 3(-2\times10^{-9})(-2\times10^{-9})(-2\times10^{-9}+1)$

$= -1.2\times10^{-17}$

(h) Potential at $S_1$.

$r_{11} = 2nm$

$r_{31} = 4+2$
$= 6nm$

$r_{21} = \sqrt{4^2+2^2}$
$= 4.47nm$

$V = \sum \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_{i2}}$

$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_{11}} + \frac{q_2}{r_{21}} + \frac{q_3}{r_{31}}\right]$

$= \frac{1}{4\pi\varepsilon_0}\left[\frac{3e}{2} + \frac{2e}{4.47} - \frac{5e}{6}\right]\times10^{9}$

$= -1.6041$

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Potential at $S_2$,

$$v = \sum \frac{1}{4\pi\epsilon_0} \cdot \frac{q_i}{r_{i2}}$$

$$= \frac{1}{4\pi\epsilon_0}\left[\frac{q_1}{r_{12}} + \frac{q_2}{r_{22}} + \frac{q_3}{r_{32}}\right]$$

$r_{12} = \sqrt{4^2+2^2}$

$= 4.47nm$

$r_{22} = 2nm$

$r_{32} = \sqrt{6^2+4^2}$

$= 7.211nm$

$$= \frac{1}{4\times3.1416\times8.854\times10^{-12}}\left[\frac{3e}{4.47} + \frac{2e}{2} - \frac{5e}{7.211}\right]\times10$$

$$= -1.4078$$

(i). Total potential at $S_1 = V_{cas_1} + V_{diapoles_1}$

$$= (1.2\times10^{-17}) - (1.6039)$$

$$= -1.6039$$

Total potential at $S_2 = V_{cas_2} + V_{dipoles_2}$

$$= (-1.2\times10^{-17}) - 1.4077$$

$$= -1.4077$$

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(J)

$$V_{S_2'} = \frac{KP}{r_{S_1S_2}}$$

$$= \frac{9\times10^{9}\times1.6\times10^{-19}}{4\times10^{-9}}$$

$$= 0.359\ V$$

$$V_{netS_2'} = V_{netS_2'} + V_{S_2'}$$

$$= 0.359 - 1.407$$

$$= -1.048\ V$$

Potential Energy.

$$U = V_{netS_2'} \times P$$

$$= -1.048 \times 1.6\times10^{-19}$$

$$= -1.676\times10^{-19}$$