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section: 16

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Ans to the Q: N: 1

(a)

$$\vec{r}_{q,p} = \vec{r}_p - \vec{r}_q$$

$$= (48\hat{k}) - (21\hat{i})$$

$$= 48\hat{k} \quad -21\hat{i}$$

(b)

$$|r_{q,p}| = \sqrt{(-21)^2 + (48)^2}$$

$$= 52.3927$$

$$\therefore \vec{E} = \frac{k \cdot q \cdot \vec{r}_{q,p}}{|\vec{r}_{q,p}|^3}$$

$$= \frac{8.987\times10^9 \times 15\times10^{-6}}{(52.3927)^3} \times (-21\hat{i} + 48\hat{k})$$

$$= 0.8758 \times (-21\hat{i} + 48\hat{k})$$

$$= -18.3708\hat{i} + 41.9904\hat{k}$$

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(c)

$$\vec{E}_L(P) = \int d\vec{E} = \int \frac{k\,dq \cdot \vec{r}_{sp}}{(r_{sp})^3}$$

$$= \int k\,dq \frac{z\hat{k} - y'\hat{j}}{\left(\sqrt{z^2+(y')^2}\right)^3}$$

$$\Rightarrow \vec{E}_y(P) + \vec{E}_z(P) = k\lambda \int dy' \left[- \frac{y'\hat{j}}{\{z^2+(y')^2\}^{\frac{3}{2}}} + \frac{z\hat{k}}{\{z^2+(y')^2\}^{\frac{3}{2}}} \right]$$

$$\therefore E_y(P) = -k\lambda \int_0^L dy' \frac{y'}{\{z^2+(y')^2\}^{\frac{3}{2}}} \;\text{---}\; (i)$$

Let, $y' = z\tan\theta$

$$\Rightarrow dy' = z\sec^2\theta\, d\theta$$

$$\therefore E_z(P) = k\lambda z \int_0^{\tan^{-1}\left(\frac{L}{z}\right)} \frac{z\sec^2\theta\, d\theta}{(z^2+z^2\tan^2\theta)^{\frac{3}{2}}}$$

$$\Rightarrow \quad = \frac{k\lambda z^2}{z^3} \int_0^{\tan^{-1}\left(\frac{L}{z}\right)} \frac{\sec^2\theta\, d\theta}{(1+\tan^2\theta)^{\frac{3}{2}}}$$

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$$E_z(P) = \frac{k\lambda}{z} \int_0^{\tan^{-1}\left(\frac{L}{z}\right)} \frac{\sec^2\theta \, d\theta}{\sec^3\theta}$$

$$= \frac{k\lambda}{z} \int_0^{\tan^{-1}\left(\frac{L}{z}\right)} \cos\theta \, d\theta$$

$$= \frac{k\lambda}{z} \left[\frac{y'}{\sqrt{z^2 + (y')^2}} \right]_0^L$$

$$= \frac{k\lambda}{z} \times \frac{L}{\sqrt{z^2 + L^2}}$$

From (i),

$$E_y(P) = -k\lambda \int_0^{\tan^{-1}\left(\frac{L}{z}\right)} \frac{(z\tan\theta)\cdot(z\sec^2\theta \, d\theta)}{\left(z^2 + z^2\tan^2\theta\right)^{\frac{3}{2}}}$$

$$= -k\lambda \int_0^{\tan^{-1}\left(\frac{L}{z}\right)} \frac{z^2 \tan\theta \cdot \sec^2\theta}{z^3 \sec^3\theta} \, d\theta$$

$$= \frac{-k\lambda}{z} \int_0^{\tan^{-1}\left(\frac{L}{z}\right)} \tan\theta \cdot \cos\theta \, d\theta$$

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$$= -\frac{k\lambda}{z}\int_{0}^{\tan^{-1}\left(\frac{L}{z}\right)} \sin\theta \, d\theta$$

$$= \frac{-k\lambda}{z}\Big[-\cos\theta\Big]_{0}^{\tan^{-1}\left(\frac{L}{z}\right)}$$

$$= -\frac{k\lambda}{z}\left[-\frac{z}{\sqrt{z^2+(y')^2}}\right]_{0}^{L}$$

$$= -\frac{k\lambda}{z}\left[\frac{-z}{\sqrt{z^2+L^2}} + \frac{z}{yz}\right]$$

$$= \frac{k\lambda}{\sqrt{z^2+L^2}} - \frac{k\lambda}{z}$$

$$\therefore \vec{E}_c(P) = k\lambda\left[\frac{1}{\sqrt{z^2+L^2}} - \frac{1}{z}\right]\hat{j} + k\lambda\left[\frac{L}{z\sqrt{z^2+L^2}}\right]\hat{k}$$

$$= 0\hat{i} - 1422.941667\hat{j} + 5268.825\hat{k}$$

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(d)

$$\vec{E}_{net} = \vec{E}_q + \vec{E}_{c(p)}$$

$$= -18.371666\hat{i} + 0\hat{j} + 41.99054\hat{k} + 0\hat{i} - 1522.951666\hat{j} + 4268.825\hat{k}$$

$$= -18.371666\hat{i} - 1522.951666\hat{j} + 5310.8154\hat{k}$$

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Ans to the Q: N: 2.2

(a)

Dipole moment, $\vec{P} = q_1 r_1 + q_2 r_2 + q_3 r_3$

$= (69\times10^{-9} \times (55\hat{i} - 43\hat{j}) + 69\times10^{-9} \times (32\hat{i} + 45\hat{j})$

$+ -138\times10^{-9} (-30\hat{i} + 62\hat{j}))$

$= 3.795\times10^{-6}\hat{i} - 2.967\times10^{-6}\hat{j} + 2.208\times10^{-6}\hat{i} + 3.105\times10^{-6}\hat{j}$

$+ 4.14\times10^{-6}\hat{i} - 8.556\times10^{-6}\hat{j}$

$= (1.0143\times10^{-5}\hat{i} - 8.418\times10^{-6}\hat{j})$ C.nm

$= (1.0143\times10^{-14}\hat{i} - 8.418\times10^{-15}\hat{j})$ C.m

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(b)

x component of $\vec{E}$ is $0 \ NC^{-1}$

y " " $\vec{E} = -\dfrac{\sigma}{2\epsilon_0}$

$$= -\frac{28 \times 10^{-6}}{2 \times 8.855 \times 10^{-12}}$$

$$= -1581206.234 \ NC^{-1}$$

(c)

$$\tau = \vec{P} \times \vec{E}$$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1.0153 \times 10^{-15} & & -8.418 \times 10^{-15} \\ 0 & & -1581206.234 \end{vmatrix}$$

$$|\tau| = |\vec{P} \times \vec{E}|$$

$$= |P_x E_y - E_x P_y|$$

$$= |(1.0153 \times 10^{-15} \times -1581206.234) - 0|$$

$$= 1.6038 \times 10^{-8}$$

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(d)

x component of $\vec{E} = 0$

y - " " $\vec{E} = \frac{\sigma}{2\epsilon_0}$

$= \frac{28 \times 10^{-6}}{2 \times 8.855 \times 10^{-12}}$

$= 1581206.234$

(e)

$\tau = \vec{p} \times \vec{E}$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1.0153 \times 10^{-15} & & -8.418 \times 10^{-15} \\ 0 & & 1581206.235 \end{vmatrix}$$

$= |(1.0153 \times 10^{-15} \times (-8.418 \times 10^{-15}))| \hat{k}$

$= 1.6038 \times 10^{-8} \hat{k}$

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Ans to the Q: N: 2.3

(a)

$$\vec{E}_1 = \frac{6}{2\epsilon_0}$$

$$= \left| \frac{-29 \times 10^{-12}}{2 \times 8.854 \times 10^{-12}} \right|$$

$$= 1.6376 \ N/C$$

$$\vec{E}_2 = \vec{E}_1$$

$$= 1.6376 \ N/C$$

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(b)

Net flux is 0. Because gaussian surface doesn't enclose infinite charge sheet. As this is a sphere, it will be 0.

(c)

$$\phi = \frac{\rho \times 4\pi R^3}{3\epsilon_0}$$

$$= \frac{3.2\times10^{-12} \times 4\pi \times 4^3}{3\times 8.854 \times10^{-12}}$$

$$= 968.902$$

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(d)

$$|\vec{E}_2| = \frac{\Phi}{A}$$

$$= \frac{\rho\, 4\pi R^3}{3\varepsilon_0 \cdot 4\pi r^2}$$

$$= \frac{32 \times 10^{-12} \times 4^3}{3 \times 8.855 \times 10^{-12} \times 8^2}$$

$$= 1.2047 \text{ N/C}$$

$$|\vec{E}_3| = |\vec{E}_2|$$

$$= 1.2047 \text{ N/C}$$

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(e)

$$\phi_{net} = \phi_s + \phi_i$$

$$= \frac{\rho \cdot 4\pi R^3}{3 \epsilon_0}$$

$$= \frac{32\times10^{-12} \times 4\pi \times 4^3}{3\times \epsilon_0}$$

$$= 968.902 \ Nm^2/C$$

(f)

$$\vec{E}_{net} = (0\hat{i} - 0)\hat{i} + \left(\frac{\sigma}{2\epsilon_0} - \frac{4\pi R^3 \rho}{3\epsilon_0 \cdot 4\pi r^2}\right)\hat{j}$$

$$= 0\hat{i} + (-1.637 - 1.2057)\hat{j}$$

$$= 0\hat{i} - 2.852\hat{j}$$

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(g)

$$\{\vec{E}_{xp_2}\} = 1.2047\hat{i} - 1.637\hat{j}$$

(h)

$$\vec{E}_{xp_3} = 0\hat{i} + (1.2047 - 1.637)\hat{j}$$

$$= 0\hat{i} - 0.4323\hat{j}$$