KING FHAD UNIVERSITY OF PETROLEUM & MINERALS
DEPARTMENT OF PHYSICS

PHYSICS 102 (992)
SOLUTION (CHAPTER 23)

Q.1 Calculate the direction and magnitude of the electric field at point P in Figure 23.1.

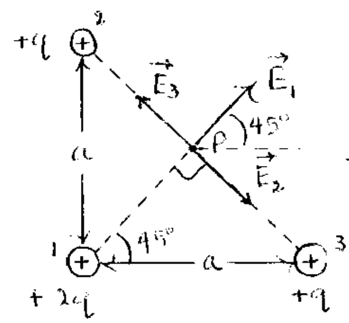


FIGURE 23.1

$$\vec{E}_{net} = \vec{E}_1 = \frac{k(2q)}{\left(\frac{a}{2}\sqrt{2}\right)^2}\left(\cos 45\,\hat{i} + \sin 45\,\hat{j}\right)$$

$$= \frac{4kq}{a^2}\left(\frac{\sqrt{2}}{2}\hat{i} + \frac{\sqrt{2}}{2}\hat{j}\right) = \frac{2\sqrt{2}\,kq}{a^2}\left(\hat{i} + \hat{j}\right)$$

$$|\vec{E}_{net}| = \frac{4}{4\pi\epsilon_0 a^2}q = \frac{q}{\pi\epsilon_0 a^2}$$

Direction: along bisector away from the triangle.

Note: $\vec{E}_2$ and $\vec{E}_3$ cancel.

Q.2 What are the magnitude and direction of the electric field at the center of the square of Figure 23.2, if $q = 1.0 \times 10^{-8}$ C and a = 5.0 cm?

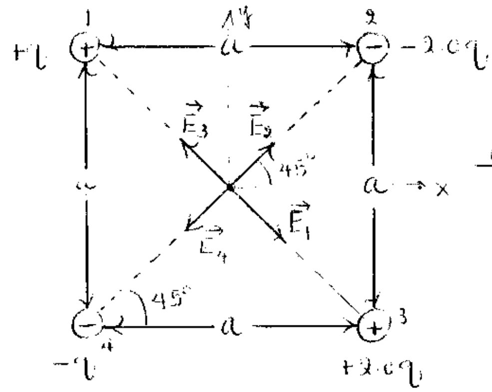


FIGURE 23.2

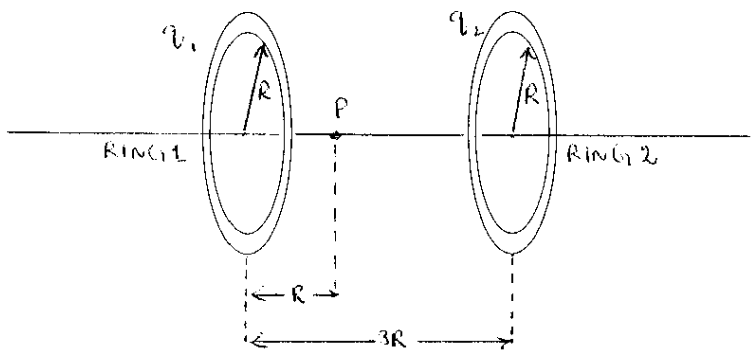
The horizontal components cancel

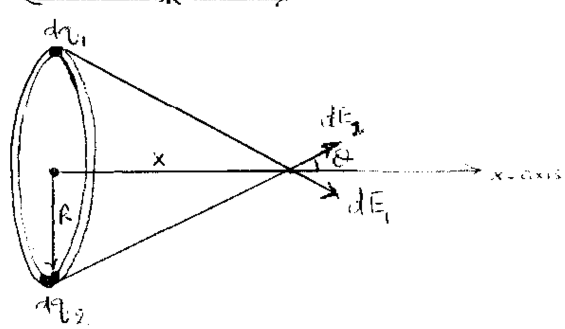
$$\vec{E}_{net} = \left[2 \cdot \frac{2qk_e}{\left(\frac{1}{2}a\sqrt{2}\right)^2} \cdot \frac{\sqrt{2}}{2} - 2\frac{qk_e}{\left(\frac{1}{2}a\sqrt{2}\right)^2} \cdot \frac{\sqrt{2}}{2} \right] \hat{j} = \frac{2qk_e}{a^2 \frac{2}{4}} \cdot \frac{\sqrt{2}}{2} \hat{j}$$

$$\vec{E}_{net} = \frac{2\sqrt{2}\, k_e \,(1 \times 10^{-8})}{(5 \times 10^{-2})^2} \hat{j} = 1.0 \times 10^{5} \hat{j} \text{ N/C}.$$

$\vec{E}_{net}$ is along the positive y-axis.

Q.3 Figure 23.3 shows two parallel non-conducting rings arranged with their central axes along a common line. Ring 1 has uniform charge q_1 and radius R; ring 2 has uniform charge q_2 and the same radius R. The rings are separated by a distance 3R. The net electric field at point P on the common line, at distance R from ring 1, is zero. What is the ratio q_1/q_2?





$$\int \frac{R\,dq}{R^2+x^2}\cos\theta = \frac{R}{(R^2+x^2)}\cdot\frac{x}{(R^2+x^2)^{\frac{1}{2}}}\int dq = \frac{RxQ}{(R^2+x^2)^{3/2}}$$

Apply this result to each loop.

$$\frac{R(R)q_1}{(R^2+R^2)^{3/2}} - \frac{R(2R)q_2}{[R^2+(2R)^2]^{3/2}} = 0$$

$$\frac{q_1}{2^{3/2}R^3} - \frac{q_2}{5^{3/2}R^3} = 0 \Rightarrow \frac{q_1}{q_2} = \left(\frac{2}{5}\right)^{3/2} = 0.253$$

Q.4 A thin rod is bent into a semicircle of radius r. A charge +q is uniformly distributed along the upper half, and a charge –q is uniformly distributed along the lower half, as shown in Figure 23.4. Find the magnitude and direction of the electric field E at P, the center of the circle.

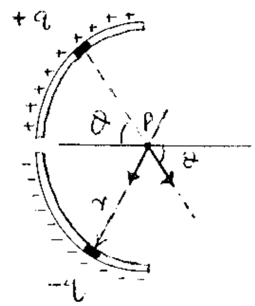


FIGURE 23.4

$$dq = \frac{q}{\frac{1}{4}(2\pi r)} \cdot r\,d\theta = \frac{2 q r}{\pi r}\,d\theta = \frac{2q}{\pi}\,d\theta$$

$$E_y = 2k\int_0^{\pi/2} \frac{dq}{r^2}\sin\theta = \frac{2k}{r^2}\cdot\frac{2q}{\pi}\int_0^{\pi/2} d\theta\,\sin\theta$$

$$= \frac{4kq}{\pi r^2}\left(-\cos\theta\right)\Big|_0^{\pi/2}$$

$$E_y = \frac{4kq}{\pi r^2}$$ along the $-y$ axis.

Q.5 An object having a mass of 10.0 g and a charge of $+8.00 \times 10^{-5}$ C is placed in an electric field E with $E_x = 3.00 \times 10^3$ N/C, $E_y = -600$ N/C, and $E_z = 0$. (a) What are the magnitude and direction of the force on the object? (b) If the object is released from rest at the origin, what will be its coordinates after 3.00 s?

$m = 10.0 \times 10^{-3}$ kg , $q = 8.00 \times 10^{-5}$ C

$E_x = 3.00 \times 10^3$ N/C , $E_y = -600$ N/C , $E_z = 0$

(a) $\vec{F} = q\vec{E} = 8.00 \times 10^{-5} (3.00 \times 10^3 \hat{i} - 600 \hat{j})$

$\vec{F} = (8.00 \times 10^{-5})(600)(5\hat{i} - \hat{j}) = 0.048(5\hat{i} - \hat{j})$ N

$|\vec{F}| = 0.048\sqrt{5^2 + 1^2} = 0.245$ N

(b) $\vec{a} = \frac{0.048}{10 \times 10^{-3}} (5\hat{i} - \hat{j}) = 4.8(5\hat{i} - \hat{j})$

$\vec{r} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$

$\vec{v}_0 = 0$

$\vec{r} = \frac{1}{2}\vec{a}t^2 = \frac{1}{2}(4.8)(5\hat{i} - \hat{j})(3)^2$

$\vec{r} = 108\hat{i} - 21.6\hat{j}$

$x = 108$ m, $y = 21.6$ m.