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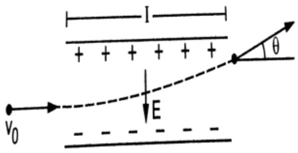
Solution of DPP – 2

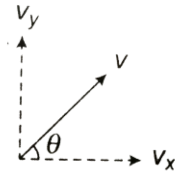
1. Farce Experience by charge $= 25 \times 10^{-3}$ N charge $q = 5 \times 10^{-6}$C

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

$$E = \frac{25 \times 10^{-3}}{5 \times 10^{-6}} = 5 \times 10^{+3}\ \text{N/C}$$

2. Uniform Electric field $E = 91 \times 10^{-6}$ V/m $E = 9.1 \times 10^{-5}$ V/m





time taken by electron to reach from A to B.

in $x = \text{dir}^n$.

$$t = \frac{1}{v_0} = \frac{1}{4 \times 10^3} = 2.5 \times 10^{-4}\text{sec}$$

Motion in γ-dir^n

$u_{y=0}$ $v_y = u_y + a_y t$

$Vy = 0 + \frac{eE}{m}t$ [force on electron opposite to dir^n of electric field]

$$v_y = \frac{eE}{m}t = \frac{1.6 \times 10^{-19} \times 9.1 \times 10^{-5} \times 2.5 \times 10^{-4}}{9.1 \times 10^{-31}}$$

$= 4 \times 10^{-28} \times 10^{+31} = 4 \times 10^3$ m/s

$\tan\theta = \frac{v_y}{v_x} = \frac{4\times10^3}{4\times10^3} = 1$ $\quad\quad \theta = 45°$

3. $q_A = 4 \times 10^{-6}$C $\quad\quad q_R = -64 \times 10^{-6}$c

Electric field at point P is zero

$|E_A| = |\vec{E}_B|$

$$\frac{K4 \times 10^{-6}}{x^2} = \frac{k64 \times 10^{-6}}{(90 + x)^2}$$

$(90 + x)^2 = 16x^2$

$(90 + x) = 4x$

$90 = 3x$

$x = 30$ cm " Left from A , along the line joining?"

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4. Net electric field on D due to A & C

$$E_1 = \sqrt{E_n^2 + E_B^2} = \sqrt{\left(\frac{kq_0}{q^2}\right)^2 + \left(\frac{kq_0}{q^2}\right)^2}$$

$$E_1 = \frac{kq_0}{q^2}\sqrt{2}$$

Electric field at D due to B

$$E_2 = \frac{kq_0}{2q^2}$$

E_1 & E_2act along Same line

So Net electric field at D

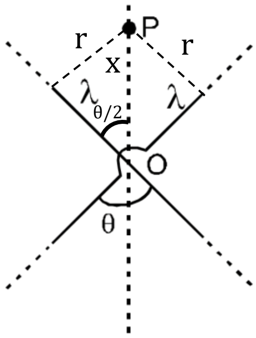
$$E_{net} = E_1 + E_2 = \frac{Kq_0}{a^2}\left(\sqrt{2} + \frac{1}{2}\right)$$

6. $E = \frac{2k\lambda}{r}$

λ is the linear charge density

r is perpendicular distance

$$E = \frac{2k\lambda}{r}$$



And the direction of this electric field will be away from the wire

According to the question, it is given that $OP = x$

Let us assume that the length $AP = PB = r$

Now according to the figure,

$$x\sin\frac{\theta}{2} = r$$

Now we know that $E = \frac{2k\lambda}{r}$

Now, we will replace the value of r from the above expression. So, we will get

$$E = \frac{2k\lambda}{x\sin\frac{\theta}{2}}$$

So, the net electrical charge will be

$$E_{net} = 2E\sin\frac{\theta}{2} = 2\left(\frac{2k\lambda}{x\sin\frac{\theta}{2}}\right) \times \sin\frac{\theta}{2}$$

Therefore, the magnitude of the net electrical charge will be

$E_{net} = \frac{4k\lambda}{x}$ And the direction of this net charge will be along OP.

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7. mass of bob $= 60\text{ g} = 0.06\text{Kg}$

charge of bob $= 6 \times 10^{-6}\text{C}$

We know, $F = qE$

$T = 2\pi\sqrt{\frac{\ell}{10}}$ (when g is eff) ......(1)

$F = ma$ So, $ma = qE$

$$a = \frac{qE}{m} = \frac{6 \times 10^{-6} \times 5 \times 10^{4}}{0.06} = \frac{6 \times 5 \times 10^{-2} \times 10}{6}$$
$$= 5\text{ m/s}^2$$

Because Electrostatic force act on upward direction so, effective acceleration

$= g - a = 10 - 5 = 5\text{ m/s}^2$

Time period $T = 2\pi\sqrt{\frac{\ell}{a_{eff}}}$

$$T' = 2\pi\sqrt{\frac{1}{5}} \dots\dots\dots (2), \frac{T}{T'} = \sqrt{\frac{1}{2}}\ T' = \sqrt{2}\,T$$

$T' = \sqrt{2} \times 100 = 100 \times 1.414 = 141.1 \approx 141.1\text{sec}$

8. Field due to segment 1 is

$$\vec{E}_1 = \left[\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\imath} + \left[-\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\jmath}$$

Field due to segment 2 is

$$\vec{E}_2 = \left[-\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\imath} + \left[\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\jmath}$$

Field due to quarter shape wire segment 3 is

$$\vec{E}_3 = \left[\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\imath} + \left[\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\jmath}\ (\because \theta_1 = 90°, \theta_2 = 0°)$$

The resultant field is the superposition of the fields due to each segment i.e.

$$\vec{E}^{i.} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 \qquad \text{(i)}$$

Substituting the values of $\vec{E}_1, \vec{E}_2$, and $\vec{E}_3$ in Eq. (i), we get

$$\vec{E} = \left[\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\imath} + \left[\frac{\lambda}{4\pi\varepsilon_0 R}\right]\hat{\jmath}$$

$$|\vec{E}| = \left[\left(\frac{\lambda}{4\pi\varepsilon_0 R}\right)^2 + \left(\frac{\lambda}{4\pi\varepsilon_0 R}\right)^2\right]^{1/2} = \frac{\sqrt{2}\lambda}{4\pi\varepsilon_0 R}$$

Here,

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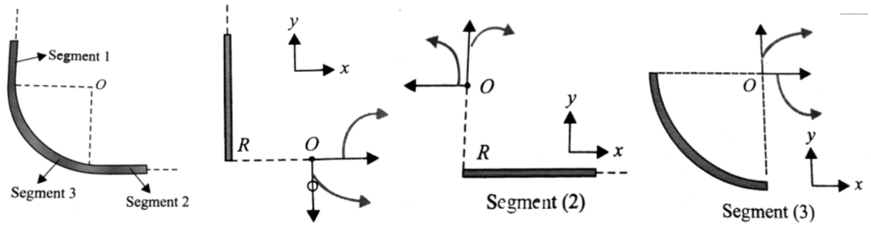
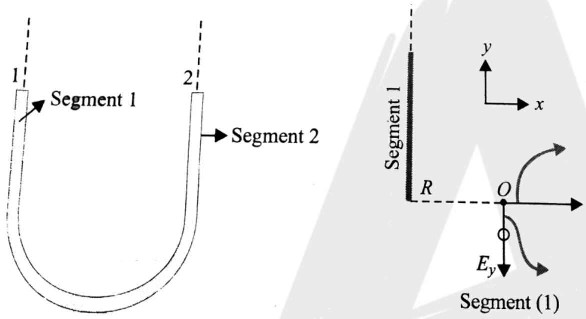
$$E_x = E_y = \frac{\lambda}{4\pi\varepsilon_0 R}$$

Hence, the resultant field will make an angle of 45° with the axis.



b. For, field due to segment 1 is



$$\vec{E}_1 = \frac{\lambda}{4\pi\varepsilon_0 R}[\hat{i} - \hat{j}]$$

Field due to segment 2 is

$$\vec{E}_{x_2} = -\frac{\lambda}{4\pi\varepsilon_0 R}\hat{i}$$

$$\vec{E}_{y_2} = -\frac{\lambda}{4\pi\varepsilon_0 R}\hat{j}$$

$$\vec{E}_2 = -\frac{\lambda}{4\pi\varepsilon_0 R}[\hat{i} + \hat{j}]$$

Field due to segment 3 is

$$\vec{E}_3 = \frac{\lambda}{2\pi\varepsilon_0 R}\hat{j}$$

From the principle of superposition of electric fields.

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

$$= \frac{\lambda}{4\pi\varepsilon_0 R}[\hat{i} - \hat{j}] - \frac{\lambda}{4\pi\varepsilon_0 R}[\hat{i} + \hat{j}] + \frac{\lambda}{2\pi\varepsilon_0 R}\hat{j} = 0$$

Hence, the net field is zero.

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9. length = ℓ and mass = m charge = q

field strength = E

$$T = 2\pi\sqrt{\frac{\ell}{g^2 + \left(\frac{qE}{m}\right)^2}}$$

10. It will be left to - Q as there the direction of electric failed due to $-Q$ and 2Q are opposite and the separation due Q is letter then that of 2Q as to equalize the magnitude of fields.

$$E_1 = \frac{kQ}{d^2}, \quad E_2 = \frac{2KQ}{(d+\ell)^2}$$

11. The electric field due to the ring an it & axis at a distance x is given by:-

$$E = \frac{kqx}{(x^2 + R^2)^{3/2}}$$

To find maximum electric field, we will use the concept of maximum and minimum:-

$$\frac{dE}{dx} = kq\frac{(x^2 + R^2)^{3/2} - 3/2(x^2 + R^2)^{1/2} \cdot 2x^2}{(x^2 + R^2)^3}$$

Now, $\frac{dE}{dx} = 0 \Rightarrow (x^2 + R^2)^{3/2} = \frac{3}{2} \times 2x^2(x^2 + R^2)^{1/2}$

$$\Rightarrow x^2 + R^2 = 3x^2$$

$$\Rightarrow 2x^2 = R^2$$

$$\Rightarrow x^2 = \frac{R^2}{2}$$

$$\Rightarrow x = \pm\frac{R}{\sqrt{2}}$$

So $E_{max} = \dfrac{k \cdot q \cdot R}{\sqrt{2}\left(\frac{R^2}{2} + R^2\right)^{3/2}} = \dfrac{k \cdot q \cdot 2R}{3\sqrt{3}R^3}$

$$E_{max} = \frac{1}{4\pi E_0}\frac{2q}{3\sqrt{3}R^2}$$

12. The acceleration is: $a = \frac{qE}{m}$

Also, $v = u + at$

$$v = 0 + \frac{qE_t}{m} = v = \frac{qE_t}{m}$$

The kinetic energy is

$$k = \frac{1}{2}mv^2 = k = \frac{1}{2}\,m\left(\frac{qE}{m}t\right)^2 = k = \frac{q^2E^2t^2}{2\,m}$$

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13. any of the above three situations is possible depending on the magnitude of K

15. Time period of oscillating pendulum $T = 2\pi\sqrt{\frac{\ell}{a_{eff}}}$

Initial time period $T=2\pi\sqrt{\frac{\ell}{g}}$

Where,

g_{eff} is the effective acceleration due to gravity and some other factors.

Here,

$g_{eff} = \left(g - \frac{F_{electrostatic}}{m}\right)$the

$T_{new} = 2\pi\sqrt{\frac{\ell}{g-qE/m}}$

time period will increase.

16. When $-q$ moves in an elliptical orbit about Q, as in solar system, the angular momentum is a constant. But the linear velocities and hence linear momentum will not be a constant.

$I_\omega = Mr^2 \cdot \frac{v}{r} = Mvr$ changes.

As r changes, v as well as ω change but $I\omega =$ constant.

17. Constant force only change mean position

Time period remains same , so frequency also same

$T=2\pi\sqrt{k/m}$ $\omega=\sqrt{k/m}$

18. **Case1:** Charge q is displaced towards right by a very small distance x.

Net force acting on the charge particle,

$$\vec{F} = \frac{\lambda q}{2\pi\varepsilon_0(r+x)}\hat{\imath} + \frac{\lambda q}{2\pi\varepsilon_0(r-x)}(-\hat{\imath})$$

$$= \frac{\lambda g}{2\pi\varepsilon_0}\left[\frac{r-x-r+x}{r^2-x^2}\right](\hat{\imath})$$

$$\vec{F} = -\frac{\lambda q}{\pi\varepsilon_0 r^2}x(\hat{\imath})\ [\because x << r]$$

or $F = -\omega^2 x$, which is S.H.M, equation. Hence charge $+q$ will perform S.H.M. when displaced by a small distance.

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Case II: Charge $-q$ is displaced towards right by a very small distance x.

Net force acting on the charged particle

$$\vec{F} = \frac{-\lambda q}{2\pi\varepsilon_0(r+x)}(\hat{i}) + \frac{-\lambda g}{2\pi\varepsilon_0(r-x)}(-\hat{i})$$

$$= \frac{-\lambda q}{2\pi\varepsilon_0}\left[\frac{r-x-r-x}{r^2-x^2}\right](\hat{i})$$

$$\vec{F} = \frac{\lambda q}{\pi\varepsilon_0 r^2}x(\hat{i})\ [\because r \gg x]$$

$F \propto x$

Hence, charge $-q$ continues to move in the direction of its displacement.