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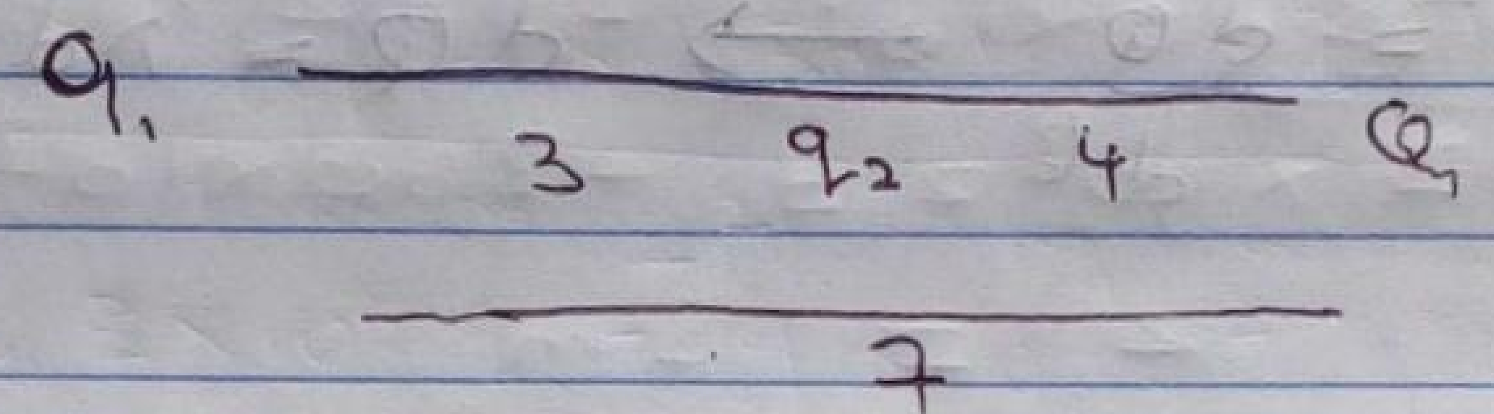
Mechatronics Engineering
19/ENG05/058 PHY 102

2a. An electric field is the region of space in which an electric charge will experience an electric force while electric field intensity / strength is the force per unit charge or magnitude of electric field.

bi) $q_1 = 8nC$ $q_2 = 12nC$

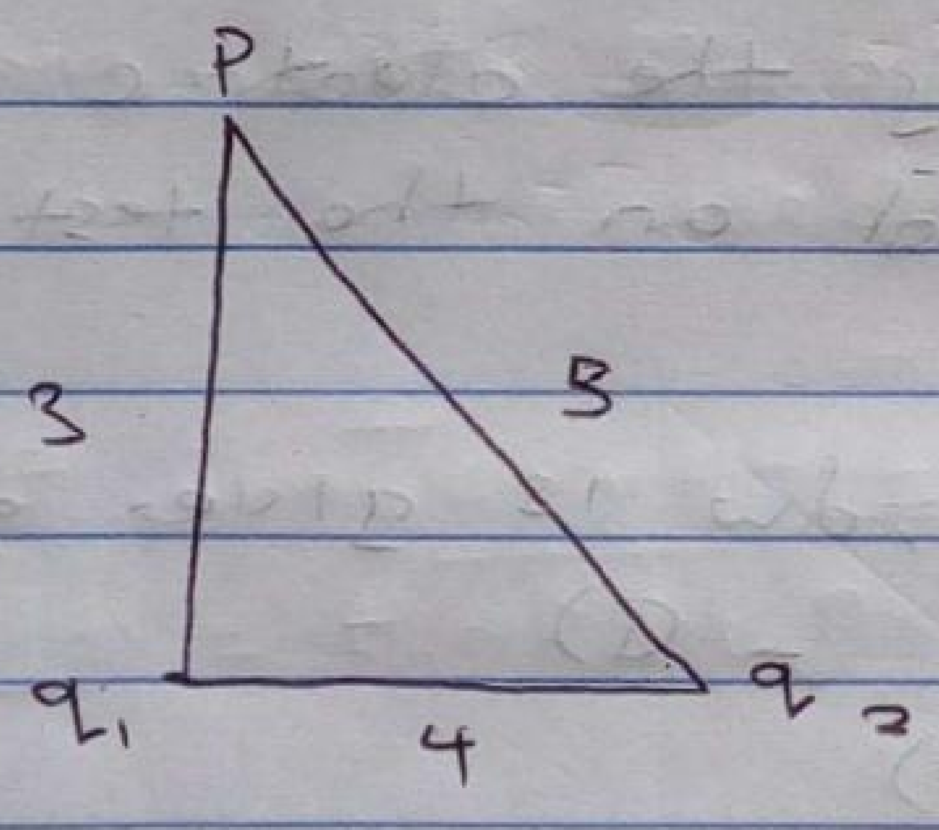


$$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 9\times10^{-9}}{7^2} = 1.469 N/C$$

$$E_2 = \frac{k_1 q_2}{r_1^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12 N/C$$

$$E_{net} = E_1 + E_2 = (1.469 N/C + 12 N/C) = 13.469 N/C$$

ii)



$$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8 N/C$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32 N/C$$

G	θ	x-component	y-component
$E_1 = 8 N/C$	$90°$	$8\cos\theta = 0$	$8\sin\theta = 8 N/C$
$E_2 = 4.32 N/C$	36.9	$4.32\cos\theta = 3.45$	$4.32\sin\theta = 2.60 N/C$
		$\Sigma x = 3.45 N/C$	$\Sigma y = 10.60 N/C$

$$E_{net} = \sqrt{3.45^2 + 10.6^2}$$
$$= 11.15 N/C$$

But $E_p = 0$

$$= -11.15 N/C$$

3a. Volume charge density ; ρ

$$\rho = \frac{dQ}{dV} \Rightarrow dQ = \rho dV$$

ii. Surface charge density σ

$$\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$$

iv Linear charge density, λ

$$\lambda = \frac{dQ}{dl} \longrightarrow dQ = \lambda dl$$

b The electrical potential difference between two points in an electric field can be defined as the workdone per unit charge against electrical forces when a charge is transported from one point to another

force exerted by the electric field $f = q_0 E$

External force exerted on the test charge, $f = -q_0 E$.

Elemental workdone, dw is given as

$$dw = f \cdot dl \quad - (1)$$

But $f = -q_0 E \quad - (2)$

Put equation (2) in (1)

$$dw = -q_0 E dl \quad - (3)$$

Then total workdone in moving the test charge from A to B

$$W(A \rightarrow B)_{Ag} = -q_0 \int_A^B E dl \quad - (4)$$

from the definition of electrical potential difference

$$V_B - V_A = \frac{W(A \rightarrow B)_{Ag}}{q_0}$$

Putting equation (4) in (5) yields

$$V_B - V_A = -\int_A^B E dl$$

$q_1 = 10\mu c$ $\qquad V = 0$

$Q_2 = -2\mu c$

for x

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{rQ_1} + \frac{Q_2}{rQ_2}\right]$$

$$\cancel{0 = 9\times10^9 \left[10\times10^{-6}(4+x)\right.}$$

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{10\times10^{-6}}{x} - \frac{2\times10^{-6}}{4+x}\right]$$

$$0 = 9\times10^9\left[\frac{10\times10^{-6}(4+x) - x(2\times10^{-6})}{x(4+x}\right]$$

$$0 = 9\times10^9\left[40\times10^{-6} + 10\times10^{-6}x - 2\times10^{-6}x\right]$$

$$0 = 9\times10^9\left[40\times10^{-6} + 8\times10^{-6}x\right]$$

$$0 = 360\times10^3 + 72\times10^3 x$$

$$-72\times10^3 x = 360\times10^3$$

$$x = -5m$$

~~At~~ y,

$$V = 9\times10^9\left[\frac{10\times10^{-6}}{y} + \left(\frac{-2\times10^{-6}}{4-y}\right)\right]$$

$$0 = 9\times10^9\left[\frac{10\times10^{-6}(4-y) - y(2\times10^{-6})}{y\cdot(4-y)}\right]$$

$$0 = 9\times10^9\left[40\times10^{-6} - 10\times10^{-6}y - 2\times10^{-6}y\right]$$

$$0 = 9\times10^9\left[40\times10^{-6} - 12\times10^{-6}y\right]$$

$$0 = 360\times10^3 - 108\times10^3 y$$

$$\frac{108\times10^3 y}{} = \frac{360\times10^3}{}$$

$$y = 3.33m$$

At z

$$V = 9\times10^{9}\left[\frac{10\times10^{-6}}{z} + \left(-\frac{2\times10^{-6}}{z-4}\right)\right]$$

$$0 = 9\times10^{9}\left[\frac{10\times10^{-6}(z-4) - z(2\times10^{-6})}{z(z-4)}\right]$$

$$0 = 9\times10^{9}[10\times10^{-6}z - 40\times10^{-6} - 2\times10^{-6}z]$$

$$0 = 9\times10^{9}[-40\times10^{-6} + 8\times10^{-6}z]$$

$$0 = -360\times10^{3} + 72\times10^{3}z$$

$$-72\times10^{3}z = -360\times10^{3}$$

$$z = 5\,m$$

∴ the position on the x axis -5m, 3.33m and 5m

4a Magnetic flux is the number of magnetic lines of force passing through a given closed surface which is the magnetic field. The SI unit is Weber.

b $m = 9.11\times10^{-31}\,kg$ $r = 1.4\times10^{-7}\,m$ $\theta = 90^{\circ}$ $B = 3.5\times10^{-1}$

$F = \frac{mv^2}{r}$ $F = qvB\sin\theta = \frac{mv^2}{r}$

$q = \frac{m\cancel{v^2}v}{r\cancel{v}B\sin\theta}$ $q = \frac{mv}{rB\sin\theta}$

$$q = \frac{9.11\times10^{-31}\times3\times10^{8}}{3.5\times10^{-1}\times\sin 90\times1.4\times10^{7}} = 5.578\times10^{-5}C$$

$$\omega = \frac{qB}{m_e} = \frac{5.578\times10^{-5}\times3.5\times10^{-1}}{9.11\times10^{-31}}$$

$$= 2.14\times10^{15}\ rads^{-1}$$

c. The acceleration or motion of the electron is uniform circular so it will have centripetal acceleration $\frac{v^2}{r} = 0$

$$F_b = qvB = ma$$

$$F_b = qvB = m \cdot \frac{v^2}{r}$$

$$q = \frac{mv}{rB} = r = \frac{mv}{qB\sin\theta} \quad \text{and } \omega = \frac{v}{r}$$

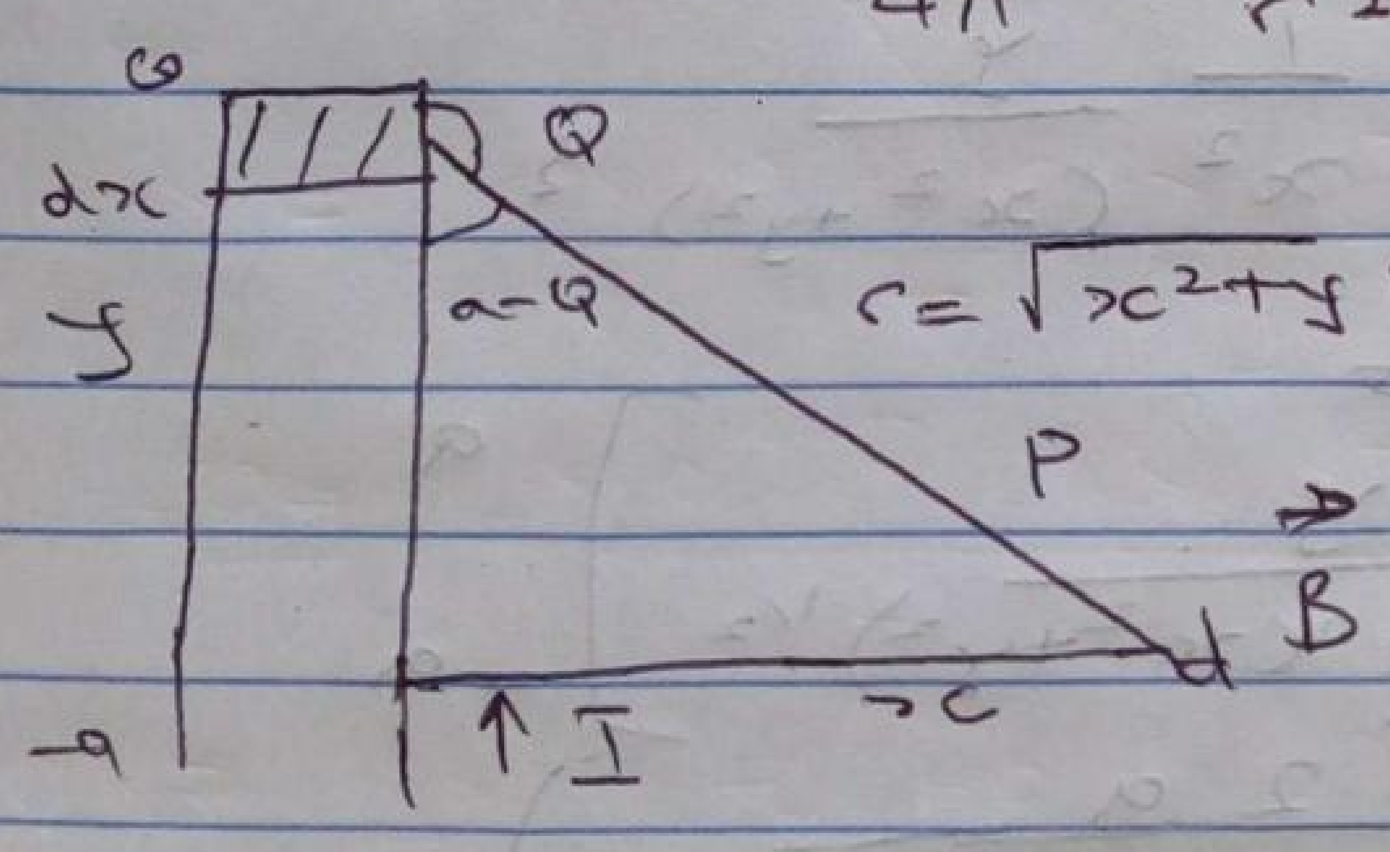
Since it is angular $q = \frac{mv}{rB\sin\theta}$ and $q = 5.578 \times 10^{-5}\,C$

$$\omega = \frac{v}{r} \quad \omega = \frac{vqB}{mv} = \omega = \frac{qB}{m}$$

Solving ω will now be $2.14 \times 10^{15}\,\text{rad}\,s^{-1}$

5 Biot-savart law is an equation that describes the magnetic field circled by a current-carrying wire and allows for the calculation of its strength is

$$\overrightarrow{dB} = \frac{\mu_0}{4\pi} \frac{I\overrightarrow{dl} \times \hat{r}}{r^2} = B = \frac{\mu_0 I}{2\pi r}$$



Applying the Biot-savart law, we find the magnitude of the field $d\vec{B}$

$$B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl\sin\theta}{r^2}$$

$$\sin(\pi - \theta) = \sin\theta$$

$$\therefore B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl\sin(\pi - \theta)}{r^2}$$

from diagram $r^2 = x^2 + y^2$ (Pythagoras theorem)

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin(\pi - \theta)}{x^2+y^2} \quad --(1)$$

But $\sin(\pi - \theta) = \frac{x}{\sqrt{x^2+y^2}} = \frac{x}{(x^2+y^2)^{1/2}} \quad --(2)$

Substituting (2) in (1) we have

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2+y^2)(x^2+y^2)^{1/2}}$$

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2+y^2)^{3/2}}.$$

Recall $dl = dy$

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{x}{(x^2+y^2)^{3/2}} dy$$

$$B = \frac{\mu_0 Ix}{4\pi}\int_{-a}^{a} \frac{1}{(x^2+y^2)^{3/2}} dy \quad --(3)$$

Using special integrals:

$$\int \frac{dy}{(x^2+y^2)^{3/2}} = \frac{1}{x^2}\frac{y}{(x^2+y^2)^{1/2}}$$

Equation (3) becomes

$$B = \frac{\mu_0 Ix}{4\pi}\left[\frac{y}{x^2(x^2+y^2)^{1/2}}\right]_{-a}^{a}$$

$$B = \frac{\mu_0 Ix}{4\pi}\left(\frac{2a}{x^2(x^2+a^2)^{1/2}}\right)$$

$$B = \frac{\mu_0 I}{4\pi x}\left(\frac{2a}{(x^2+a^2)^{1/2}}\right)$$

When the length $2a$ of the conductor is very great in comparison to its distance x from point P, we consider it ~~infinitely~~ infinitely long. That is, when a is much larger than x,

$(x^2+a^2)^{1/2} \simeq a$, as $a \to \infty$

$\therefore B = \frac{\mu_0 I}{2\pi x}$ But $x = r$ (if $a = 0$) $B = \frac{\mu_0 I}{2\pi r}$