Phy 102

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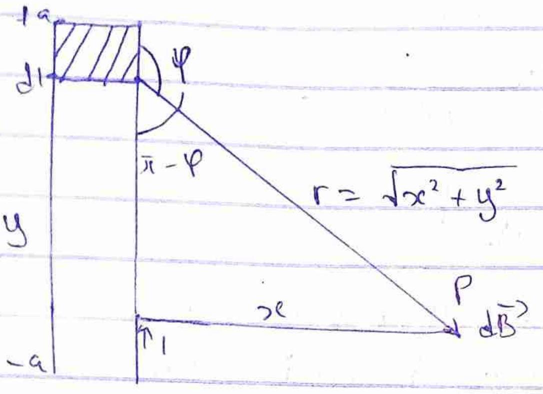
5a) Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I) the change in length, the radius and inversely proportional to square of the radius (r^2). Mathematically expressed as

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

μ_0 is a constant called permeability of free space.

5b) Magnetic field of a straight current carrying conductor



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

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

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

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

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

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

but $\sin(\pi - \varphi) = \frac{x}{x^2+y^2} = \frac{x}{(x^2+y^2)^{1/2}}$ —— (2)

Substitute 2 into ~~the~~ 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 $dl = dy$

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

Using special integrals :

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

Equation 3 therefore becomes

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

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

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

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

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

$$\therefore B = \frac{\mu_0 I}{2\pi x}$$

In a physical situation, we have axial symmetry about the y-axis. Thus, at all points in a circle of radius r, around the conductor, the magnitude of B is

$$B = \frac{\mu_0 I}{2\pi r} \quad — (4)$$

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4a) Magnetic flux is the strength of magnetic field represented by line of force. It is usually represented by the symbol ϕ.

b) Given: $m = 9.11 \times 10^{3}$ kg $\qquad \theta = 90°$

$r = 1.4 \times 10^{-7}$ m $\qquad w = ?$

$B = 3.5 \times 10^{-1}$ weber/m^2 $\qquad q = 1.6 \times 10^{-19}$ C

$$w = \frac{qB}{m_e} = \frac{-1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$$

$$w = -6.15 \times 10^{10} \text{ rad/sec}$$

c) In the question we were given parameters which are:

i) the mass of the electron $= 9.11 \times 10^{-3}$ kg

ii) A radius $= ~~1.4~~ \times 10^{-7}$ m

iii) Magnetic field of 3.5×10^{-1} weber/m^2

We were asked to, find the cyclotron frequency (w) of the moving electron. The cyclotron frequency is the same as circular speed. It is referred to as cyclotron frequency ~~of~~ a because it is a frequency of an accelerator called cyclotron.

$$\text{Angular Speed } (w) = \frac{v}{r} = \frac{qB}{m}$$

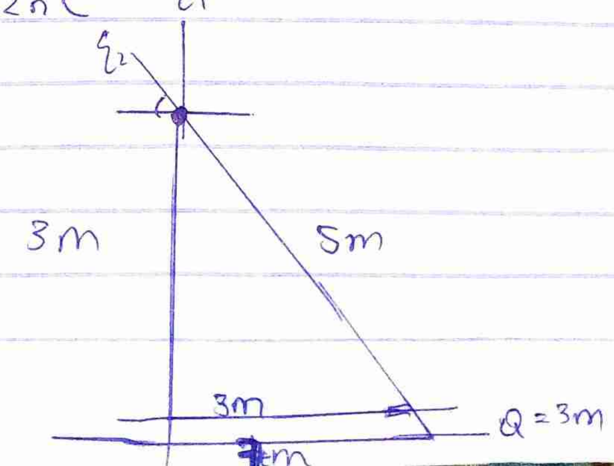
SECTION A

2a) An electric field is a region of space in which an electric force is experience. While electric field intensity is the force per unit charge. Electric field intensity can be mathematically expressed as

$$E = \frac{F\,(N)}{q_0\,(C)}$$

b) $Q_1 = 8$ nC $\qquad x = 4$ m

$Q_2 = 12$ nC $\qquad E_1$



i. $E_{net} = EQ_1 + EQ_2$

$EQ_1 = \frac{kQ}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = 1.469\, N/C$

$EQ = \frac{kQ_2}{r_1^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12\, N/C$

$E_{net} = 1.469 + 12$

$= 13.469 \approx 13.5\, N/C$

ii. $E_{net\,Q} = E_1 + E_2$

$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8\, N/C$

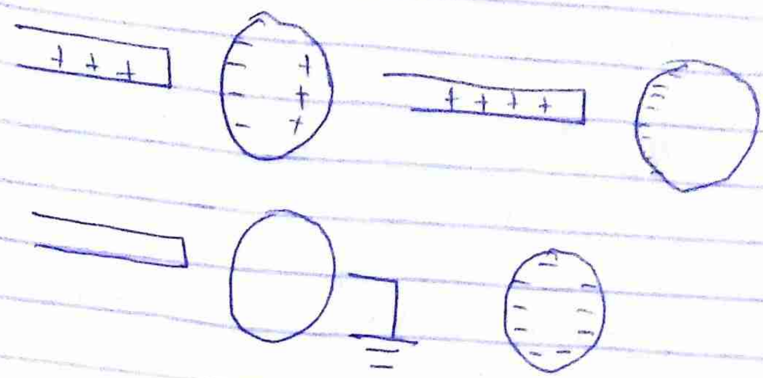
$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\, N/C$

Vector	Degree	x-component	y-component
$E_1 = 8\, N/C$	90°	$8\cos 90 = 0$	$8\sin 90 = 8$
$E_2 = 4.32\, N/C$	36.9	$-4.32\cos 36.9 = -3.45$	$4.32\sin 36.9 = 2.57$
		$\Sigma f_x = -3.45$	$\Sigma f_y = 10.57$

$E_{net\,Q} = \sqrt{(-3.45)^2 + (10.59)^2}$

$= 11.14\, NC^{-1}$

1a)



b) Given: $f = 1N$ $\qquad q_1 q_2 = Q = 5.0 \times 10^{-5} C$

$r = 2m$

$Q = 5.0 \times 10^{-5} C$

$$f = \frac{kq_1 q_2}{r^2}$$

$$\frac{1}{1} \times = \frac{9 \times 10^9 \times q_1 q_2}{2^2}$$

$$\frac{4}{9 \times 10^9} = \frac{\cancel{9 \times 10^9} \times q_1 q_2}{\cancel{9 \times 10^9}}$$

$$q_1 q_2 = \frac{4}{9 \times 10^9}$$

$q_1 q_2 = 4.44 \times 10^{-10}$ — (1)

recall $q_1 + q_2 = 5.0 \times 10^{-5}$

$q_1 = 5.0 \times 10^{-5} - q_2$

Put eqn 2 in 1

$q_2 (5.0 \times 10^{-5} - q_2) = 4.44 \times 10^{-10}$

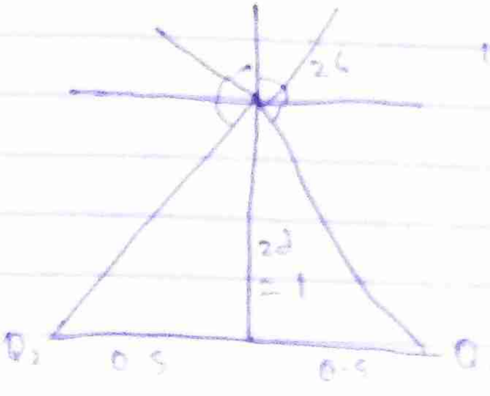
$\cancel{5.0 \times 10^{-5} q_2 - (q_2)^2 = 4.44 \times 10^{-10}}$

$-q_2^2 + 5.0 \times 10^{-5} q - 4.44 \times 10^{-10}$

$q_2 = 3.85 \times 10^{-5} C$ or $1.155 \times 10^{-5} C$

$\therefore q_1 = 3.85 \times 10^{-5}$, $q_c = 1.155 \times 10^{-5} C$

c)



hyp $= \sqrt{1^2 + 0.5^2}$

hyp $= \sqrt{1.25}$

$= 1.1$

$$\tan\theta = \frac{1}{0.5} = 2$$

$\tan^{-1} 2 = 63.43$

$E_P = E_{q_1} + E_{q_2} + E_q$

$E_{q_1} = \frac{kq_1}{r^2} = \frac{9\times 10^9 \times 8\times 10^{-6}}{1.1^2} = 59504\ NC^{-1}$

$E_{q_2} = \frac{kq_2}{r^2} = \frac{9\times 10^9 \times 8\times 10^{-6}}{1.1^2} = 59504\ NC^{-1}$

$E_q = \frac{kq}{r^2} = \frac{9\times 10^9 \times q}{1^2} = 9\times 10^9 q\ NC^{-1}$

Vector	Angle	X- Component	Y- Component
$E_{q_1} = 59504$	$63.4°$	$-59504 \cos 63.4 = -26643\ N/C$	$59504 \sin 63.4 = 53205\ NC^{-1}$
$E_{q_2} = 59504$	$63.4°$	$59504 \cos 63.4 = 26643\ N/C$	$59504 \sin 63.4 = 53205\ NC^{-1}$
$E_q = 9\times 10^9 q$	90	$9\times 10^9 q \cos 90 = 0$	$9\times 10^9 q \sin 90 = 9\times 10^9 q$
		$E_x = 0$	$E_y = 106410 (+ 9\times 10^9 q)$

$E_P = \sqrt{0^2 + (106410 + 9\times 10^9 q)^2}$

$E_P = 106410 + 9\times 10^9 q$

at $E_P = 0$, it will be

$106410 + 9\times 10^9 q = 0$

$\frac{\cancel{9\times 10^9} q}{\cancel{9\times 10^9}} = -\frac{106410}{9\times 10^9}$

$q = -1.182 \times 10^{-5}\ C$

$q = -12\ \mu C$