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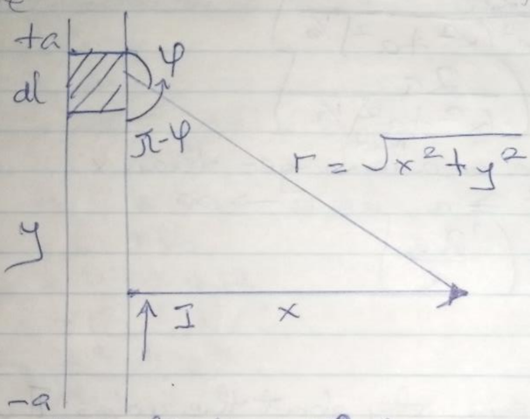
Matric No: 19/ENG06/043
Course: PHY102

Assignment

5 Biot-Savart law states the magnetic intensity at any point due to a steady current in an infinitely long straight wire is directly proportional to the current and inversely proportional to the distance from point to wire.



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

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

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

$r^2 = \sqrt{x^2+y^2}$

$r^2 = x^2 + y^2$

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

$\sin(\pi-\varphi) = \cancel{\frac{x}{r}} \quad \frac{x}{r}$

$= \frac{x}{(x^2+y^2)^{1/2}}$ — (ii)

Substituting 11 into 1

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

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

$dl = dy$

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

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

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

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

When length 2a or a is much larger than x

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

$$\therefore B = \frac{\mu_0 I}{2\cancel{4}\pi x}\left(\frac{\cancel{2}\cancel{a}}{\cancel{a}}\right)$$

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

There is axial symmetry about the y axis. Thus all points ~~are~~ in a circle radius r

$x = r$

$$B = \frac{\mu_0 I}{2\pi r}$$

3)

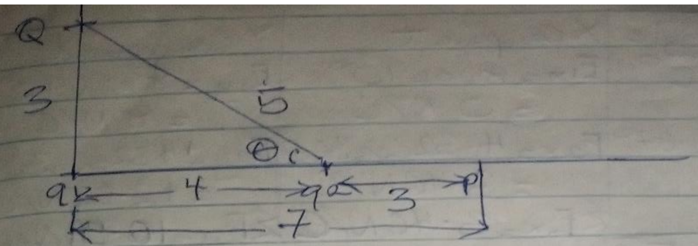
2

a) Electric field is a region of space in which an electric charge will experience an electric force. The electric field strength (E)/intensity can be defined as the force per unit charge

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

b) $Q_1 = 8nC$ at the origin

$Q_2 = 12nC$ at $x = 4m$



i) $E_1 = \frac{kq_1}{r_1^2}$

$= \frac{9\times10^9 \times 8\times10^{-9}}{7^2}$

$= \cancel{10.29\,N/C}$ $1.47\,N/C$

$E_2 = \frac{kq_2}{r_2^2}$

$= \frac{9\times10^9 \times 12\times10^{-9}}{3^2}$

$= 12\,N/C$

$\Sigma E = E_1 + E_2$

$= 1.47 + 12$

$= 13.5\,N/C$

ii) $r^2 = 3^2 + 4^2$

$r = \sqrt{9+16}$

$r = \sqrt{25}$

$r = 5m$

$\theta = \sin^{-1}(3/5)$

$\theta = 36.87^\circ$

$E_1 = \frac{kq_1}{r_1^2}$

$= \frac{9\times10^9 \times 8\times10^{-9}}{3^2}$

$= 8\,N/C$

$E_2 = \frac{kq_2}{r_2^2}$

$= \frac{9\times10^9 \times 12\times10^{-9}}{5^2}$

$= 4.32\,N/C$

Vector	Angle	X Component	Y Component
$E_1 = 8 N/C$	90°	$E_{1x} = 8\cos 90^\circ$ $= 0 N/C$	$E_{1y} = 8\sin 90^\circ$ $= 8 N/C$
$E_2 = 4.32 N/C$	36.87°	$E_{2x} = 4.32\cos 36.87^\circ$ $= 3.46 N/C$	$E_{2y} = +4.32\sin 36.87^\circ$ $= +2.59 N/C$
		$\Sigma E_x = 3.46 N/C$	$\Sigma E_y = 10.59 N/C$

$$E = \sqrt{\Sigma E_x^2 + \Sigma E_y^2}$$
$$= \sqrt{(3.46)^2 + \cancel{(5.41)}^2 (10.59)^2}$$
$$= \sqrt{\cancel{29.27} + 11.97 + 112.15}$$
$$= \sqrt{\cancel{41.24}} = \sqrt{124.12}$$
$$= 11.1 N/C$$

(3)

a) i) Volume charge density, $\rho = \frac{dQ}{dV}$

$$dQ = \rho dV$$

ii) Surface charge density, $\sigma = \frac{dQ}{dV}$

$$dQ = \sigma dV$$

iii) Linear charge density, $\lambda = \frac{dQ}{dL}$

$$dQ = \lambda dL$$

b) The electric potential difference between two points in an electric field can be defined as the work done per unit charge against electrical forces when a charge is transported from one point to the other. It is measured in volts or J/C

$dW = F \cdot dL$

but $F = -q_0 E$

$dW = -q_0 E dL$

The work done in moving a test charge from A to B

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

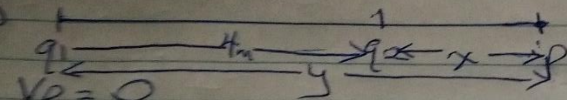
From the definition of electric potential difference

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

Because

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

c)



$V_P = 0$

$Q_1 = 10\mu C$

$Q_2 = -2\mu C$

$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

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

$$0 = \frac{10\times10^{-6}}{4+x} - \frac{2\times10^{-6}}{x}$$

$$\frac{2\times10^{-6}}{x} = \frac{10\times10^{-6}}{4+x}$$

$2(4+x) = 10x$

$8 + 2x = 10x$

$8 = 8x$

$x = 1$

$y = x + 4$

$y = 1 + 4$

$y = 5$

$\therefore V = 0$ at 5m on the x axis

(4)

a) Magnetic flux is defined as the strength of a magnetic field represented by lines of force. It is usually represented by the symbool Φ.

b) Cyclotron frequency $= \frac{qB}{2\pi m}$

$B = 3.5\times10^{-1}$ Weber/m^2

$m = 9.11\times10^{-31}$ Kg

$q = -1.6\times10^{-19}$ C

$$f = \frac{-1.6\times10^{-19} \times 3.5\times10^{1}}{2\times3.142\times9.11\times10^{-31}}$$

$$f = \frac{-5.6\times10^{-20}}{5.72\times10^{-30}}$$

$$f = -0.979\times10^{10}$$

$$f = -9.79\times10^{9}\,Hz$$

c) iii) The charge is negative because the electron is in motion. The frequency is a cyclotron frequency because it moves on a circular orbit.