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ELECT/ELECT ENGINEERING

19/ENG04/055

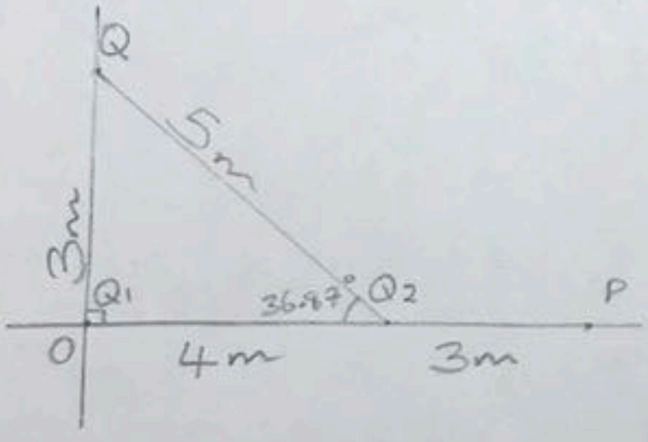
PHY 102 ASSIGNMENT

2(a) An electric field is a region of space in which an electric charge will experience an electric force while the electric field intensity is the measure of strength of electrical force per unit charge at any point in the electric field denoted by E and is measured in Newton per coulomb (N/C)

Mathematically,

Electric field Intensity (E) = $\frac{F(N)}{q_0(C)}$ where F is force in Newtons and q_0 is unit charge in coulomb

2(b)



b(i) Net electric field (E) = $E_1 + E_2$

$$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{49} = 1.47\ N/C$$

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

$$E = 12 + 1.47 = 13.47\ N/C$$

b(ii) $$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{9} = 8\ N/C$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{25} = 4.32\ N/C$$

Vector	Angle	X-Component	Y-Component
$E_1 = 8\,N/C$	90°	$8\cos 90 = 0\,N/C$	$8\sin 90 = 8\,N/C$
$E_2 = 4.32\,N/C$	36.87°	$-4.32\cos 36.87 = -3.46\,N/C$	$4.32\sin 36.87 = 2.59\,N/C$
		$\sum E_x = -3.46\,N/C$	$\sum E_y = 10.59\,N/C$

$$E = \sqrt{\sum E_x^2 + \sum E_y^2}$$

$$E = \sqrt{(-3.46)^2 + (10.59)^2}$$

$$E = \sqrt{124.1197} = 11.14\,N/C$$

3(a) $E = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2} \Rightarrow dE = \frac{1}{4\pi\varepsilon_0} \times \frac{dQ}{r^2}$

(i) Volume charge density. $\rho = \frac{dQ}{dV} \Rightarrow dQ = \rho dV$

(ii) Surface charge density, $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

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

where dQ = charge element, dV = volume element, dA = area element and dL = length element.

3(b) The electric potential difference between two points in an electric field is 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 Volt (v) or joules per coulomb (J/C). It is a scalar quantity.

The formula is derived as follows

elemental work done$(dW) = F \cdot dL \ldots$ (i)

$$F = -q_0 E \ldots \text{(ii)}$$

substitute (ii) into (i)

$$dW = -q_0 E dL \ldots \text{(iii)}$$

Total work done in moving test charge from A to B is

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

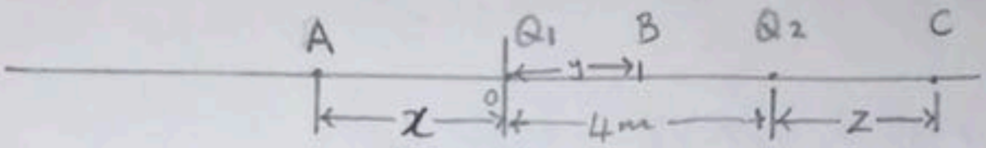
From the definition

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

Putting (iv) in (v)

Electric potential Difference $(V_B - V_A) = -\int_A^B E dL$ (vi)

3(c)



For $V = 0$, it could be in three possible positions

(i) In front of Q_1 and Q_2

(ii) In between Q_1 and Q_2

(iii) Behind Q_1 and Q_2

(i) In front of Q_1 and Q_2 (A)

$$V = k \times \left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right), \quad 0 = k \times \left(\frac{10 \times 10^{-6}}{x} - \frac{2 \times 10^{-6}}{4 + x}\right)$$

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

$$4 \times 10^{-5} + 10 \times 10^{-6} x = 2 \times 10^{-6} x$$

$$4 \times 10^{-5} = -8 \times 10^{-6} x$$

$$x = -5m$$

(ii) In between Q_1 and Q_2 (B)

$$0 = k \times \left(\frac{10 \times 10^{-6}}{y} - \frac{2 \times 10^{-6}}{4 - y}\right)$$

$$4 \times 10^{-5} - 10 \times 10^{-6} y = 2 \times 10^{-6} y$$

$$1.2 \times 10^{-5} y = 4 \times 10^{-5}$$

$$y = 3.33m$$

(iii) Behind Q_1 and Q_2 (C)

$$0 = k \times \left(\frac{10 \times 10^{-6}}{4 + z} - \frac{2 \times 10^{-6}}{z}\right)$$

$$10 \times 10^{-6} z = 8 \times 10^{-6} + 2 \times 10^{-6} z$$

$$8 \times 10^{-6} z = 8 \times 10^{-6}$$

$$z = 1m$$

distance from origin to C is $4 + 1 = 5m$

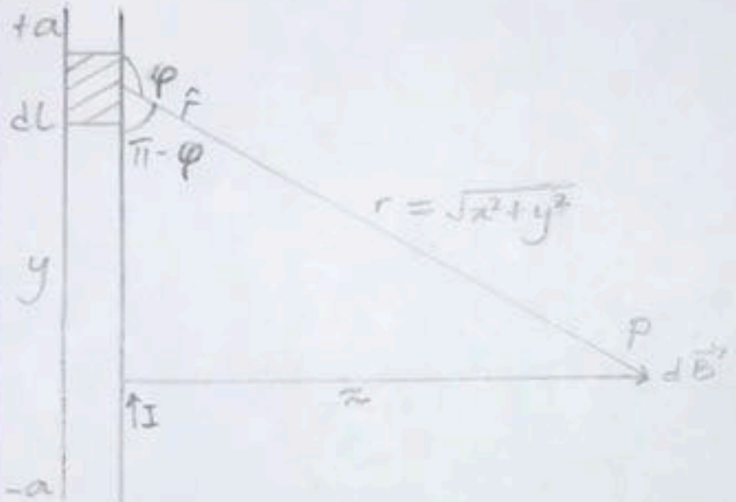
5(a) The Biot-Savart Law is based on the observations for the magnetic field $d\vec{B}$ at a point P associated with a length element $d\hat{l}$ of a wire carrying a steady current I.

Mathematically, it is expressed as

$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{L}\times\hat{r}}{r^2}$$ where μ_0 is a constant called permeability of free space

$\mu_0 = 4\pi \times 10^{-7}\, T.m/A$

5(b)



By 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 diagram, $r^2 = x^2 + y^2$ (pythagoras theorem)

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

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

Substituting $(**)$ into $(*)$

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

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

Recall $dl = dy$

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

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

Using special Integrals

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

Equation $(* * *)$ 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 its distance x from point P, we consider it infinitely long. That is, when larger than x.

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

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

At all points, in a circle of radius r, around the conductor the magnitude of B becoms

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

6(a) Faraday's law can be applied in the production of sound in an electric guitar. The coil in this case is called the pickup coil is placed near the vibrating guitar string which is made of a metal that can be magnetized. A permanent magnet in the coil magnetizes the profurn of the string nearest the coil. When the string vibrates at a frequency, its magnetized segment produces a changing magnetic flux through the coil. The changing flux induces an emf in the coil that is fed to an amplifier. The output of the amplifier is sent to the loudspeakers producing the sound we hear.

6(b)

(i) $$|\xi| = \frac{N\Delta\Phi_B}{\Delta t} = \frac{N(\Phi_{B(2)} - \Phi_{B(1)})}{t_2 - t_1}$$

$$= \frac{300((10-0)0.01)}{0.5}$$

$$= \frac{30}{0.5} = 60\,\text{v}$$

(ii) $$I = \frac{E}{R} = \frac{60}{2} = 30\,\text{A}$$

6(c) $$E = IR = 8 \times 0.1 = 0.8\,\text{v}$$

$$\xi = \frac{NBA}{t}$$

$$\frac{B}{t} = \frac{\xi}{NA} = \frac{0.8}{75 \times 0.004} = 2.67\ \text{Tesla/sec}$$