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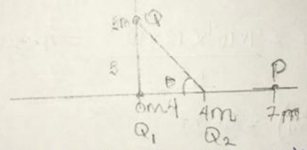
Section A

Question 2

2a. Electric field is a region of space in which an electric charge will experience an electric force while electric field intensity is defined as the force per unit charge.

2b (i)



(i) net electric field at a point P on the x axis

$$E_{Q_1} = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{(7)^2} = 1.4694\ N/C$$

$$E_{Q_2} = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12\ N/C$$

Resolution of electric field strength

	Horizontal component	Vertical component
E_{Q_1}	1.4694	0
E_{Q_2}	12	0
	13.4694	0

$$E = \sqrt{(\Sigma f x)^2 + (\Sigma f y)^2}$$
$$= \sqrt{(13.4694)^2 + 0^2}$$
$$= \sqrt{(13.4694)^{\cancel{2}}}$$
$$E = 13.4694$$
$$= 13.5\ N/C$$

2b(ii) Distance Q_2 to $Q = \sqrt{3^2 + 4^2} = \sqrt{25} = 5$

$$EQ_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8$$

$$EQ_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32$$

$$\theta = \tan^{-1}(3/4) = 36.87^\circ$$

	Horizontal component	Vertical Component
EQ_1	0	$8 \sin 90 = 8$
EQ_2	$-\cos 36.87 \times 4.32$ $= -3.4559$	$\sin 36.87 \times 4.32$ $= 2.592$
	-3.4559	10.592

$$E = \sqrt{(\Sigma f x)^2 + (\Sigma f y)^2}$$
$$= \sqrt{(-3.4559)^2 + (10.592)^2}$$
$$= \sqrt{124.1337088} = 11.14$$
$$\therefore E = 11.1\ N/C$$

Question 3

3a (i) Volume charge Density

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

$$\therefore dQ = \rho dV$$

(ii) Surface charge Density

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

$$dQ = \sigma dA$$

(iii) Liniear charge Density

$$\lambda = \frac{dQ}{dL}$$

$$dQ = \lambda dL$$

3b. Electric potential dofference is the work done per unit charge against electrical force when a charge is transported from one point to the other.

$$dW = F.dL$$

$$F = -q_0 E$$

$$dW = -q_0 E dL$$

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

From definition

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

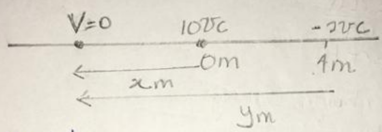
Comparing the two equations

$$q_0(V_B - V_A) = -q_0\int_A^B E\,dL$$

$$(V_B - V_A) = \int_A^B E\,dL$$

$$(V_B - V_A) = -\int_A^B E\,dL$$

3c.



$ym = xm + 4m$

$$V = K\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

$Q_1 = 10\mu C \quad r_1 = x$

$Q_2 = -2\mu C \quad r_2 = x + 4$

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

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

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

$$2\times10^{-6}x = 10\times10^{-6}x + 40\times10^{-6}$$

$$-10\times10^{-6}x + 2\times10^{-6}x = 40\times10^{-6}$$

$$-8\times10^{-6}x = 40\times10^{-6}$$

$$x = -5$$

when $x = -5$, $y = -5+4$, $y = -1$

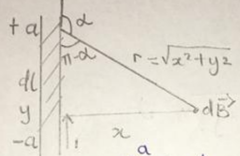
$\therefore$ Distance are $\underline{-5 \text{ and } -1}$

Section B

Question 5

5a. Biot-Savart Law $= d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \hat{r}}{r^2}$

5b.



$$\int d\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{d\vec{l} \times \hat{r}}{r^2}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{d\vec{l}\,\sin\theta}{r^2}$$

$$\sin\theta = \sin\pi-\alpha = \frac{x}{\sqrt{x^2+y^2}}, \quad r=\sqrt{x^2+y^2}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{d\vec{l}\,\sin(\pi-\alpha)}{r^2}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{d\vec{l}\,\sin(\pi-\alpha)}{(x^2+y^2)^{1/2\times 2}}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{d\vec{l}\,\sin(\pi-\alpha)}{(x^2+y^2)}$$

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

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

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

$$\vec{B} = \frac{\mu_0 I x}{4\pi}\int_{-a}^{a} \frac{1}{(x^2+y^2)^{3/2}}\, dl$$

$$dl = dy$$

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

Using special integrals

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

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

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

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

when $a \to \infty$ (a starts to become large)

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

$$B = \frac{\mu_0 I}{4\pi}\left[\frac{2a}{x\,a}\right] = \frac{\mu_0 I}{\cancel{4}_2\pi}\left[\frac{\cancel{2}a}{x}\right]$$

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

but $x = r$

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

Question 6

6a. The coil in this case called the pickup coil is placed near the vibrating guitar string which is made of a metal that can be magnetized. A permanent magnet inside the coil magnetize the portion of the string nearest to the coil. When the string vibrates at some frequency, its magnetised 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, which produces the sound waves we hear.

6b. (i) $\text{Emf} = |\mathcal{E}| = N \frac{d\Phi_B}{dt}$

$N = 300$ turns

$d\Phi_B = BA\cos\theta$

$d\Phi_B = 10 \times 0.1m \times 0.1m \cos\theta$

$d\Phi_B = 0.1$

$d\Phi_B = 0 \times 0.1 \times 0.1 \times \cos\theta$

$= 0$

$dt = 0.5sec$

$\text{emf} = 300 \frac{(0.1 - 0)}{0.5}$

$= 300 \frac{(0.1)}{0.5}$

Induced emf $= \underline{60 \text{ volts}}$

(ii) Induced current

$V = IR$

$I = V/R$

$\therefore V = 60$ volts, $R = 2.0\Omega$

$I = \frac{60 \text{ volts}}{2\Omega} = \underline{30 \text{ Amperes}}$

i) Induced emf $= |\mathcal{E}| = N \dfrac{d\Phi_B}{dt}$

$\Phi_B = BA\cos\theta$

$|\mathcal{E}| = N \dfrac{d\, BA\cos\theta}{dt}$

Induced emf $=$ current $\times$ resistance

$= 0.1A \times 8$ ohms

$= 0.8$ volts

Area $= 0.05\,m \times 0.08\,m = 4\times10^{-3}\,m^2$

$\cos\theta = 1$, $N = 75$ turns

$\therefore$ $|\mathcal{E}| = N \dfrac{dBA}{dt}$

0.8 volts $= 75 \times 4\times10^{-3}\,m^2 \dfrac{dB}{dt}$

$\dfrac{dB}{dt} = \dfrac{0.8 \text{ volts}}{75\times4\times10^{-3}\,m^2}$

$\dfrac{dB}{dt} = 2.667$ volts$/m^2$

$\therefore$ The rate of B to induce current of 0.1A

$\dfrac{dB}{dt} = 2.667$ volts$/m^2$