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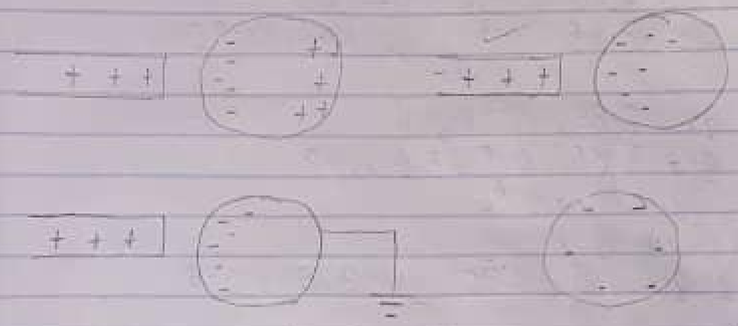
Course: Physics 102
Dept: MBBS
M/N: 19/mb01/122

1) (a) Explain with a diagram how you can produce a negatively charged sphere by induction



A positively charged rubber rod is brought near an uncharged conducting sphere that is insulated. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on the sphere by some electrons (-ve) move to the side farthest from the rod. If a conducting wire is put the +ve electrons move to the earth and if the wire is removed, the sphere is left with a negative charge

(b) Each of two small spheres is charged positive by the combined charge being 5.0×10^{-5} C. If each sphere is repelled from the other by a force of 1.0N when the spheres are 2.0m apart, calculate the charge on each sphere

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

$F = 1.0N \qquad d = 2.0m$

$F = \frac{k q_1 q_2}{r^2} = \frac{Fr^2}{k} = q_1 q_2$

$$B = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}} \times \hat{\imath}$$

Case: At the centre of the loop

$$B = \frac{\mu_0 I R^2}{2(R^2)^{3/2}} \times 1 = \frac{\mu_0 I R^2 \hat{\imath}}{2R^3}$$

$$= \frac{\mu_0 I \hat{\imath}}{2R}$$

Second method

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

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

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

From the diagram $r^2 = x^2+y^2$

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

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

Substitute (ii) into (i)

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

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

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

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

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

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

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

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Alex B Bryggs 19/March/2022

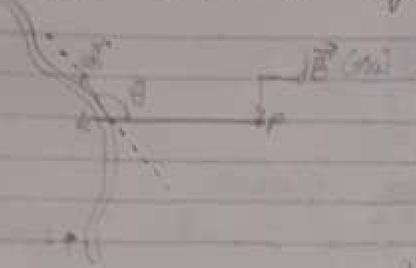
5) State the Biot - Savart Law

Biot - Savart law states that 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

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

Note $\mu_0 = 4\pi \times 10^{-7}\ Tm/A$ (permeability of free space)

5b) Use the Biot - Savart law, show that magnitude of field carrying conductor is given as $B = \frac{\mu_0 I}{2\pi r}$



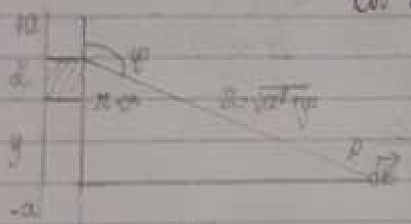
$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin\theta}{r^2}$$

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

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

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

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



Note that substitution

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

$$\cos\theta = \frac{R}{r} = \frac{R}{\sqrt{x^2+R^2}}$$

Note $dB_x = dB\cos\theta = \frac{\mu_0}{4\pi x^2 + R^2} \times Idl \times \frac{R}{\sqrt{x^2+R^2}} = \frac{\mu_0 I dl}{4\pi} \times \frac{R}{\sqrt{x^2+R^2}}$

The summation of circumference in the loop $2\pi R$. Hence the magnitude field at point P caused by the entire loop is

$$B = B_x l = \frac{\mu_0 I (2\pi R)}{4\pi} \times \frac{R}{(x^2+R^2)^{1/2}} \times C$$

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

$q_1 q_2 = 4.44 \times 10^{-10} C$

$q_1 + q_2 = 5.0 \times 10^{-5} C$ - ①

$q_1 q_2 = 4.44 \times 10^{-10}$

$q_1 = 5.0 \times 10^{-5} - q_2$ - ⑪

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

$5.0 \times 10^{-5} q^2 - q_2^2 = 4.4 \times 10^{-10} C$

$q^2 - 5.0 \times 10^{-5} q_2 + 4.44 \times 10^{-10} = 0$

$q_2 = 3.85 \times 10^{-5} C$ or $1.15 \times 10^{-5} C$

Put $q_2 = 3.85 \times 10^{-5} C$ (eqn 1)

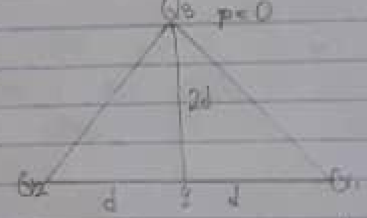
$q_1 + 3.85 \times 10^{-5} = 5.0 \times 10^{-5}$

$q_1 = 1.15 \times 10^{-5} C$

Put q_1 into eq 1

$\underline{q_1 = 1.15 \times 10^{-5} C \quad q_2 = 3.85 \times 10^{-5}}$

c) Three charges were positioned as shown in the figure below $Q_1 = Q_2 = 8\mu C$ and $d = 0.5m$, determine the electric field at P is zero



$$E = \frac{F}{q}$$

$$F = \frac{Q_2 \times Q_1 \times k}{r^2}$$

$$F = \frac{(8 \times 10^{-9})^2 \times 9 \times 10^9}{(1)^2} = 6.4 \times 10^{-11}$$

$F = 6.4 \times 10^{-11} N$

$F_e = Q_1 \times Q_2 / d^2 \times k$

$$F_{21} = \frac{9 \times 10^9 \times (8 \times 10^{-6})^2}{1m^2}$$

$F_{21} = 72 \times 10^{-3} N$

$E_1 = 9 \times 10^9 \times 8 \times 10^{-6} / (0.5)^2 =$

$2.88 \times 10^5 N/C = E_2$

$E_{net} = E_1 + E_2 = 5.76 \times 10^5 N/C$

$$q = \frac{F}{E} = \frac{72 \times 10^{-3}}{5.76 \times 10^5} = \underline{12.5 \times 10^{-8} C}$$

Alex B Briggs 19/mb01/122

4) What is magnetic flux?
Magnetic flux is what generates the field around a magnetic material. It is the measurement of the total magnetic field which passes through a given area. Its SI unit is Weber (Wb) or Volt-seconds. It consists of photons

4) An electron with a rest mass of 9.11×10^{-31} kg moves in a circular orbit of radius 1.4×10^{-7} m in a uniform magnetic field of 3.5×10^{-1} Wb/m perpendicular to the speed with which electrons moves. Find the cyclotron frequency of the moving electron

$f = \frac{qB}{2m\pi}$ $m = 9.11 \times 10^{-31}$ kg $q = 1.6 \times 10^{-19}$ C

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

$B = 3.5 \times 10^{-1}$ Wb/m^2 $\theta = 90°$

$f = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1} \times 7}{2 \times 9.11 \times 10^{-31} \times 22}$

$= \cancel{3.928 \times 10^{-10}}$ rad/s =

$f = \cancel{3.93 \times 10^{10}}$ rad/s

$f = \cancel{3.93 \times 10^{10}}$ rad/s

3.92×10^{-19}

4.0084×10^{-29}

$= 0.9779 \times 10^{10}$

normal frequency = 9.779×10^{9} Hertz

Cyclotron frequency

$\omega = \frac{qB}{m}$

$\omega = \frac{1.6 \times 10^{-19} \times 0.35}{9.11 \times 10^{-31}}$

$\omega = 6.147 \times 10^{20}$

cyclotron frequency

6.75×10^{10} rad/s

5) We were given m as 9.11×10^{-31} kg (mass of electron), radius = 1.4×10^{-7} m and $B = 3.5 \times 10^{-1}$ Wb/m^2. We were asked to find the cyclotron frequency which is the angular frequency. The formula also the inverse of the period $T = 2\pi m/qB$ where $f = 1/T = qB/2\pi m$. However $\omega = qB/m$ (which shows cyclotron frequency). It is called cyclotron frequency because it is the frequency of an oscillator called cyclotron.

Recall, ω = angular speed

$\omega = \frac{qB}{m}$

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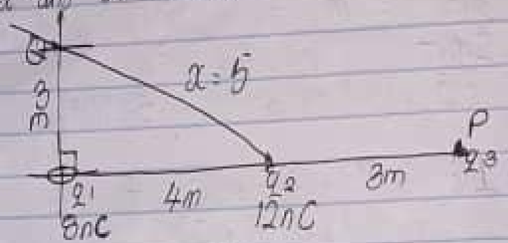
2a) Distinguish between the term electric field and electric field intensity

i) An electric field is a region of space in which an electric charge will experience an electric force.

ii) Electric field intensity / Electric field strength is defined as the force per unit charge. It is mathematically written as

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

2b) A positive charge $Q_1 = 8nC$ is at the origin, and a second positive charge $Q_2 = 12nC$ is on the x-axis at $x = 4m$



$$E_1 = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = \frac{72}{49}$$

$$= 14.694\ N/C$$

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

$$E_{net} = E_1 + E_2$$

$$= 0.46 + 12)\ N/C = 13.5N/C$$

E at Point Q on the y axis at y = 3m due to charge

$$c^2 = a^2 + b^2$$

$$c^2 = 4^2 + 3^2 \quad c = 5$$

$$E_2 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32N/C$$

$$E_1 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8N/C$$

2b)

Vector	angle	x-comp	y com
$E_1 = 8N/C$	90^0	$\cos 90 \times 8 = 0$	$\sin 90 \times 8 = 8$
$E_2 = 4.32$	36.87^o	$3.45\ N/C$	$\cos 36.87 \times 4.32 = 2.59$
		$3.45N/C$	$10.59N/C$

$E_{net} = \sqrt{\Sigma E_x^2 + \Sigma E_y^2}$

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

$E_{net} = 11.12N/C$