Wale-Fadine Oluwatunmise Benita
Medicine and Surgery
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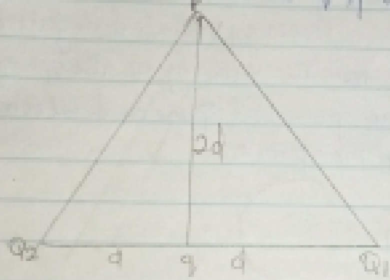
PHY 102

Section A

1a) Explain with the aid of a diagram how you can produce a negatively charged sphere by method of induction

b) Each of two small spheres is charged positively, 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.

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



3) State the formulation of the following identities of charge: i) Volume charge density ii) Surface charge density iii) Linear charge density

b) Explain with appropriate equations, the electric potential difference

c) Two point charges $Q_1 = 10\mu C$ and $Q_2 = -2\mu C$ are arranged along the x-axis at $x = 0$ and $x = 4m$ respectively, find the position along x-axis where $V = 0$

Section B

4)a) What is Magnetic flux? b) 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} weber/meter square, perpendicular to the speed with which electron moves. Find the cyclotron frequency of the moving electron.

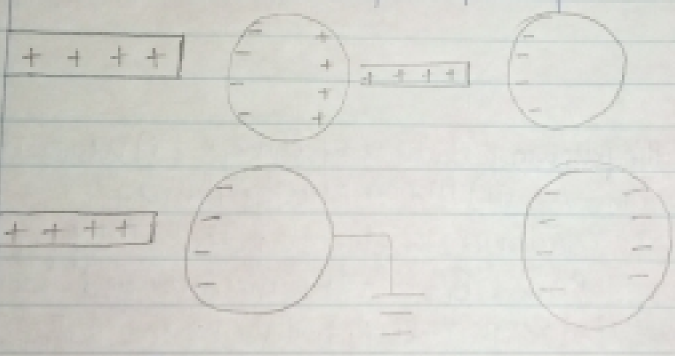
5a) State the Biot Savart Law

b) Using the Biot Savart Law, show that the magnitude of the magnetic field of a straight current carrying conductor is given as

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

SOLUTIONS

1a) Charging by induction: Electric charges can be obtained on an object without touching it by a process called electrostatic induction. Consider a positively charged rubber rod brought to a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to ground as shown below. The repulsive force between the protons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some protons move to the side of the sphere farthest away from the rod. The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of protons away from this location. If a grounded conducting wire is then connected to the sphere, some of the protons leave the sphere and travel to the earth. If the wire to ground is then removed, the conducting sphere is left with an excess of induced negative charge. Finally, when the rubber rod is removed from the vicinity of the sphere, the induced negatively charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.



1b $K = 9\times10^{9}$

$q_1 = q_2 = 5\times10^{-5}C$

$F = 1N$

$d = 2m$

Recall that $K = 9\times10^{9}$

$$F = \frac{Kq_1q_2}{r^2}$$

$$F = \frac{9\times10^{9}\times(q_1q_2\,5\times10^{-5})}{2^2}$$

$4 = 9\times10^{9} \times 5\times10^{-5} q_1 + 9\times10^{9} q_2$

$4 = 4.5\times10^{5} q_1 + 9\times10^{9} q_2$

$9\times10^{9} q_2 - 4.5\times10^{5} q_1 + 4 = 0$

$q_1 = 0.0000111\,C$

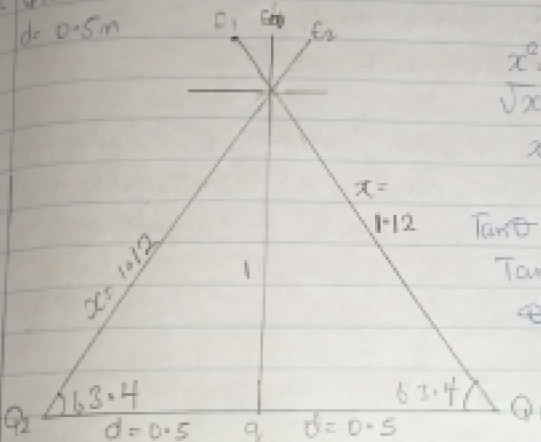
$q_2 = 0.0000088\,C$

$q_1 = 1.11\times10^{-5}\,C$

$q_2 = 8.8\times10^{-5}\,C$

c) $Q_1 = Q_2 = 8\,\mu C$

$d = 0.5\,m$



$x^2 = 1^2 + 0.5^2$

$\sqrt{x} = \sqrt{1.25}$

$x = 1.12$

$\tan\theta = \frac{o}{a}$

$\tan\theta = 1/0.5 = 2$

$\theta = \tan^{-1}(2)$

$\theta = 63.4$

$E_1 = \frac{Kq_1}{r_1^2} = \frac{9\times10^{9}\times8\times10^{-6}}{(1.12)^2} = 5739.795918$

$E_2 = \frac{Kq_1}{r_2^2} = \frac{9\times10^{9}\times8\times10^{-6}}{(1.12)^2} = 5739.795918$

$Kq = \frac{Kq}{r^2} = \frac{9\times10^{9}\times q}{1} = 9\times10^{9} q$

Vector	Angle	x - comp	y - com
$E_1 = 5739.79518$	63.4°	$E_1 \times \cos\theta$ -2570.045785	5132.262889
$E_2 = 5739.79518$	63.4	2570.045785	5132.262889
$E_q = 9\times10^{9} q$		$E_q\cos 90 = 0$	$9\times10^{9} q$
		$\Sigma x = 0$	$\Sigma y = 10264.52568$

Magnitude $= \sqrt{(\Sigma x)^2 + (\Sigma y)^2}$

$E_q = \sqrt{(0)^2 + (10264.52568)^2}$

$0 = 9\times10^{9} q + 10264.52568$

$$q = \frac{-10264.52568}{9\times10^{9}}$$

$q = 1.140502853 \times 10^{-6}$

$\therefore q = 11.4\,\mu C$

36.

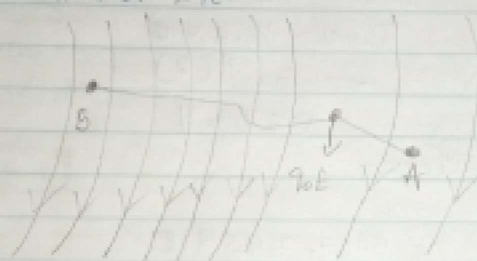
i) Volume charge density, $\rho = \frac{dQ}{dv}$, $dQ = \rho dv$

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

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

38. Electric potential difference dr

It is the work done per unit charge against electrical forces when a charge is transported from one point to the other. It is a scalar quantity and is measured in V or J/C.



Suppose a test charge q_0 is moved from point A to point B along an arbitrary path inside an electric field E. The electric field $\vec{E}$ exerts a force $F = q_0E$ on the charge as shown in the diagram. To move the test charge from A to B at constant velocity, an external force of $F = q_0E$ must act on the charge.

$dw = f \cdot dl$ --- 1)

$F = q_0 E$ --- 2)

Substitute (2) in (1)

$dw = q_0 E\, dl$ --- 3)

Work done in moving the test charge from A to B is

$W(A \to B)_{Ag} = -q_0 \int_A^B E\, dl$ --- 4)

$V_B - V_A = \frac{W(A \to B)_{Ag}}{q_0}$ --- 5)

Putting eq (4) in (5) $V_B - V_A = -\int_A^B E\, Dl$ --- 6)

Section B

4a magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces.

4b $m = 9 \times 10^{-31}$ kg

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

$B = 3.5 \times 10^{-1}$ meter^2

Cyclotron frequency = Angular Speed

$$W = \frac{v}{r} = \frac{qB}{m}$$

$$W = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$$

$$W = 62.22\ T^{-1}$$

Mass of the electron $= 9.11 \times 10^{-3}$ kg

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

Magnetic field $= 3.5 \times 10^{-1}$ W

Recall that angular speed is $W = \frac{v}{r} = \frac{qB}{m}$

Substituting we have $\frac{q_B}{m} = \frac{6 \times 10^{-10} \times 3.5 \times 10^{-10}}{9.11 \times 10^{-31}} = 6.22.22\,T^{-1}$

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 radius (r^2).

$$dB = \frac{\mu_0}{4\pi} \frac{I\, dl \times r}{r^2}$$

μ

5b $B = \frac{\mu_0}{4\pi} \int_{-a}^{a} \frac{dl \sin\phi}{r^2}$

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

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

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

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

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

Substituting 2 into 1 we have

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

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

$dl = dy$

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

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

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

μ_0-

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

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

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

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