SALAWU-ERIH ELIZABETH
19/MHS01/393
Medicine and surgery
PHY 102
09/04/2020

Assignment

SECTION A
(Ques 1&3)

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

When a negatively charged rubber rod is brought near an uncharged conducting sphere that is insulated therefore there are no conducting path to ground. The repulsive forces between the electrons in the rod and those in the sphere will result in a redistribution of charges where some electrons move to the side of the sphere farthest away from the rod. The region of the sphere near the negatively charged rod has an excess positive charge due to migration of electrons from that location. If a grounded conducting wire is then connected to the sphere, some of the electrons will leave the sphere and travel to Earth. When the wire to ground is removed, the conducting sphere is left with an excess of induced positive charge.

Ultimately, when the rubber rod is removed from the surroundings of the sphere, the induced positive charge remains on the ~~grg~~ ungrounded sphere and becomes uniformly distributed over the surface of the sphere.

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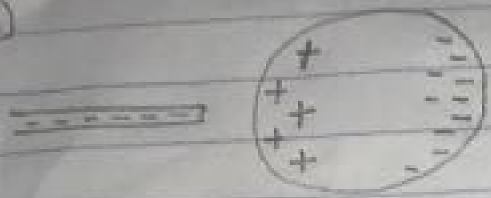

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3

4

1b) 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.

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

$$= \frac{1\times(2)^2}{(9\times10^9)} = 4.44444444\times10^{-10}$$

$$\simeq 4.44\times10^{-10}\ C^2$$

Now we have two equations for the two unknowns q_1 and q_2

$$q_2 = 5.0\times10^{-5} - q_1$$

$$q_1 q_2 = 4.44\times10^{-10}$$

$$q_1(5.0\times10^{-5} - q_1) = 4.44\times10^{-10}$$

$$= (5.0\times10^{-5} q_1 - q_1^2) = 4.44\times10^{-10}$$

$$= q_1^2 - (5.0\times10^{-5} q_1) + 4.44\times10^{-10} = 0$$

A quadratic formula

$$q_1, q_2 = \frac{(5\times10^{-5}) \pm \sqrt{(5\times10^{-5})^2 - 4(4.44\times10^{-10})}}{2}$$

$q_1 = 3.84\times10^{-5}$ C , $q_2 = 1.16\times10^{-5}$ C

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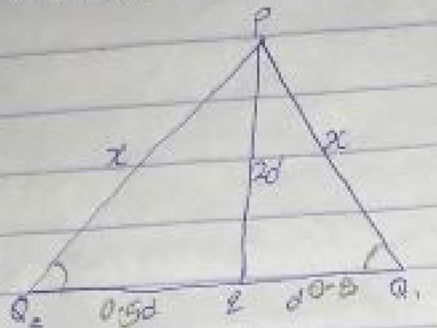
1 C) Three spheres are positioned as shown in the figure. If $Q_1 = Q_2 = 8\mu C$ and $d = 0.5m$, determine q if the electric field at P is zero.



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

$x^2 = 1.25$

$x = \sqrt{1.25}$

$x = 1.12$

$E_1 = \frac{kq_1}{r^2} = \frac{(9\times10^9)\times(8\times10^{-6})}{(1.12)^2} = 57.4\times10^3\ N/C$

$E_2 = \frac{(9\times10^9)\times(8\times10^{-6})}{(1.12)^2} = 57.4\times10^{-3}\ N/C$

$E_q = \frac{(9\times10^9)\times q}{1} = 9\times10^9 q$

Vector	Angle	x-component	y-component
$E_1 = 57.4\times10^3$	$E_1 = 63.4°$	$(57.4\times10^3)\times\cos(63.4)$ $= 25701.372\ N/C$	$(57.4\times10^3)\times\sin(63.4)$ $= 51324.453\ N/C$
$E_2 = 57.4\times10^{-3}$	$E_2 = 63.4°$	$57.4\times10^{-3}\times\cos(63.4)$ $= 25701.372\ N/C$	$(57.4\times10^3)\times\sin(63.4)$ $= 51324.453\ N/C$
$E_q = 9\times10^9 q$	90°	$9\times10^9 q\times\cos(90) = 0$	$9\times10^9 q\times\sin(90)$ $= 9\times10^9 q\ N/C$
		$\Sigma E_x = 51402.744$	$\Sigma E_y = 102648.906$

magnitude $= \sqrt{(E_x)^2 + (E_y)^2}$

$E_q = \sqrt{(0)^2 + (102648.906)^2}$

since $E_q = 0$

$0 = (9\times10^9 q) + (102648.906)$

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Making q the subject =

$$q = \frac{-102648.906}{9 \times 10^{9}}$$

$$q = -1.1405434 \times 10^{-5}$$

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

3a, State the formulation of the following (densities) of charges:

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

3b, Explain with appropriate equations, the electric potential difference.

The electric potential difference between two points in an electric field is the work done per unit charge against electrical forces when a charge is transported from one point to another point.

It is measured in Volt (V) or Joules per Coulomb (JC^{-1}). It is also a Scalar quantity.

Formula for electric potential difference is:

$$\Delta V = \frac{F.d}{q}$$

V = Potential difference (voltage)

F.d = Work done (force x distance)

q = charge

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3c, 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 the x-axis at where $V = 0$

$V = \frac{KQ}{r}$

Q_1

~~[illegible]~~

to the left $(x < 0)$

~~[illegible]~~ $-2x = 10(4+x)$

$x = \frac{-40}{8} = -5m$

∴ in between

~~[illegible]~~ $0 = 40 - x - 2x$

→ This is not in between the points

∴ to the right

~~[illegible]~~ $10x - 40 = 2x$

$8x = 40$ or $x = 5m$

SECTION B

(Ques 4 & 5)

4 a) What is magnetic flux?

Magnetic flux can be defined as the strength of the magnetic field which can be represented by line of forces. It is represented by the symbol Φ, Mathematically given as $\Phi = B.dA$

4 b, ~~[illegible]~~ $M = 9 \times 10^{-31} kg$

$r = 1.4 \times 10^{-9} M$

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

∴ Cyclotron frequency = angular speed

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

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$$W = \frac{qB}{m} = \frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9\times10^{-31}}$$

$\therefore W = 6.2222222222\times10^{10}$

$\therefore W = 6.22\times10^{10}\ T^{-1}$

4c, In the question we were given parameters such as
i, mass of the electron $= 9.11\times10^{-31}$ kg
ii, radius of 1.44×10^{-7} m
iii, magnetic field of 3.5×10^{-1} Wb/m^2
then asked to calculate the cyclotron frequency which is equal to the angular speed. The cyclotron frequency is a frequency of an accelerator called cyclotron.
Recall that angular speed $= W = \frac{v}{r} = \frac{qB}{m}$
substituting it into the equation, we have;

$$\frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9.11\times10^{-31}} = 6.22\times10^{-10}\ T^{-1}$$

5a, State the Biot - Savart Law
The 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 the square of radius (r^2)".
It can be represented mathematically as:

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

$\mu_0 \rightarrow$ a constant called permeability of free space
$\mu_0 = 4\pi\times10^{-7}\ \frac{T.m}{A}$

$\vec{B} \rightarrow$ Wbm^{-2}

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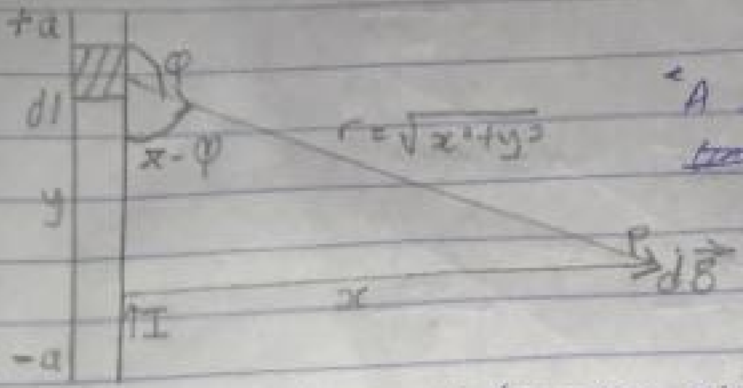
5b)



"A section of a straight ~~line~~ current carrying conductor"

Applying Biot-Savart law, at find the magnitude of the field $d\vec{B}$

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

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

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

From the diagram, $r^2 = x^2+y^2$ (Pythagoras theorem)

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

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

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

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

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

As $dl = dy$ $\therefore$

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

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

Using special integrals:-

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

Continuation:

∴ Equation (***) becomes:-

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

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

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

When the length 2a of the conductor is very great compared to its distance x from point P, it is said to be indefinitely long. = $(x^2+a^2)^{1/2} \simeq a$, as $a \to \infty$

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

In a physical situation, we have axial symmetry about the y-axis ∴ ~~B at all point~~ magnitude of B at all points in a circle of radius r, around the conductor is:-

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