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PHY 102

1a.) Charging by Induction

Electric chargers can be obtained on an object without touching it by a process called ~~Electr~~ ELECTROSTATIC INDUCTION consider a positively charged rubber rod brought near a neutral (uncharged conducting sphere that is insulated so that there is no conducting path to the ground as shown below. The repulsive force between the protons in the rod and those in the sphere cause a redistribution of charges in the sphere so that some protons move in the sides of the sphere farthest away from the rod

The region of the sphere nearest the positively charged rod had an excess of negative charges because of the migration of protons away from this location. If is grounded conducting wire is then connected to the sphere as in 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 negatively induced charge remains on the ungrounded sphere and become uniformly distributed over the surface of the sphere

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

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

$F = 1N$

$d = 2m$

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

$1 = \frac{9\times10^{9}(q_1q_2\ 5\times10^{-5})}{2^2}$

$4 = 9\times10^{9} \times 5\times10^{-5} q_1 + 9\times10^{9} q^2$

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

$9\times10^{9} q_2 + 4.5\times10^{5} q_1 = 4.0$

$q_2 = 0.0000111c$

$q_1 = 1.11\times10^{-5}c$

$q_2 = 0.000038c$

$q_2 \simeq 3.8\times10^{-5}c$

1c $q_1 = q_2 = 8\mu$
$d = 0.5m$

Determine q if electric field at point P is zero

$\tan\theta = \frac{opp}{adj} = \frac{1}{0.5}$

$\tan\theta = 2$

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

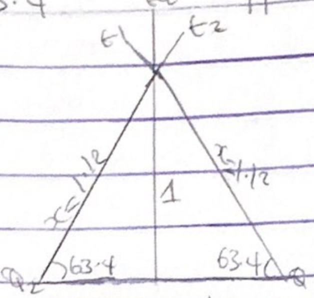
$\theta = 63.4$

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

$x^2 = 1.25$

$x = \sqrt{1.25}$

$x = 1.12$



d=0.5 d=0.5

$E_1 = E_2$

$E_1 = \frac{kq}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2}$

5939.7959

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

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

$0_q = \sqrt{0^2 + 10264.52568^2}$

$0 = 9\times10^9 q + ~~1026~~ 1026$

$q = \frac{10264.52568}{9\times10^9} = 1.140028 \times 10^{-8}$

$q \approx 1.14\mu C$

VECTOR	ANGLE	x-comp	y-comp
$E_1 = 5739.795918$	63.4°	cos 63.4 = 2570.045785	Sin 5132.262839
$E_2 = 5739.795918$	63.4°	2570.045785	5132.262859
$E_q = 9\times10^9 q$	90°	$E_q \cos\theta = 0$	~~sin θ~~ 10264.52568

3a:) volume charge density

$\rho = \frac{dq}{dv} \rightarrow dQ = \rho dV$

ii.) Surface charge density

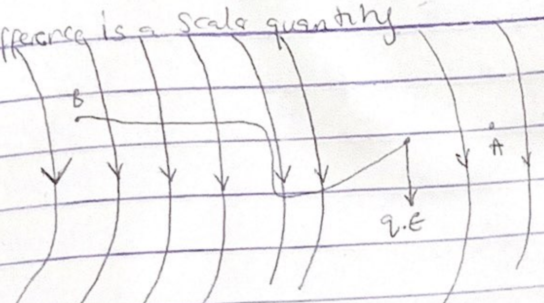
$\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

iii.) Linear charge density

$\lambda = \frac{dQ}{dl} \rightarrow dQ = \lambda dl$

Electrical potential difference

The electrical potential difference between two points in an electrical field can be defined as the workdone per unit charge against electrical forces when a charge is transported from one point to another. It is measured in volt (V) or Joules per Columb (J/C) electrical potential difference is a scalar quantity



consider the diagram, suppose a test charge q_0, is moved from point A to B along an arbitrary path inside in an electric field, E. The electrical field exerts a force, $f = q.E$ on the charge as shown. To move the charge from A to B constant velocity an external force of $f = -q_0 E$ must act on the charge. Therefore the elemental workdone, dw is given as

$dW = F.dl$ ... (1)

$F = q_0 E$ ... (2)

substituting eq (2) in eq (1) yields

$dw = -q_0 E dl$

Then total workdone in moving the test charge from A to B is:

$W(A \rightarrow B)_{ext} = -q_0 \int_A^B E dl$

from the definition of electrical potential difference,

$$VB - VA = \frac{U(A \to B) \Delta q}{q_0} \quad \ldots (5)$$

Putting eq(4) in (5) yields

$$VB - VA = -\int_A^B f\,dL \quad \ldots (6)$$

SECTION B

4a Magnetic flux is defined as the Strength of the magnetic field which can ~~be~~ be represented by line of forces. It is represented by Φ. $\Phi \cdot B \cdot dA$

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

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

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

cyclotron frequency = angular frequency

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

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

$$w = 62222222222.22222 T^{-1}$$

4c In the question, we were given parameters such as

i.) mass of the electron = ~~9 x~~ 9.11×10^{-31} kg

ii.) A radius of 1.4×10^{-9} m

iii.) magnetic ~~flux~~ field of 3.5×10^{-1} weber/m^2

and we are asked to find the cyclotron frequency which is equal or the same thing as angular speed. It is cyclotron frequency because it is a frequency of an accelator called cyclotron

Recall that

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

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

$w = 62222222222.222227^{-1}$

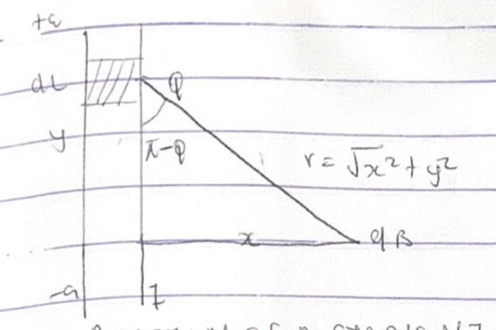
Since the cyclotron frequency is equal to angular speed, the cyclotron frequency is $62222222222.22222T^{-1}$, having a unit of $1/T$ which is equal to the unit of frequency.

5c.) 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 the radius. It can be represented mathematically by

$$\vec{dB} = \frac{\mu_0 I \vec{dl} \times \hat{r}}{4\pi r^2}$$ where μ_0 is a constant called permeability

$\mu = 4\pi\times10^{-7}$ $T = \frac{m}{A}$

The Unit of $\vec{B}$ is weber / metre square



A SECTION OF A STRAIGHT CURRENT CARRYING CONDUCTOR

Applying the Biot Savart law, we find the magnitude of the field $\vec{dB}$

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

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

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

from diagram

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

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

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

Substituting (ii) into (i)

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

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

Recall $dl = dy$

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

Using Special Integrals:

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

Eq (iii) becomes

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

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

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 a is much large than x

$$(x^2+a^2)^{1/2} \simeq a$$

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

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

$$B = \frac{\mu_0 I}{2\pi r} \quad (*)$$

Equation (*) defines the ~~magnitude~~ of the ~~magnetic~~ magnitude of the magnetic ~~magnitude~~ field flux density B near a long, straight current carrying conductor.