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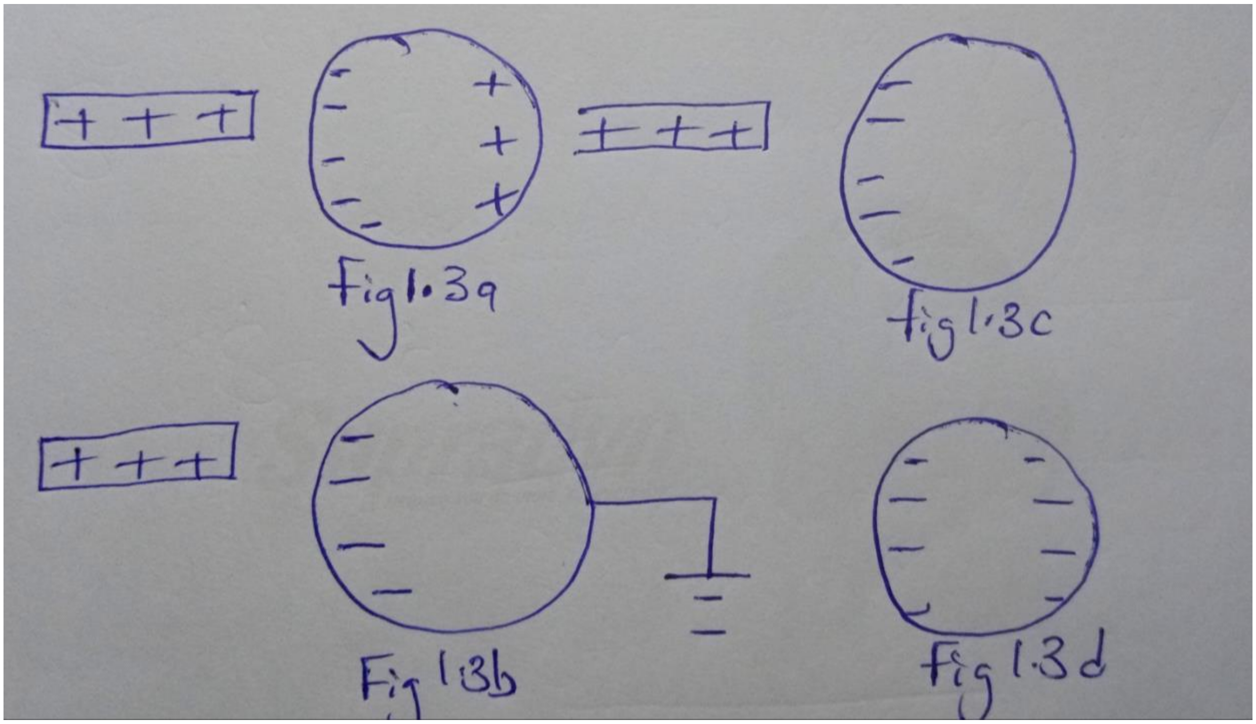
SECTION A

1a. Charging by Induction: A body can also receive charge by electrostatic induction, without touching an object. If a positively charged rubber rod is brought near a neutral conducting sphere which is insulated so that there is no conducting path to the ground. 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 (fig1.3a) The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of protons away from its location. Let's say a grounded conducting wire is connected to the sphere, as in (fig. 1.3b), some of the protons leave the sphere and travel to the earth. If the wire to ground is then removed (fig. 1.3c), the conducting sphere is left with an excess of induced negative charge. Lastly, when the rubber rod is removed from the vicinity of the sphere (fig. 1.3d) the induced negatively charge

remains on the underground sphere and becomes uniformly distributed over the surface.

Diagram:



$K = 9\times10^{9}$

b) $Q_1 + Q_2 = 5\times10^{-5}\,C$

$F = 1N$

$d = 2m$

Calculate the charge on each sphere?

Recall $k = 9\times10^{9}$

$F = \frac{kQ_1Q_2}{r}$

$1 = \frac{9\times10^{9} \times (Q_1 \; Q_2 \; 5\times10^{-5})}{2^2}$

$4 = 9\times10^{9}\times5\times10^{-5}Q_1 - 9\times10^{9}Q_2$

$4 = 4.5\times10^{5}Q_1 - 9\times10^{9}Q_2$

$9\times10^{9}Q_2 - 4.5\times10^{5}Q_1 + 4 = 0$

$Q_1 = 0.0000111\,c$

$Q_2 = 0.000038\,c$

$\sim Q_1 = 1.11\times10^{-5}\,c$

$\sim Q_2 = 3.8\times10^{-5}\,c$

1c. $Q_1 = Q_2 = 8u\,C$

$d = 0.5m$

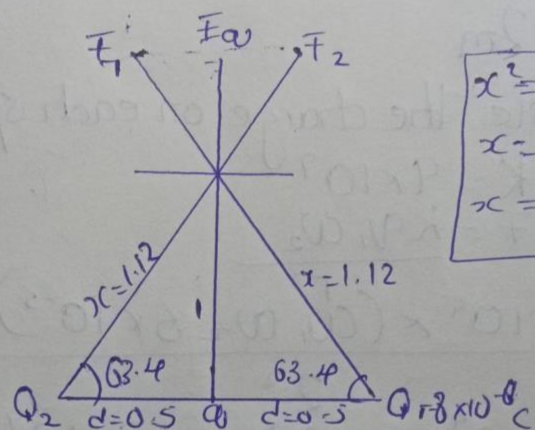
determine Q if electric field at a point P is zero

$\theta =$

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

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

$\theta = 63.4$



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

$x = \sqrt{1.25}$

$x = 1.12$

$E_1 = \frac{KQ_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 5739.795918$

$E_2 = \frac{KQ_2}{r_2^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2} = 5739.795918$

$E_Q = \frac{KQ}{r^2} = \frac{9\times10^9 \times Q}{1} = 9\times10^9 Q$

Vector	angle	x-comp	y-comp
$E_1 = 5739.795918$	$63.4°$	$E\times\cos\theta$ -2570.0458	$E_1\times\sin\theta$ 5132.26283
$E_2 = 5739.795918$	$63.4°$	2570.0458	5132.26385
$E_Q = 9\times10^9 Q$	$90°$	$E_Q\cos\theta = 0$ $E_x = 0$	$9\times10^9 Q$ $E_y =$ 10264.5256

1c. continued

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

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

Since $\Sigma q = 0$

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

make q subject of the formula

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

$$q = 1.140502853\times10^{-10}$$

$$\approx q = 11.\mu 4 C$$

3a)

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

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

iii) Linear charge density, $\lambda = \frac{dQ}{dL}$, in $dQ = \lambda\, dL$

3b. ELECTRIC POTENTIAL DIFFERENCE

The electric potential difference between two points in an electric field can be defined as the work done per unit charge against electrical forces when a charge is transported from one point to the other. It is measured in volt (v) or Joules per coulomb (J/C). Electric potential difference is a scalar quantity.

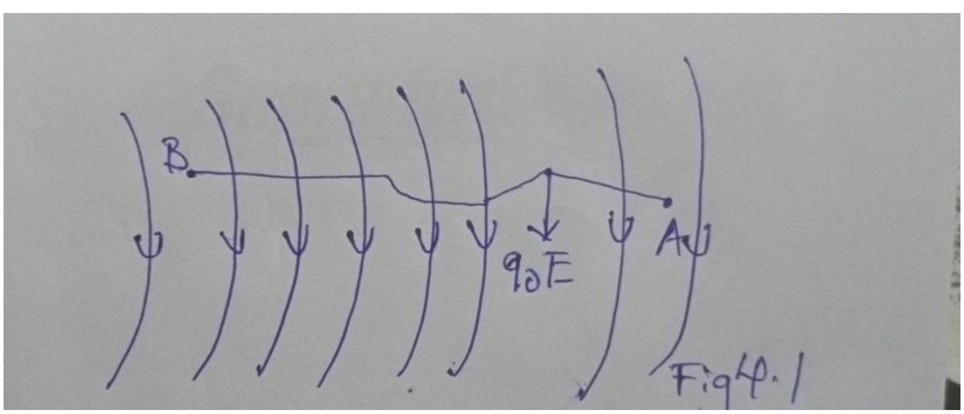


Fig4.1

Consider the diagram above, 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 E exerts a force F = q_0E on the charge as shown in fig 3.1. To move the test charge from A to B at constant velocity, an external force of F = -q_0E must act on the charge. Therefore, the elemental work done dW is given as:

$$dW = F.\,dl \quad ... \quad (1)$$

But

$$F = -q_0E \qquad ... \quad (2)$$

Substituting equation (2) in (1) yields

$$dW = -q_0EdL \ \ldots \ (3)$$

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

$$W(A\text{'n }B)_{Ag} = \int_B^A EdL \ \ldots \quad (4)$$

From the definition of electric potential difference, it follows that:

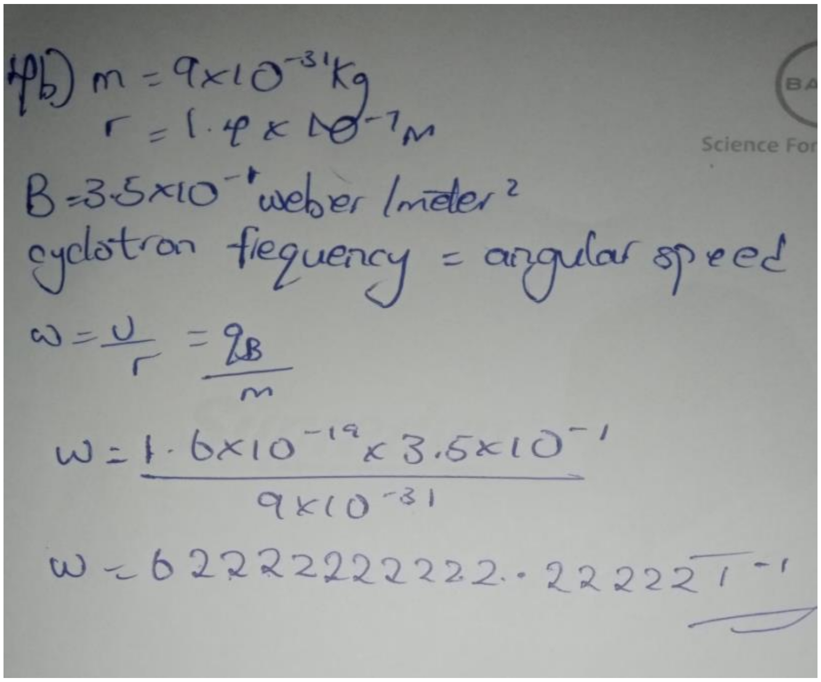
$$V_B - V_A = \frac{W(A'nB)Ag}{q0} \ \ldots \quad (5)$$ Putting equation (4) in (5) yields

$$V_B - V_A = -\int_A^B EdL \ \ldots \qquad (6)$$

SECTION B.

4a. magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces. It is represented by the symbol Φ.mathematically give

n as Φ=B. d A

4b. 

4b) $m = 9\times10^{-31}$ kg
$r = 1.4 \times 10^{-7}$ m
$B = 3.5\times10^{-1}$ weber/meter^2
cyclotron fiequency = angular speed
$\omega = \frac{v}{r} = \frac{qB}{m}$
$\omega = \frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9\times10^{-31}}$
$\omega = 62222222222.22222 T^{-1}$

4c. i.mass of the electron $=9.11\text{x}10^{-31}$ kg

ii.A radius of $1.4\text{x}10^{-7}$m

iii.magnetic field of $3.5\text{x}10^{-1}$weber\meter square

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

Recall that angular speed is given as $\omega=\frac{v}{r}=\frac{qB}{m}$

Substituting we have $\omega = \frac{v}{r} = \frac{1.6*10^{-10}*3.5*10\text{^}-10}{9.11*10\ \text{^}-31}$

$\frac{qB}{m} = \frac{1.6\times10^{-19}\text{x}3.5\text{x}10\text{^}-1}{9.11\text{x}10\text{^}-31}$=62222222222.22222$T^{-1}$

SO since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to =62222222222.22222^{T-1} , having a unit as 1\T which is equal to the unit of frequency dimensionally.

5b.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). It can be represented mathematically by

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

where μ_o is a constant called Permeability of free space.

$$\mu_o = 4\pi \times 10^{-7}\, T.\frac{m}{A}$$

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

5b. Magnetic Field of a Straight Current Carrying Conductor

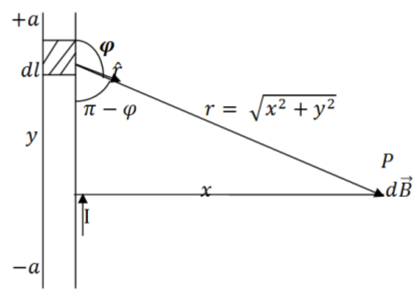


Fig 1: A section of a Straight Current Carrying Conductor

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

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

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

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

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

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

$$\text{But } \sin(\pi - \varphi) = \frac{x}{\sqrt{x^2 + y^2}} = \frac{x}{(x^2 + y^2)^{1/2}} \quad \ldots \qquad (**)$$

Substituting $(**)$ into $(*)$, we have

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

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

Recall $\quad dl = dy$

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

$$B = \frac{\mu_o Ix}{4\pi} \int_{-a}^{a} \frac{1}{(x^2 + y^2)^{3/2}} dy \quad \ldots \qquad (***)$$

Using special integrals:

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

Equation $(***)$ therefore becomes

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

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

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

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 larger than x,

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

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

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

$$B = \frac{\mu_o I}{2\pi r} \qquad \dots \qquad (\#)$$

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