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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 near 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 same 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, 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, 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 ungronded spher and becomes uniformly distributed over the surface of the sphare.

1b $K = 9 \times 10^9$

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

$F = 1N$

$d = 2m$

Calculate the Charge on each Sphere?

Recall that

$K = 9 \times 10^9$

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

$$1 = \frac{9 \times 10^9 \times (q_1 q_2 \; 5 \times 10^{-5})}{2^2}$$

$4 = 9 \times 10^9 \times 5 \times 10^{-5} q_1 + 9 \times 10^9 q_2$

$4 = 4.5 \times 10^5 q_1 + 9 \times 10^9 q_2$

It is a quadratic equation

$9 \times 10^9 q_2 - 4.5 \times 10^5 q_1 + 4 = 0$

$q_1 = 0.0000111c$

$q_2 = 0.000138c$

$\simeq$ ~~a~~ $\simeq q_1 = 1.11 \times 10^{-5} C$

$\simeq q_2 = 3.8 \times 10^{-5} C$

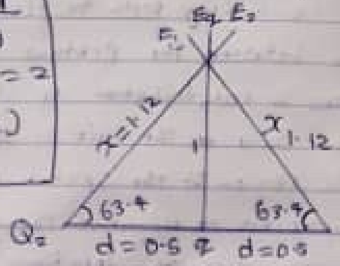
1c $Q_1 = Q_2 = 8 \mu C$

$d = 0.5 m$

determine ~~Q~~ ~~q~~ electric field at a point p is ~~E~~ zero

~~T~~ ~~θ~~

$$\boxed{\begin{aligned} \tan\theta &= \frac{opp}{Adj} \\ \tan\theta &= \frac{1}{0.5} = 2 \\ \theta &= \tan^{-1}(2) \\ \theta &= 63.4 \end{aligned}}$$



$$\boxed{\begin{aligned} x^2 &= 1^2 + 0.5^2 \\ \sqrt{x^2} &= \sqrt{1.25} \\ x &= \sqrt{1.25} \\ x &= 1.12 \end{aligned}}$$

$$E_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5739\ 795918$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{1.12^2} = 5739.795\ 918$$

$$E_q = \frac{kq}{r^2} = \frac{9 \times 10^9 \times q}{1} = 9 \times 10^9 q$$

Vector

	angle	x-comp	y-comp
$E_1 = 5739.795918$			
	63.4°	$E_1 \times \cos\theta$	5132.262539
	E_1	~~-2570.045765~~ -2570.045765	
$E_2 = 5739.795918$	63.4°	2570.045765	5131.262839
$E_q = 9 \times 10^9 q$	90°	$E_q \cos 90 = 0$	$9 \times 10^9 q$
		$E_x = 0$	$E_y = 10264.52568$

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

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

~~Since~~ Since $E = 0$

~~$0 = 9 \times 10^9 q + 10264.52568$~~

$0 = 9 \times 10^9 q + 10264.52568$

making q subject of formulae

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

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

$\simeq q = 11.4 \mu C$

3a

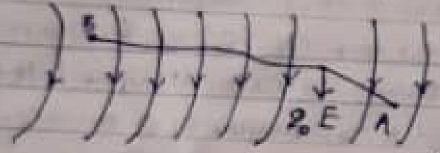
(i) volume charge density, $\rho = \frac{dQ}{dV} \rightarrow dQ = \rho dV$

(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. ELECTRIC POTENTIAL DIFFERENCE

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



~~Fig 4.1~~ Fig. 4.1

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:

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

But

$$F = -q_0E .... (2)$$

Substituting equation (2) in (1) yields

$$dW = -q_0EdL .... (3)$$

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

$$W(A \to B)_{ext} = -q_0\int_A^B EdL ... (4)$$

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

$V_B - V_A = \frac{W(A \to B)_{ext}}{q_0}$ (5) putting equation (4) in (5) yields

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

Section B

4a magnetic flux is defined as the strength of the magnetic

field which can be represent by line forces. It is repre-
sented by the symbol Φ. mathematically given as $\oint B \cdot dA$

4b] $\omega = V/r = qB/m$

$m = 9.11 \times 10^{-31} kg$, $r = 1.4 \times 10^{-7} m$, $B = 3.5 \times 10^{-1}$ tesla

$\omega = qB/m_e$ $q_e = 1.6 \times 10^{-19} c$

where m_e = mass of electron $= 1.6^{-19} kg$

$$\omega = \frac{(1.6 \times 10^{-19}) \times (3.5 \times 10^{-1})}{(9.11 \times 10^{-31})}$$

$\omega = 6.15 \times 10^{10}$ rad/s

4c] In the quest on we were given paramters such as
i. mass of the electron $= 9.11 \times 10^{-31} kg$
ii. A radius of $1.4 \times 10^{-7} m$
iii. magnetic field of 3.5×10^{-1} weber / meter square

And you are asked to find the cyclotion 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 $\omega = V/r = \frac{qB}{m} = \frac{1.6 \times 10^{-10} \times 3.5 \times 10^{-10}}{9.11 \times 10^{-31}}$

$\frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}} = 6.15 \times 10^{10}$ rad/s

So since cyclotron frequency is equal to angular speed the cyclotion frequency is equal to 6.15×10^{10} rad/s having a unit as 1/1 which is equal to the unit of frequency dimensionally

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). It can be represented mathematically by

$$\cancel{dB = \mu_0 Idl \times r} \quad dB = \frac{\mu_0 Idl \times r}{4\pi r^2}$$

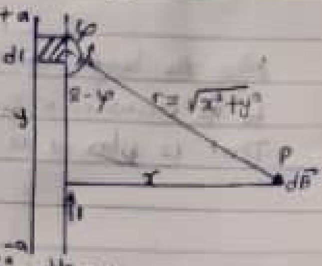
where μ_0 is a constant called permeability of free space

$\mu_0 = 4\pi \times 10^{-7} T \cdot \frac{m}{A}$

The unit of B is weber\meter square

5b magnetic Field of Straight Current Carrying Conductor ~~Conductor~~

Fig 1: A Section of a Straight Carrying Conductor Applying The Biot law, we find magnitude of the field dB



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

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

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

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

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

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

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

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

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

Recall $dl=dy$

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

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

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

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

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

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

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

$\simeq a$, as $a \to \therefore B = \frac{\mu_0 I}{2\pi x}$

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

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

Equation (H) defines the magnitude of the magnetic field of flux density B near a long, straight Current Carrying Conductor.