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COURSE; PHY 102

HOLIDAY ASSIGNMENT

SECTION A

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

ANSWER

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 some protons move to the side of the sphere farthest away from the rod (fig 1.3a). The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of protons away from 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 (fig 1.3c), then 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 (fig. 1.3 d), the induced negatively charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere

Diagram

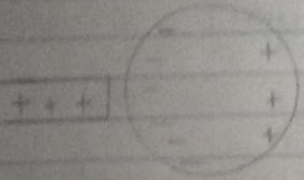


fig 1.3a

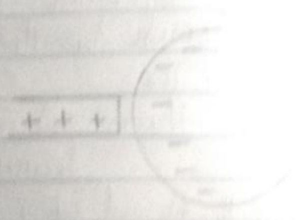


fig 1.3c

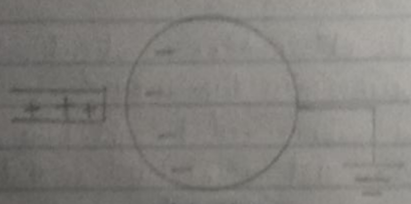


fig 1.3b

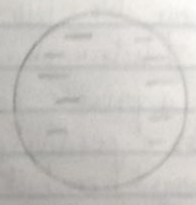


fig 1.3d

b) Each of two sphere 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.

Answer

$K = 9 \times 10^9$

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

$f = 1.0$N

$d = 2$m

Recall that

$K = 9 \times 10^9$

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

$$1 = \frac{(9 \times 10^9) \times (q_1q_2 \; 5 \times 10^{-5})}{2^2}$$

1b Continues

$$4 = 9 \times 10^{9} \times 5 \times 10^{-7} q_1 + 9 \times 10^{9} q_2$$

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

This is a quadratic equation

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

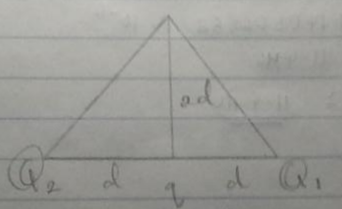
$$q_1 = 0.0000111c$$

$$q_2 = 0.000038c$$

$$q_1 \simeq \underline{\underline{1.11 \times 10^{-5} c}}$$

$$q_2 \simeq \underline{\underline{3.8 \times 10^{-5} c}}.$$

1c 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.



Answer

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

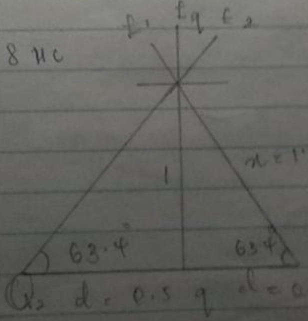
$d = 0.5m$

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

$\tan\theta = \frac{1}{0.5} = 2$

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

$\theta = 63.4°$



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

$\sqrt{x^2} = \sqrt{1.25}$

$x = \sqrt{1.25}$

$x = 1.12$

$$E_1 = \frac{Kq_1}{r^2} = \frac{(9 \times 10^{9}) \times (8 \times 10^{-6})}{(1.12)^2} = 5739.795918$$

$$E_2 = \frac{Kq_2}{r^2} = \frac{(9 \times 10^{9}) \times (8 \times 10^{-6})}{(1.12)^2} = 5739.795918$$

$$E_q = \frac{Kq}{r^2} = \frac{(9 \times 10^{9}) \times q}{(1)} = 9 \times 10^{9} q$$

1c Continues

Vector	Angle	x-comp	y-comp
$E_1 = 5739.795918$	63.4°	$E_1 \cos\theta = -2570.045785$	$E_1 \sin\theta = 5132.262$[illegible]
$E_2 = 5739.795918$	63.4°	2570.045785	5132.262839
$E_q = 9 \times 10^9 q$	90°	$E_q \cos\theta = 0$	$9 \times 10^9 q$
		$E_x = 0$	$E_y = 10264.52568$

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

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

Since $E = 0$

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

Making q subject of formula

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

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

$$q \simeq 11.4\,\mu C$$

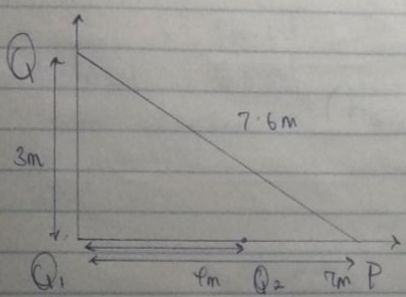
$$q \simeq \underline{\underline{11.4\,\mu C}}$$

2a) Distinguish between the terms, electric field and electric field intensity.

Electric Field	Electric Field Intensity
This is a region around a charge in which it exerts electrostatic force on another charge	This is the strength of electric field at any point in space

b)i) The net electric field at a point P on the x-axis at $x = 7m$.

Answer



Where $Q_1 = 8nc$

$Q_2 = 12nc$

Recall $E = \frac{kq_1}{r^2}$

$E_1 = \frac{(9 \times 10^9 \; Nm^2/c) \times (8 \times 10^{-9} c)}{(7.0m)^2}$

$E_1 = 1.47N/c$

$E_2 = \frac{(9 \times 10^9 \; Nm^2/c) \times (12 \times 10^{-9} c)}{(3.0m)^2}$

$E_2 = 12 N/c$

Vector	Angle	x - component	y - component
$E_1 = 1.47N/c$	0°	$E_{1x} = 1.47 \cos 0^\circ = 1.47 N/c$	$E_{1y} = 1.47 \sin 0^\circ = 0$
$E_2 = 12N/c$	0°	$E_{2x} = 12 \cos 0^\circ = 12 N/c$	$E_{2y} = 12 \sin 0^\circ = 0$
		$\Sigma E_x = 13.47 N/c$	$\Sigma E_y = 0$

$E_{net} = \sqrt{(E_x)^2 + (E_y)^2} = \sqrt{(13.47)^2 + (0)^2}$

$= \sqrt{181.4409}$

$E_{net} = 13.47 N/c$

ii) The electric field at a point Q on the y axis at y = 3m due to the charges

Answer

$Hyp^2 = 3^2 + 4^2$

$Hyp^2 = 9 + 16 = 25$

$Hyp = \sqrt{25}$

$Hyp = 5m$

Electric field relation to point Q

$E_1 = \frac{KQ_1}{r_1^2}$

where $r_1 = 3m$

$E_1 = \frac{(9 \times 10^9) \times (8 \times 10^{-9})}{(3^2)}$

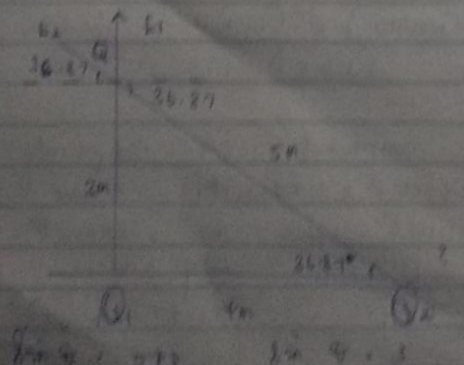
$E_1 = \frac{72}{9} = 8 N/C$

$E_2 = \frac{KQ_2}{r_2^2}$

where $r_2 = 5m$

$E_2 = \frac{(9 \times 10^9) \times (12 \times 10^{-9})}{(5)^2}$

$E_2 = \frac{108}{25} = 4.32 N/C$



$\sin\theta = \frac{3}{5}$, $\sin\theta = \frac{3}{5}$, $\sin\theta = 0.6$

$\theta = \sin^{-1}(0.6)$

$\theta = 36.87^\circ$

Vector	Angle	x - component	y - component
$f_1 = 8 N$	90°	$8\cos 90^\circ = 0 N$	$8\sin 90^\circ = 8 N$
$f_2 = 4.32 N$	36.87°	$4.32\cos 36.87^\circ = 3.46$	$4.32\sin 36.87^\circ = 2.59$
		$\Sigma f_x = 3.46 N$	$\Sigma f_y = 10.59 N$

$f = \sqrt{(\Sigma f_x)^2 + (\Sigma f_y)^2}$

$f = \sqrt{(3.46)^2 + (10.59)^2}$

$f = \sqrt{124.1197}$

$f = 11.14 N$

$\tan\theta = \dfrac{|\Sigma f_y|}{|\Sigma f_x|} = \dfrac{|10.59|}{|3.46|}$

$\tan\theta = 3.0607$

$\theta = \tan^{-1}(3.0607)$

$\theta = 71.91^\circ$

Section B

a) What is Magnetic flux?

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 given as $\phi = B \cdot dA$

(b) In the question we were given parameters 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 we 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,

$$\omega = \frac{v}{r} = \frac{qB}{m} = 1.6 \times 10^{-10} \times 3.5 \times 10^{-10}$$

$$\frac{qB}{m} = \frac{(1.6 \times 10^{-19}) \times (3.5 \times 10^{-1})}{(9.11 \times 10^{-31})} = 62222222222.22222 T^{-1}$$

c) So since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $= 62222222222.22222 T^{-1}$, having a unit of ~~frequ~~ as $\frac{1}{T}$ which is equal to the unit of frequency dimensionally.

5 a) State the Biot - Savart Law

Biot - savart law states that the magnetic field is directly popotional to the product permeability of free space (μ), the current (I), the change in length, the radius and inversely propor-tional to the square of radius (r^2). It can be represented mathematically by;

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

Where μ_0 is a constant called permeability of free space

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

The unit of B is weber / metre square.

6b) Proof; $B = \frac{\mu_0 I}{2\pi r}$

Magnetic field of a straight current carrying conductor

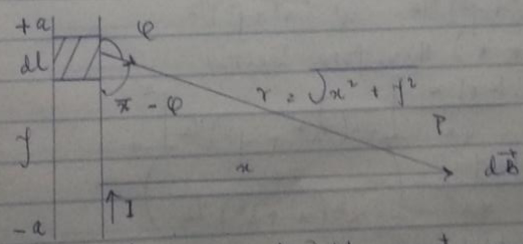


Fig 1; A section of a straight current carrying conductor
Applying the Biot - Savart law, we find the magnitude of the field dB

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

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

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

5b Continues,

From diagram above,

$$r^2 = x^2 + y^2 \quad \text{(Pythagoras theorem)}$$

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

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

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

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

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

Recall $dl = dy$

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

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

Using special integrals,

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

Equation $(***)$ therefore becomes

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

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

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

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

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

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