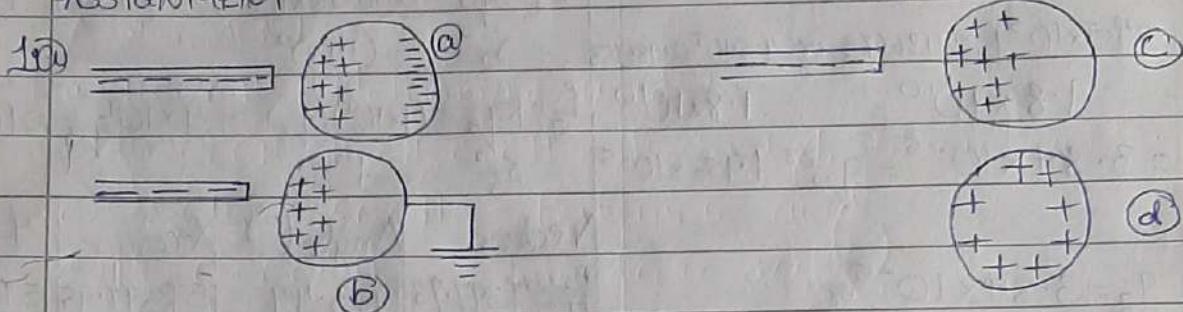


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COURSE: PHY 102

ASSIGNMENT.



Electric charges can be obtained removed as in C, the conducting on an object without touching it by a process called electrostatic induction. Consider a negatively charged rubber rod brought near a neutral, insulated, and conducting sphere as in A. The repulsive force between the electrons in the rod and those in the sphere cause a redistribution of charges on the sphere as seen in B.

$$1b) q_1 + q_2 = 5.0 \times 10^{-5} C$$

$F = 1.0 N ; R = 2.0 m$

The region of the sphere nearest q_1 = ? q_2 = ? $K = 9 \times 10^9$
 to the negatively charged rod has an excess of positive

$$q_1 = 5.0 \times 10^{-5} C - q_2$$

$$1.0 = \frac{(9 \times 10^9)(5.0 \times 10^{-5})}{r^2} q_2$$

charge because of the migration of electrons away from this rod. If a grounded conducting wire is then connected to the sphere, as in D, some of the electrons leave the sphere and travel to the earth. If the wire is

$$4 = (9 \times 10^9)(5.0 \times 10^{-5} q_2 - q_2^2)$$

$$4 = 4.5 \times 10^5 q_2 - 9 \times 10^9 q_2^2$$

$$9 \times 10^9 q_2^2 - 4.5 \times 10^5 q_2 + 4 = 0$$

$$\text{Using the formula } \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

$$= (-4.5 \times 10^5) \pm \sqrt{(-4.5 \times 10^5)^2 - 4 \times 4 \times 10^9}$$

$$2(9 \times 10^9)$$

$$= 4.5 \times 10^5 + 24186773 \text{ or } 4.5 \times 10^5 - 24186773$$

$$1.8 \times 10^{10}$$

$$1.8 \times 10^{10}$$

$$= 3.84 \times 10^{-5} = q_2 \text{ or } 1.16 \times 10^{-5}$$

$$q_2 = 3.84 \times 10^{-5}$$

$$q_1 = 5.0 \times 10^{-5} - 3.84 \times 10^{-5}$$

$$q_1 = 1.16 \times 10^{-5}$$

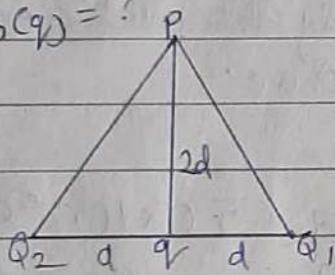
$$\therefore q_1 = 1.1 \times 10^{-5} \text{ C}$$

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

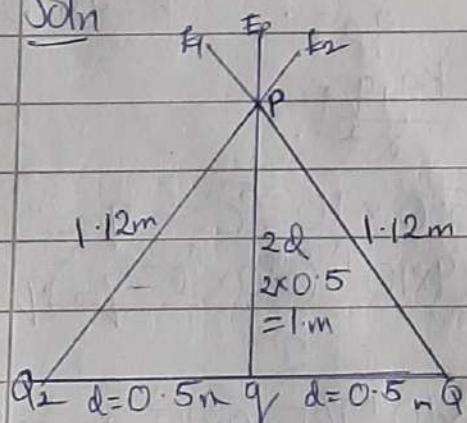
$$1c) Q_1 = Q_2 = 8 \mu\text{C}$$

$$d = 0.5 \text{ m}$$

$$q_3(q_3) = ?$$



Sohm



Using pythagoras theorem,

$$c^2 = a^2 + b^2$$

$$c = \sqrt{0.5^2 + 1^2}$$

$$c = \sqrt{1.25} = 1.12 \text{ m}$$

$$F_1 = kq_1 = \frac{(9 \times 10^9)(8 \times 10^{-6})}{r_1^2} = 57397.95 \text{ N/C}$$

$$F_2 = kq_2 = \frac{(9 \times 10^9)(8 \times 10^{-6})}{r_2^2} = 57397.95 \text{ N/C}$$

$$F_3 = kq_3 = \frac{(9 \times 10^9)(q_3)}{r_3^2} = 9 \times 10^9 q_3 \text{ N/C}$$

Vector	Angle ($^\circ$)	X-comp	Y-comp
$F_1 = 57397.95$	63.49	57397.95	57397.95
	$\cos 63.49$	$\sin 63.49$	
	$= 25619.8$	$= 51362.9$	
$F_2 = 57397.95$	63.49	57397.95	57397.95
	$\cos 63.49$	$\sin 63.49$	
	$= 25619.8$	$= 51362.9$	
$F_3 = 9 \times 10^9 q_3$	0	$9 \times 10^9 \cos 0$	$9 \times 10^9 q_3 \sin 0$
		0	0
		.	$= 9 \times 10^9$
$E_{fx} =$		$E_{fy} =$	
		-25619.8	51362.9
		+25619.8	+51362.9
		+0	+9 $\times 10^9 q_3$
		$\frac{1}{4} \pi = 0$	$= 102725.8 + 9 \times 10^9 q_3$
			$+ 9 \times 10^9 q_3$

Considering $\Delta q_3 Q_1 P$,

$$\cos \theta_{q_3} = \frac{0.5}{1.12}$$

$$\theta_{q_3} = \cos^{-1} \left(\frac{0.5}{1.12} \right) = 63.49^\circ$$

$$E_f = \sqrt{E_{fx}^2 + E_{fy}^2}$$

$$E_{fx} = 0 ; E_{fy} = 102725.8 + 9 \times 10^9 q_3$$

$$E_f = \sqrt{(102725.8)^2 + (9 \times 10^9 q_3)^2}$$

$$E_f = 0 \text{ from question.}$$

$$-102725.8 = q_3$$

$$9 \times 10^9$$

$$q_3 = -11.4 \times 10^{-6} = -11 \mu\text{C} \parallel$$

2a An electric field is a region of space in which an electric charge will experience an electric force while electric field intensity can be defined as the force per unit charge. It can be expressed mathematically as,

$$F = F(N)$$

$$\text{N/C}$$

The unit is (N/C) Newton per coulomb.

$$F_2 = \frac{kq_2}{r^2} = \frac{(9 \times 10^9)(12 \times 10^{-9})}{3^2} = 12 \text{ N/C}$$

Vector	Angle	X-comp	Y-comp
$F_1 = 1.469 \text{ N/C}$	0°	$1.469 \cos 0$	$1.469 \sin 0$
		= 1.469	= 0
$F_2 = 12 \text{ N/C}$	0	$12 \cos 0$	$12 \sin 0$

$$F_{\text{tot}} = \sqrt{13.469^2 + 12^2} = 13.469 \text{ N/C}$$

$$F = \sqrt{(13.469)^2 + (0)^2}$$

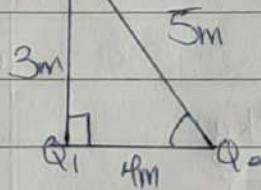
$$F = \sqrt{(13.469)^2} = 13.46 \text{ N/C}$$

Net at $x=7$ is 13.46 N/C
 $\approx 13.5 \text{ N/C}$

(B) $q_1 = +8 \text{ nC} = 8 \times 10^{-9} \text{ C}$
 $q_2 = +12 \text{ nC} = 12 \times 10^{-9} \text{ C}$
 $x = 4 \text{ m}$.

i) Net at $x = 7 \text{ m}$.

ii) Net at $y = 3 \text{ m}$



Using Pythagoras Theorem

$$c^2 = a^2 + b^2$$

$$c^2 = 5^2 = 4^2 + 3^2$$

$$c = \sqrt{25} = 5 \text{ m}$$

$$\tan \theta = 3/4; \theta = \tan^{-1}(0.75) = 37^\circ$$

Vector	Angle	X-comp	Y-comp
$F_1 = 8 \text{ N/C}$	90°	$8 \cos 90 = 0$	$8 \sin 90 = 8$

$$F_2 = 4.32 \text{ N/C} \quad 37^\circ \quad 4.32 \cos 37^\circ = 4.32 \sin 37^\circ = 3.45 \quad 2.5998$$

$$F_{x2} = 3.45 \quad F_{y2} = 10.998$$

$$F_1 = \frac{kq_1}{r^2} = \frac{(9 \times 10^9)(8 \times 10^{-9})}{3^2} = 8 \text{ N/C}$$

$$F_1 = \frac{kq_1}{r_1^2} = \frac{(9 \times 10^9)(8 \times 10^{-9})}{7^2} = 1.469 \text{ N/C}$$

$$F_2 = \frac{kq_2}{r_2^2} = \frac{(9 \times 10^9)(12 \times 10^{-9})}{5^2} = 4.32 \text{ N/C}$$

$$kF = \sqrt{2Fx^2 + 2Fy^2}$$

$$F_{\text{net}} = \sqrt{(3.45)^2 + (10.5998)^2}$$

$$F_{\text{net}} = \sqrt{11.90 + 112.36}$$

$$F_{\text{net}} = \sqrt{124.25576}$$

$$F_{\text{net}} = 11.1477 \text{ N/C}$$

$$F_{\text{net}} = 11.150 \text{ N/C}$$

SECTION B

4a) Magnetic flux can be defined as the number of magnetic field lines passing through a given closed surface. It can also be said to be the average magnetic field times the perpendicular area that it penetrates. The SI unit is Weber (Wb).

$$\text{b) Mass} = 9.11 \times 10^{-31} \text{ kg}$$

$$\text{Radius} (r) = 1.4 \times 10^{-7} \text{ m}$$

$$\text{flux density, } B = 3.5 \times 10^{-1} \text{ T/m}^2$$

$$\text{Cyclotron frequency} = ?$$

$$\text{Cyclotron frequency} = \frac{qB}{m}$$

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

$$= 6.1477 \times 10^{10} \text{ rad/s}$$

c) In the question 4(b) above the mass of the electron

is given as $9.11 \times 10^{-31} \text{ kg}$, the charge on the electron is $1.6 \times 10^{-19} \text{ C}$. The radius (r) = $1.4 \times 10^{-7} \text{ m}$ and the cyclotron frequency, unknown.

Cyclotron frequency is also or more commonly known as

angular speed. This is because the charge particle oscillates at this angular frequency in the type of accelerator called cyclotron.

Using the formula for angular speed $\frac{qB}{m} = \omega$; the speed was found

to be $6.1477 \times 10^{10} \text{ rad/s}$ which is the speed with which the electron circulated in the cyclotron accelerator.

5. The Biot-Savart law states

that the magnitude of the vector $d\vec{B}$ (dB) is directly proportional to the product of the current, I , the magnitude of the length element $d\vec{l}$, the radius, r and is inversely proportional to the square of radius r . Mathematically, $d\vec{B} = \frac{\mu_0 I d\vec{l} \times \vec{r}}{4\pi r^2}$

where μ_0 is constant called Permeability of free space.

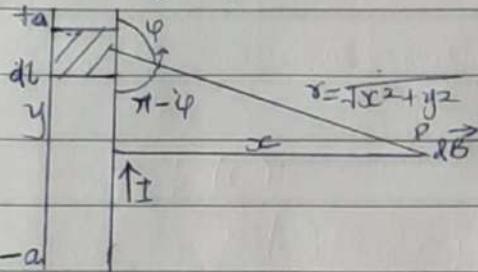
$$\mu_0 = 4\pi \times 10^{-7} \text{ T.m/A.}$$

Unit of B is Weber/Meter Square.

5b The total magnetic field \vec{B} created at some point by a current I of the finite size is $\vec{B} = \frac{\mu_0}{4\pi} \int_{-a}^a \frac{Idl \hat{x}}{x^2}$

Magnitude of the magnetic field is

$$B = \frac{\mu_0}{4\pi} \int_{-a}^a \frac{Idl \sin \theta}{x^2}$$



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

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

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

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

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

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

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

Substituting ② into ①,

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

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

Recall, $dl = dy$

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

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

Using special integrals:

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

Equation 3 becomes:

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

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

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

When the length $2a$ of the conductor is very great or comparison to its distance x from point P , we consider it far away

long i.e. $(x^2 + a^2)^{1/2} \approx a$, as $a \rightarrow \infty$

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

In a physical situation, there is axial symmetry about y -axis thus, in a circle of radius r ,

$$B = \frac{\mu_0 I}{2\pi r} \quad \text{This equation defines the magnitude of the magnetic field of flux density } B \text{ near a long, straight current carrying conductor.}$$