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19/MHS01/032

COLLEGE OF MEDICINE AND HEALTH SCIENCES

MEDICINE AND SURGERY

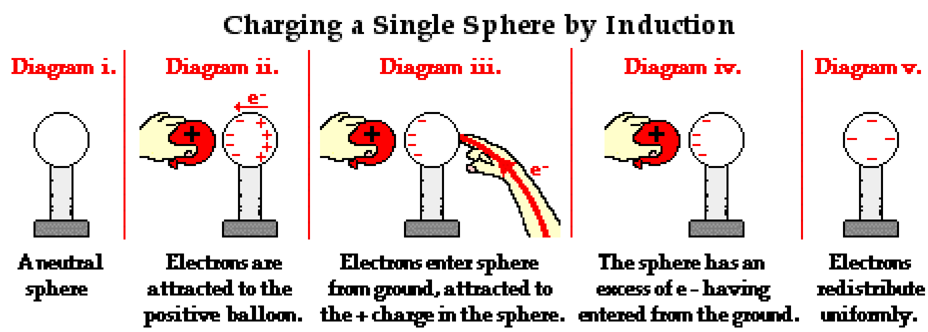
PHY 102

ASSIGNMENT

SECTION A

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

A negatively charged rod is brought near a neutral(uncharged) conducting sphere that is insulated so that there is no conducting path to ground. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some electrons move to the side of the sphere farthest away from the rod. The region of the sphere nearest the negatively charged rod has an excess of positive charge because of the migration of electrons away from this location. If a grounded conducting wire is then connected to the sphere, some of the electrons leave the sphere and travel to the earth. If the wire to the ground is then removed, the conducting sphere is left with an excess of induced positive charge. Finally, when the rubber rod is removed from the vicinity of the sphere, the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.



(b) Each of two small spheres is charged positively, the combined charge being 5.0 x 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.

SOLUTION

$Q_1 + Q_2 = 5.0 \times 10^{-5}$C-------(1)

F= 1.0N, k= 9 x 10^9Nm^2C^2, r= 2.0m

$F = kQ_1Q_2 \div r^2$

$Q_1Q_2 = 1.0 \times (2)^2 \div 9 \times 10^{-9}$

$Q_1Q_2 = 4.44 \times 10^{-10}$---------(2)

From (1)

$Q_1 = 5.0 \times 10^{-5}C - Q_2$

Substituting the above in (2)

$(5.0 \times 10^{-5}C - Q_2)\, Q_2 = 4.44 \times 10^{-10}$

$5.0 \times 10^{-5}CQ_2 - Q_2^2 = 4.44 \times 10^{-10}$

$-Q_2^2 + 5.0 \times 10^{-5}CQ_2 - 4.44 \times 10^{-10} = 0$

$Q_2 = 1.15 \times 10^{-5}C$ OR $3.85 \times 10^{-5}C$

HENCE;

When

$Q_1 = 1.15 \times 10^{-5}C$

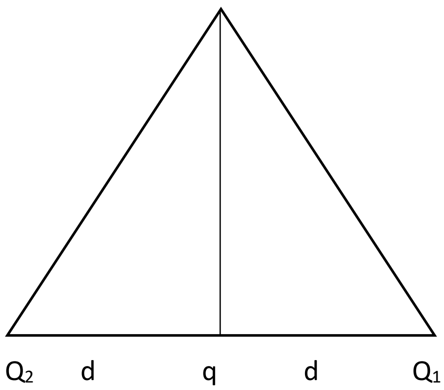
$Q_2 = 3.85 \times 10^{-5}C$

When

$Q_1 = 3.85 \times 10^{-5}C$

$Q_2 = 1.15 \times 10^{-5}C$

(c) 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.



<u>SOLUTION</u>

$Q_1 = 8\mu C = 8 \times 10^{-6}$

$Q_2 = 8\mu C = 8 \times 10^{-6}$

D = 0.5m

2d = 2 x 0.5 = 1

From one of the right angled triangles above;

$X^2 = 1^2 + 0.5^2$

$X^2 = 5/4$

$X = \sqrt{5}/2$

$\Theta = \sin^{-1}(1/\sqrt{5}/2)$, $\Theta = 63.4°$

$E_1 = Kq_1/r^2 = 9 \times 10^9 \times 8 \times 10^{-6}/(\ \sqrt{5}/2\ )^2 = 5.76 \times 10^4C$

$E_2 = kq_2/r^2 = 9 \times 10^9 \times 8 \times 10^{-6}/(\ \sqrt{5}/2\ )^2 = 5.76 \times 10^4C$

$E_3 = kq/r^2 = 9 \times 10^9 \times q\ /1 = 9 \times 10^9 qC$

Vectors	Angles	X-component	Y-component
5.76×10^4C	63.4°	$5.76 \times 10^4C\cos(63.4) = -25790.9$	$5.76 \times 10^4C\sin(63.4) = 51503.28$
5.76×10^4C	63.4°	$5.76 \times 10^4C\cos(63.4) = -25790.9$	$5.76 \times 10^4C\sin(63.4) = 51503.28$
9×10^9qC	90	$9 \times 10^9qC\cos(90) = 0$	$9 \times 10^9qC\sin(90) = 9 \times 10^9q$

$E_x = 0$

$E_y = 103006.56 + 9 \times 10^9 q$

$E = \sqrt{\mathrm{Ex2} + Ey2}$

But E = 0

$0 = \sqrt{0^2} + \sqrt{}(103006.56 + 9\ \times 10^{-9}q)^2$

$0 = \sqrt{}(103006.56 + 9\ \times 10^{-9}q)^2$

$0 = 103006.56 + 9\ \times 10^{-9}q,\ \frac{-103006.53}{9 \times 10^{-9}} = q$

$Q = -1.14 \times 10^{-5} = -11 \times 10^{-6}C$

$Q = -11\mu C$

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

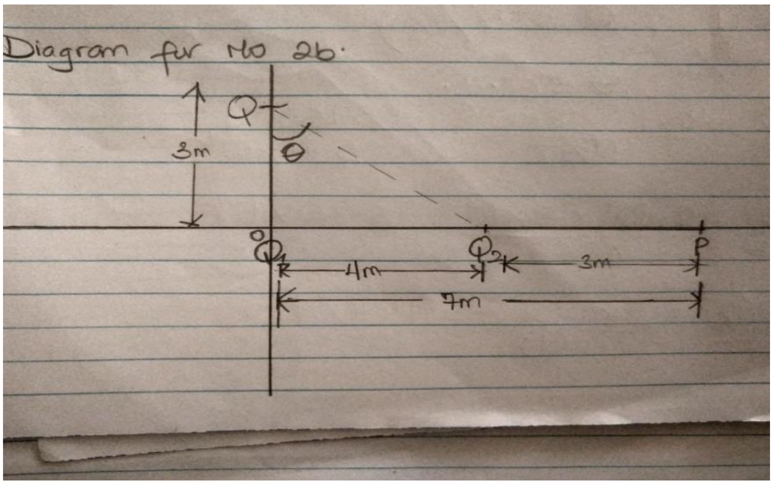
An electric field is defined as a region of space in which an electric charge will experience an electric force **while** Electric field intensity is defined as the force per unit charge.

(b) A positive charge Q_1= 8nC is at the origin, and a second positive charge Q_2= 12nC is on the x-axis at x= 4m. Find

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

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

SOLUTION



(i) Net electric field at point P

$E_1 = \frac{kq1}{r^2} = \frac{9\times10^9\times8\times10^{-9}}{7^2} = 1.468N/C$

$E_2 = \frac{kq2}{r^2} = \frac{9\times10^9\times12\times10^{-9}}{3^2} = 12N/C$

Vector	Angle	X-component	Y-component
1.469	0	1.469cos (0) = 1.469	1.469sin (0) = 0
12	0	12cos (0) = 12	12sin (0) = 0

E= $\sqrt{Ex2} + \sqrt{Ey2}$

E= $\sqrt{(13.469)^2}$

E= 13.5N/C

(ii) From the diagram;

$4^2+3^2= x^2$

$X^2= 16 + 9 = 25$

X= 5m

Tanϴ=4/3, ϴ= $\tan^{-1}(4/3)$, ϴ= 53.1°

$E_1 = \frac{kq1}{r^2} = \frac{9\times10^9\times8\times10^{-9}}{3^2} = 8N/C$

$E_2 = \frac{kq2}{r^2} = \frac{9\times10^9\times12\times10^{-9}}{5^2} = 4.32N/C$

Vector	Angle	X-component	Y-component
8N/C	90°	8cos (90) = 0	8sin (90) = 8
4.32N/C	53.1°	4.32cos (53.1) = 2.60	4.32sin (53.1) = 3.45

E_X= 2.60 + 0 = 2.60, E_Y= 8 + 3.45 = 11.45

E=$\sqrt{Ex2} + \sqrt{Ey2}$

E= $\sqrt{(2.60)^2} + \sqrt{(11.45)^2}$

E= 11.74N/C.

SECTION B

4(a) What is magnetic flux?

The magnetic flux is defined as the strength of the magnetic field represented by lines pf force. It is usually represented by the symbol ϕ.

(b) An electron with a rest mass of 9.11 x 10^{-31}kg moves in a circular orbit of radius 1.47 x 10^{-7}m in a uniform magnetic field of 3.5 x 10^{-1} Weber/meter square, perpendicular to the speed with which electron moves. Find the cyclotron frequency of the moving electron.

<u>SOLUTION</u>

Rest mass = 9.11 x 10^{-31}kg, radius of orbit = 1.47 x 10^{-7}m, magnetic flux density =3.5 x 10^{-1} Weber/meter square, cyclotron frequency of the moving electron = ɯ

ɯ=$\frac{v}{r}$ but v=$\frac{qBr}{m} = \frac{1.60 \text{ x } 10{-}19\text{x } (0.35) \; x \; (1.47 \text{ x } 10{-}7)}{9.11 \text{ x } 10{-}31}$=8605.93m/s

ɯ=$\frac{v}{r}$ =$\frac{8605.93}{1.47 \text{ x } 10{-}7}$ = 6.147 x 10^{-10}rad/s

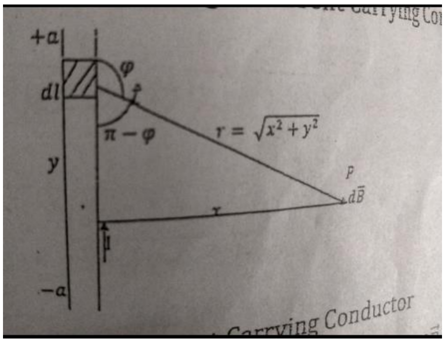
(c)Discuss your answer in 4b above

The cyclotron frequency is 6.147 x 10^{-10}rad/s meaning that the moving electron accelerates at the rate of this angular speed which is also referred to as cyclotron frequency.

5(a) State the Biot-Savart Law.

The Biot-Savart law states that: “the magnetic intensity at any point due to a steady current in an infinitely long straight wire is directly proportional to the current and inversely proportional to the distance from point to wire.

(b) Using the Biot-Savart law, show that the magnitude of the magnetic field of a straight current-carrying conductor is given as B=$\frac{\mu_0 I}{2\pi r}$



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

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

B=$\frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{dl sin(\pi-\varphi)}{\text{x2+ y2}} --- (*)$

But Sin$(\pi-\varphi)$=$\frac{x}{\sqrt{\text{x2+ y2}}} = \frac{x}{(x^2+y^2)^{1/2}} --- (**)$

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=$\frac{\mu_{0\,I}}{4\pi}\int_{-a}^{a}\frac{x}{(x^2+y^2)^{3/2}}\,dy$

B=$\frac{\mu_{0\,Ix}}{4\pi}\int_{-a}^{a}\frac{1}{(x^2+y^2)^{3/2}}\,dy$---(***)

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=$\frac{\mu_{0\,Ix}}{4\pi}\left[\frac{y}{x^2(x^2+y^2)^{1/2}}\right]_{-a}^{a}$

B=$\frac{\mu_{0\,Ix}}{4\pi}\left(\frac{2a}{x^2(x^2+a^2)^{1/2}}\right)$

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, $(x^2+a^2)^{\frac{1}{2}}$ ≅ a, as a→ ∞ ∴ B=$\frac{\mu_{0\,I}}{2\pi x}$

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=$\frac{\mu_{0\,I}}{2\pi r}$ − − − (#)

The equation above defines the magnitude of the magnetic field of flux density B near a long, straight current carrying conductor.