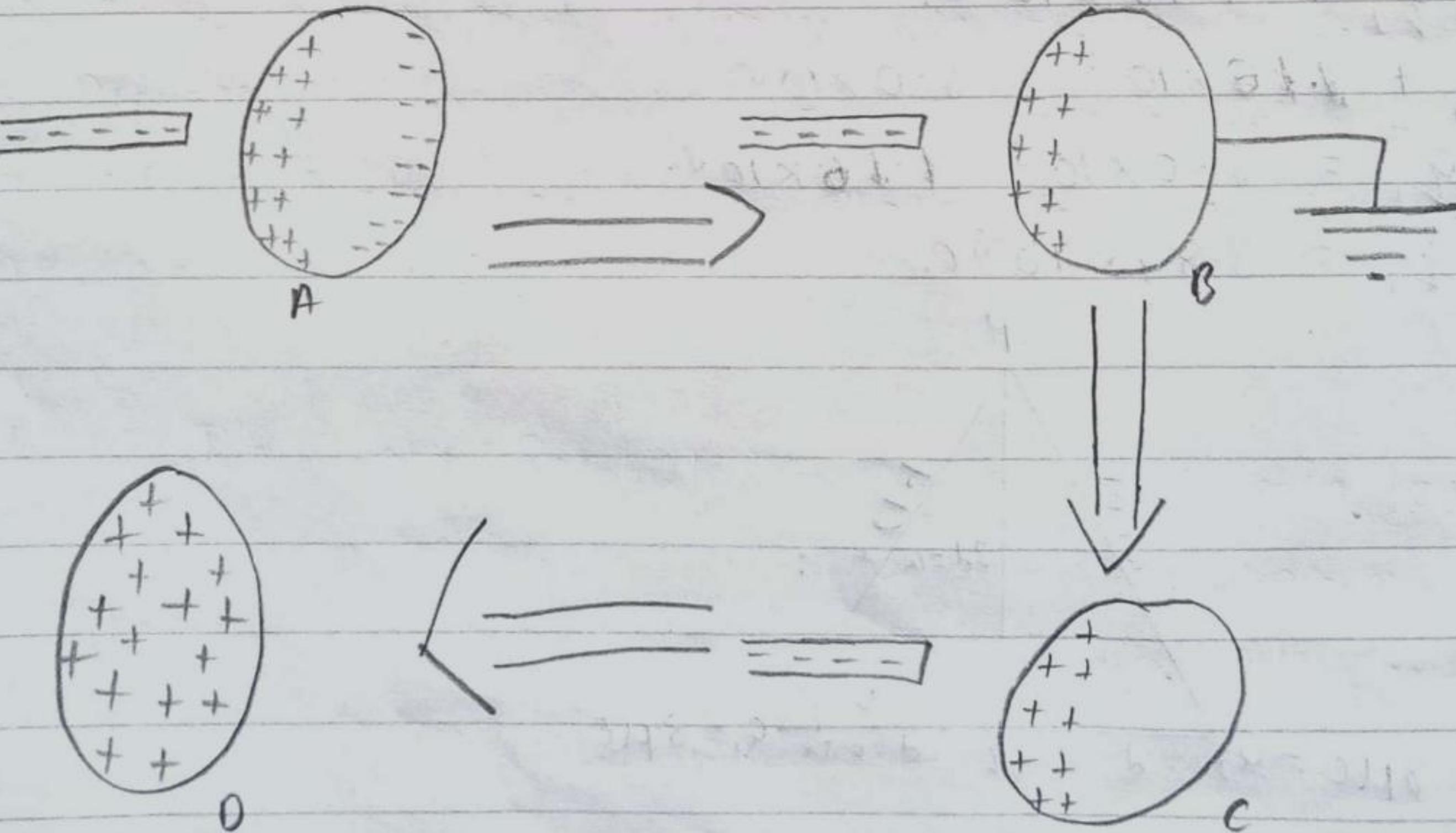


19/ENG 02/080.

## Assignment

19. Consider a negatively charged rod brought near a neutral 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 cause a redistribution of charges in the sphere so that some electrons move to the side of 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 to the ground. If the grounded wire is then removed, the conducting sphere will contain excess induced positive charge. When the rubber rod is removed from close, and the grounded wire is removed, the positive charge becomes uniformly distributed in the sphere.



$$\textcircled{b} \quad q_1 + q_2 = 5.0 \times 10^{-8} \text{ C}, \quad F = 1.0 \text{ N}, \quad r = 2.0 \text{ m}$$

$$F = K \frac{q_1 q_2}{r^2} \quad q_1 = 5.0 \times 10^{-8} \text{ C} - q_2$$

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

$$1.0 = \frac{(9 \times 10^9) (5.0 \times 10^{-8}) q_2}{2^2}$$

$$1.0 = \frac{(9 \times 10^9) q_2 (5.0 \times 10^{-8} - q_2)}{4}$$

$$1.0 \times 4.5 \times 10^5 q_2 - 9 \times 10^9 q_2^2$$

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

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

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

$$\text{When } q_2 = 3.84 \times 10^{-5} \text{ C.}$$

$$q_1 + 3.84 \times 10^{-5} = 5.0 \times 10^{-8}$$

$$q_1 = 5.0 \times 10^{-8} - 3.84 \times 10^{-8}$$

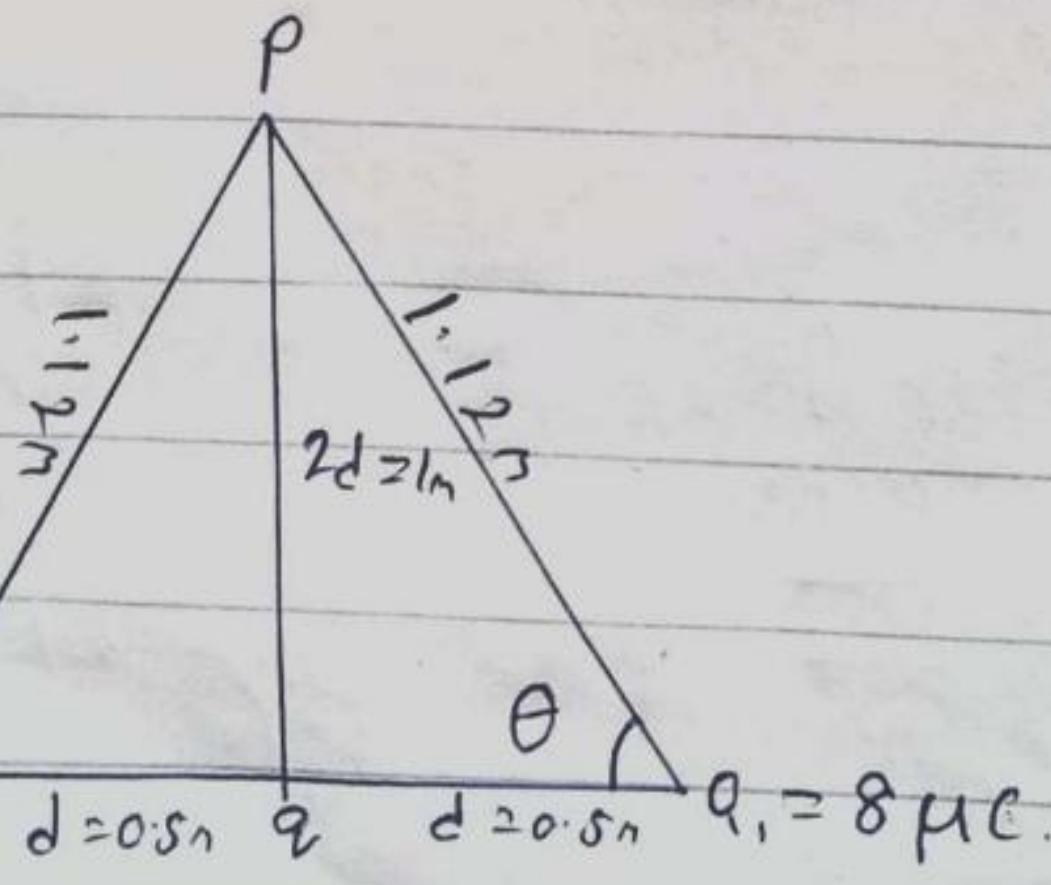
$$q_1 = 1.16 \times 10^{-8}$$

$$\text{When } q_2 = 1.16 \times 10^{-5} \text{ C.}$$

$$q_1 + 1.16 \times 10^{-5} = 5.0 \times 10^{-8}$$

$$q_1 = 5.0 \times 10^{-8} - 1.16 \times 10^{-8}$$

$$q_1 = 3.84 \times 10^{-8} \text{ C.}$$



$$DC^2 = 1^2 + 0.8^2$$

$$DC^2 = 1 + 0.64$$

$$\sqrt{2C} = \sqrt{1.25}$$

$$2C = 1.125$$

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

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

$$\theta = 63.43^\circ$$

$$E_1 = \frac{kq_1}{r_1^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.125)^2} = 8.74 \times 10^4$$

$$E_2 = \frac{kq_2}{r_2^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.125)^2} = 8.74 \times 10^4$$

$$E_q = \frac{kq}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{1} = 9 \times 10^9 q$$

Vector	Angle	$x$ -Component	$y$ -Component
$E_1 = 8.74 \times 10^4$	$63.43^\circ$	$8.74 \times 10^4 \times \cos 63.43^\circ$ = $-2.87 \times 10^4$	$8.74 \times 10^4 \times \sin 63.43^\circ$ = $8.13 \times 10^4$
$E_2 = 8.74 \times 10^4$	$63.43^\circ$	$8.74 \times 10^4 \times \cos 63.43^\circ$ = $2.87 \times 10^4$	$8.74 \times 10^4 \times \sin 63.43^\circ$ = $8.13 \times 10^4$
$E_q = 9 \times 10^9 q$	$90^\circ$	$9 \times 10^9 q \times \cos 90^\circ$ = 0	$9 \times 10^9 q \times \sin 90^\circ$ = $9 \times 10^9 q$

$$\sum x_C = 0$$

$$\sum y = 1.03 \times 10^5$$

$$E_q = \sqrt{(\sum x_C)^2 + (\sum y)^2}$$

$$9 \times 10^9 q = \sqrt{0^2 + (1.03 \times 10^5)^2}$$

$$\underline{9 \times 10^9 q} = \underline{1.08 \times 10^5}$$

$$\frac{9 \times 10^9}{9 \times 10^9} q = \frac{1.08 \times 10^5}{9 \times 10^9}$$

$$q = 1.14 \times 10^5 C = 11.4 \times 10^{-6} C.$$

$$q = 11 \mu C.$$

49. Magnetic Flux is defined as the number of magnetic field lines passing through a given closed surface. It gives the measurement of the total magnetic field that passes through a given surface area.

b.  $\omega$  (Cyclotron frequency) =  $\frac{qB}{m}$

$$= \frac{1.60 \times 10^{-19} \times 3.8 \times 10^{-1}}{9.11 \times 10^{-31}}$$
$$= 6.15 \times 10^9 \text{ rad/s.}$$

50. The Biot-Savart Law States that it is a mathematical expression which illustrates the magnetic field produced by a stable electric current in the particular electromagnetism of physics. It tells the magnetic field towards the magnitude, length, direction, as well as closeness of the electric current.

50. In the question we were given parameters such as

- i. Mass of the electron =  $9.11 \times 10^{-31}$ , (ii) The radius of  $1.4 \times 10^{-7} \text{ m}$
- (iii) Magnetic field of  $3.8 \times 10^{-1}$  Weber / meter square, and I was asked to find the Cyclotron frequency which is ~~the~~ same thing as Angular Speed ( $\omega$ ).

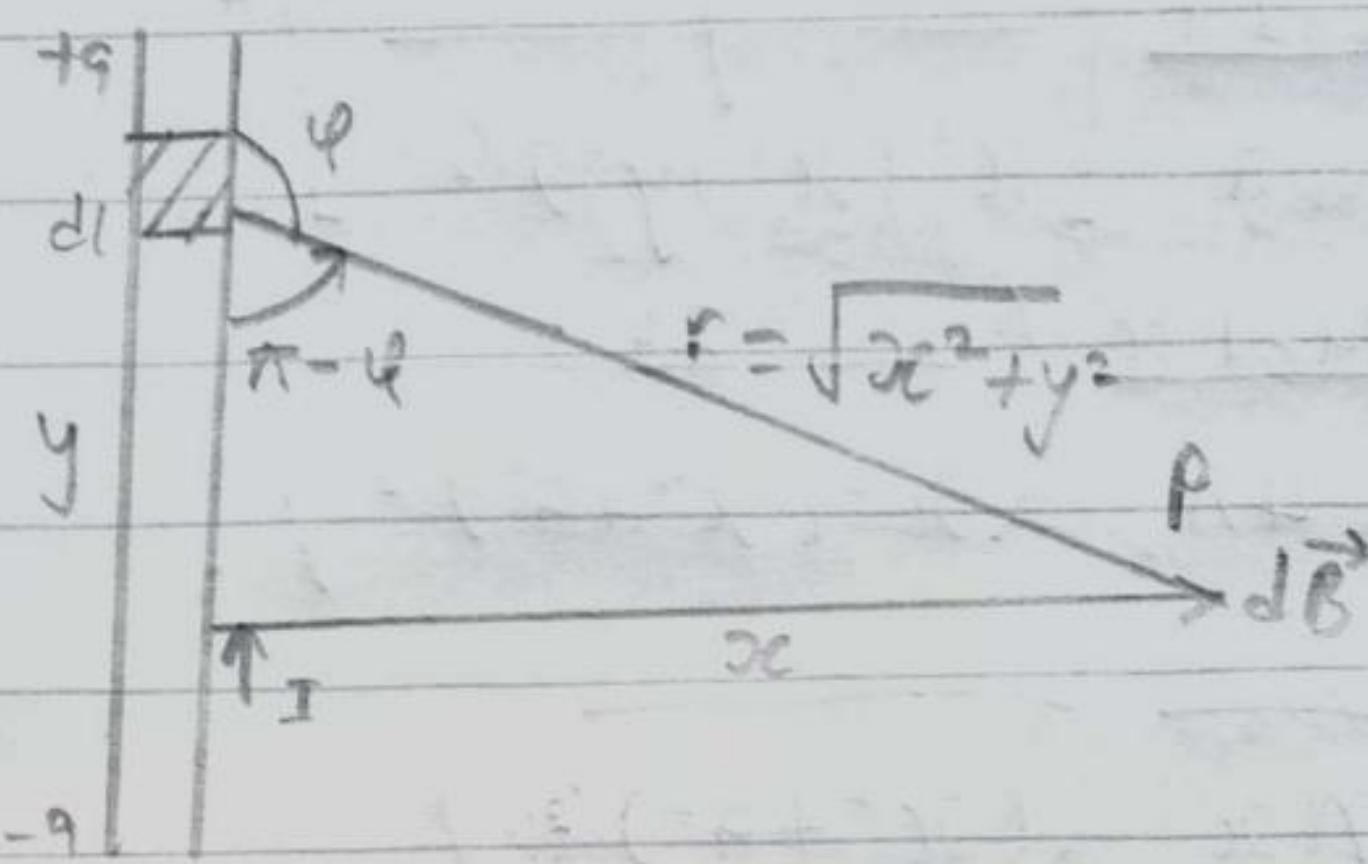
Recall that angular speed is given as  $\omega = \frac{v}{r} = \frac{qB}{m}$

where  $q$  is the charge of the electron;  $B$  is the magnetic flux; and  $m$  is the mass of the electron.

When our parameters are substituted into the above equation, our answer is  $\omega = 6.15 \times 10^9 \text{ rad/s}$ . It has a unit of rad/s because we are dealing with cyclotron frequency.

8b

## Magnetic Field of a straight Current Carrying conductor.



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

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

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

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

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

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

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

Substituting  $\textcircled{**}$  into  $\textcircled{*}$ , we have.

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

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

Recall  $dl = dy$ .

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

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

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

$$B = \frac{\mu_0 I x}{4\pi} \left[ \frac{y}{x^2 + y^2} \right]^{\frac{1}{2}},$$

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

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

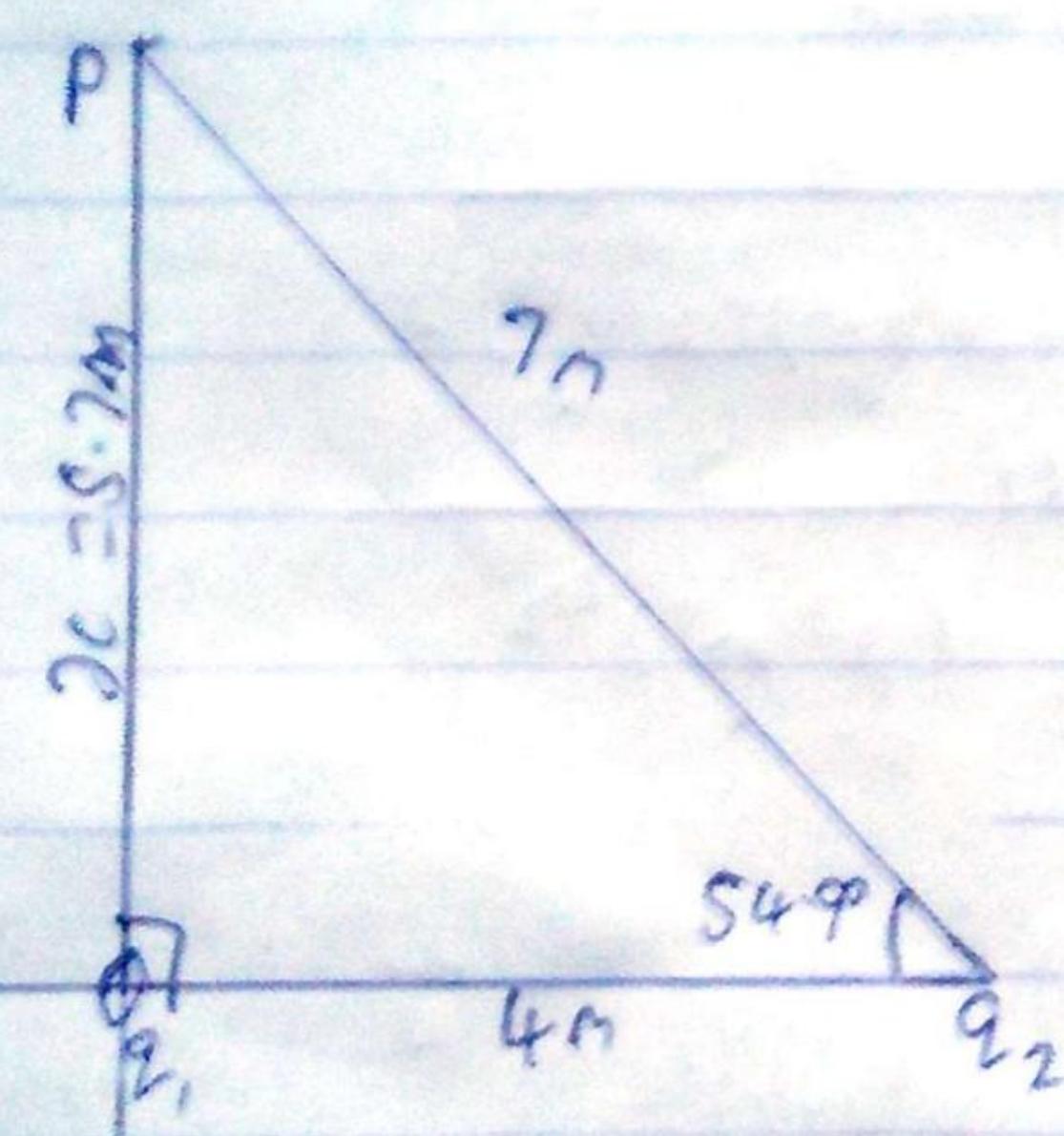
When the length  $2a$  of the conductor is very great in comparison to its distance  $x$  from point P, we consider it infinitely long. That is, when  $a$  is much larger than  $x$ ,

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

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

(a) Electric field is a region of space in which an electric charge will experience an electric force. Electric field intensity at a point in space is the quantitative expression of the intensity of an electric field at a particular location.

(b)



$$DC^2 = 7^2 - 4^2 \Rightarrow 49 - 16$$

$$DC = \sqrt{35}$$

$$DC = 5.7m$$

$$\tan \theta = \frac{5.7}{4}$$

$$\theta = \tan^{-1} (1.425)$$

$$\theta = 54.9^\circ$$

$$E_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(5.7)^2} = 2.22 \times 10^3 \text{ N/C}$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-6}}{(7)^2} = 2.20 \times 10^3 \text{ N/C}$$

Vector	Angle	$\times$ - Component.	$\gamma$ -Component
$E_1 = 2.22 \times 10^3$	$90^\circ$	$2.22 \times 10^3 \times \cos 90^\circ$ $= 0$	$2.22 \times 10^3 \times \sin 90^\circ$ $= 2.22 \times 10^3$
$E_2 = 2.20 \times 10^3$	$54.9^\circ$	$2.20 \times 10^3 \times \cos 54.9^\circ$ $= 1.27 \times 10^3$	$2.20 \times 10^3 \times \sin 54.9^\circ$ $= -1.8 \times 10^3$

$$\Sigma x = 1.27 \times 10^3 \text{ N/C}, \quad \Sigma y = 4.2 \times 10^3 \text{ N/C.}$$

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

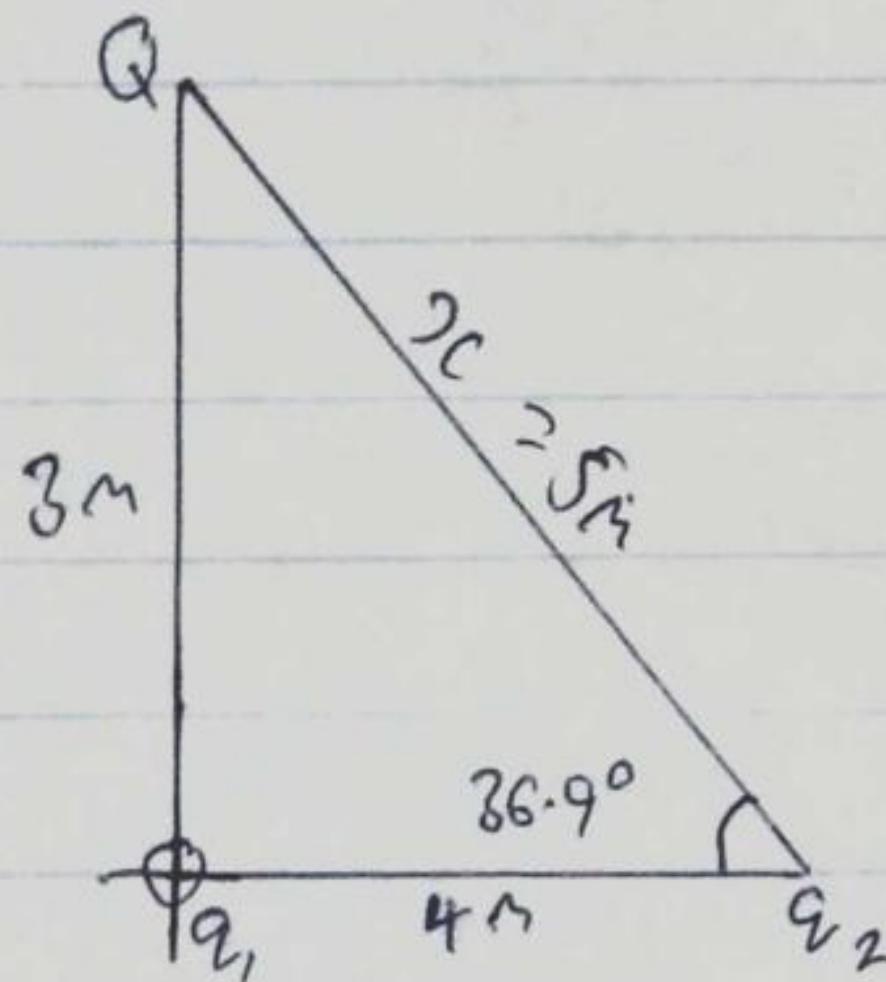
$$E = \sqrt{(1.27 \times 10^3)^2 + (4.2 \times 10^3)^2}$$

$$E = \sqrt{1789300}$$

$$E = 13.4 \times 10^2 \text{ N/C.}$$

∴ net electric field at point P =  $13.4 \times 10^2 \text{ N/C.}$

(1)



$$QC^2 = 3^2 + 4^2 \Rightarrow 9 + 16$$

$$QC = \sqrt{25}$$

$$QC = 5$$

$$\tan \theta = \frac{3}{4}$$

$$\theta = \tan^{-1}(0.75)$$

$$\theta = 36.8^\circ$$

$$E_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{3^2} = 8 \times 10^3 \text{ N/C.}$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-6}}{5^2} = 4.32 \times 10^3 \text{ N/C.}$$

$$\therefore \Sigma x = 3.8 \times 10^3 \text{ N/C}, \quad \Sigma y = 1.1 \times 10^4 \text{ N/C.}$$

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

$$E = \sqrt{(3.8 \times 10^3)^2 + (1.1 \times 10^4)^2}$$

$$E = \sqrt{13328 \times 10^4}$$

$$E = 11.8 \times 10^3 \text{ N/C.}$$

∴ net electric field at point Q =  $11.8 \times 10^3 \text{ N/C.}$