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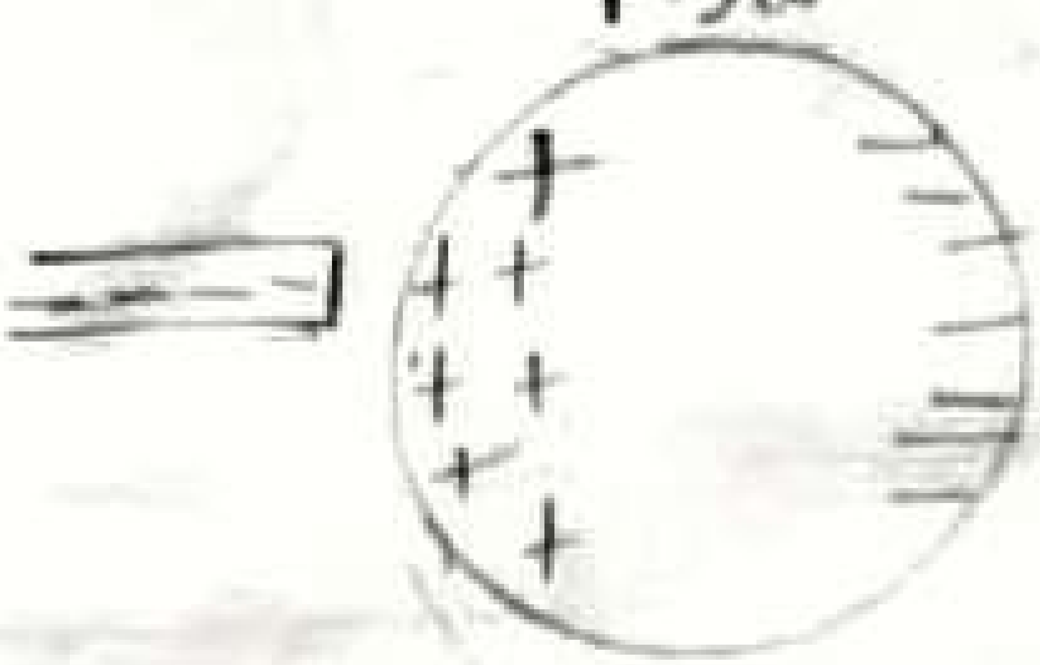
19/MHSO1/019

(1a) charging by induction :

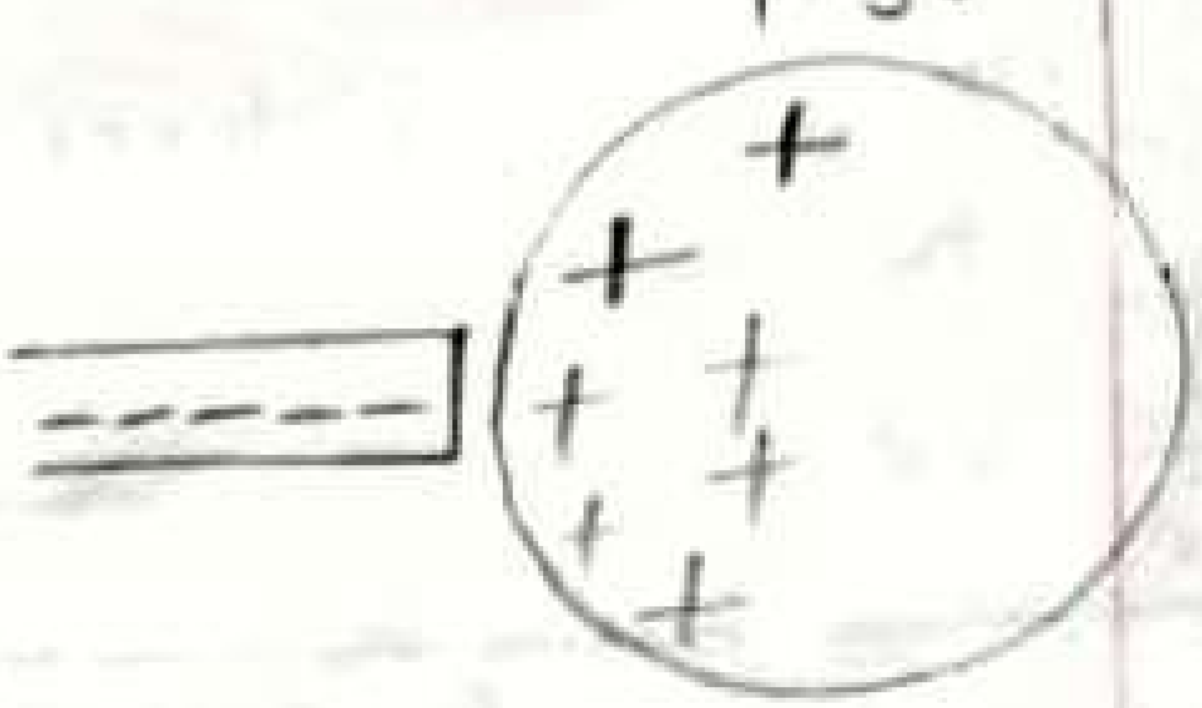
Electric Charges can be obtained on an object without touching it, by a process called electrostatic induction. Consider a positively charged rubber rod brought near a neutral conducting sphere that is insulated so that there is no conducting path. The repulsive force between the protons in the rod and 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. 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 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

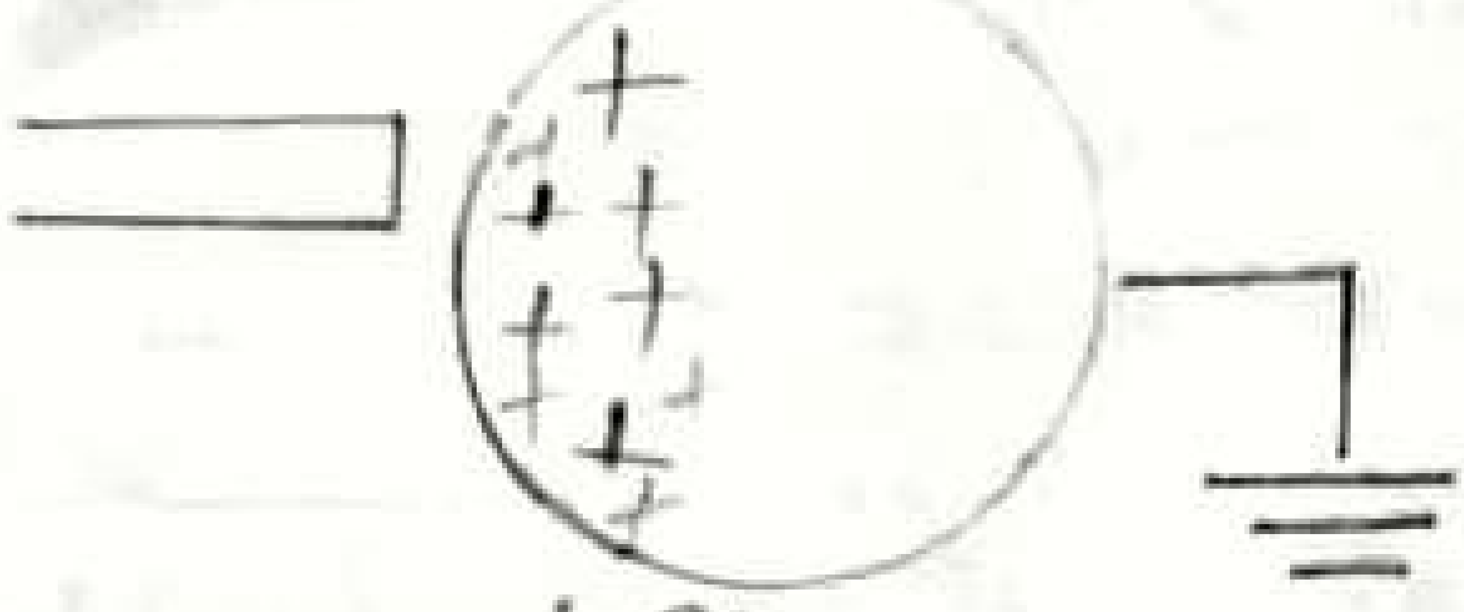
finally, when the rubber rod is removed from the vicinity of the sphere, the induced negatively charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.

1.3a

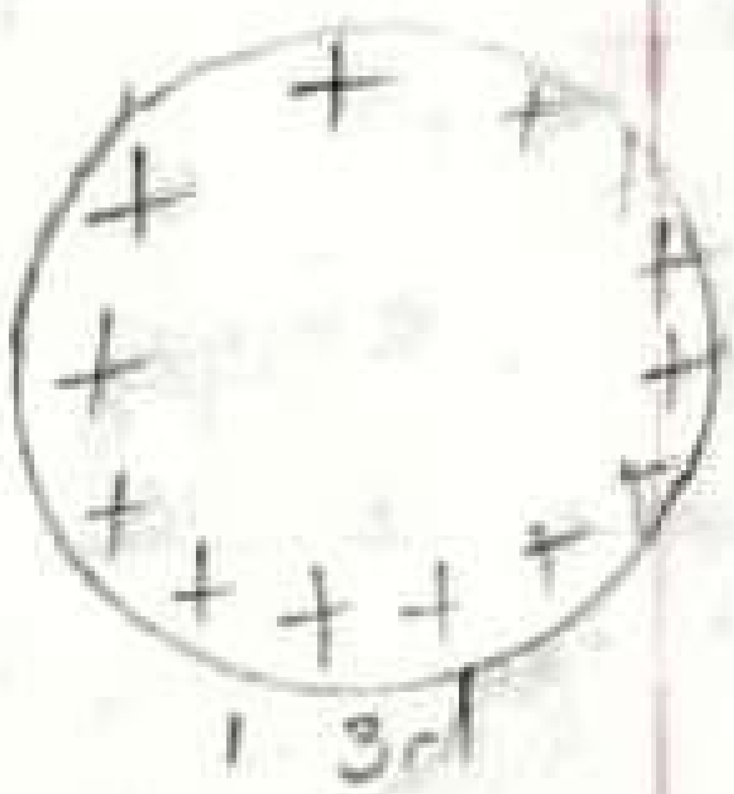


1.3c





1.3b



1.3d

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

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

$F = 1.0N$

$d = 2.0$

Calc the charge on each sphere

recall

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

$$1 = 9 \times 10^{9} = (q_2 - 5.0 \times 10^{-5}) = q_2$$

$$4.44 \times 10^{-10} = (q_2 - 5.0 \times 10^{-5}) q_2$$

$$4.44 \times 10^{-10} = q_2^2 - 5.0 \times 10^{-5} q^2$$

$$q_2 = 1.14 \times 10^{-5}$$

$$q_1 = 5.0 \times 10^{-5} - 1.4 \times 10^{-5}$$

$$= 3.86 \times 10^{-5} C$$

$q_1 = 3.86 \times 10^{-5} C$, $q_2 = 1.14 \times 10^{-5} C$

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

$d = 0.5m$

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

$\theta = \tan^{-1} 1/0.5$

$\theta = 63.4$

$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 5739.79$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 5739.79$

$E_q = \frac{kq}{r^2} = \frac{9\times10^9 \times q}{(1)^2} = 9\times10^9 q$

vector	Angle	x comp	y comp
5739.79	63.4	2570.045	5132.26
5739.79	63.4	2570.045	5132.26
$9\times10^9 q$	90	0	$9\times10^9 q$
		0	$E_y = 10264.52568 q$

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

$= \sqrt{0 + (1.0264.52568)^2}$

$= 0$

$0 = 9\times10^9 q + 10264.52568$

$q = \frac{-10264.52568}{9\times10^9} = 1.14050285 3\times10^{-6}$

$= 11.4\mu C$

2a An electric field is a region of space in which an electric charge will experience an electric force while the electric field strength or intensity can be defined as the force per unit charge. Mathematically it is given as: $E = F(N)/q(C)$ it is measured in Newton coulomb (N/C)

b $Q_1 = 8\mu C$, $Q_2 = 12\mu C$, $x = 4m$, $K = 9\times10^9$

(i) $x = 7m$

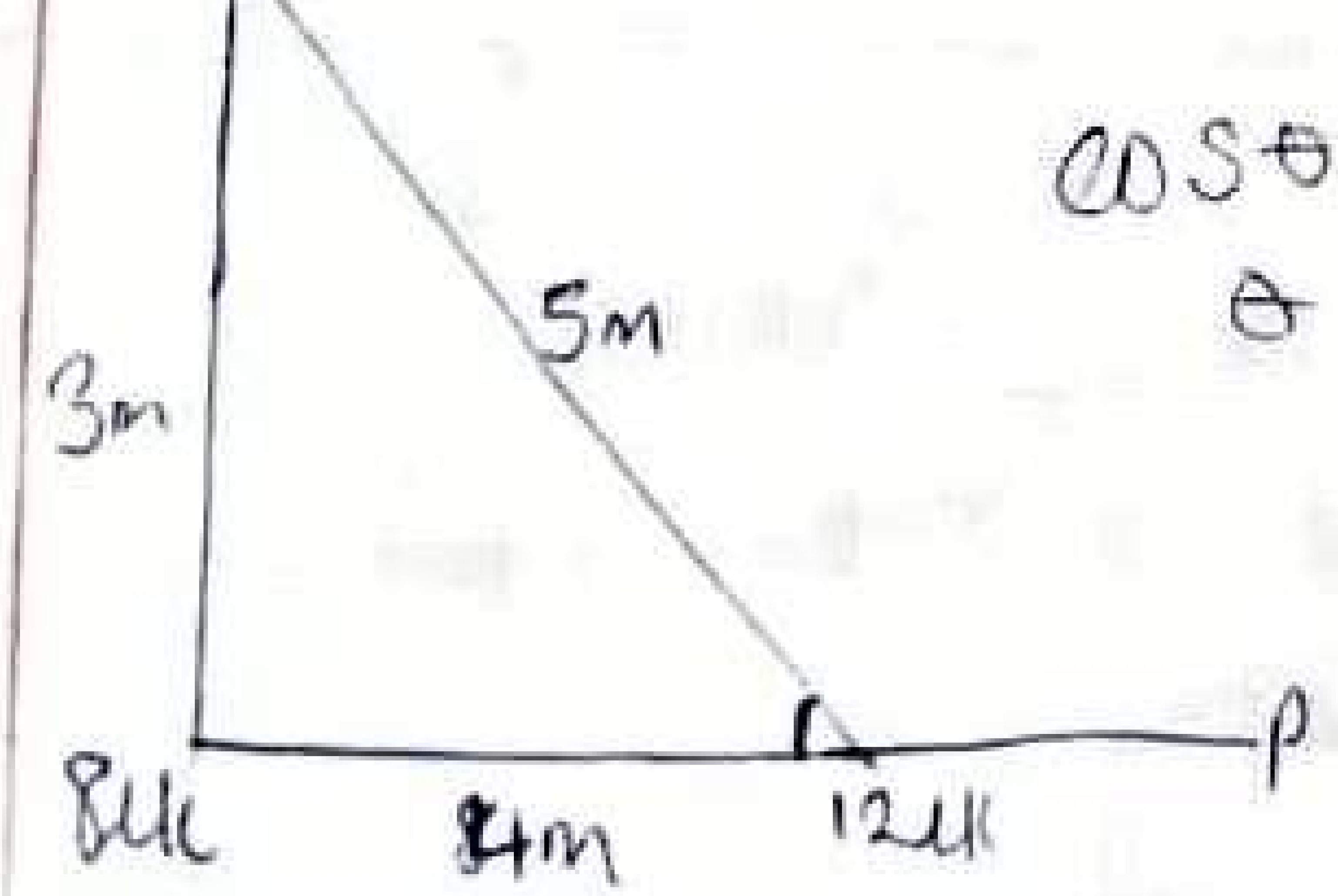
$E_1P = \frac{Kq_1P}{r^2} = \frac{9\times10^9 \times (8\times10^{-9})}{7^2} = 1.469 N/C$

$E_2P = \frac{Kq_2P}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12 N/C$

$E_{net} = 12 + 1.469$

$= 13.469 N/C$

ii



$\cos\theta = 4/5$

$\theta = 36.87$

$$E_1q = \frac{Kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-7}}{3^2} = 8\,N/C$$

$$E_2q = \frac{Kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\,N/C$$

Vector	Angle	x Comp	y Comp
$E_1q = 8\,N/C$	90°	$8\cos 90 = 0$	$8\sin 90 = 8$
$E_2q = 4.32\,N/C$	36.87°	$4.32\cos 36.87 = 3.46$	$4.32\sin 36.87 = 2.59$
		$E = 3.46\,N/C$	$E = 10.59\,N/C$

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

$$= 11.\ N/C$$

SECTION B

4a 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 $\phi = B dA$

4b $m = 9 \times 10^{-31} Kg$

$r = 1.4 \times 10^{-7} m$

$B = 3.5 \times 10^{-1}$ weber/m^2

cyclotron frequency = angular speed

$\omega = \frac{v}{r} = \frac{qB}{m}$

$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$

$\omega = 62222222222.22222 T^{-1}$

4c in the question we were given parameters like

(i) Mass of the electron = 9.11×10^{-31} Kg

ii A radius of $1.4 \times 10^{-7} m$

iii Magnetic field of 3.5×10^{-1} weber/m^2

we were asked to find cyclotron frequency which is otherwise called 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 $\omega = \frac{v}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-10}}{9.11 \times 10^{-31}}$

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

So since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $6.2222222222.22222 T^{-1}$, having a unit of $1/T$ 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_0), the current (I), the change in length, the radius and inversely proportional to square of radius (r^2) it can be represented mathematically by

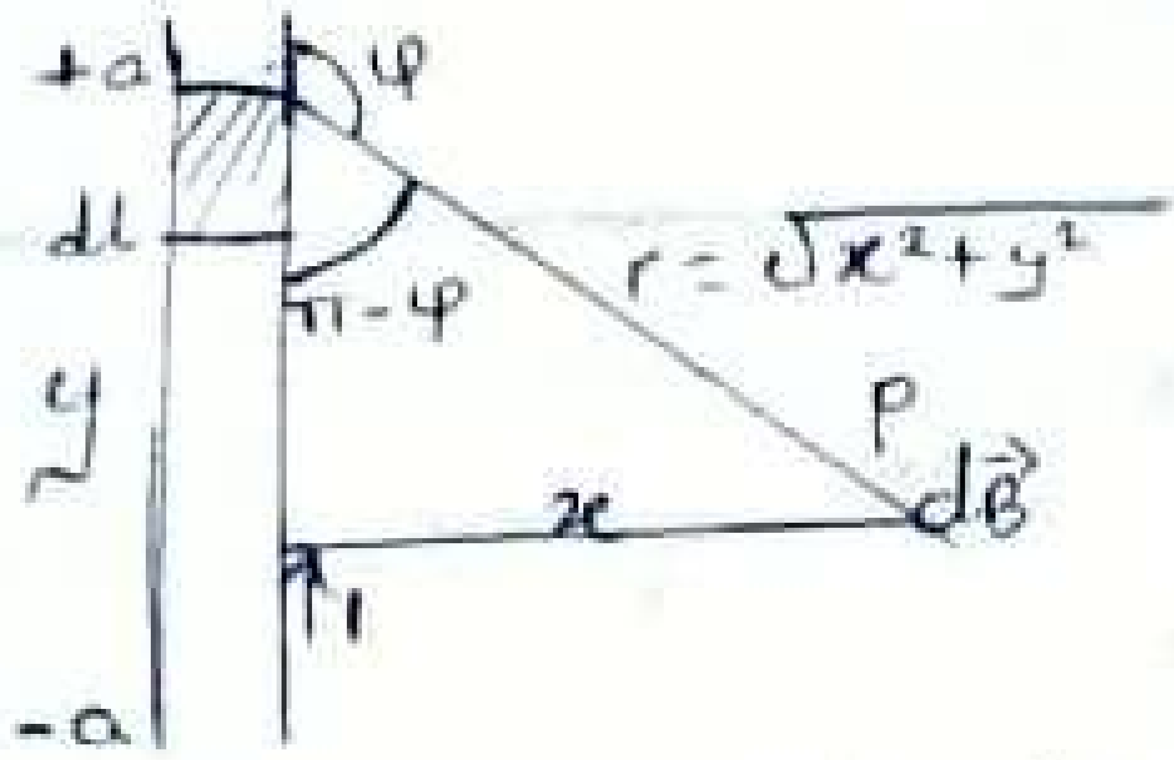
$$dB = \frac{\mu_0}{4\pi} \frac{I\, dl \times r}{r^2}$$

where μ_0 is a constant called permeability of free space

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

The unit of B is weber/m^2

5b Magnetic field of a straight current carrying conductor



A section of a straight current carrying conductor. Applying the Biot-savart law, we find 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

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

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

Substituting equ i into (ii) 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 $dl = dy$

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

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

Using special integrals

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

Eq (iii) becomes

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

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

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