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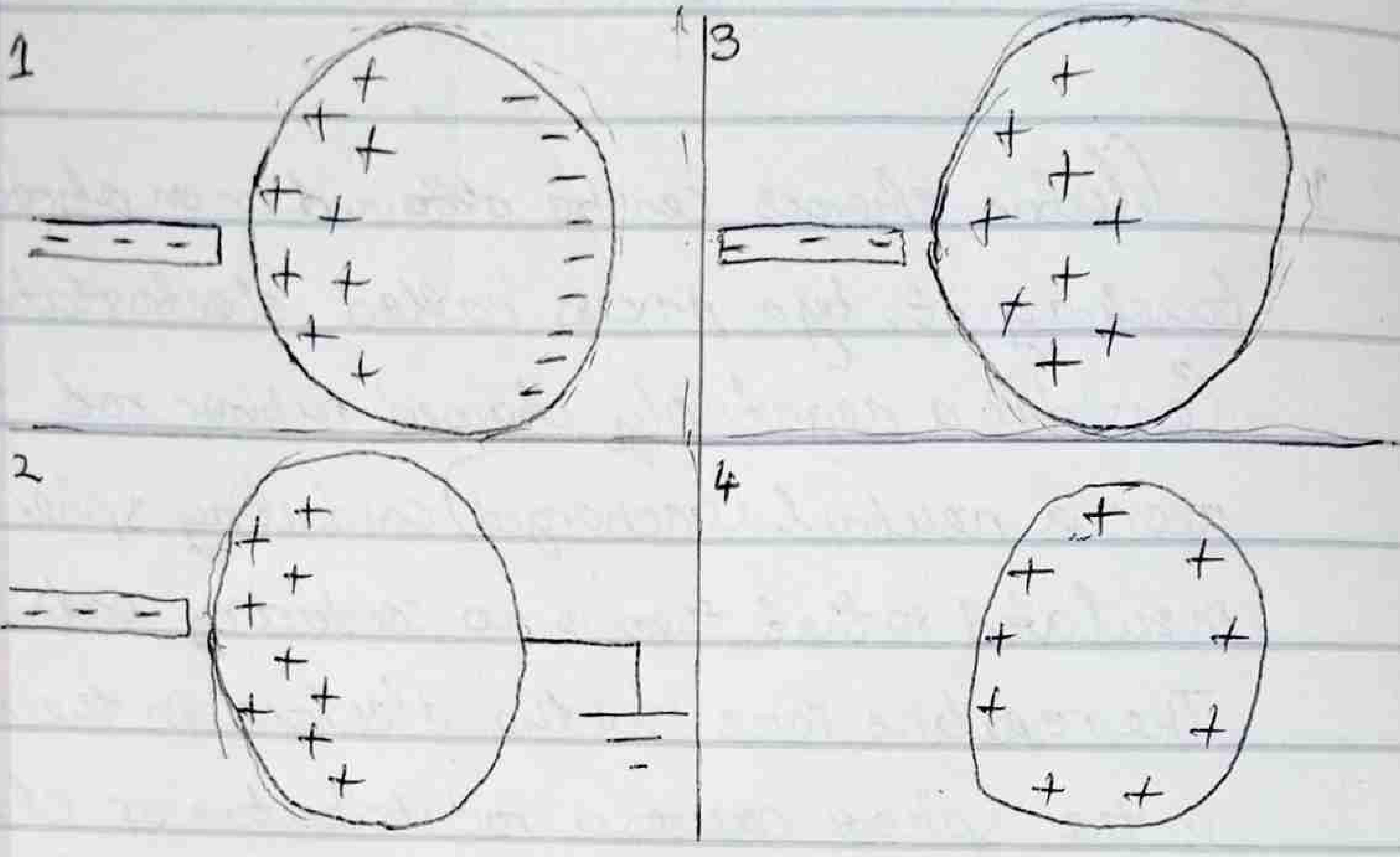
19/MHS01/156
COVID-19 HOLIDAY ASSIGNMENT

1 Electric charges can be obtained on an object without touching it, by a process called electrostatic induction. Consider a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to the ground. The repulsive force btw the electrons in the rod and those in the sphere causes a redistribution of charges on the 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 ground. When the wire is removed, the conducting sphere is left with an excess of induced positive charge. When the rubber rod is finally 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



Charging by Induction

~~1-b~~

1b Let q_1 and q_2 be the charges such that

$$q_1 + q_2 = 5.0\times10^{-5}\,C$$

$$q_1 = 5.0\times10^{-5}\,C - q_2$$

Using Colomb's Law

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

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

$$\frac{1 \times 2^2}{9 \times 10^9} = (5 \times 10^{-5} - q_2) q_2$$

$$4.4 \times 10^{-10} = 5 \times 10^{-5} q_2 - q_2^2$$

$$q_2^2 - 5 \times 10^{-5} q_2 + 4.4 \times 10^{-10} = 0$$

$$a = 1 \; ; \; b = -5 \times 10^{-5} \; ; \; c = 4.4 \times 10^{-10}$$

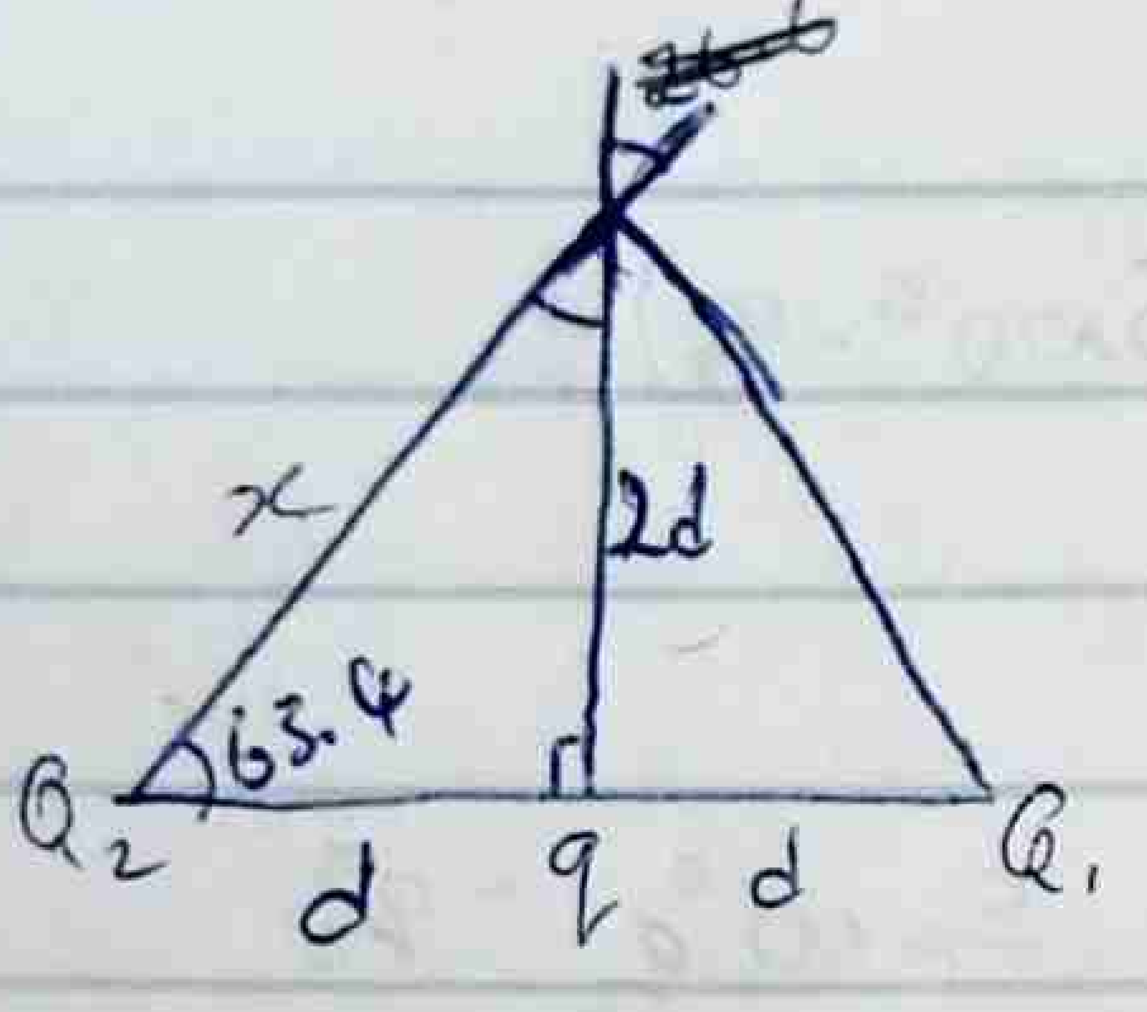
$$\cancel{q_2 = -b^2} \pm \cancel{\sqrt{4ac}}$$

$$q_2 = \frac{-b^2 \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{(5 \times 10^{-5})^2 \pm \sqrt{(-5 \times 10^{-5})^2 - 4(1 \times 4.4 \times 10^{-10})}}{2(1)}$$

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

1c



$x^2 = d^2 + (2d)^2$

$x^2 = d^2 + 4d^2$

$x = \sqrt{5d^2}$

$x = \sqrt{5}d$

$\theta = \sin^{-1} \frac{2d}{\sqrt{5}d}$

$\theta = 63.4$

$$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(\sqrt{5}d)^2} = \frac{72{,}000}{5(0.5)^2}$$

$$E_1 = 57{,}600 \text{ N/C}$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(\sqrt{5}\ d)^2} = \frac{72{,}000}{5(0.5)^2}$$

$$E_2 = 57{,}600 \text{ N/C}$$

$$E_3 = \frac{kq}{r^2} = \frac{9\times10^9 q}{1^2} = 9\times10^9 q$$

Vector	Angle	X - Component	Y - Component
$E_1 = 57{,}600$ N/C	$63.4°$	$-57600 \cos 63.4°$	$57600 \sin 63.4°$
		$= -25790.9$	$= 51503.3$
$E_2 = 57{,}600$ N/C	$63.4°$	$57600 \cos 63.6°$	$57600 \sin 63.4$
		$= 25790.9$	$= 51503.3$
$E_3 = 9\times10^9 q$	$90°$	0	$9\times10^9 q$
		$\Sigma E_x = 0$	$\Sigma E_y = 103006.6 + 9\times10^9 q$

$$E = \sqrt{0^2 + (103006.6 + 9\times10^9 q)^2}$$

$$0 = 103006.6 + 9\times10^9 q$$

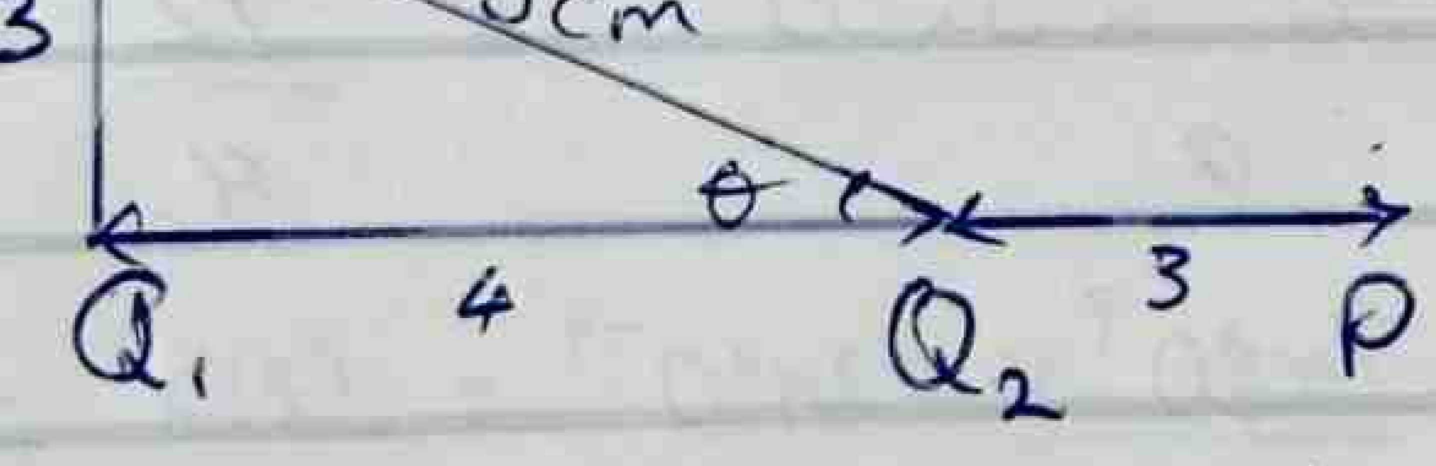
$$9\times10^9 q = -103006.6$$

$$q = \frac{-103006.6}{9\times10^9}$$

$$q = -11\times10^{-6} C$$

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

2b



$\theta = \sin^{-1} 3/5$

$\theta = 36.87°$

$$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{49} = \frac{72}{49} = 1.468$$

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$$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{9} = \frac{108}{9} = 12$$

$$E^2 = E_x^2 + E_y^2$$

Vector	Angle	X-Component	Y-Component
$E_1 = 1.469$	0	$1.469\cos 0 = 1.469$	0
$E_2 = 12$	0	$12\cos 0 = 12$	0
		$\Sigma E_x = 13.469$	$\Sigma E_y = 0$

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

$$E_{net} = 13.469\ N/C$$

$$E_{q_3 q_1} = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{9} = \frac{72}{9} = 8N/C$$

$$E_{q_3 q_2} = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{25} = \frac{108}{25} = 4.32\ N/C$$

Vector	Angle	X-Component	Y Component
8	$0°$	$8\cos(0)$	$8\sin(0)$
		$= 8$	$= 0$
4.32	$36.86°$	$4.32\cos(36.86)$	$4.32\sin(36.86)$
		$= 3.46$	$= 2.59$
		$\Sigma E_x = 11.46$	$\Sigma E_y = 2.59$

$$\cancel{E^2 = \sqrt{E_x}}$$

$$E = \sqrt{\Sigma E_x^2 + \Sigma E_y^2}$$

$$= \sqrt{131.3316 + 6.7081}$$

$$= \sqrt{138.0397}$$

$$E_{net} = 11.749$$

4a Magnetic flux is a measurement of the total magnetic field which passes through a given area and it is represented by lines of force. It is usually represented by Φ and is given as

$$\Phi = BA\cos\theta$$

The S.I unit is Weber (Wb)

b

$$\omega = \frac{qB}{m} = \frac{1.6\times10^{-19}C\times(0.35T)}{9.11\times10^{-31}} = 6.15\times10^{10}$$

$$\omega = 6.15\times10^{10}\ rad/s$$

c Cyclotron frequency is the same thing as angular speed "ω" which is measured in (rad/s) and given as:

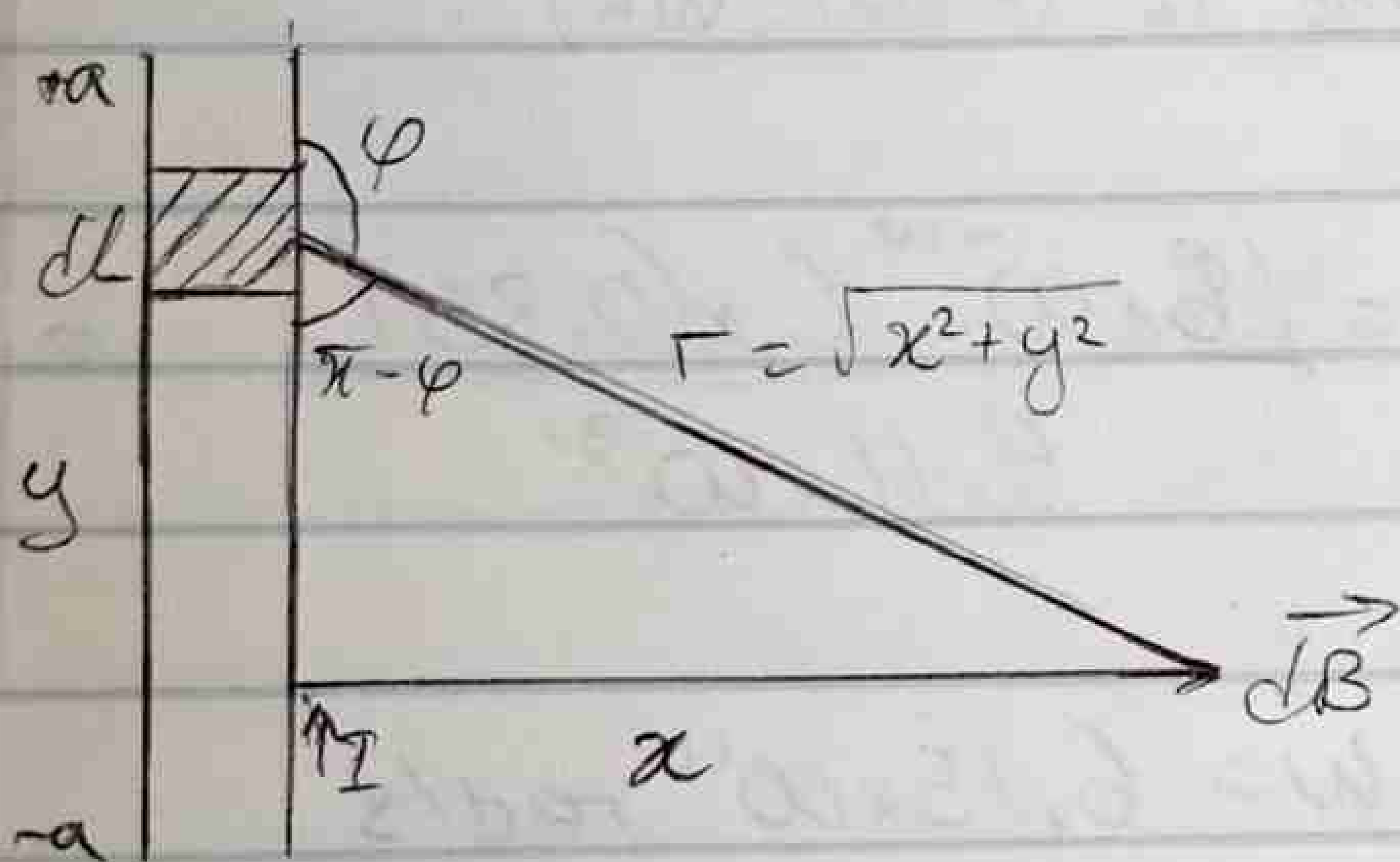
$$\omega = \frac{V}{r} = \frac{qB}{m}$$

5a $\vec{dB} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$ ⇒ The Biot-Savart Law

where μ_0 is ~~called~~ a constant called "Permeability of free space"

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

b



Applying Biot-Savart Law

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

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

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

Since $r = \sqrt{x^2+y^2}$

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

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

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

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

but $dl = dy$

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

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

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~~

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

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

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

When in a circle of radius r

$$\boxed{B = \frac{\mu_0 I}{2\pi r}}$$