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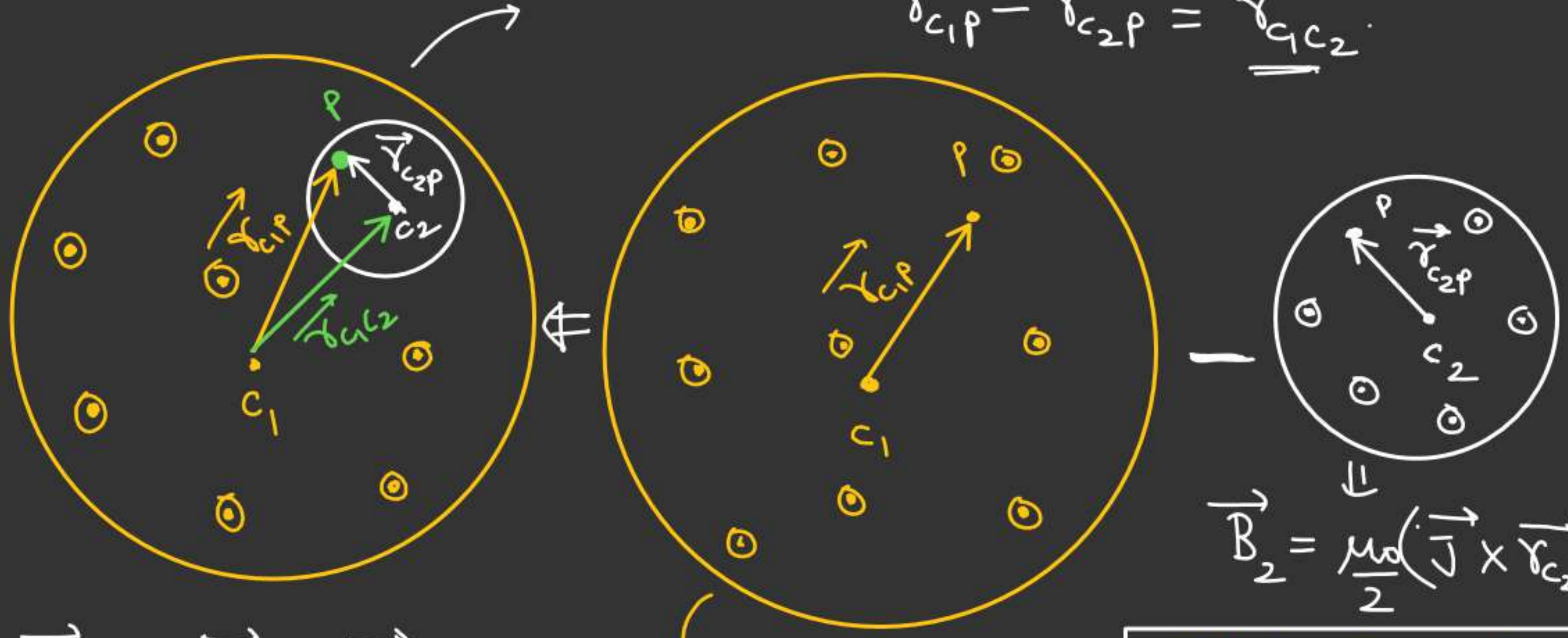
Magnetic field Inside the Cylindrical Cavity of a Very long Cylinder

Top View

By Δ Law

$$\vec{r}_{c_1p} = \vec{r}_{c_1c_2} + \vec{r}_{c_2p}$$

$$\vec{r}_{c_1p} - \vec{r}_{c_2p} = \vec{r}_{c_1c_2}$$



$$\vec{B}_2 = \frac{\mu_0}{2}\left(\vec{J} \times \vec{r}_{c_2p}\right)$$

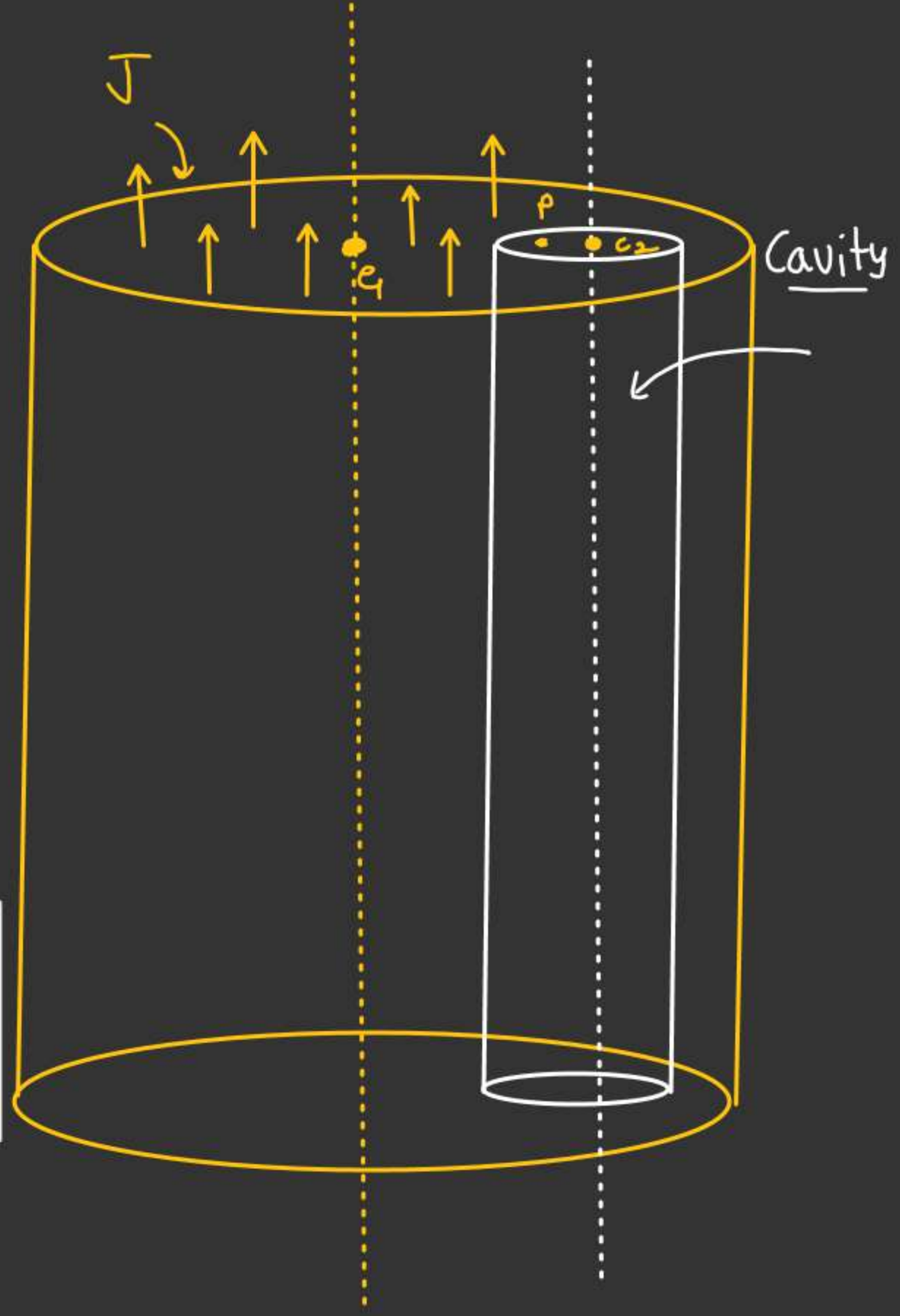
$$\vec{B}_1 = \frac{\mu_0}{2}\left(\vec{J} \times \vec{r}_{c_1p}\right)$$

$$\vec{B}_p = \vec{B}_1 - \vec{B}_2$$

$$\frac{\mu_0 \vec{J}}{2} \times \left(\vec{r}_{c_1p} - \vec{r}_{c_2p}\right)$$

$$\boxed{\vec{B}_{\text{Cavity}} = \frac{\mu_0}{2}\left(\vec{J} \times \vec{r}_{c_1c_2}\right)}$$

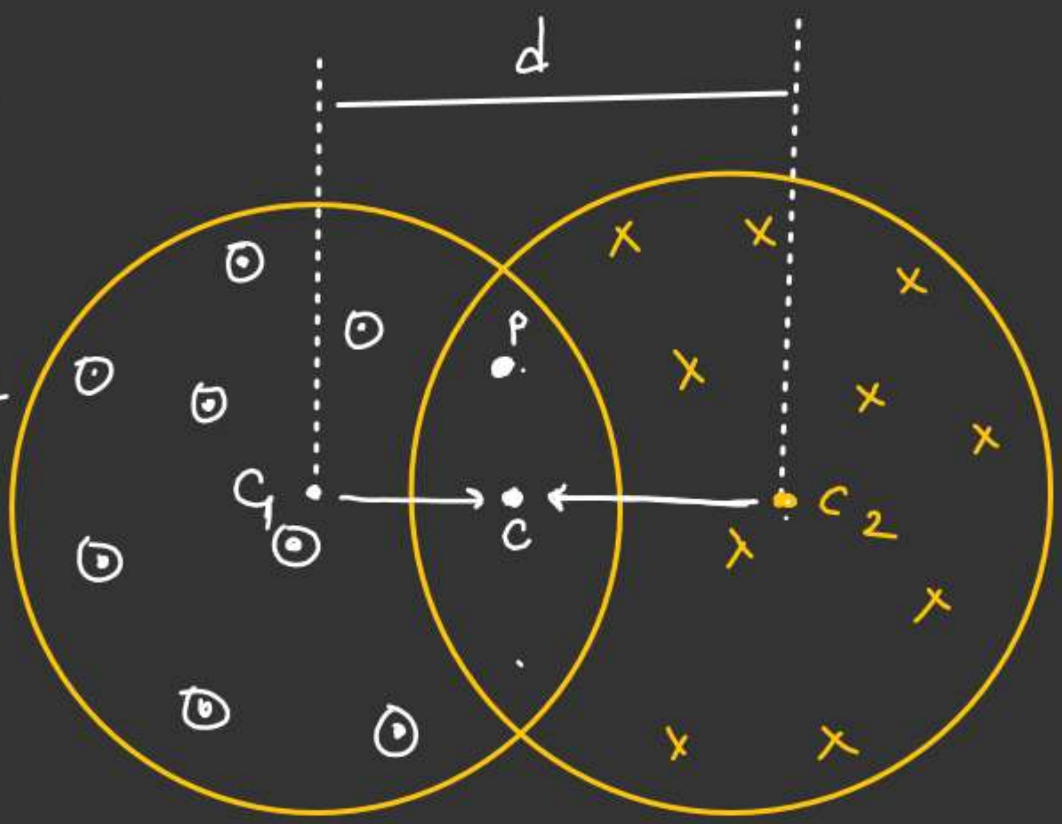
Note:- Magnetic field inside the Cavity is uniform



$J \rightarrow$ (Current density in both the Cylindrical conductor)

$\vec{B}_P = ??$

$\vec{r}_{c_2c} = -\vec{r}_{cc_2}$

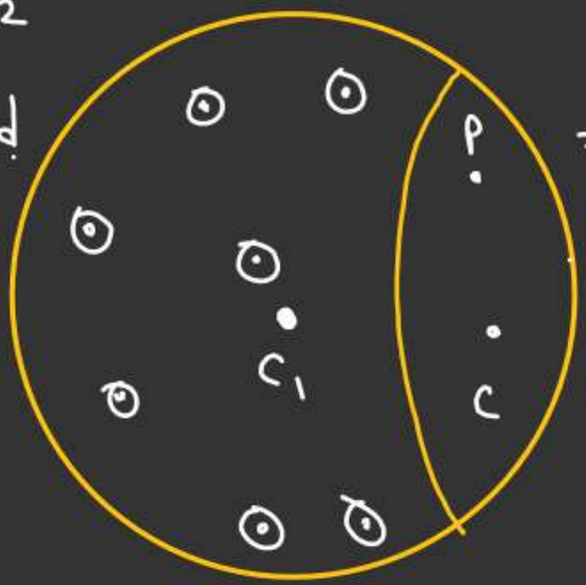


$$\vec{B}_P = \vec{B}_1 - \vec{B}_2$$

$$\vec{B}_P = \frac{\mu_0}{2}\vec{J} \times (\vec{r}_{c_1c} - \vec{r}_{c_2c})$$

$J \perp r_{c_1c_2}$

$|\vec{r}_{c_1c_2}| = d$



$$\Rightarrow \vec{B}_1 = \frac{\mu_0}{2}(\vec{J} \times \vec{r}_{c_1c})$$

$$\vec{B}_2 = \frac{\mu_0}{2}(\vec{J} \times \vec{r}_{c_2c})$$

$$\vec{B}_P = \frac{\mu_0}{2}\vec{J} \times (\vec{r}_{c_1c} + \vec{r}_{cc_2})$$

$$\vec{B}_P = \frac{\mu_0}{2}\vec{J} \times (\vec{r}_{c_1c_2})$$

$$|\vec{B}_P| = \left(\frac{\mu_0}{2} J r_{c_1c_2}\right) = \left(\frac{\mu_0 J d}{2}\right)$$

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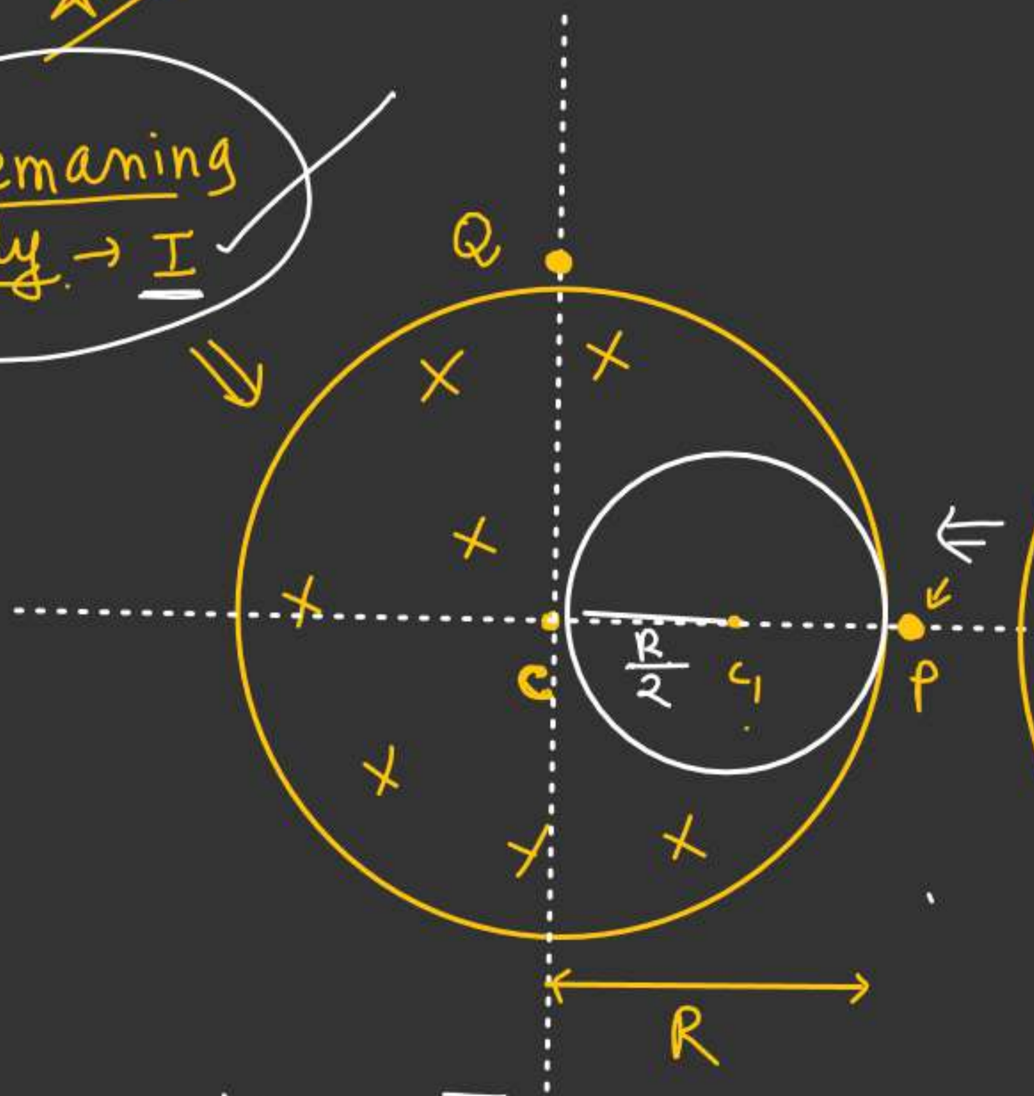
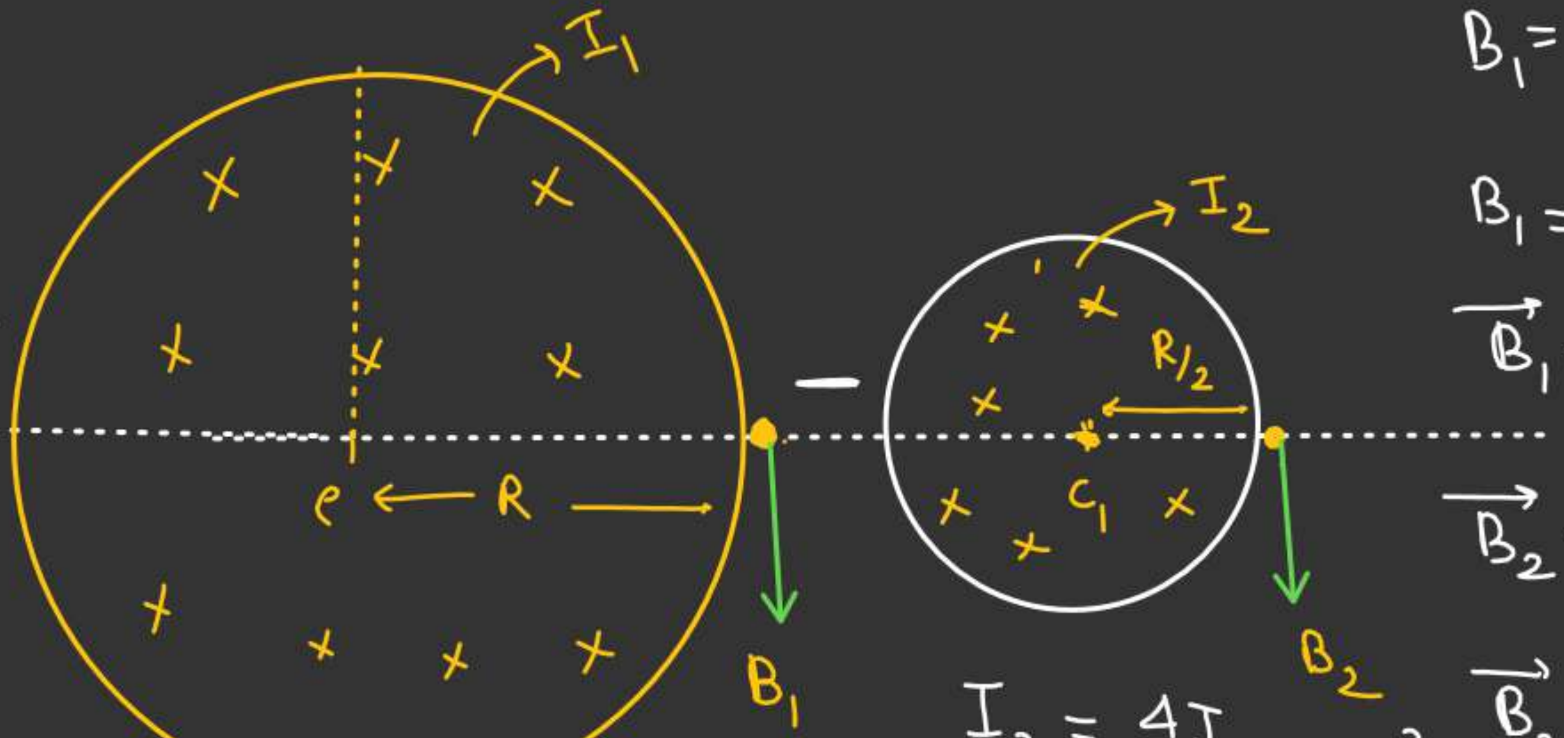
Find Magnetic field at P & Q if I be the current in the Conductor shown in fig.

Remaning body → I





$$J = \frac{I}{\left(\pi R^2 - \frac{\pi R^2}{4}\right)} = \left(\frac{4I}{3\pi R^2}\right)$$

$$I_1 = J \times \pi R^2 = \frac{4I}{3\pi R^2} \times \pi R^2 = \left(\frac{4I}{3}\right)$$

$$I_2 = \frac{4I}{3\pi R^2} \times \frac{\pi R^2}{4}$$

$$I_2 = \left(\frac{I}{3}\right)$$

$$B_1 = \frac{\mu_0 I_1}{2\pi R}$$

$$B_1 = \frac{\mu_0}{2\pi R} \times \frac{4I}{3}$$

$$\vec{B}_1 = \frac{2\mu_0 I}{3\pi R}(-\hat{j})$$

$$\vec{B}_2 = \frac{\mu_0}{2\pi\left(\frac{R}{2}\right)} \times \frac{I}{3}(-\hat{j})$$

$$\vec{B}_2 = \frac{\mu_0 I}{3\pi R}(-\hat{j})$$

$$\vec{B}_P = \vec{B}_1 - \vec{B}_2$$

$$= -\left[\frac{2\mu_0 I}{3\pi R} - \frac{\mu_0 I}{3\pi R}\right]\hat{j} = -\frac{\mu_0 I}{3\pi R}\hat{j}$$

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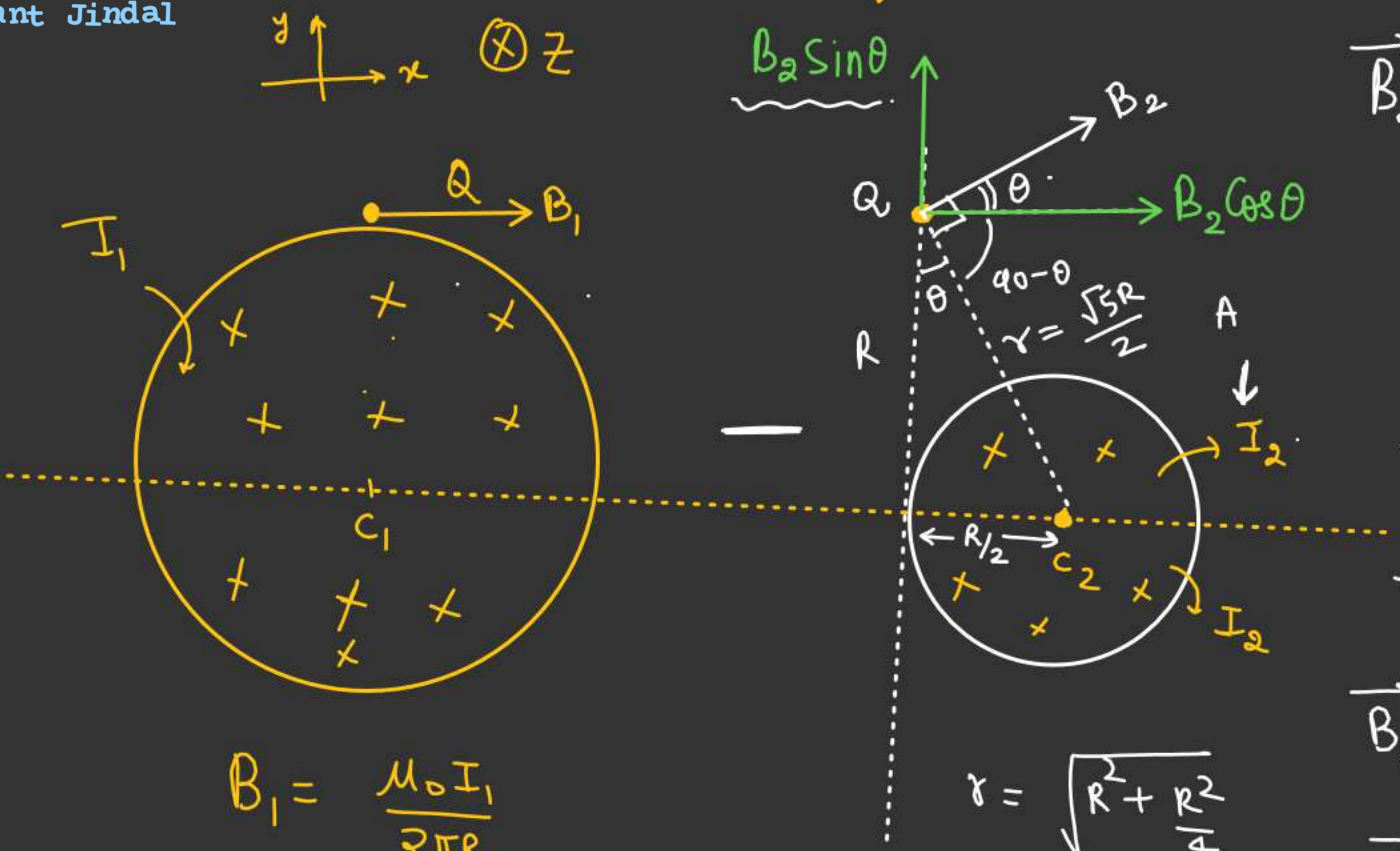

$$B_1 = \frac{\mu_0 I_1}{2\pi R}$$

$$B_1 = \frac{\mu_0}{2\pi R}\times\left(\frac{4I}{3}\right)$$

$$\vec{B}_1 = \left(\frac{2\mu_0 I}{3\pi R}\right)\hat{i}$$ ✓

$$r = \sqrt{R^2 + \frac{R^2}{4}}$$

$$r = \sqrt{\frac{5R^2}{4}} = \frac{\sqrt5 R}{2}$$

$$B_2 = \frac{\mu_0 I_2}{2\pi r} = \frac{\mu_0}{2\pi\left(\frac{\sqrt5 R}{2}\right)}\left(I/3\right)$$

$$B_2 = \frac{\mu_0 I}{\sqrt5(3\pi R)}$$

$$\vec{B}_2 = B_2\cos\theta\,\hat{i} + B_2\sin\theta\,\hat{j}$$

$$= B_2\left[\cos\theta\,\hat{i} + \sin\theta\,\hat{j}\right]$$

$$= B_2\left[\frac{2R}{\sqrt5 R}\hat{i} + \frac{R}{2}\times\frac{2}{\sqrt5 R}\hat{j}\right]$$

$$= B_2\left[\frac{2}{\sqrt5}\hat{i} + \frac{1}{\sqrt5}\hat{j}\right]$$

$$= \frac{\mu_0 I}{\sqrt5(3\pi R)}\left[\frac{2}{\sqrt5}\hat{i} + \frac{1}{\sqrt5}\hat{j}\right]$$

$$\vec{B}_2 = \frac{2\mu_0 I}{15\pi R}\hat{i} + \frac{\mu_0 I}{15\pi R}\hat{j}$$ ✓

$$\vec{B}_Q = \left(\vec{B}_1 - \vec{B}_2\right)$$

$$\frac{8\mu_0 I}{15\pi R}\hat{i} - \frac{\mu_0 I}{15\pi R}\hat{j}$$ ✓

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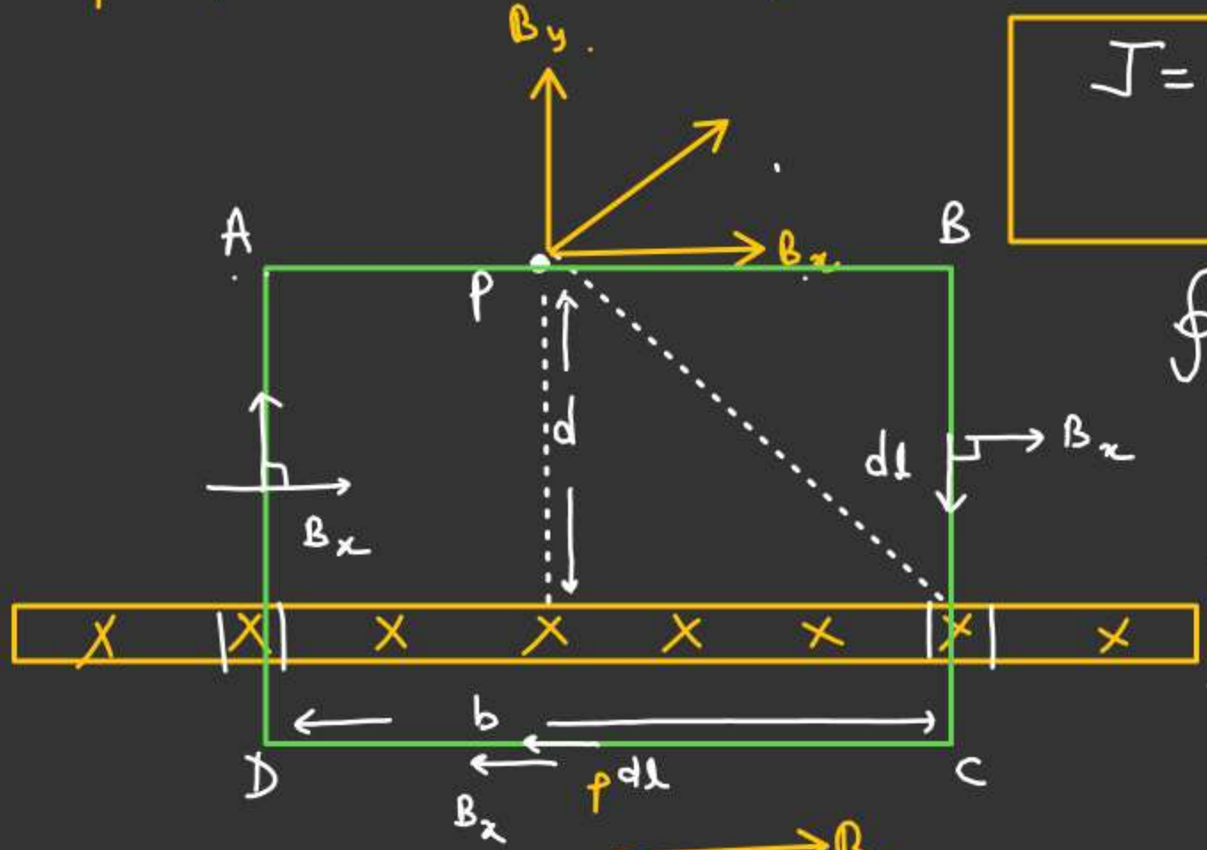
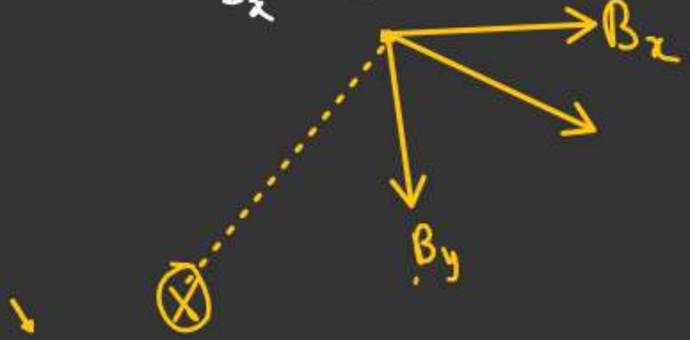
Very large Conducting plate

Find Magnetic field at any point P perpendicular to plate





$\boxed{J = \text{Current per Unit Width}}$

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 I_{enc}$$

$$\int_{AB}\vec{B}\cdot\vec{dl} + \underbrace{\int_{BC}\vec{B}\cdot\vec{dl}}_{0} + \int_{CD}\vec{B}\cdot\vec{dl} + \underbrace{\int_{DA}\vec{B}\cdot\vec{dl}}_{0} = \mu_0 I$$

$$2B\cancel{b} = \mu_0 J \cancel{b}$$

$$\boxed{B = \frac{\mu_0 J}{2}}$$

d → Very Small as Compared to dimension of the plate