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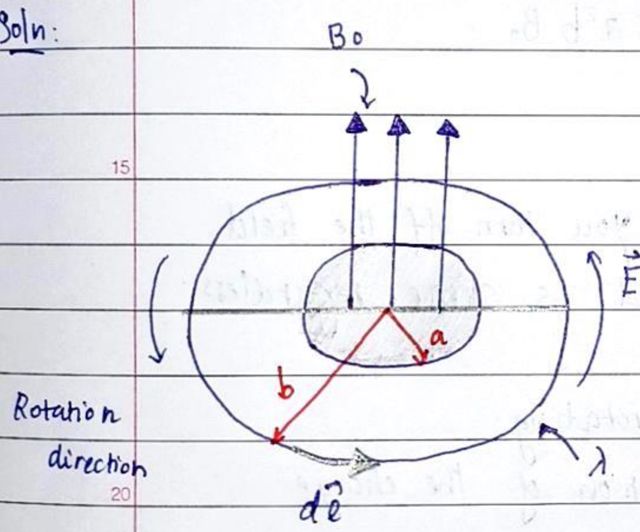
PH1213 · PRESENTATION

Q·5 A line charge λ is glued onto the rim of a wheel of radius b, which is then suspended horizontally, (as shown in fig below), so that it is free to rotate (the spokes are made of some non conducting material - wood, maybe). In the central region, out to radius a, there is a uniform magnetic field B_0, pointing up. Now someone turns the field off. What happens?

Soln:



The changing magnetic field will induce an electric field, curling around the axis of the wheel. This electric field exerts a force on the charges at the rim, and the wheel starts to turn.

According to Lenz's law, it will rotate in such a direction that its field tends to restore the upward flux. The motion, then is counterclockwise as viewed from above.

Faraday's law, applied to the loop at radius b, says

$$\oint \vec{E} \cdot d\vec{l} = E(2\pi b) = -\frac{d\phi}{dt} = -\pi a^2 \cdot \frac{dB}{dt}$$

$$E = -\frac{a^2}{2b}\frac{dB}{dt}\,\hat{\phi}.$$

The torque on a segment of length $d\vec{l}$ is $(\vec{r} \times \vec{F})$ or $b\lambda E\, dl$.

The total torque on the wheel is therefore

$$N = b\lambda \left(-\frac{a^2}{2b}\frac{dB}{dt}\right)\oint dl$$

$$N = -b\lambda\pi a^2 \frac{dB}{dt}$$

Angular momentum imparted to the wheel is

$$\int N\,dt = -\lambda\pi a^2 b \int_{B_0}^{0} dB = \lambda\pi a^2 b B_0.$$

It doesn't matter how quickly or slowly you turn off the field; the resulting angular velocity of the wheel is same regardless.

Here its the electric field that did the rotating
Here magnetic field is zero at the location of the charge

When we switch off the magnetic field, electric field automatically appears and its the electric field that turned the wheel.

Total change in momentum only depends on initial and final magnetic field.