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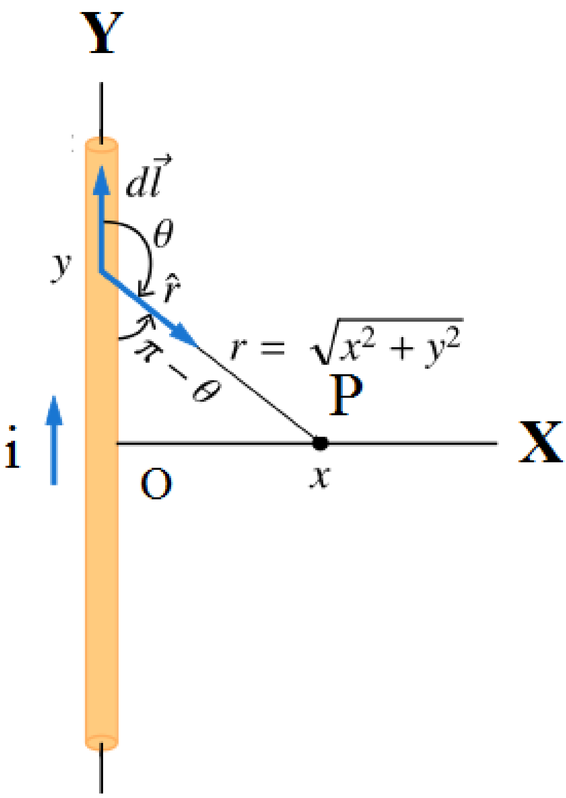
MAGNETIC FIELD DUE TO A LONG STRAIGHT CURRENT CARRYING CONDUCTOR

(తిన్నని విద్యుత్ప్రవాహ వాహకం వల్ల విద్యుత్ క్షేత్రం)

Consider an infinite long current carrying conductor carrying current 'i' as shown in the following figure.



The aim of this topic is to derive an expression for magnetic induction 'B' due to the conductor at point 'P' with the help of Biot – Savart law. Let the distance of 'P' from the point 'O' is 'x'. Further, consider a small element of length 'dl' at a distance of 'y' from 'O' as shown in the figure. Let 'r' be the distance between the element and point 'P' and θ be the angle in clockwise direction between the direction of current and the line joining the element to point 'P'. Using Biot-Savart law, the magnitude of 'dB' at point 'P' due the element 'dl' is given by

$$dB = \frac{\mu_0}{4\pi} \times \frac{idl\sin\theta}{r^2}$$

The field due to the whole conductor is given by

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$B = \int dB = \int_{-\infty}^{+\infty} \frac{\mu_0}{4\pi} \times \frac{idl sin\theta}{r^2} \quad = \frac{\mu_0 i}{4\pi} \times \int_{-\infty}^{+\infty} \frac{dl sin\theta}{r^2}$ ----(1)

From the figure, $r = (x^2 + y^2)^{\frac{1}{2}}, sin\theta = sin(\pi - \theta) = \frac{y}{r}$

and $sin\theta = \frac{y}{(x^2+y^2)^{\frac{1}{2}}}$

By substituting these values in equation (1), one can get,

$B = \frac{\mu_0 i}{4\pi} \times \int_{-\infty}^{+\infty} \frac{xdl}{(x^2+y^2)^{\frac{3}{2}}}$ ----(2)

To solve this integral, let y=xtanα, dy=xsec^2αdα, when these values used, the limits of the above change to -π/2 to +π/2

Therefore, $B = \frac{\mu_0 i}{4\pi} \times \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \frac{x \times x\sec^2\alpha d\alpha}{(x^2+x^2tan^2\alpha)^{\frac{3}{2}}} = \frac{\mu_0 i}{4\pi} \times \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \frac{x^2\sec^2\alpha d\alpha}{x^3(1+tan^2\alpha)^{\frac{3}{2}}} = \frac{\mu_0 i}{4\pi} \times \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \frac{x^2\sec^2\alpha d\alpha}{x^3(sec^2\alpha)^{\frac{3}{2}}}$

$\Longrightarrow B = \frac{\mu_0 i}{4\pi x} \times \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \cos\alpha d\alpha = \frac{\mu_0 i}{4\pi x} [sin\alpha]_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} = \frac{\mu_0 i}{4\pi x} [1+1] \Longrightarrow B = \frac{\mu i}{2\pi x} \quad \frac{weber}{meter^2}$ $or\ Tesla$ ----(3)

Equation (3) an expression due to a long straight current carrying conductor at a distance of 'x'.

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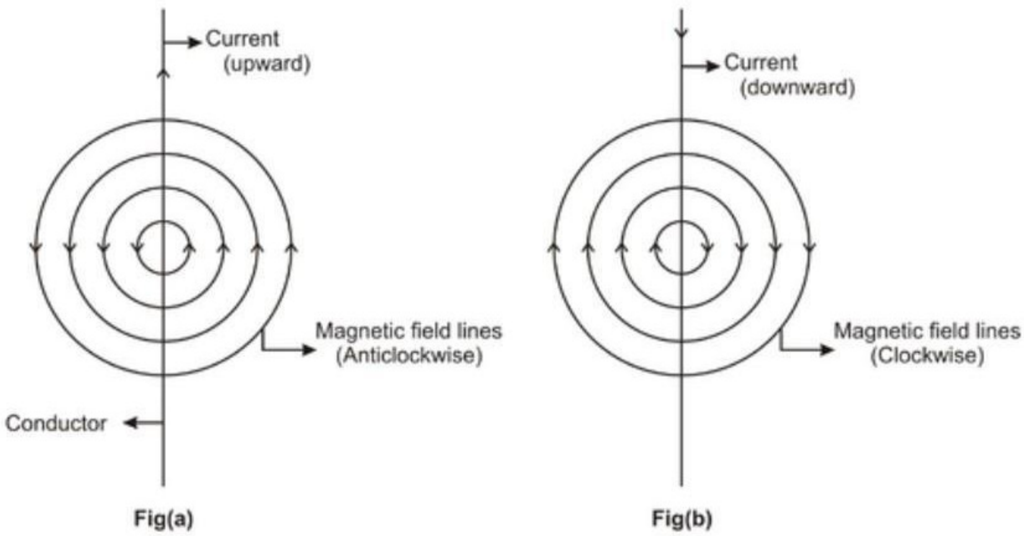
The magnetic lines of force around the straight conductor are assumed to be concentric circles as shown in the following figure



The lines near the conductor will be more and far from the conductor will be less.

Model questions(మాదిరి ప్రశ్నలు):

1. Derive an expression for magnetic field due to a long straight current carrying conductor
2. Applying Biot Savart Law, derive an expression for magnetic field due to a long straight conductor carrying current.

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3. Calculate the intensity of magnetic field due to a long straight conductor carrying current.
4. State and explain Biot Savart law. Derive an expression for the magnetic induction at a point due to an infinitely long straight conductor carrying current.

References:

1. Unified Physics, Volume III, Jai Prakash Nath Publications, Meerut

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