$$B = \frac{\mu_0}{4\pi}\frac{Ia}{r^3}2\pi a$$

$$B = \frac{\mu_0}{2}\frac{Ia^2}{r^3}$$

$$B = \frac{\mu_0 Ia^2}{2(a^2+x^2)^{3/2}} \quad [r = \sqrt{a^2+x^2}]$$

For N turns,

$$B = \frac{\mu_0 NI\ \ ^2}{2(a^2+x^2)^{3/2}} \quad [r = \sqrt{a^2+x^2}]$$

Special Cases:

1. If, x>>>a, in this case the value of a can be neglected as compare to x,

$$\boxed{B = \frac{\mu_0 NIa^2}{2(x^2)^{3/2}} = \frac{\mu_0 NIa^2}{2x^3}}$$

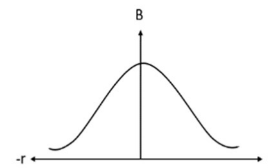
2. If x=0,

$$\boxed{B = \frac{\mu_0 NIa^2}{2a^3} = \frac{\mu_0 NI}{2a}}$$

This is the case of magnetic field due to circular coil at the center.

Note:

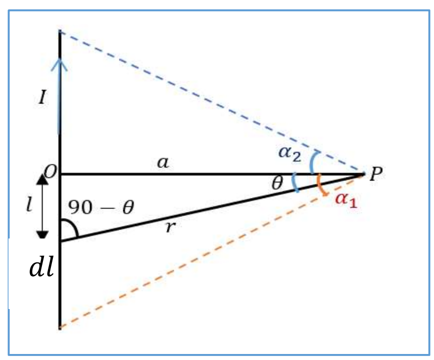
- If the point on the axis of the coil is at a distance equal to radius of the coil, i.e. $x = a$, then, $B = \frac{\mu_0 NI}{\sqrt{32}a}$
- The variation of magnetic field (B) and distance (r) of a point on the axis of circular coil carrying current is represented as:



Magnetic Field due to straight conductor:

Let us take a straight conductor carrying current $'I'$ in upward direction. We have to calculate magnetic field at point $'P'$ at a distance $'a'$ from the straight conductor i.e. $OP = a$. Let us take small element of length $'dl'$. According to Biot & Savart law, magnetic field at point $'P'$ due to the small element $'dl'$,

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin(90- \ )}{r^2} --(1)$$



From fig,

$$\sin(90-\theta) = \frac{a}{r} = \cos\theta$$

$$r = a\sec\theta \ ------(2)$$

And,

$$\tan\theta = \frac{l}{a}$$

$$l = a\tan\theta$$

$$dl = asec^2\theta d\theta ---(3)$$

Using eq. (2) and (3) in eq. (1),

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\cos\theta}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Iasec^2\theta d\theta\ \cos\theta}{(a\,se\ \ )^2}$$

$$dB = \frac{\mu_0 I}{4\pi a}\cos\theta\, d\theta ----(4)$$

Now, total magnetic field can be obtained by integrating equation (4) from limit $-\alpha_1$ to α_2

$$B = \int_{-\alpha_1}^{\alpha_2} dB$$