

Magnetic Phenomena

Magnetic Field

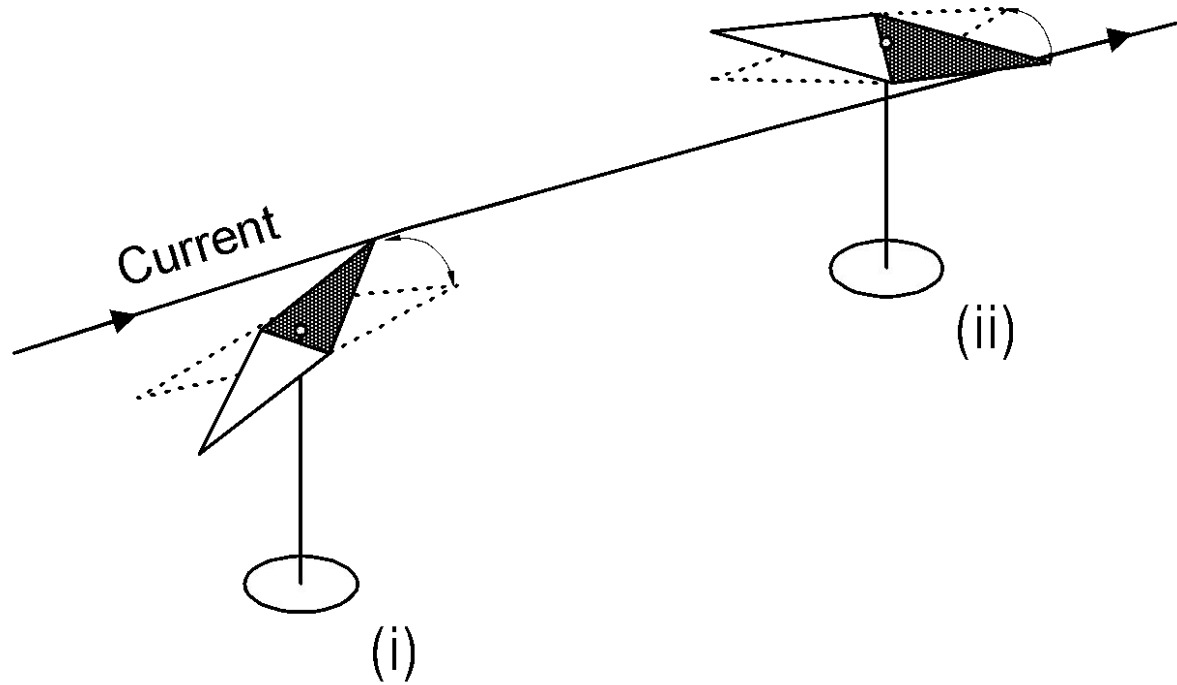
Magnetic Field

- Experiment on a Magnetic Field
- Force Lines of a Magnetic Field
- Law of Biot and Savart
- Principle of Superposition
- Magnetic Field along Axis of a Loop with Current
- Magnetic Field in a Centre of a Loop with Current
- Magnetic Field due to a Current Through a Long Straight Wire

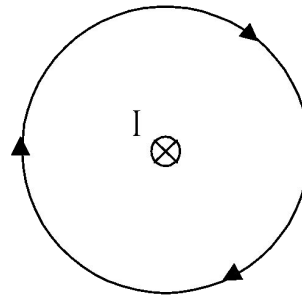
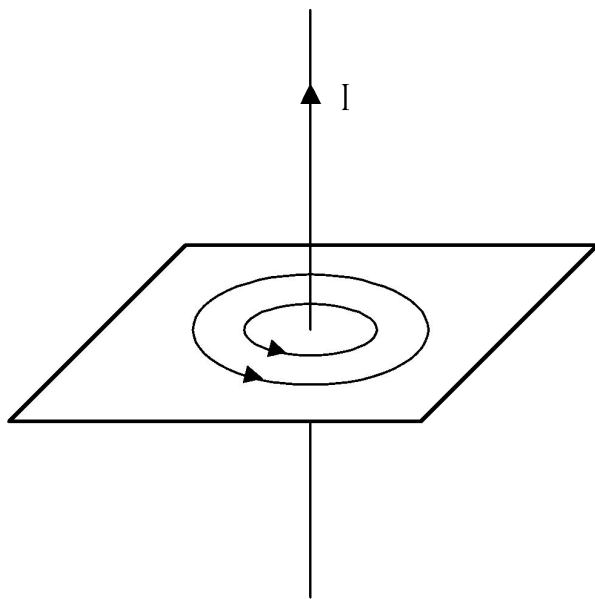
Magnetic Field (continued)

- Ampere's Circulation Law
- Intensity of the Magnetic Field Outside and Inside a Straight Wire
- Solenoid

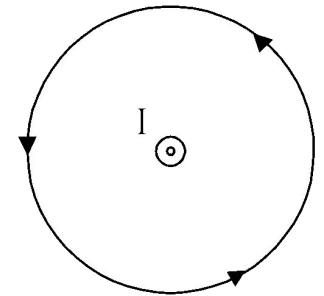
Experiment on a Magnetic Field



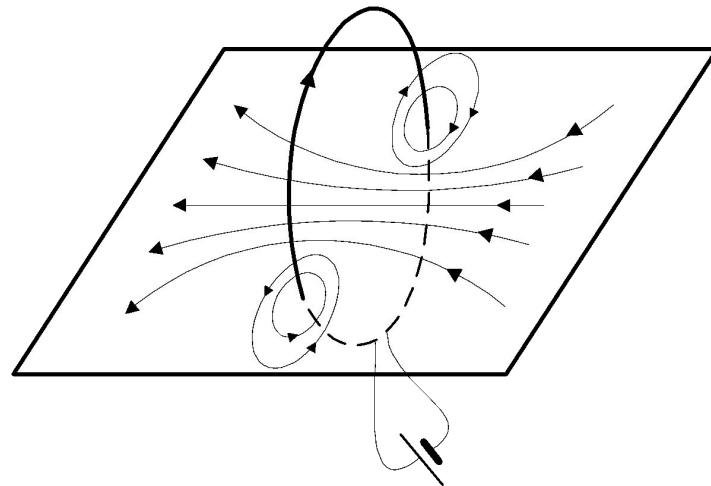
Force Lines of a Magnetic Field



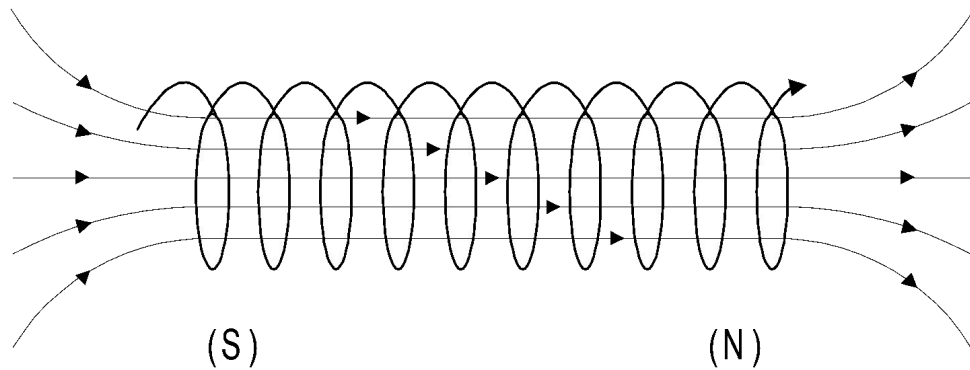
(i)



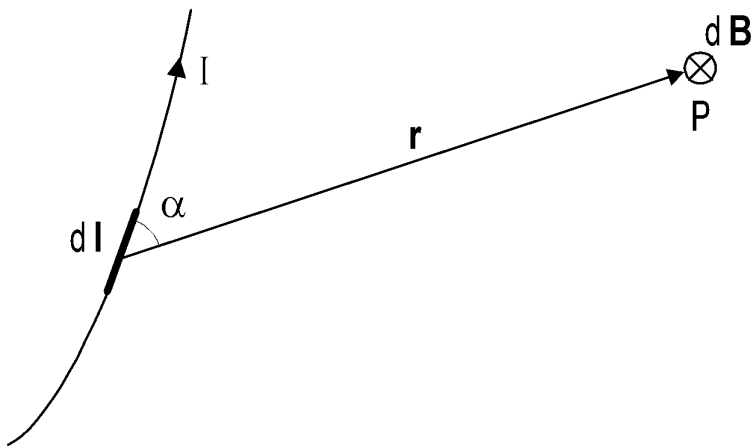
(ii)



Force Lines of a Magnetic Field



Law of Biot and Savart



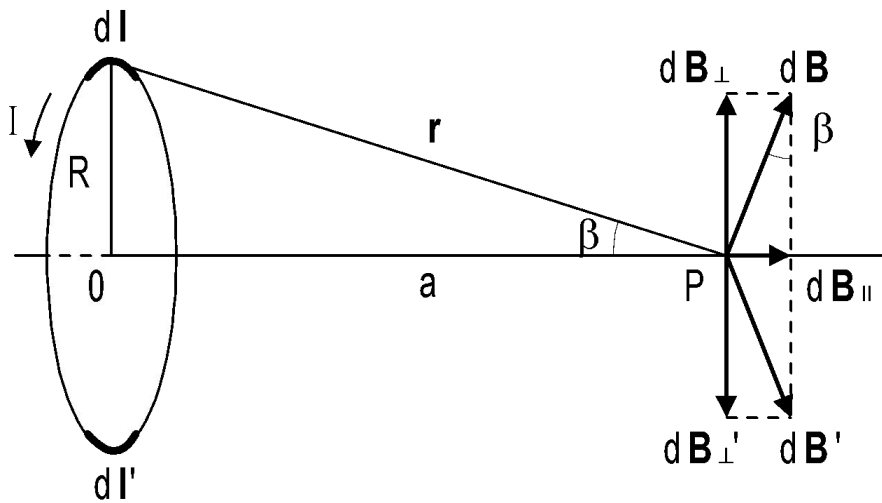
$$d\mathbf{B} = \frac{\mu_0 \mu}{4\pi} \frac{I [d\mathbf{l} \times \mathbf{r}]}{r^3}$$

$$dB = \frac{\mu_0 \mu}{4\pi} \frac{I dl \sin \alpha}{r^2}$$

Principle of Superposition

$$\mathbf{B} = \int d\mathbf{B}$$

Magnetic Field along Axis of a Loop with Current



$$dB_{\parallel} = dB \cdot \sin \beta = \frac{\mu_0 \mu}{4\pi} \frac{I dl}{r^2} \sin \beta$$

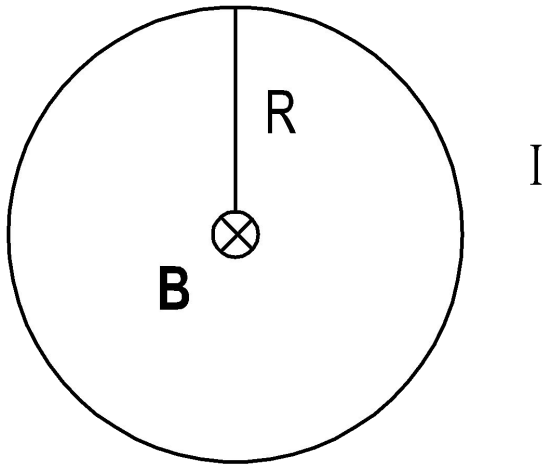
$$r = \sqrt{R^2 + a^2}$$

$$\sin \beta = \frac{R}{r} = \frac{R}{\sqrt{R^2 + a^2}}$$

$$dB_{\parallel} = \frac{\mu_0 \mu}{4\pi} \frac{IR dl}{(R^2 + a^2)^{3/2}}$$

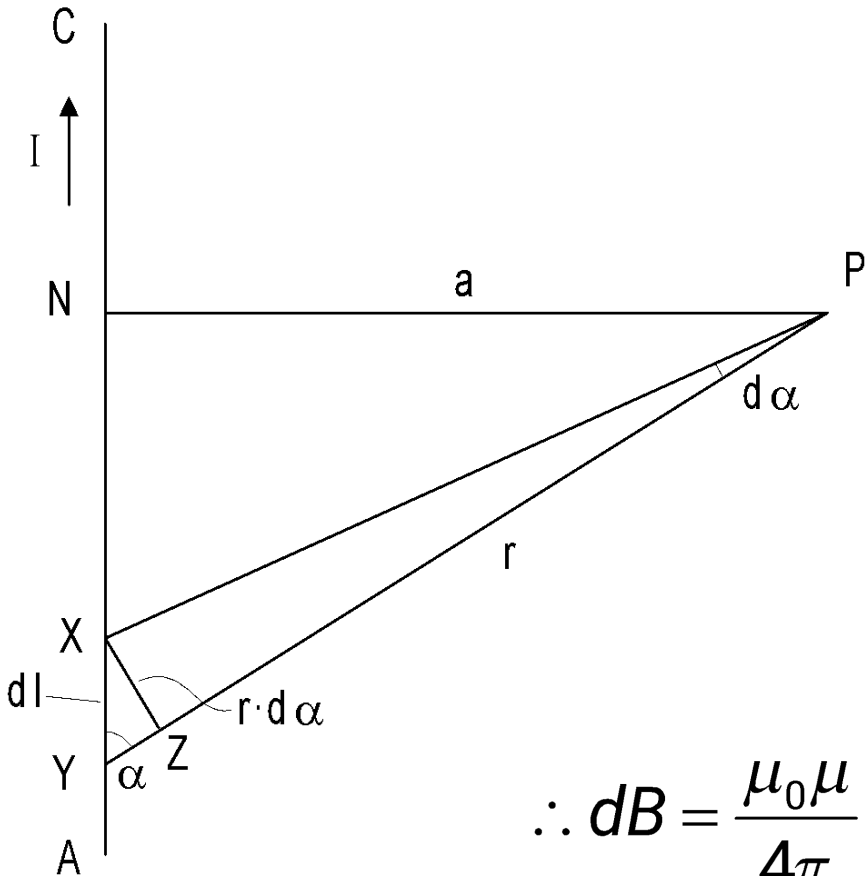
$$B = \int dB_{\parallel} = \int_0^{2\pi R} \frac{\mu_0 \mu}{4\pi} \frac{IR dl}{(R^2 + a^2)^{3/2}} = \frac{\mu_0 \mu}{2} \frac{IR^2}{(R^2 + a^2)^{3/2}}$$

Magnetic Field in a Centre of a Loop with Current



$$B = \frac{\mu_0 \mu}{2} \frac{I}{R}$$

Magnetic Field due to a Current Through a Long Straight Wire



$$dB = \frac{\mu_0 \mu}{4\pi} \frac{Idl \sin \alpha}{r^2}$$

$$a = r \sin \alpha \quad r = \frac{a}{\sin \alpha}$$

$$XZ = XY \sin \alpha = dl \sin \alpha$$

$$XZ = rd\alpha = dl \sin \alpha$$

$$\therefore dB = \frac{\mu_0 \mu}{4\pi} \frac{Idl \sin \alpha}{r^2} = \frac{\mu_0 \mu}{4\pi} \frac{Ird\alpha}{r^2} = \frac{\mu_0 \mu}{4\pi} \frac{Id\alpha}{r}$$

Magnetic Field due to a Current Through a Long Straight Wire (cont.)

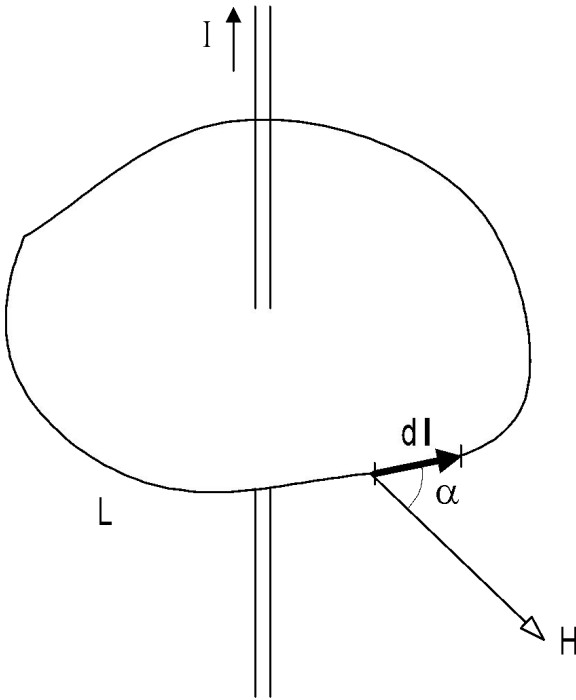
$$\therefore dB = \frac{\mu_0 \mu I \sin \alpha \cdot d\alpha}{4\pi a}$$

$$B = \frac{\mu_0 \mu}{4\pi} \int_0^\pi \frac{I \sin \alpha \cdot d\alpha}{a} = \frac{\mu_0 \mu I}{4\pi a} [-\cos \alpha]_0^\pi$$

$$\therefore B = \frac{\mu_0 \mu I}{2\pi a}$$

For a straight wire of finite length: $B = \frac{\mu_0 \mu I}{4\pi a} (\cos \alpha_1 - \cos \alpha_2)$

Ampere's Circulation Law

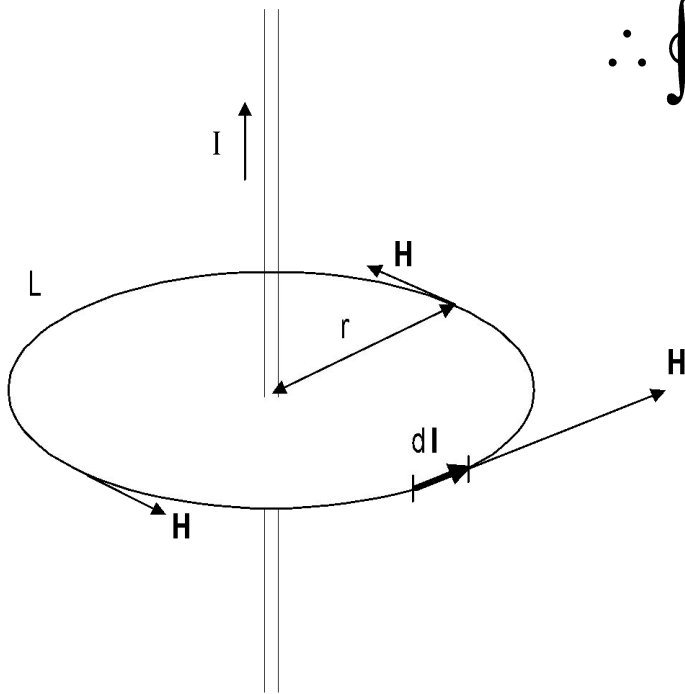


$$\oint H dl \cos \alpha = H \oint dl = \frac{I}{2\pi r} 2\pi r = I$$

$$\oint \mathbf{H} d\mathbf{l} = I \quad \oint \mathbf{H} d\mathbf{l} = \int \mathbf{j} d\mathbf{S}$$

Circulation of the magnetic field intensity round the closed loop is equal to the current enclosed by this loop.

Intensity of the Magnetic Field Outside a Straight Wire



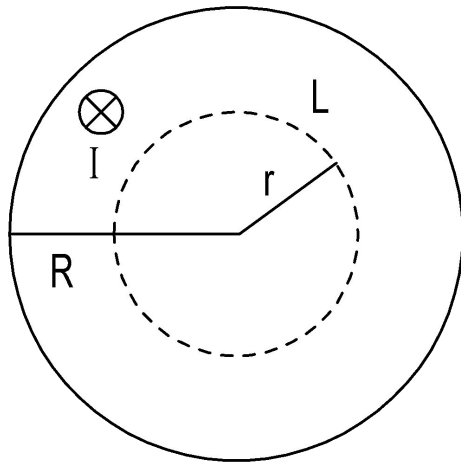
$$\therefore \oint H dl \cos \alpha = H \oint dl = H \cdot 2\pi r$$

$$H \cdot 2\pi r = I$$

$$\therefore H = \frac{I}{2\pi r}$$

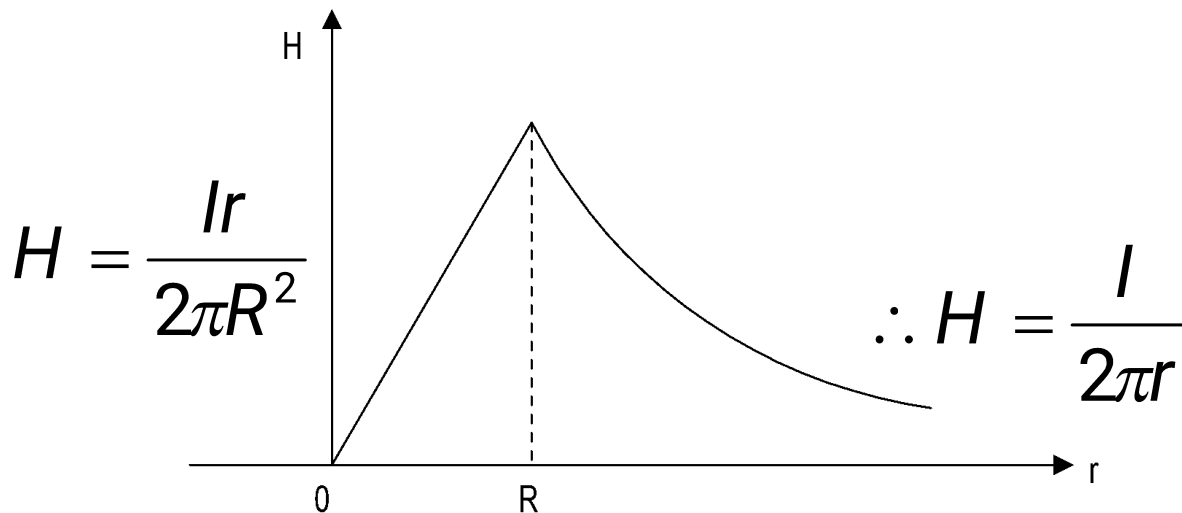
$$B = \mu_0 \mu H = \frac{\mu_0 \mu I}{2\pi r}$$

Intensity of the Magnetic Field Inside a Straight Wire



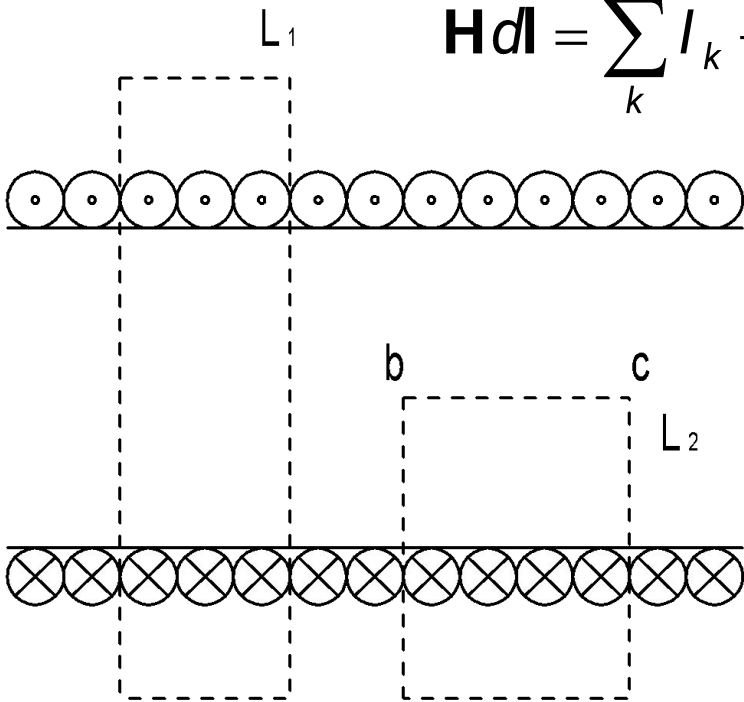
$$\oint H dl \cos \alpha = \frac{I \pi r^2}{\pi R^2}$$

$$H \cdot 2\pi r = \frac{I \pi r^2}{\pi R^2}$$



Solenoid

$$\mathbf{H}d\mathbf{l} = \sum_k I_k - \sum_k I_k = 0 \quad - \text{no field outside the solenoid}$$



$$\oint \mathbf{H}d\mathbf{l} = \int_a^b \mathbf{H}d\mathbf{l} + \int_b^c \mathbf{H}d\mathbf{l} + \int_c^d \mathbf{H}d\mathbf{l} + \int_d^a \mathbf{H}d\mathbf{l} = 0 + \int_b^c \mathbf{H}d\mathbf{l} + 0 + 0 = \sum_k I_k$$

$$\int_b^c \mathbf{H}d\mathbf{l} = Hl = nIl \quad H = nI \quad - \text{uniform field inside the solenoid}$$