# Magnetic Phenomena

## Magnetic Field

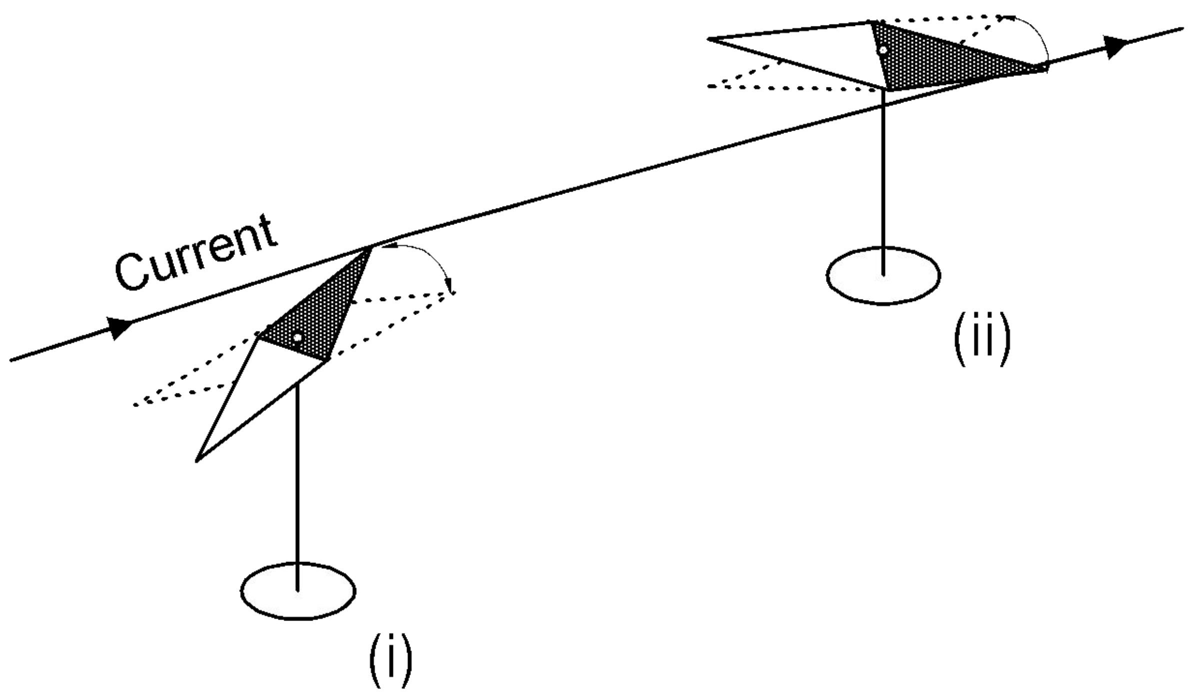
# Magnetic Field

- 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

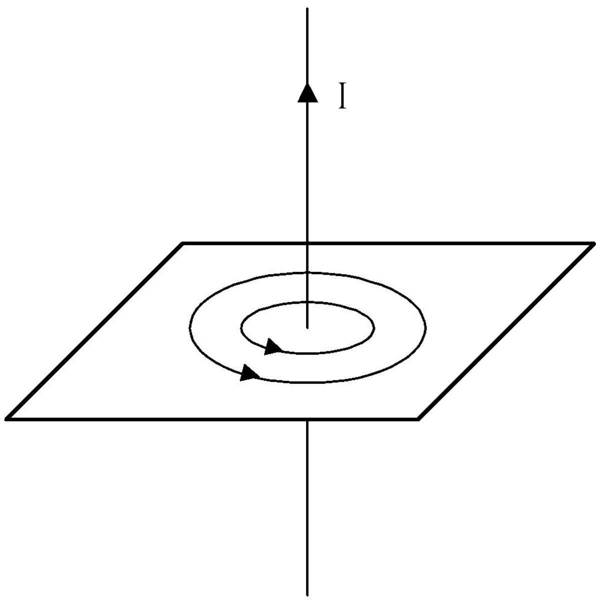
# Magnetic Field (continued)

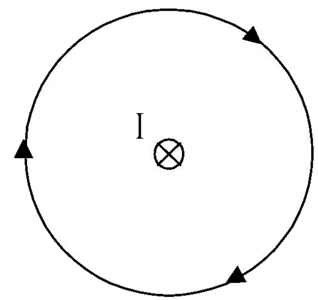
- Ampere's Circulation Law
- Intensity of the Magnetic Field Outside and Inside a Straight Wire
- Solenoid

# Experiment on a Magnetic Field

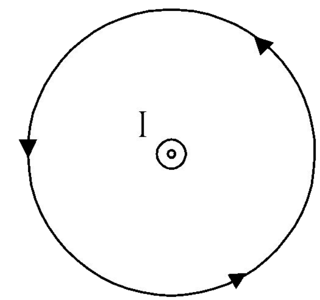


# Force Lines of a Magnetic Field

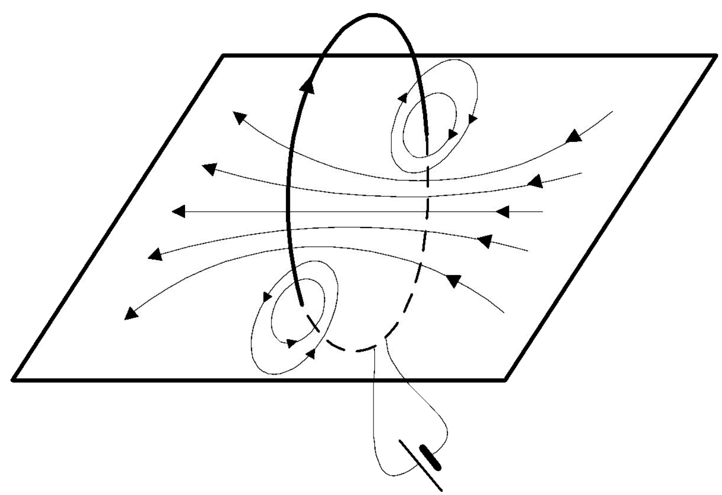


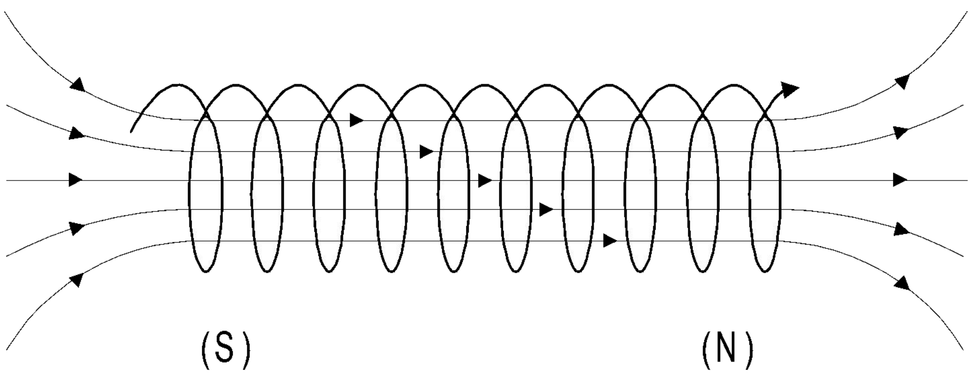

(i)



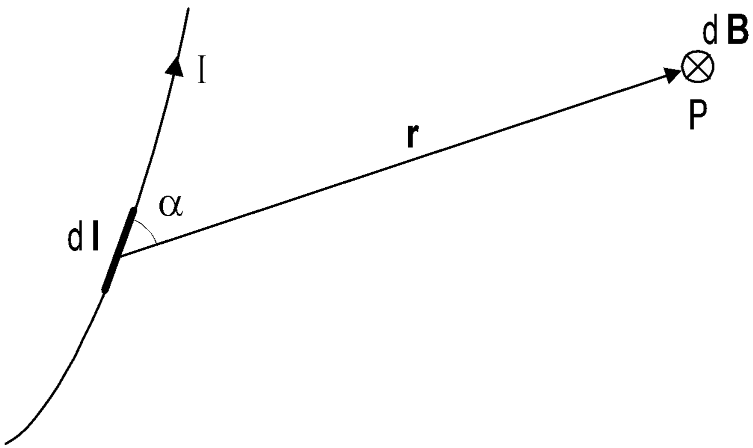

(ii)



# Force Lines of a Magnetic Field



# Law of Biot and Savart



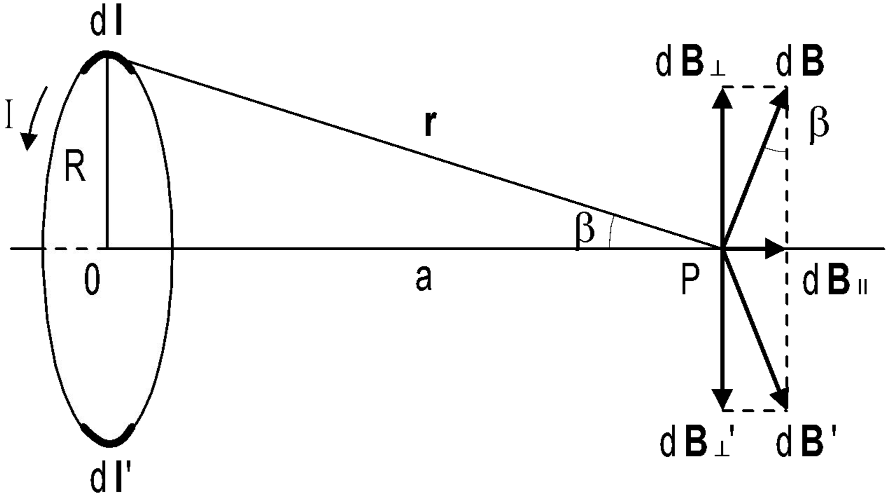

$$d\mathbf{B} = \frac{\mu_0 \mu}{4\pi} \frac{I\,[d\mathbf{l} \times \mathbf{r}]}{r^3}$$

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

# Principle of Superposition

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

# Magnetic Field along Axis of a Loop with Current




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

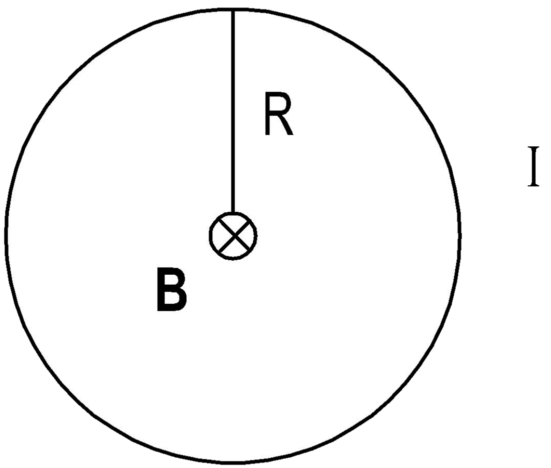
$$r = \sqrt{R^2 + a^2}$$

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

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

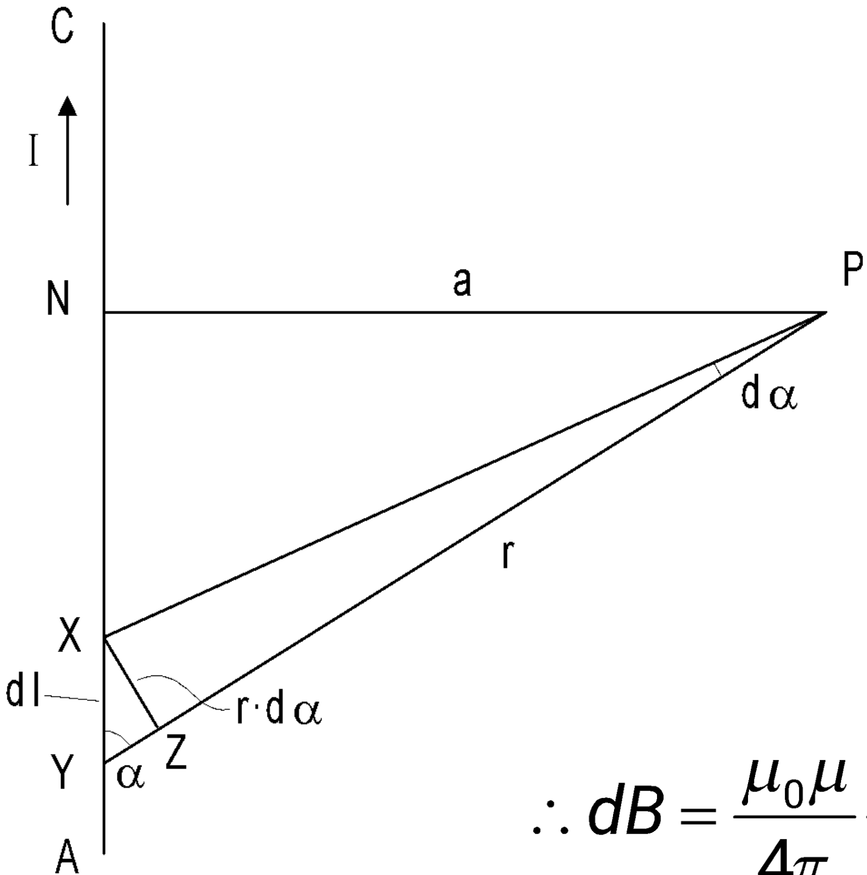
$$B = \int dB_{\parallel} = \int_0^{2\pi R} \frac{\mu_0 \mu}{4\pi} \frac{IRdl}{\left(R^2 + a^2\right)^{3/2}} = \frac{\mu_0 \mu}{2} \frac{IR^2}{\left(R^2 + a^2\right)^{3/2}}$$

# 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




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

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

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

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

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

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

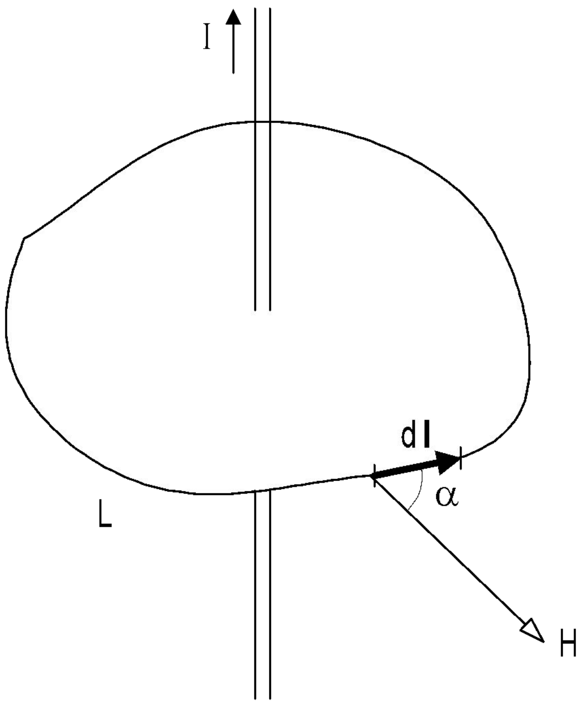
$$\therefore dB = \frac{\mu_0 \mu}{4\pi} \frac{I \sin\alpha \cdot d\alpha}{a}$$

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

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

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

# Ampere's Circulation Law

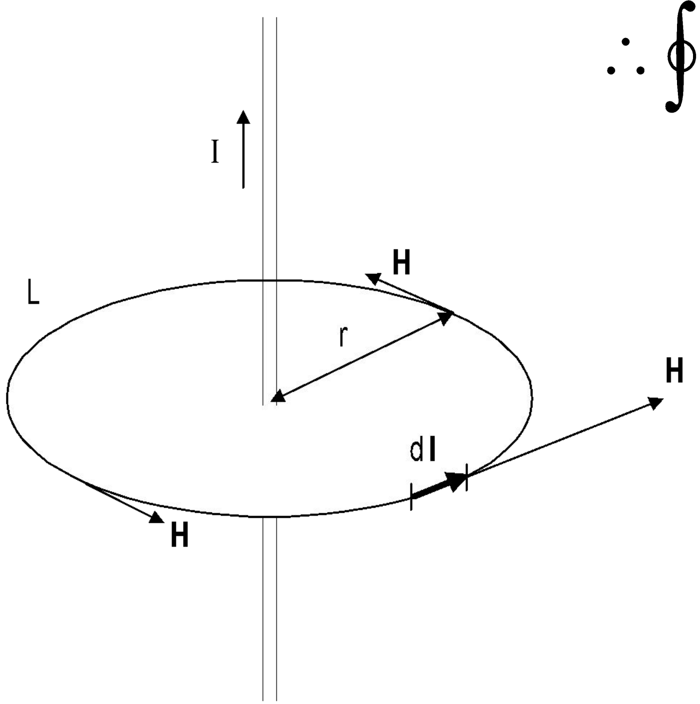



$$\oint H dl \cos\alpha = H \oint dl = \frac{I}{2\pi r} 2\pi r = I$$

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

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

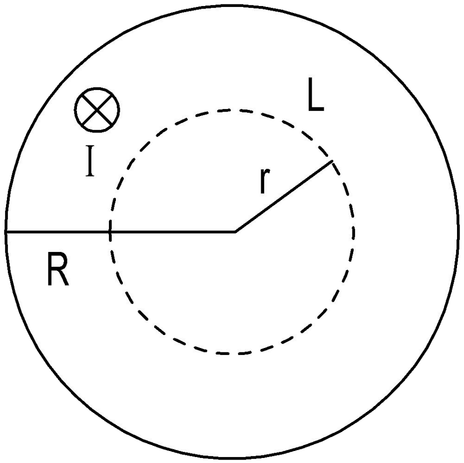



$$\therefore \oint H dl \cos\alpha = H \oint dl = H \cdot 2\pi r$$

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

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

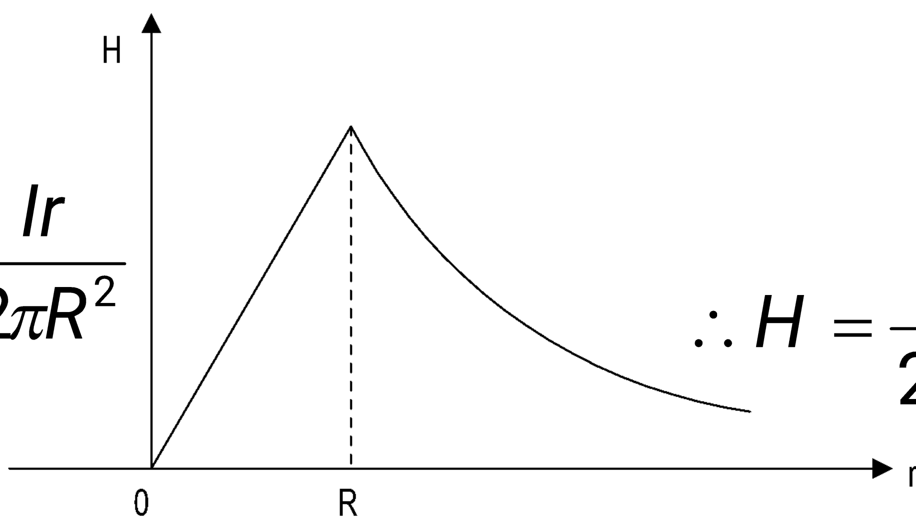
# Intensity of the Magnetic Field Inside a Straight Wire




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

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

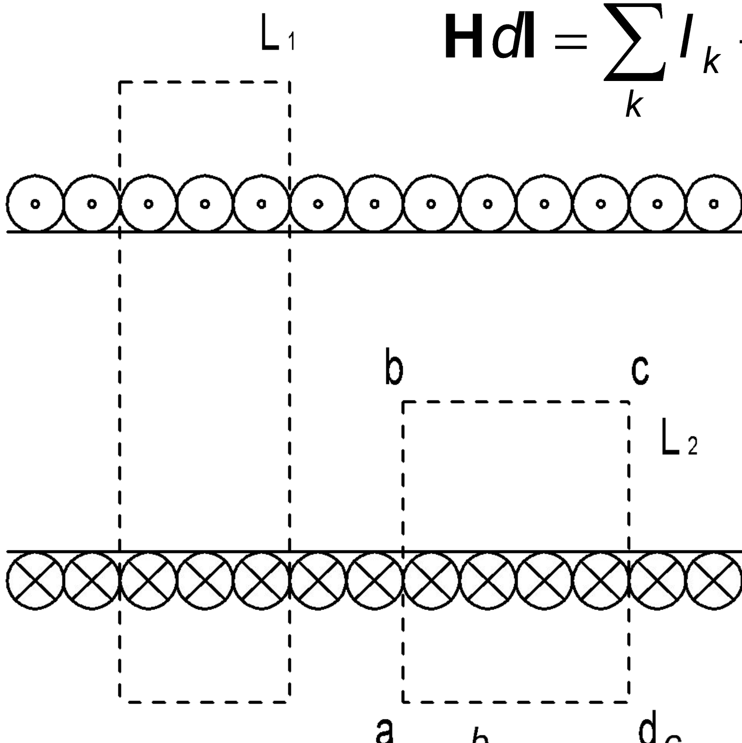
$$H = \frac{Ir}{2\pi R^2}$$




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

# Solenoid

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




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

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