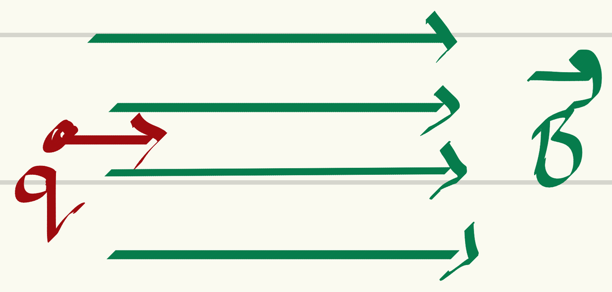
MOVING CHARGES AND MAGNETISM

FORMULA SHEET

1. Magnetic Force on Moving Charge

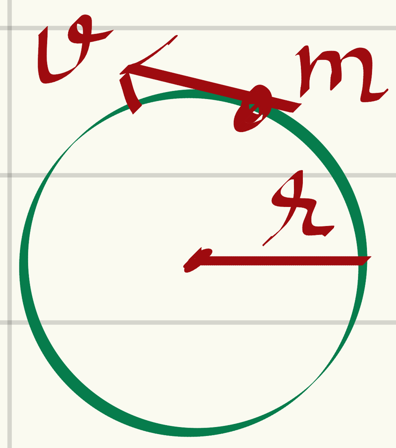


$$\vec{F} = q(\vec{v} \times \vec{B})$$

$$F = qvB\sin\theta$$

$q \rightarrow$ charge
$v \rightarrow$ velocity
$B \rightarrow$ mag. field

2. Centripetal Force on Moving Charge



$$F = \frac{mv^2}{r}$$

$m \rightarrow$ mass
$v \rightarrow$ velocity
$r \rightarrow$ radius

3. Radius of Circular Path (r)

$$r = \frac{mv}{qB} = \frac{p}{qB}$$

$$= \frac{\sqrt{2mK_E}}{qB}$$

$$= \frac{\sqrt{2mqV}}{qB} \quad [K_E = qV]$$

$p \rightarrow$ linear momentum
$K_E \rightarrow$ Kinetic energy
$V \rightarrow$ Potential

$K.E = \frac{p^2}{2m}$
$p = \sqrt{2m\,K.E}$
$= \sqrt{2mqV}$
$[W = K.E = qV]$

4. Velocity (v) $\quad v = \frac{qBr}{m}$

4. Time Period (T)

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

5. Angular Velocity (ω)

$$\omega = \frac{2\pi}{T} = \frac{qB}{m}$$

6. Frequency (ν) $\quad \nu = \frac{1}{T} = \frac{qB}{2\pi m}$

7. Kinetic Energy of Charge

$$K_E = \frac{1}{2} m v^2$$

$$= \frac{1}{2} m \left(\frac{qBr}{m}\right)^2$$

$$K_E = \frac{q^2 B^2 r^2}{2m}$$

8. For Helix

$$r = \frac{mv\sin\theta}{qB}$$

$$T = \frac{2\pi m}{qB}$$

Pitch of Helix:

$$p = \frac{2\pi m v\cos\theta}{qB}$$

9. Lorentz Force on Moving charge

$$\vec{F} = \vec{F}_e + \vec{F}_m$$

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

10. Biot-Savarts Law

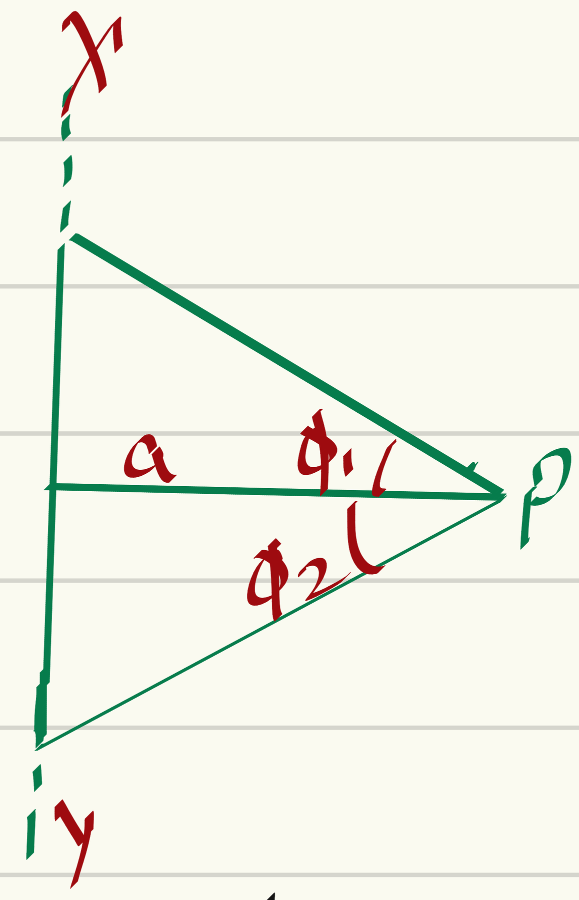
$$dB = \frac{\mu_0}{4\pi} \frac{I\,dl\sin\theta}{r^2}, \quad \frac{\mu_0}{4\pi} = 10^{-7}\,TmA^{-1}$$

vector form - $$\vec{dB} = \frac{\mu_0}{4\pi} \frac{I(\vec{dl} \times \vec{r})}{r^3}$$

11. **Application of Biot-Savarts Law**

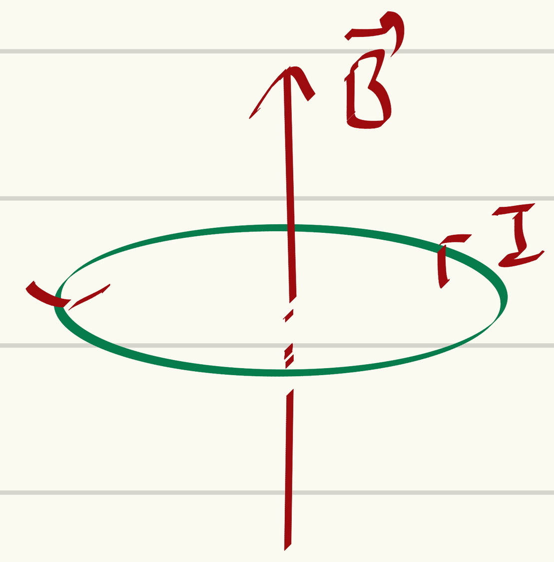
$$B = \frac{\mu_0 I}{4\pi a}[\sin\phi_1 + \sin\phi_2]$$

For straight wire, $B = \dfrac{\mu_0 I}{2\pi a}$ $\quad [\because \phi_1 = \phi_2 = 90°]$



12. **Magnetic field at the centre of current carrying circular loop and coil-**

- $B = \dfrac{\mu_0 I}{2R}$ $\quad$ [for loop $N=1$]



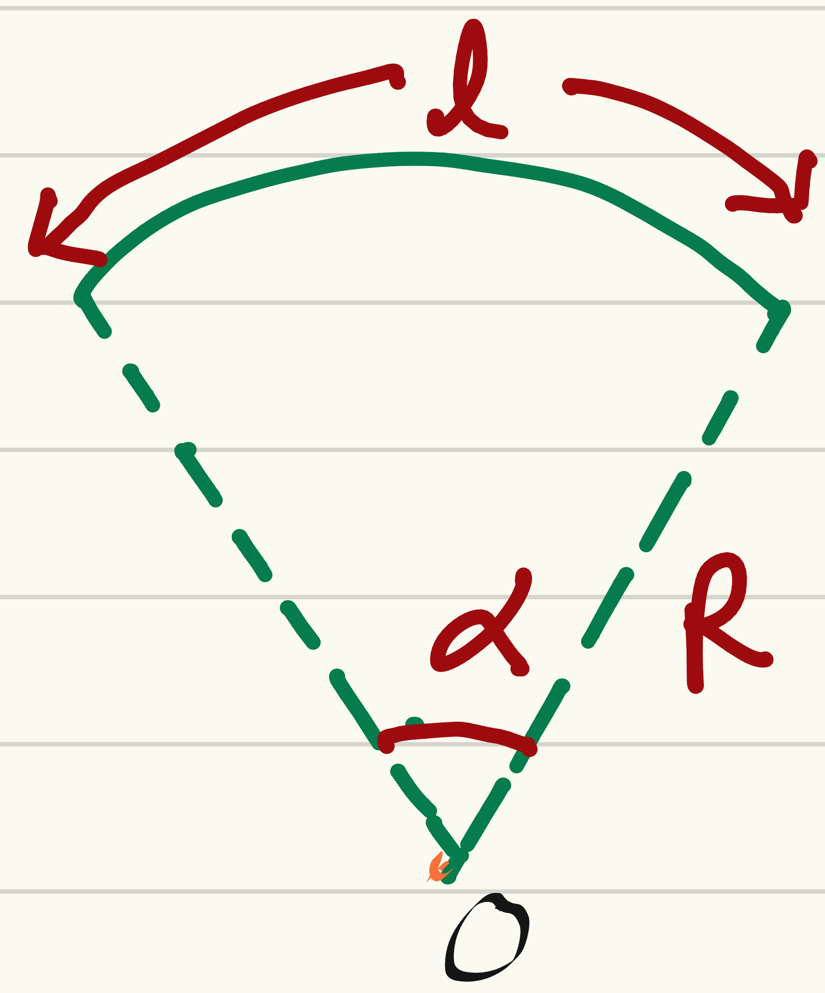
- $B = \dfrac{\mu_0 N I}{2R}$ $\quad$ [$N \rightarrow$ no. of turns in coil]

13. **Magnetic field at the centre of current carrying circular arc-**

$$B_{arc} = \frac{\mu_0 I}{4\pi R} \times \alpha$$

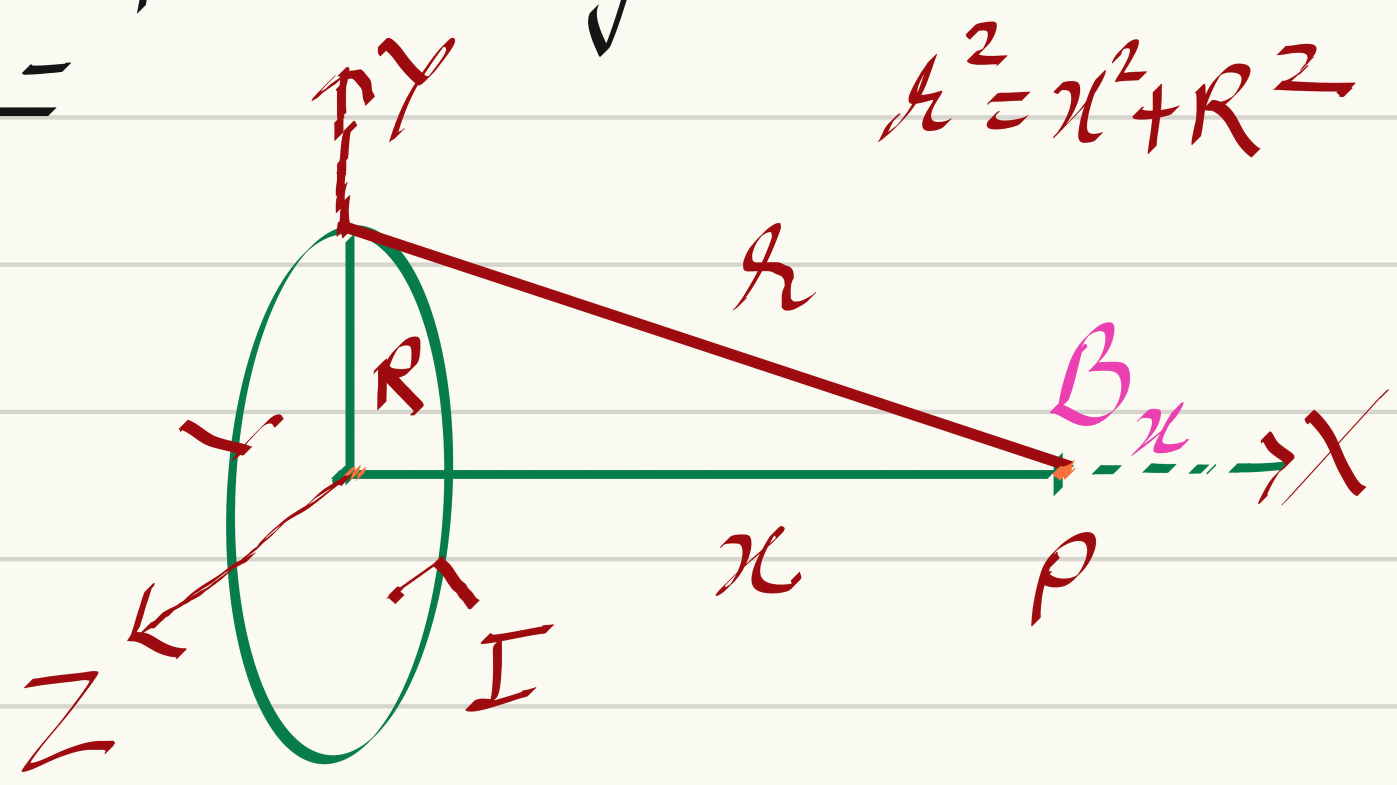
$$= \underbrace{\left(\frac{\mu_0 I}{2R}\right)}_{B_{circle}} \times \frac{\alpha}{2\pi}$$

$$\boxed{B_{arc} = \frac{B}{2\pi} \times \alpha}$$



14. **Magnetic field at axial point of the current carrying circular coil-**

$$B_x = \frac{\mu_0 N I R^2}{2(x^2+R^2)^{3/2}}$$



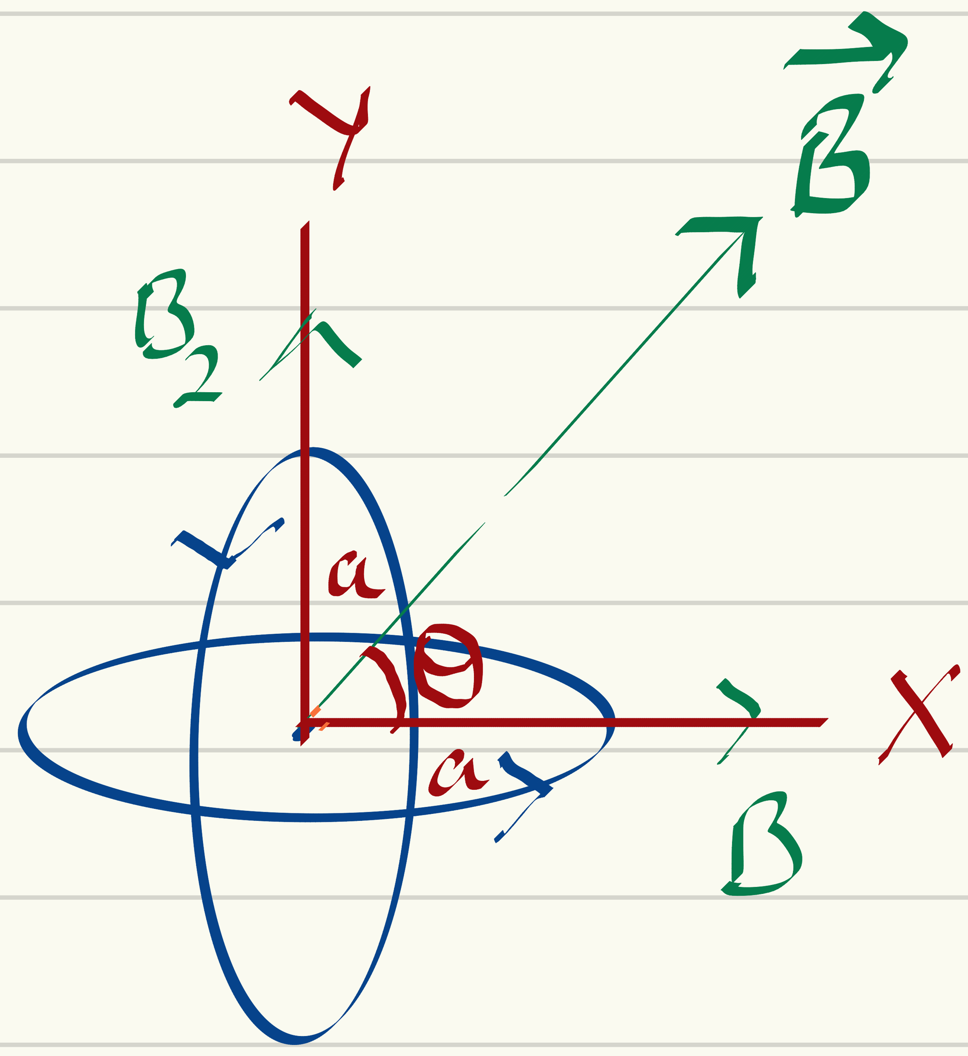
$I \rightarrow$ Anticlockwise

(1) At the centre, $x = 0$

$$B_{centre} = \frac{\mu_0 N I}{2R}$$

(ii) At points far off from centre, $x >> R$

$$B = \frac{\mu_0 N I}{4\pi} \frac{2\pi R^2}{x^3}$$



a → Radius of both rings

* $B = \sqrt{B_1^2 + B_2^2}$

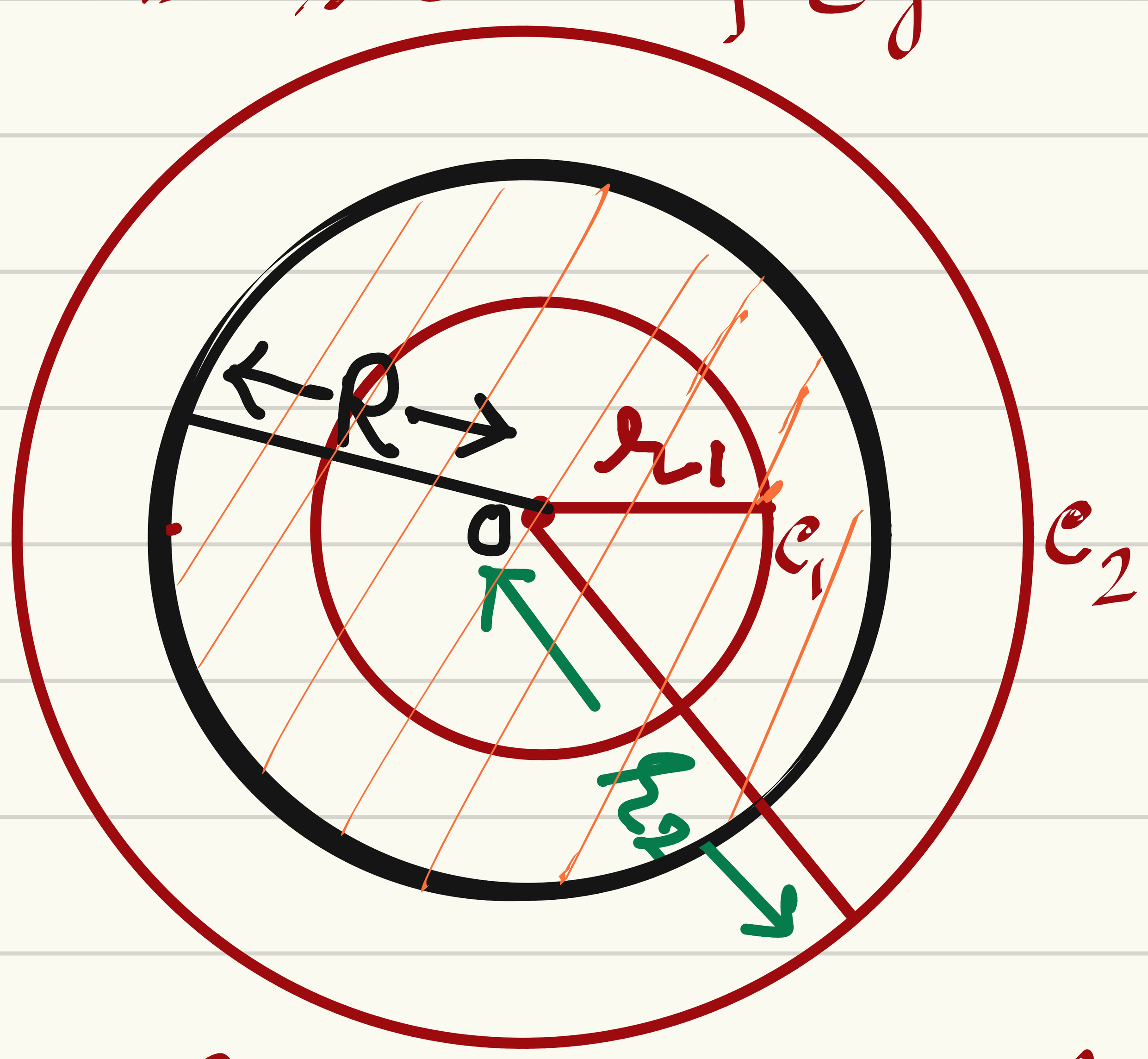
$\tan\theta = \frac{B_2}{B_1}$

For identical coils $B_1 = B_2$

 $B = \sqrt{2}\left(\frac{\mu_0 N I}{2a}\right)$ and hence $\theta = 45^\circ$

15 <u>Magnetic field due to cylindrical conductor.</u>

cross-section of cylinder



e_1, e_2 are amperial loop

(i) $r < R$ [for r_1]

$$B_{inside} = \frac{\mu_0 I r}{2\pi R^2}$$

$$B_{in} \propto r$$

(ii) for $r = 0$ [at 'O']

$$B_{centre} = 0$$

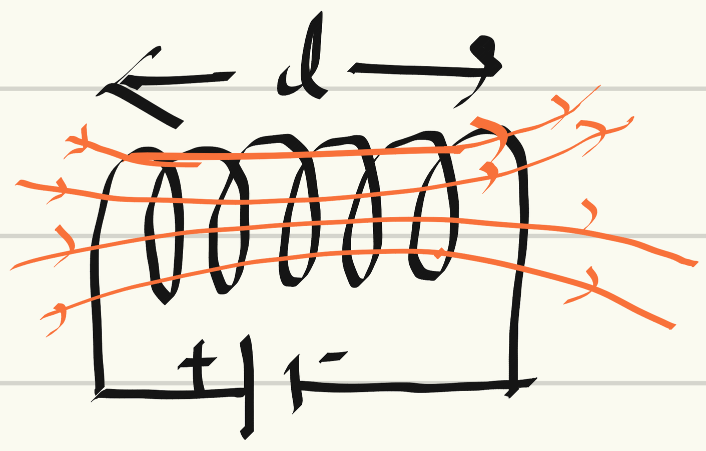
(iii) for $r = R$ [On the surface of cylinder]

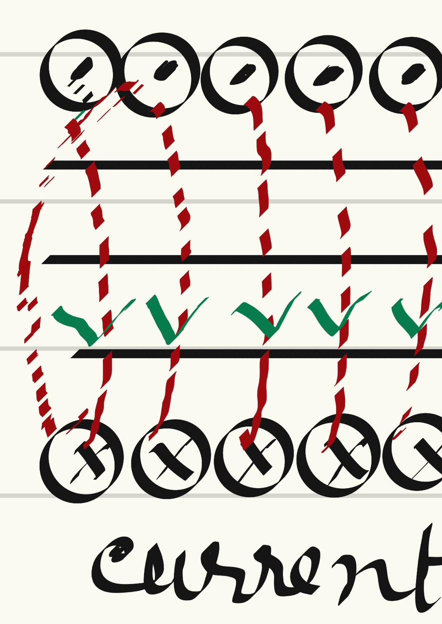
$$B_{surface} = \frac{\mu_0 I}{2\pi R} \quad [B\,max]$$

(iv) for $r > R$ [for r_2]

$$B_{out} = \frac{\mu_0 I}{2\pi r} \qquad B_{out} \propto \frac{1}{r}$$

16. Magnetic field due to a solenoid





$$B = \mu_0 n I$$
$$= \frac{\mu_0 N I}{l}$$

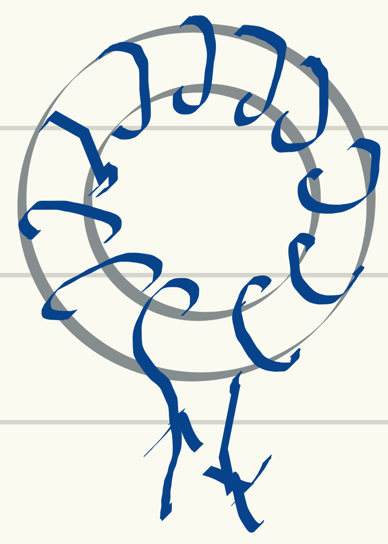
$N \rightarrow$ Total no. of turns in solenoid

$n \rightarrow$ no. of turns per unit length

* Mag. field at both axial end points of infinite length solenoid

$$B = \frac{\mu_0 n I}{2}$$

17. Magnetic field due to a toroid

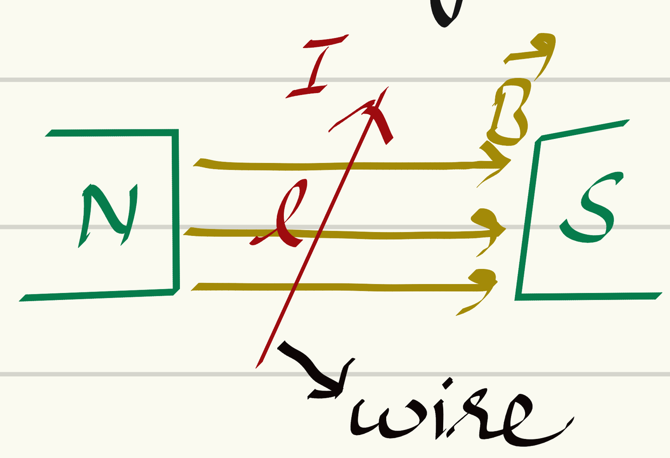


$$B = \mu_0 n I$$

where $n = \dfrac{N}{2\pi R}$

$R \rightarrow$ mean radius of toroid

18. Current carrying conductor in magnetic field -

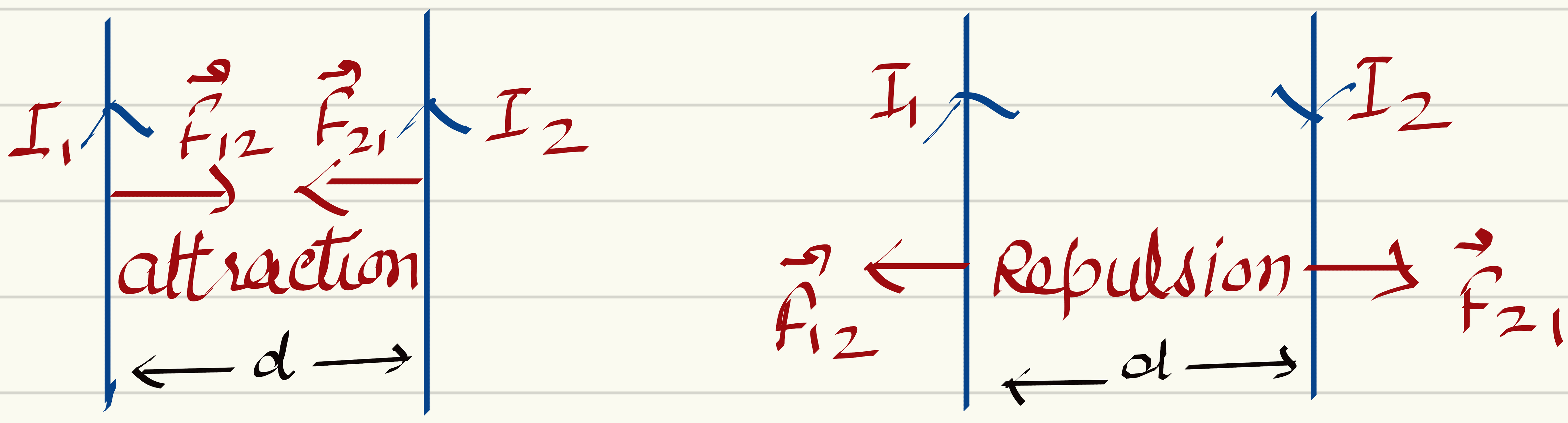


$$F = I l B \sin\theta$$
$$\vec{F} = I(\vec{l} \times \vec{B})$$
$$F = \int dF = \int I B \, dl \sin\theta$$

or $$\vec{F} = \int I(d\vec{l} \times \vec{B})$$

* $F = 0$, for $\theta = 0°$
* $F_{max} = IBl$, for $\theta = 90°$

19. Magnetic force between two parallel current carrying conductors -



$$F_{12} = F_{21} = \frac{\mu_0 I_1 I_2}{2\pi d} \cdot l$$

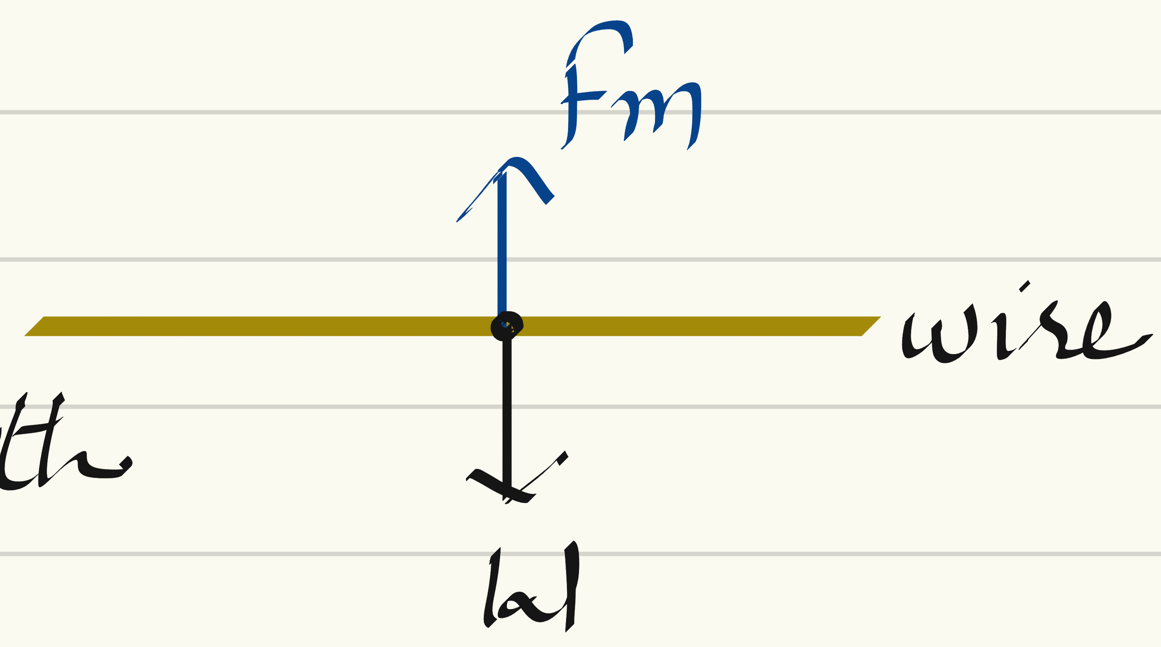
$$[\vec{F}_{12} = -\vec{F}_{21}]$$

20 Equilibrium of free wire -

$F_m = W \Rightarrow I l B \sin\theta = mg$

$F_m \rightarrow$ mag. force per unit length

$W \rightarrow$ Weight of unit length



@jyotisharmaphysics

21. Magnetic dipole moment (M)

- for bar magnet

$$\vec{M} = 2 q_m \vec{l} = 2 m \vec{l}$$

$q_m \rightarrow$ Pole strength

$l \rightarrow$ Axial vector

$q_m \rightarrow m$ (pole strength)

- For current loop

$$\vec{M} = I\vec{A}$$

$A \rightarrow$ Area of the loop

unit - $A\text{-}m^2$

22 Coulomb's law of mag. force (only for bar magnet)

$$F = k \frac{q_{m_1} q_{m_2}}{r^2}$$

$K < \frac{\mu_0}{4\pi}$ (S.I.)

$K <$ 1 (CGS)

23. <u>Magnetic moment in magnetic field:-</u>

- Torque on mag. dipole

$$\tau = MB\sin\theta \qquad [M = m(2l)]$$

$$\vec{\tau} = \vec{M}\times\vec{B} \qquad [\text{For bar magnet}]$$

- $\tau = NIAB\sin\theta$ [For coil or loop]
  $NIA = M$

24. <u>Moving coil Galvanometer-</u>

- $$I = \frac{K}{NBA}\alpha$$

  $K \rightarrow$ Torsional constant
  $\alpha \rightarrow$ deflection
  $A \rightarrow$ Area

  $I \propto \alpha$

- Current Sensitivity (I_s)

$$I_s = \frac{\alpha}{I} = \frac{NAB}{K} \quad (\text{Rad/Amp})$$

- Voltage Sensitivity -

$$V_s = \frac{\alpha}{V} = \frac{\alpha}{IR} = \frac{NAB}{KR} \quad (\text{Rad/volt})$$

25. <u>Work done in Rotating a dipole -</u>

$$W = \int dW = \int \tau\, d\theta$$

$$W = MB(\cos\theta_1 - \cos\theta_2)$$

$$= -MB\cos\theta$$

$$W = -\vec{M}\cdot\vec{B} \qquad [\text{For } \theta_1 = 90^\circ, \theta_2 = \theta]$$

26. <u>Conversion of Galvanometer</u> -

(i) Into Ammeter

$$S = \left(\frac{I_g}{(I - I_g)}\right) G$$

$S \rightarrow$ Shunt (resistance)
$I_g \rightarrow$ current in galvano.
$G \rightarrow$ Resistance of galvano.
$I \rightarrow$ Total current

$$R_{eff} = \frac{GS}{G+S}$$

(ii) Into Voltmeter

$$R = \frac{V}{I_g} - G$$

$R \rightarrow$ high resistance
$V \rightarrow$ Potential difference