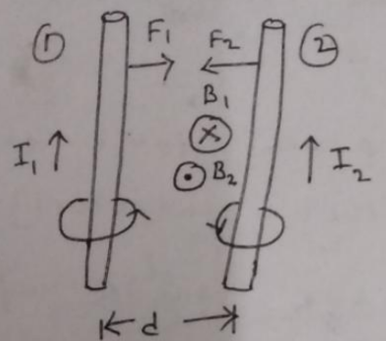
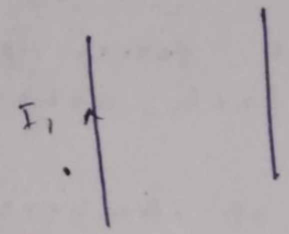
Forces between two infinitely long straight parallel conductors carrying currents -





Consider two infinitely long parallel conductors carrying current I_1 and I_2 in the same direction.

The magnetic field at any point on the conductor (2) due to current I_1 in the conductor (1) is given by

$$B_1 = \frac{\mu_0}{4\pi}\left(\frac{2I_1}{d}\right)$$

Force experienced per unit length of conductor (2) in the magnetic field B_1 is given by

$$F_2 = B_1 I_2 \times 1 = B_1 I_2$$

$$\text{or } F_2 = \frac{\mu_0}{4\pi}\left(\frac{2I_1}{d}\right) I_2 = \frac{\mu_0}{4\pi}\left(\frac{2I_1 I_2}{d}\right)$$

Applying Fleming's L.H.R. to conductor (2), the direction of F_2 is in the plane of the conductor directed towards conductor 1

Similarly $F_1 = B_2 I_1 \times 1 = \frac{\mu_0}{4\pi}\left(\frac{2I_1 I_2}{d}\right)$

By LHR, F_1 lies in the plane of the conductor and directed towards conductor (2)

F_1 and F_2 are equal and opposite, so these forces pull the conductors towards each other.

Definition of Ampere (from force experienced by current carrying parallel conductors)

Force experienced per metre length of conductor

$$F = \frac{\mu_0}{4\pi}\left(\frac{2 I_1 I_2}{d}\right) N m^{-1}$$

Let $I_1 = I_2 = 1A$

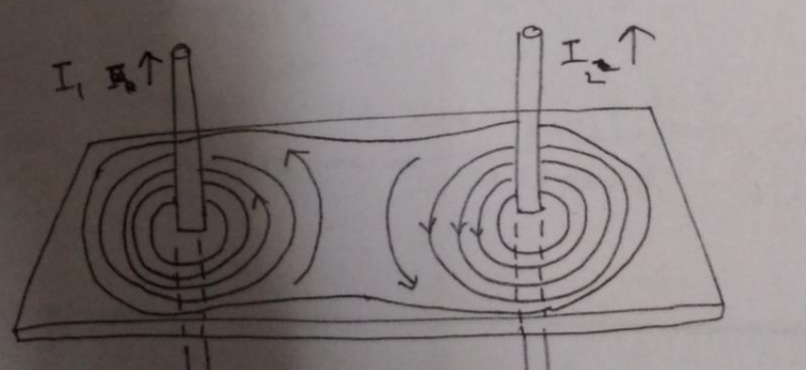
$d = 1m$

$$F = \frac{4\pi \times 10^{-7} \times 2 \times 1 \times 1}{4\pi \times 1}$$

$$= 2 \times 10^{-7} N m^{-1}$$

Thus, ampere is that current which if maintained in two infinitely long parallel conductors of negligible c/s area seperated by 1m in vacuum causes a force of 2×10^{-7} N on each metre of the other wire.

If current in both parallel wires is equal and in the same direction then magnetic at a point exactly half way bet^n the wires is $B_p = B_1 - B_2 = 0$



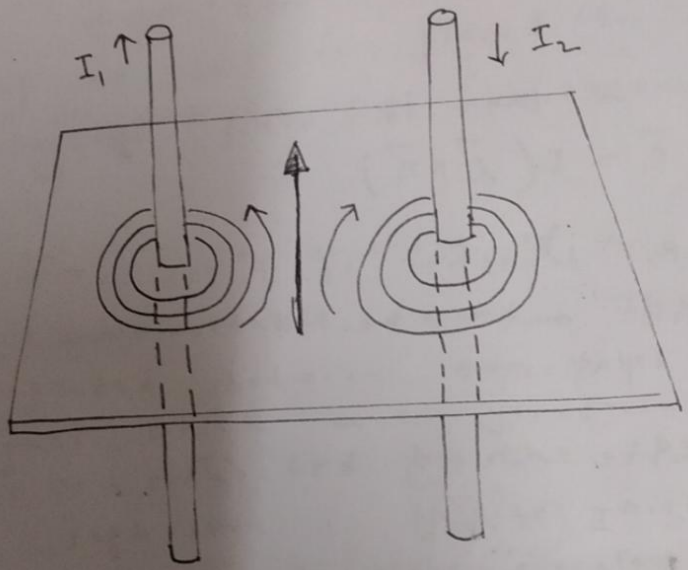
$$B_1 = \frac{\mu_0 2I}{4\pi d}$$

$$B_2 = \frac{\mu_0 2I}{4\pi d}$$

But if the wires carry current in the opposite direction then

$$B_p = B_1 + B_2$$

$$= 2\left[\frac{\mu_0 2I}{4\pi d}\right]$$



current Loop: (circular, rectangular etc)

Torque on current carrying rectangular loop placed in uniform magnetic field.

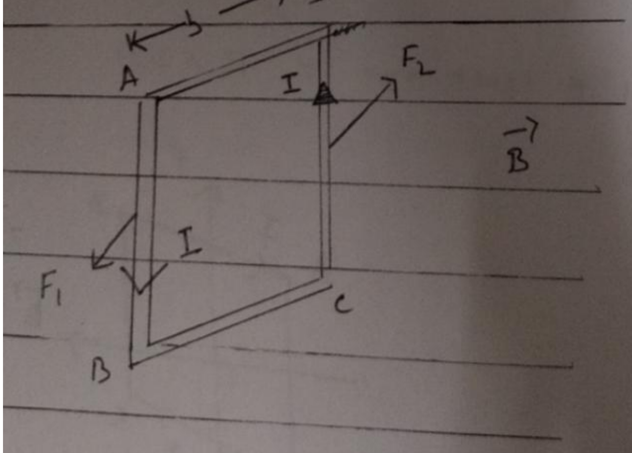


Fig 1

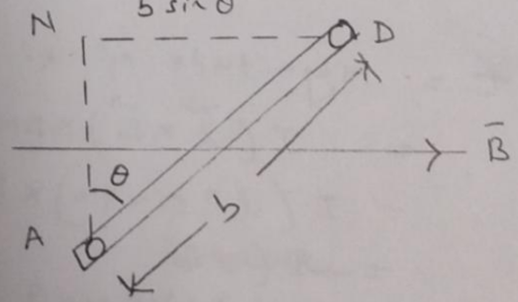


Fig 2

Consider a rectangular conducting loop ABCD of length l and breadth b placed in uniform magnetic field $\vec{B}$. Let I flows in anticlockwise direction. Let θ be the angle bet^n the normal (n) of the plane of the loop and the magnetic field $\vec{B}$

Force acting on arm AB of the loop

$$\vec{F_1} = I(\vec{l} \times \vec{B})$$

Applying LHR, direction of F_1 is ⊥ to the length of arm AB and directed outward of the sheet of paper

Similarly, force acting on CD

$$\vec{F_2} = I(\vec{l} \times \vec{B})$$

$\vec{F_2}$ is ⊥ to the length of arm CD and is directed inside the sheet of the paper

(Force acting on the arm BC and DA are equal, opposite and act along the same line, hence they cancel each other.

∴ F_1 and F_2 form a couple and rotates the loop anticlockwise

τ = Magnitude of either force × lever arm = $F_1 \times DN$

$$= I(\vec{l} \times \vec{B}) \times DN$$

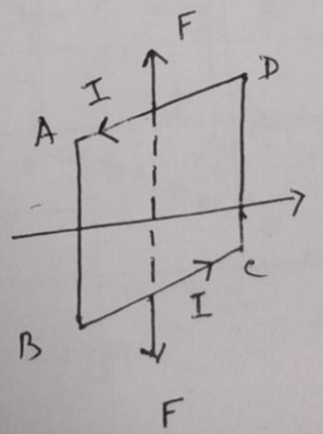
$$= I(lB\sin 90) \times b\sin\theta$$

$$= I(lb)B\sin\theta$$

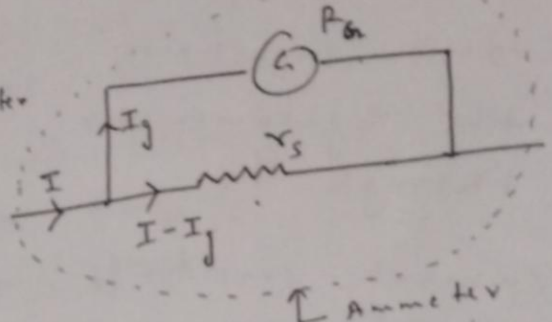
∴ $\tau = IAB\sin\theta$

If the loop has N turns, net torque

$$\tau = NIAB\sin\theta$$



Conversion of Galvanometer into Ammeter ~~with the help of shunts~~ by connecting a low resistance called shunt parallel to the galvanometer



R_G = Resistance of galvanometer
r_s = shunt resistance
I = Total current to be measured by an ammeter in the ckt

I_g = current flowing through the galvanometer corresponding to which the galvanometer gives full scale deflection.

$I-I_g$ → flows through shunt.

$$I_g R_G = (I - I_g) r_s$$

or $$r_s = \left(\frac{I_g}{I - I_g}\right) R_G$$

This is the required value of shunt resistance to convert a galvanometer into an ammeter of range 0 – I ampere

Effective Resistance of Ammeter:

$$\frac{1}{R_{eff}} = \frac{1}{R_G} + \frac{1}{r_s} = \frac{R_G + r_s}{R_G r_s}$$

or $$R_{eff} = \frac{R_G r_s}{R_G + r_s}$$

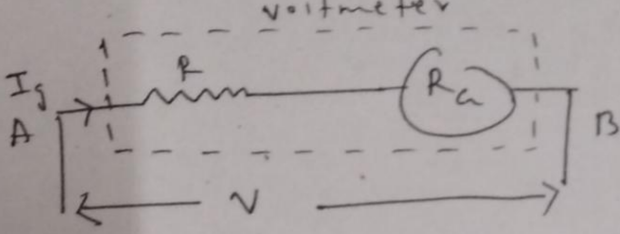
if $R_G >> r_s$, so $R_G + r_s \approx R_G$

Hence $$R_{eff} = \frac{R_G r_s}{R_G} \approx r_s$$

Thus, ammeter is a low resistance device.
Resistance of ideal ammeter is zero

Conversion of Galvanometer into voltmeter:

by connecting a high resistance in series to the galvanometer.



R_a = Resistance of galvanometer

R = Resistance of conductor

V = potential difference to be measured by the voltmeter

P.D. betn A and B is

$$V = I_g (R + R_a)$$

$$(R + R_a) = \frac{V}{I_g}$$

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

This is the required value of resistance which must be connected in series to the galvanometer to convert it into voltmeter of range 0 - V volt

Effective Resistance : $R' = R + R_a$, which is high.

Resistance of ideal voltmeter is infinite.