Magnetic fields

$$F_m = qV \times B$$

$$= qBV \sin \phi$$

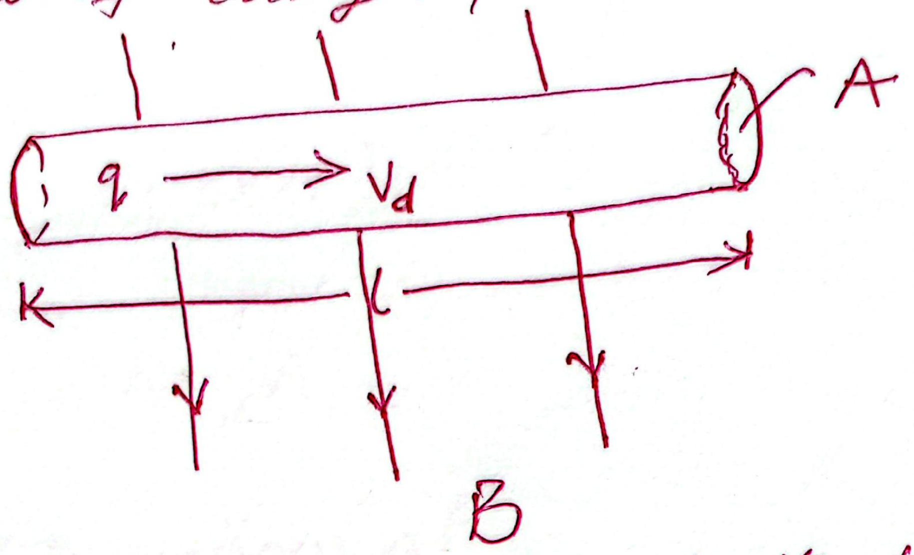
Right-hand rule; Hold your right hand open and then place your fingers forefinger in the direction of B, with your thumb pointing in the direction of V. The force F on the positive charge is directed out of the palm of your hand.

EX: A proton moves with a velocity of 8×10^6 m/s along the x-axis. It enters a region where there is a magnetic field of magnitude 2.5 T, directed at an angle of 60° to the x-axis and lying in the xy plane. Calculate the initial force and acceleration of the proton.

EX! An electron is moving along the positive x-axis at 1 percent of the speed of light. The magnetic field throughout the region is along the positive Z-axis with $B = 0.8T$. What are the magnitude and direction of the magnetic force ~~experi~~ experienced by the electron.

Magnetic force on a current-carrying conductor

Current-carrying wire moving thru magnetic field experiences magnetic force, because current is is flow of charge particles.



Consider a wire of length l carrying current and the wire is moving through magnetic field B. And the x-sectional area of the wire is A assuming magnetic field is ⊥ to the wire. Each charge q in the wire ~~expert~~ experiences magnetic force F given by

$$F = qV_dB.$$

V_d is the drift velocity of the charge.

The total force experienced by the wire is F_m which is the force on a single charge multiply by the total no of charges in the wire.

The vol of the wire is Al

The total no of carriers (charges) is given by

$$N = nAL$$

where n is the number of charges per volume i.e charge density.

$$\therefore F_m = F \times N$$

$$= (qV_dB)(nAL)$$

However current in the wire is given by $I = nqV_dA$

$$F_m = BnqV_dAL$$

$$\boxed{F_m = BIL}$$ force on current carrying wire

This equation holds when the current and magnetic field are at rt-angle to each other, otherwise

$$F_m = L\,B \times I \text{ (B cross I)}$$

$$F_m = BIL\sin\phi \text{ (ϕ is the angle btw B and I)}$$

$$F_m = B_\perp IL$$

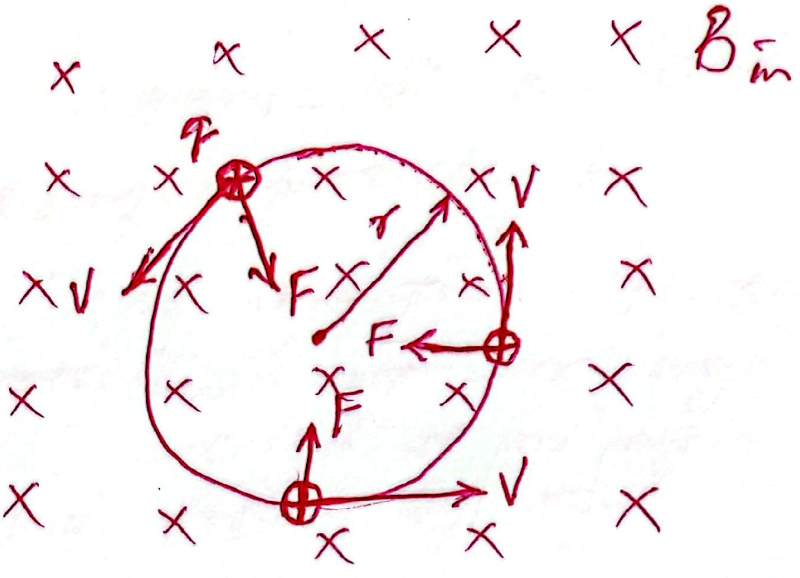
$B_\perp$ is the component of B for to I

Ex: A wire carries a current of 20A from east to west. Assume that the magnetic field of the earth is horizontal at this location directed from south to north and that it has a magnitude of 0.5×10^{-4} T. Find the force on a 30 m length of the wire.

Ex: A wire 1.2 m in length carries a current of 4A in a uniform magnetic field of magnitude 0.02T. Calculate the magnitude of the magnetic force on the wire if the angle btw the magnetic field and the direction of the current in the wire is (a) 30° (b) 90° and (c) 180°

Motion of a charge particle in a magnetic field

Consider a proton moving ~~throug~~ a uniform magnetic field.



B, F and V are mutually ⊥r to each other.

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Charge q moves in circular path, F_m on it is the centripetal force. Therefore

$$F_m = qBV$$

Recall that $F_c = \frac{mv^2}{r}$

$$\Rightarrow \quad F_m = F_c$$

$$\text{or} \quad F_c = F_m$$

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

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

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

r is the radius of the circular path of the charge particle q.

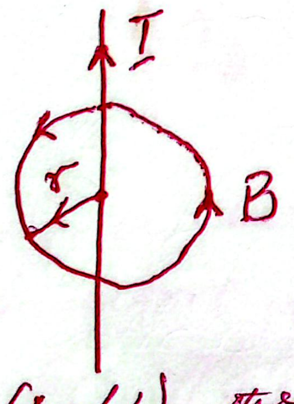
If the initial direction of the velocity of charged particle is not ~~lar~~ magnetic field ~~then~~ but instead is directed at an angle to the field, then the path follow by the particle is spiral (helix).

Ex: A proton moves in circular path of diameter 20cm with a speed of 0.5×10^5 m/s. If the plane of the path is ~~par~~ ⊥ to the magnetic field, what is the strength of the field.

Ex: A beam of protons is shot ~~in a~~ into a region of crossed electric and magnetic fields. What is the velocity of the protons, which moves through undeflected, if the electric field has a value of 10^5 N/C and the magnetic field is 2T

Magnetic Field of a Long, Straight wire and Ampere's Law

Consider, a long wire carrying steady current. ~~then~~ the current flowing thru the wire will generate magnetic field round the wire, this is illustrated below



A convenient rule for determining the direction of a magnetic field produced by a current in a wire is rt-hand screw rule

Grasp (hold) the wire with rt-hand, with the thumb along the direction of the current, the four fingers wrap round the wire in the direction of the magnetic field lines.

The magnetic field of current carrying wire at distance r is given by

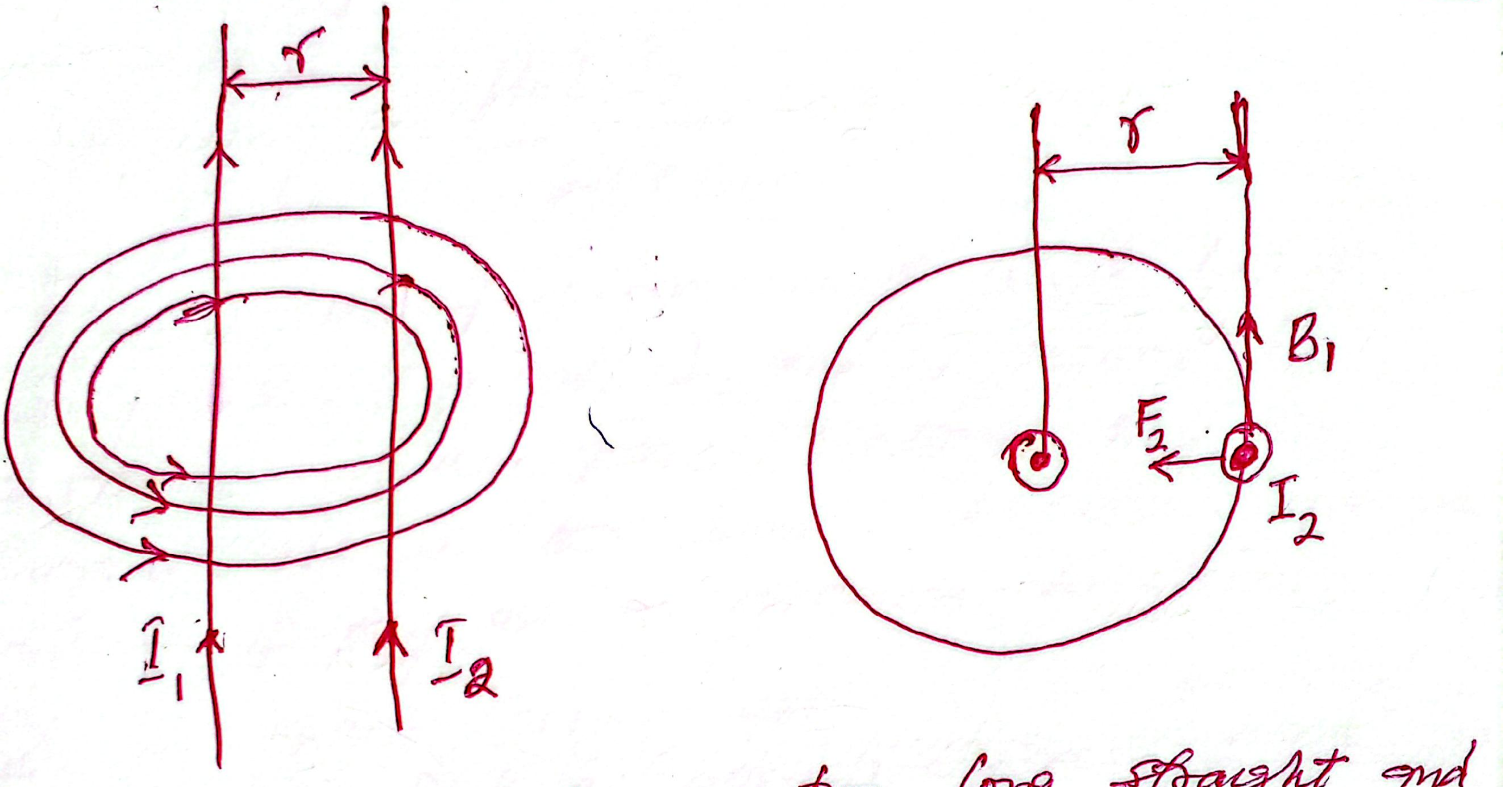
$$B = \frac{\mu_0 I}{2\pi r} \quad \text{———} \quad *\dagger* 1$$

where μ_0 is permeability of free space

~~$\mu_0 = 4\pi \times 10^{-7}$~~

$$\mu_0 = 4\pi \times 10^{-7}\ T \cdot m/A$$

Magnetic Force between Two Parallel Conductors



The force between two long straight and parallel conductors separated by a distance r can be found by applying eqn 1 *†*

Consider wire 1, the field due to I_1 at this distance r is given to be

$$B_1 = \frac{\mu_0 I_1}{2\pi r} \quad \text{———} \quad *\dagger* 2$$

The field of wire 1 is uniform along wire 2 and ~~⊥~~ ⊥r to it and so the force F_2 it exerts on wire 2 is given by

$$F = BIL\sin\phi$$

but $\phi = 90°$

$$\Rightarrow F_2 = B_1 I_2 l \quad \text{------- } \#\#\ 3$$

Substituting B_1 into we have,

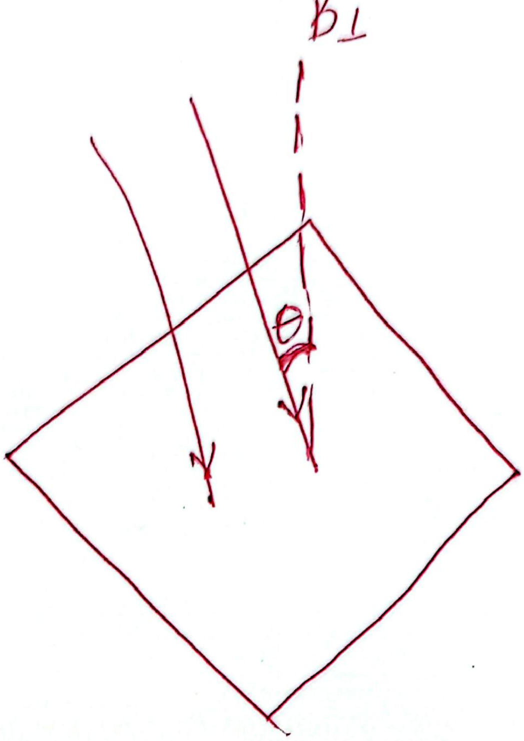
$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

F/l is the force per unit length between two parallel currents I_1 and I_2 separated by distance r. The force is attractive if the currents are in the same direction and repulsive if they are in opposite directions.

~~Ex~~: The wire carrying 400 A to the motor of a commuter train feels an attractive force of 4.00×10^{-3} N/m due to a parallel wire carrying 5.00 A to a headlight. (a) How far apart are the wires? (b) Are the currents in the same direction.

Ex: The force per meter btw the two wires of a jumper cable being used to start a stalled car is 0.225 N/m (a) What is the current in the wires, given they are separated by 2.00 cm? (b) Is the force attractive or repulsive.

Induced Emf and Magnetic Flux



Experments revealed that there is a crucial quantity called the magnetic flux ϕ, given by

$$\phi = BA\cos\theta$$

where B = magnetic field strength over A

A = Area

Any change in magnetic flux ϕ induces an e.m.f. This process is defined to be electromagnetic induction. the units of magnetic flux ϕ are $T.m^2$

$$B_\perp = B\cos\theta$$

$$\phi = B_\perp A.$$

Faraday's Law of induction

Faraday's Law states that the induced emf in a circuit is proportional to the rate of change of magnetic flux thru the circuit

$$\mathcal{E} = -N\frac{\Delta \phi}{\Delta t}$$