MOVING CHARGES AND MAGNETISM

MAGNETIC FORC

MAGNETIC FORCE ON MOVING CHARGE

When a charge q moves with velocity $\vec{V}$ in a magnetic field $\vec{B}$ then the magnetic force experienced by moving charge is given by following formula:

$\vec{F} = q\left(\vec{V} \times \vec{B}\right)$ Put q with sign.

$\vec{V}$: Instantaneous velocity

$\vec{B}$: Magnetic field at that point

DIFFERENCE BETWEEN MAGNETIC FORCE AND ELECTRIC FORCE

1. Magnetic force is always perpendicular to the field while electric force is collinear with the field.
2. Magnetic force is velocity dependent, i.e., acts only when the charged particle is in motion while electric force (qE) is independent of the state of rest or motion of the charged particle.
3. Magnetic force does no work when the charged particle is displaced while the electric force does work in displacing the charged particle

NOTE:

$\vec{F} \perp \vec{V}$ And also $\vec{F} \perp \vec{B}$ ï

$\vec{F} \perp \vec{V}$ $\therefore$ Power due to magnetic force on a charged particle is zero. (Use the formula of power P = $\vec{F}$ ρv for its proof)

Since the $\vec{F} \perp \vec{B}$ so work done by magnetic force is zero in every part of the motion. The magnetic force cannot increase or decrease the speed (or kinetic energy) of a charged particle. It's can only change the direction of velocity.

on a stationary charged particle, magnetic force is zero

If $\vec{V} \parallel \vec{B}$ then also magnetic force on charged particle is zero. It moves along a straight line if only magnetic field is acting.

Ex. A Charged particle of mass 5 mg and charge q = +2μC has velocity $\vec{V} = 2\vec{i} - 3\vec{j} + 4\vec{k}$ Find out the magnetic force on the charged particle and its acceleration at this instant due to magnetic field $\vec{B} = 3\vec{j} - 2\vec{k}.\vec{V}$ and $\vec{B}$ are in m/s and Wb/m2 respectively.

Sol. $\vec{F} = q\vec{v} \times \vec{B} = 2 \times 10^{-6}(2\vec{i} - 3\vec{j} + 4\vec{k}) \times (3\vec{j} - 2\vec{k})$

$$2 \times 10^{-6}[-6\vec{i} + 4\vec{j} + 4\vec{k}]$$

$$\vec{a} = \frac{\vec{F}}{m} = \frac{2\times10^{-6}}{5\times10^{-6}}(-6\vec{i} + 4\vec{j} + 6\vec{k})$$

$$0.8(-3\vec{i} + 2\vec{j} + 3\vec{k})$$

Ex. A charged particle has acceleration $\vec{a} = 2\vec{i} + x\vec{j}$ in a magnetic field $\vec{B} = 3\vec{j} + 2\vec{j} - 4\vec{k}$. Find the value of x.

Sol.

$$\vec{F} \perp \vec{B}$$

$$\vec{a} .\perp \text{B}$$

$$\vec{a} . \vec{B} = 0$$

$$\left(2\vec{i} + x\vec{j}\right).\left(-3\vec{i} + 2\vec{j} - 4\vec{k}\right) = 0$$

$$\Rightarrow -6 + 2x = 0$$

Lorentz force equation

When the moving charged particle is subjected simultaneously to both electric field ρE and magnetic field $\vec{B}$, the moving charged particle will experience electric force $\vec{F_e} = q\vec{E}$ and magnetic force $\vec{F_m} = q\left(\vec{V} \times \vec{B}\right)$

$$\vec{F} = q\left[\vec{E} + \vec{V} \times \vec{B}\right]$$

which is Lorentz force equation.