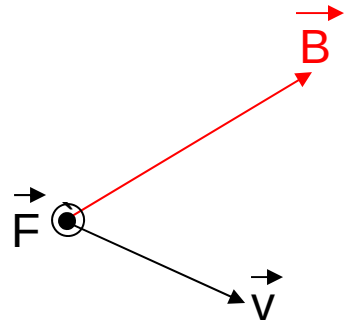
Class 24 Magnetic Force on a Current

Magnetic Force Acting on a Moving Charge

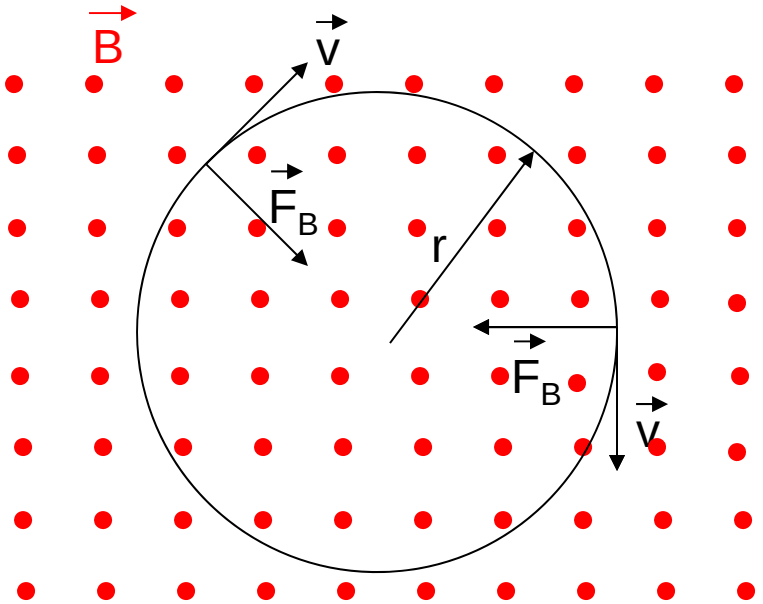
When a charge particle moves in a magnetic field B, there will be magnetic force acting on the particle:



$$\vec{F}_B = q\,\vec{v} \times \vec{B}$$

1. Unit of magnetic field is Tesla (T).
2. If there is magnetic field, only under two conditions the magnetic force on the charge particle will be zero: (i) the particle is not moving (v=0), or (ii) it is moving in parallel or antiparallel to the magnetic field ($\sin\theta=0$).
3. The magnetic force is always perpendicular to the magnetic field and the velocity.
4. The magnetic force does no work because $\vec{F}_B \cdot \vec{v} = 0$.
5. If you want to determine the direction acting on a negative charge particle, treat it like a positive charge first, then reverse the force direction at the end.

Motion of Charge Particle in a Uniform B field
$\Rightarrow$ Circular Motion of Constant Speed



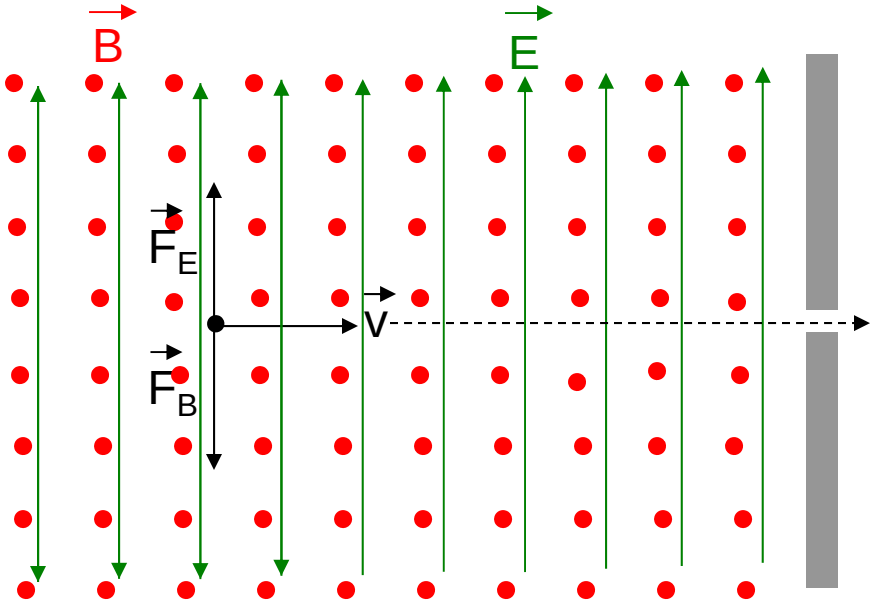
1. $\vec{F}_B$ always perpendicular to $\vec{v} \Rightarrow$ Centripetal force
2. Magnetic force does no work $\Rightarrow$ Constant speed

Equation of motion:

$$q|v \times B| = m\frac{v^2}{r} \Rightarrow \boxed{qvB = m\frac{v^2}{r}} \Rightarrow \frac{v}{r} = \frac{q}{m}B$$

$$\Rightarrow \omega = \frac{q}{m}B \leftarrow \text{Cyclotgron frequency}$$

Velocity Selector



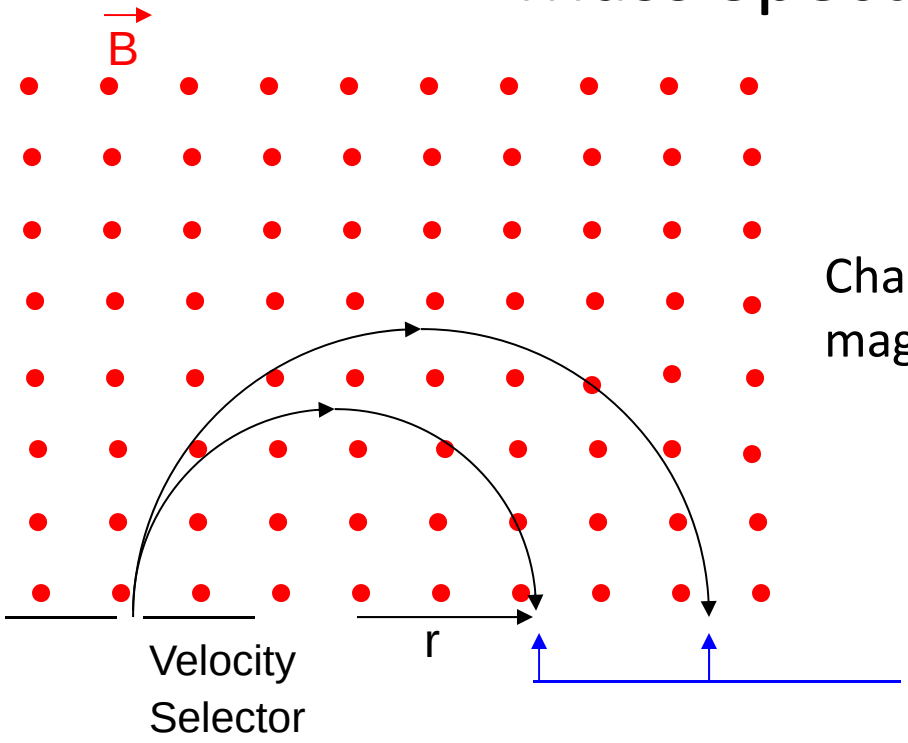
If we can balance $\vec{F}_B$ and $\vec{F}_E$, the charge particle will move in a constant speed.

Equation of motion: $F_B - F_E = 0 \Rightarrow qvB - qE = 0$

$$\Rightarrow v = \frac{E}{B}$$

Only particles with v = E/B will move with constant velocity.

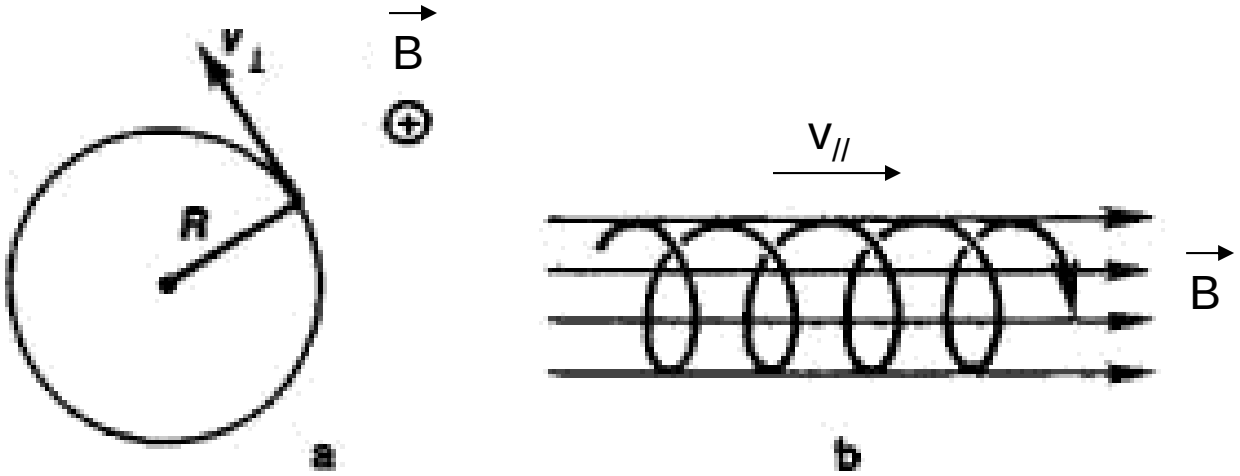
Mass Spectrometer



Charge particle enter the uniform magnetic field with the same velocity.

$$qvB = m\frac{v^2}{r} \quad \Rightarrow \quad r = \frac{v}{B}\left(\frac{m}{q}\right)$$

If there is velocity component parallel to the uniform magnetic field



The particle will perform circular motion in the plane perpendicular to the magnetic field, but at the same time moves in parallel (or antiparallel) to the magnetic field.

$$\frac{v_{\perp}}{r} = \frac{q}{m} B$$

$$v_{//} = \text{constant}$$