Physics with Synno – Move Without Contact – Lesson 8

M.3.1 Force on Moving Charges

Video: Magnetic Force on Charged Particles

In the previous section we saw the force on a current carrying wire. But a current is just a stream of charged particles. From this we can calculate the force on a single charge moving at speed v.
The force on a current is given by:

$\mathbf{F} = I\,L\,\mathbf{B}$ important

But $I = \frac{q}{t}$

and $v = \frac{distance}{time} = \frac{L}{t}$

$\therefore$ $L = v\,t$

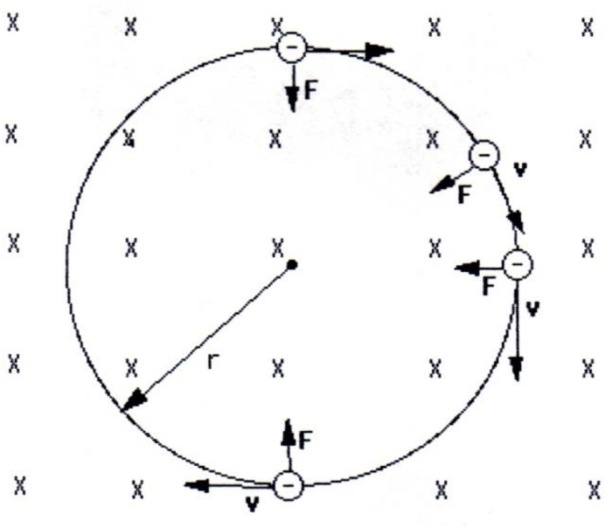
Substituting these we get

$$\boldsymbol{F} = \frac{\boldsymbol{q\,v\,t\,B}}{\boldsymbol{t}}$$

$\therefore$ $\boldsymbol{F} = \boldsymbol{q\,v\,B}$ important

The direction is worked out using the Right Hand Push Rule. Fingers point in the field direction, thumb in direction of movement, and the palm pushes in the direction of the force. This gives the direction for a positive charge, for a negative charge the direction is opposite to your thumb.

The direction of the force is perpendicular to the direction of the velocity. This causes the particle to move in a curved path. If the Magnetic field is large enough the particle will move in a circle.



We have $\mathbf{F}_{\text{magnetic}} = \mathbf{v}\ \mathbf{B}\ q$

$\mathbf{F}_{\text{circular motion}} = \frac{m\, v^2}{r}$

The force that is causing the circular motion is the magnetic force.

So $\mathbf{v}\ \mathbf{B}\ q = \frac{m\, v^2}{r}$

$$r = \frac{m\, v}{B\, q}$$

Where r is the radius of the circular motion
m is the mass of the particle

Example:
An alpha-particle of charge 3.2×10^{-19} C and mass 6.7×10^{-27} Kg is fired into a uniform magnetic field of magnitude 0.24 T north with a uniform velocity of 8.0×10^{6} m/s east.
Calculate:
a) the force on the alpha-particle
b) the radius of the circular motion

Solution

a)

$$\mathbf{F} = v\mathbf{B}q$$
$$= 8.0\times10^{6} \times 0.24 \times 3.2\times10^{-19}$$
$$= 6.1\times10^{-13} \text{ N Direction Upwards}$$

b)

$$r = \frac{m\mathbf{v}}{\mathbf{B}q}$$
$$= \frac{6.7\times10^{-27} \times 8.0\times10^{6}}{0.24 \times 3.2\times10^{-19}}$$
$$= 0.70 \text{ m}$$

M.4 Comparing Fields

- Gravitational, electric and magnetic fields are similar, but display significant differences associated with the differences in the fundamental nature of the fields.

- The direction of a field at any point is always the resultant field vector determined by adding the individual field vectors due to each mass, charge or magnetic pole within the affected region.

- A uniform field would be indicated by lines that remain evenly spaced throughout the region of the field.

- In a static (unchanging) field, the strength of the field doesn't change with time.

- The field around a monopole is radial, static but not uniform. It varies with the distance from the point source.

Quantity or description	Gravitational fields	Electrical fields	Magnetic fields
type of poles	monopoles	monopoles/dipoles	dipoles
type of force	attractive	attractive/repulsive	attractive/repulsive
extent of the field	extends to an infinite distance	can be constrained to a fixed distance	can be constrained to a fixed distance
effect of distance on field strength in a radial field	$g = G\frac{M}{r^2}$	$E = k\frac{Q}{r^2}$	
force between monopoles	$F_g = G\frac{m_1 m_2}{r^2}$	$F = k\frac{q_1 q_2}{r^2}$	
potential energy changes in a uniform field	$E_g = mg\Delta h$	$W = qV$	
force due to a uniform field	$F_g = mg$	$F = qE$	

Text Questions: Pages 61 – 62 All Questions