3055 BA SANGAM COLLEGE

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WORKSHEET 19

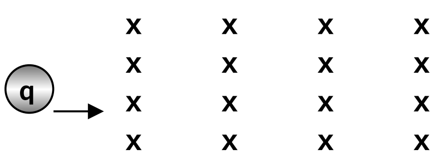
SCHOOL: BA SANGAM COLLEGE **YEAR: 13**

SUBJECT: PHYSICS **NAMEOF STUDENT: ______________________**

STRAND	**STRAND 6: MAGNETIC FIELD**
SUB-STRAND	**Motion of Charged Particle in a Magnetic Field**
LEARNING OUTCOME	To understand how a wheat stone bridge works

Force on a moving charge in a magnetic field

A current carrying conductor moving through a magnetic field experiences a force. Similarly, a charge (positive or negative) moving through a magnetic field also experiences a force.



The magnitude of the force is given by:

$$F = B\,v\,q$$

where B = magnetic field strength (T)

v = velocity of the charge (m/s)

q = charge(c)

Note:

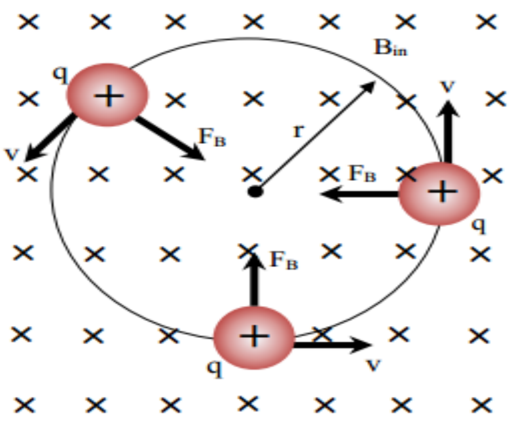
1. When charge moves perpendicular to the field, force is maximum.
2. When charge moves parallel to the field, force is zero.

The **direction** of force is given by the **right-hand rule**.

A moving charge means we have a current since I is the rate of flow of charge:

- A positive moving charge means current is flowing in that direction.
- A negative moving charge means current is moving in opposite direction.

As the particle moves through the field, the *direction of a force* is always *perpendicular* to the *velocity*. This causes the charge to move in a circular path with constant speed. It follows that:



Centripetal force = magnetic force

$$\frac{mv^2}{R} = B\,v\,q$$

$$R = \frac{mv}{Bq}$$

Where m = mass of charge (kg)
v = velocity of charge (m/s)
B = magnetic field strength (T)
q = charge (C)

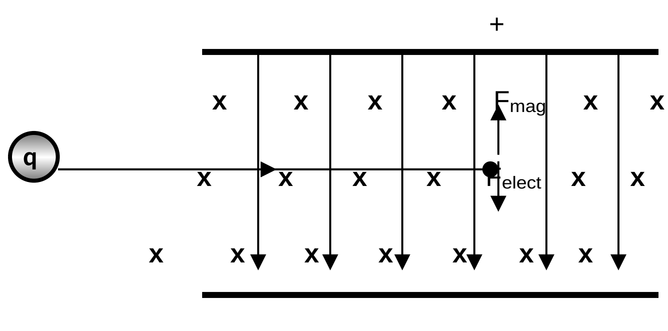
Points to Note:

1. The particle travels with *constant velocity*. The direction of velocity is the tangential to the circular path at any particular point.
2. The *acceleration* is directed towards centre and is given by:
$$a = \frac{v^2}{R}$$
3. The force is also directed towards the centre and is given by:
$$F = \frac{mv^2}{R}$$
4. The work done on the charge is 0J since *force* is perpendicular to the *velocity*.

Application of Motion of Charged Particles

1. Velocity Selector

Consider a charged particle with mass *m*, velocity *v* and charge q entering a region of space, where the electric and magnetic fields are perpendicular to the particles velocity and to each other.



If q is *positive*, electric force is downward;

$$F_{electrical} = E\,q$$

The magnetic force is acting upwards (from right hand slap rule);

$$F_{magnetic} = B\,v\,q$$

For a particular value of *v*, the electric and magnetic force will be equal in magnitude. The **resultant force** on the particle is then zero, and the particle travels in a straight line with constant velocity, *v*.

Therefore: $F_{electrical}$ = $F_{magnetic}$

$E\,q = B\,v\,q$ (q can be cancelled)

$E = B\,v$

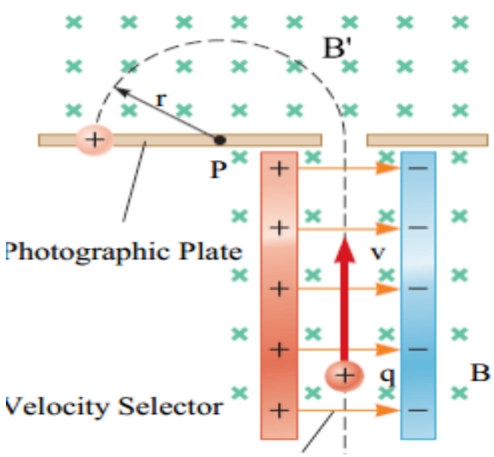
$$v = \frac{E}{B}$$

Points to Note:

1. E and B can be adjusted to produce particular speeds.
2. The velocity is independent of the charge of the particle since q cancels out in the equation.
3. Only particles with the speed equal to $\frac{E}{B}$ can pass through without being deflected by the fields

Mass Spectrometer

- Is used to determine the mass of a charge
- In a mass spectrometer, a beam of ion first passes through a velocity selector with cross electric & magnetic field and then enters a magnetic field movingin circular arc with radius, r.



- This technique is used to find masses of different isotopes of an element.
- ***Ions with larger mass travel in paths with a larger radius.***

EXAMPLE

1. A positively charged particle with mass, m= 1.6×10^{-27} kg and charge of q = 1.6×10^{-19} C travels at v = 3.2×10^{6} ms^{-1} in a magnetic field of strength B = 0.03 T. Find the radius of its circular motion in the magnetic field.

$$r = \frac{mv}{Bq} = \frac{(1.6 \times 10^{-27})(3.2 \times 10^{6})}{(0.03)(1.6 \times 10^{-19})} = 1.07\,m$$

2. A cathode ray beam is bent in a circle of radius 2 cm by a field of induction B = 4.5×10^{-3} T. Calculate the velocity of the electrons given, e = 1.60×10^{-19} C, $m_e = 9.11 \times 10^{-31}$ kg.

$$r = \frac{mv}{Bq}$$

$$v = \frac{Bqr}{m}$$

$$v = \frac{(4.5 \times 10^{-3})(1.6 \times 10^{-19})(0.02)}{9.11 \times 10^{-31}} = 15.81 \times 10^{6}\ ms^{-1}$$

EXERCISE

1. An electron enters a magnetic field of a mass spectrometer with a speed of 1.0×10^{6} ms^{-1}. If the magnetic field strength B = 1×10^{-4} T, find the radius of the path.

2. A proton of charge, q = 1.6×10^{-19} C and mass, m = 1.67×10^{-27} kg is captured in a 0.107 T magnetic field and spins along a circle of radius 4.5 cm. Find its speed knowing that it moves perpendicular to the field lines.

3. Suppose you're helping to design a leak detector that uses a mass spectrometer to detect Helium ions. The ions have a mass of 6.67×10^{-27} kg and a speed (when they emerge from velocity selector) 1.00×10^{5} ms^{-1}. They are curved in a semi-circular path by a magnetic field, B, and are detected at a distance of 10.16 cm from the photographic plate. Calculate the magnitude of the magnetic field, B.

4. A stream of deuterons is projected with a velocity of 104 ms^{-1} in a uniform magnetic field of 10^{-3} T. Find the radius of the circular path of the particle. (Mass of deuteron is 3.32×10^{-27} kg and charge of deuteron is 1.6×10^{-19} C).