Short Answer Questions – I (PYQ)

Q. 1. Find the condition under which the charged particles moving with different speeds in the presence of electric and magnetic field vector can be used to select charged particles of a particular speed. [CBSE (AI) 2017]

Ans. Consider a charge q moving with velocity v in the presence of electric and magnetic fields. The force on an electric charge q due to both of them is

$F = q\,[E\,(r) + v \times B(r)]$

$\Rightarrow F \equiv F_{electric} + F_{magnetic}$ ...(i)

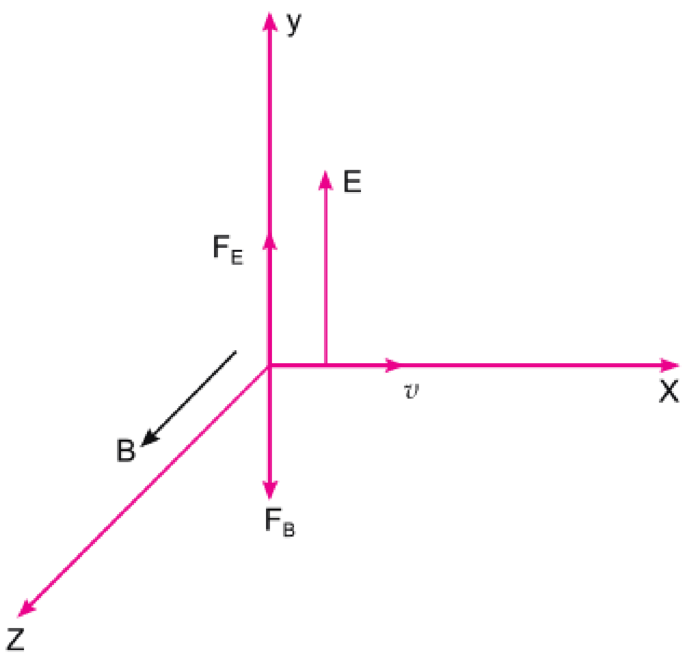
Where, v = velocity of the charge

r = location of the charge at a given time t

E(r) = Electric field

B(r) = Magnetic field

Let us consider a simple case in which electric and magnetic fields are perpendicular to each other and also perpendicular to the velocity of the particle.



$$F_E = \text{qE} = \text{qE}\,\hat{j}$$

$$F_B = \text{qv} \times B = q(v\hat{i} \times B\hat{k}) = -\ \text{qvB}\,\hat{j}$$

$$\therefore \qquad F = q(E - vB)\ \hat{j}$$

Thus, electric and magnetic forces are in opposite directions.

Suppose we adjust the values of E and B such that magnitudes of the two forces are equal, then the total force on the charge is zero and the charge will move in the fields undeflected. This happens when

$$\text{qE} = \text{qvB} \qquad \text{or} \qquad v = \frac{E}{B}$$

This condition can be used to select charged particles of a particular velocity out of a beam containing charges moving with different speeds (irrespective of their charge and mass). The crossed E and B fields therefore serve as a velocity selector.

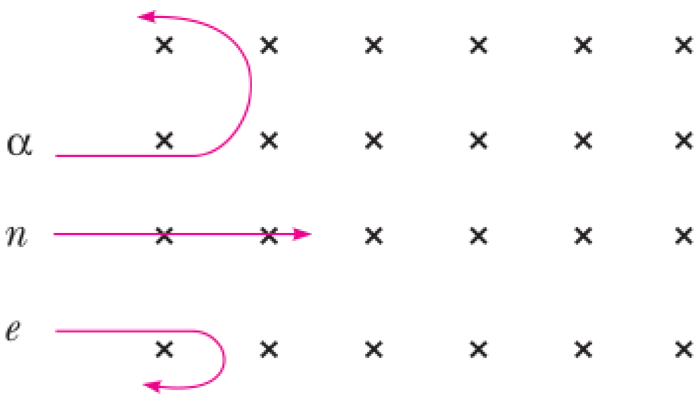
Q. 2. Answer the following questions

(i) Write the expression for the magnetic force acting on a charged particle moving with velocity v in the presence of magnetic field B.

(ii) A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going into the plane of the paper as shown. Trace their paths in the field and justify your answer. [CBSE Delhi 2016]

Ans. (i) $\vec{F} = q(\vec{v} \times \vec{B})$

(ii) Force on alpha particle and electron are opposite to each other, magnitude of charge of alpha particle is more than electron hence radius of alpha particle is more than radius of electron.



Q. 3. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies. [CBSE Delhi 2014]

Ans. A cyclotron makes use of the principle that the energy of the charged particles can be increased to a high value by making it pass through an electric field repeatedly.

The magnetic field acts on the charged particle and makes them move in a circular path inside the dee. Every time the particle moves from one dee to another it is acted upon by the alternating electric field, and is accelerated by this field, which increases the energy of the particle.

Uses: (i) It is used to bombard nuclei with high energetic particles accelerated by cyclotron and study the resulting nuclear reaction.

(ii) It is used to implant ions into solids and modify their properties or even synthesize new materials.

Q. 4. Write the expression for Lorentz magnetic force on a particle of charge 'q' moving with velocity $\vec{V}$ in a magnetic field $\vec{B}$. Show that no work is done by this force on the charged particle. [CBSE (AI) 2011]

Ans.

$$\text{Lorentz magnetic force, } \overrightarrow{F_m} = q\vec{v} \times \vec{B}$$

$$\text{Work done, } W = \overrightarrow{F_m}\vec{S} = \int \overrightarrow{F_m}\vec{v}\,\text{dt} = \int q(\vec{v} \times \vec{B}).\vec{v}\ \text{dt}$$

$$\text{As } (\vec{v} \times \vec{B}).\vec{v} = 0$$

$$\therefore \quad \text{Work, } W = 0$$

Q. 5. A charged particle enters perpendicularly a region having either (i) magnetic field or (ii) an electric field. How can the trajectory followed by the charged

particle help us to know whether the region has an electric field or a magnetic field? Explain briefly.

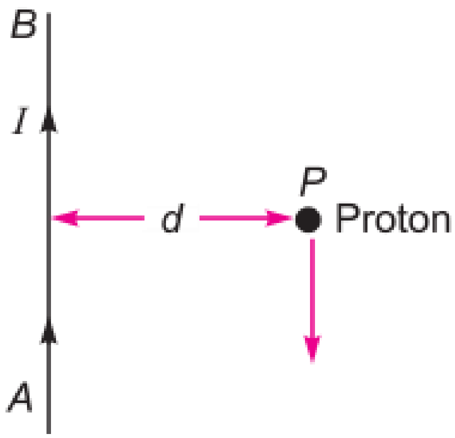
Ans. The path of the charged particle will be circular in a magnetic field. This is due to the reason that the force acting on the particle will be at right angles to the field as well as direction of motion, resulting in a circular trajectory.

In the case of electric field, the trajectory of the particle will be determined by the equation

$$s = \mathrm{ut} + \frac{1}{2}\left(\frac{\mathrm{qE}}{m}\right)t^2 \qquad \left(s = \mathrm{ut} + \frac{1}{2}\mathrm{at}^2\right)$$

Where q and m are charge and mass of the particle, E is the electric field and s is the distance travelled by the particle in time t. Thus, the trajectory will be a parabolic path.

Q. 6. A long straight wire AB carries a current I. A proton P travels with a speed v, parallel to the wire, at a distance d from it in a direction opposite to the current as shown in the figure. What is the force experienced by the proton and what is its direction? [CBSE (AI) 2010]



Ans. Magnetic field due to current carrying wire is perpendicular to plane of paper – downward.

$$i.e., \ \vec{B} = -\frac{\mu_0 I}{2\pi d}\hat{k}$$

$$\text{Force } \vec{F} = q\vec{v} \times \vec{B} = e(-v\hat{j}) \times \left(-\frac{\mu_0 I}{2\pi d}\hat{k}\right) = \frac{\mu_0 \, \mathrm{evI}}{2\pi d}\hat{i}$$

That is the magnetic force has magnitude $\frac{\mu_0 \, \mathrm{evI}}{2\pi d}$ and is directed along positive X-axis *i.e.,* in the plane of paper perpendicular to direction of $\vec{v}$ and to the right.

Q. 7. Two long and parallel straight wires carrying currents of 2 A and 5 A in the opposite directions are separated by a distance of 1 cm. Find the nature and magnitude of the magnetic force between them. [CBSE (F) 2011]

Ans. I_1=2 A, I_2 =5A, a=1 cm = 1 × 10^{-2} m

Force between two parallel wires per unit length is given by

$$F = \frac{\mu_0}{2\pi} \cdot \frac{I_1 I_2}{a} = 2 \times 10^{-7} \times \frac{2\times5}{1\times10^{-2}} = 20 \times 10^{-5} N(\text{ Repulsive })$$

Q. 8. A short bar magnet of magnetic moment 0.9 J/T is placed with its axis at 30° to a uniform magnetic field. It experiences a torque of 0.063 J.

(i) Calculate the magnitude of the magnetic field.

(ii) In which orientation will the bar magnet be in stable equilibrium in the magnetic field? [CBSE (F) 2012]

Ans. (i)

We know $\vec{\tau} = \vec{M} \times \vec{B}$

or $\tau = M B \sin \theta$

$0.063 = 0.9 \times B \times \sin 30^\circ$

or $B = 0.14$ T

(ii) The position of minimum energy corresponds to position of stable equilibrium.

The energy (U) = –MB cos θ

When θ = 0° ⇒ U = – MB = Minimum energy

Hence, when the bar magnet is placed parallel to the magnetic field, it is the state of stable equilibrium.

Q. 9. A magnetised needle of magnetic moment 4.8 × 10–2 J T–1 is placed at 30° with the direction of uniform magnetic field of magnitude 3 × 10–2 T. Calculate the torque acting on the needle. [CBSE (F) 2012]

Ans.

We have, $\tau = M B \sin\theta$

where $\tau \rightarrow$ Torque acting on magnetic needle

$M \rightarrow$ Magnetic moment

$B \rightarrow$ Magnetic field strength

$$\text{Then } \tau = 4.8 \times 10^{-2} \times 3 \times 10^{-2} \sin 30^0 = 4.8 \times 10^{-2} \times 3 \times 10^{-2} \times \frac{1}{2}$$

$$\tau = 7.2 \times 10^{-4} \text{ Nm}$$

Q. 10. State two reasons why a galvanometer cannot be used as such to measure current in a given circuit. [CBSE Delhi 2010]

OR

Can a galvanometer as such be used for measuring the current? Explain.

Ans. A galvanometer cannot be used as such to measure current due to following two reasons.

(i) A galvanometer has a finite large resistance and is connected in series in the circuit, so it will increase the resistance of circuit and hence change the value of current in the circuit.

(ii) A galvanometer is a very sensitive device, it gives a full scale deflection for the current of the order of microampere, hence if connected as such it will not measure current of the order of ampere.

Short Answer Questions – I (OIQ)

Q. 1. An electron beam passes through a region of crossed electric and magnetic fields of strength E and B respectively. For what value of electron-speed the beam will remain undeflected?

Ans. The electron beam will pass undeflected if electric force and magnetic force on electron is equal and opposite i.e., eE = evB

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

Q. 2. An α–particle and a proton are moving in the plane of paper in a region where there is a uniform magnetic field directed normal to the plane of the paper. If the particles have equal linear momenta, what would be the ratio of the radii of their trajectories in the field?

Ans.

Radius of circular path of a charged particle, $r = \frac{mv}{qB} = \frac{P}{qB}$.

For same linear momentum and magnetic field B,

$$r \propto \frac{1}{q}$$

$$\therefore \quad \frac{r_\alpha}{r_p} = \frac{q_p}{q_\alpha} = \frac{+e}{+2e} = \frac{1}{2}$$

Q. 3. A particle of mass 'm', with charge 'q' moving with a uniform speed 'v', normal to a uniform magnetic field 'B', describes a circular path of radius 'r'. Derive expressions for the (i) time period of revolution and (ii) kinetic energy of the particle.

Ans. (i) Motion of charged particle in perpendicular magnetic field: The magnetic force on charged particle qvB sin 90° provides the necessary centripetal force for a circular path, so

$$qvB = \frac{mv^2}{r} \Rightarrow v = \frac{qBr}{m}$$

But $v = \frac{2\pi r}{T}$ where T is time period

$$\frac{2\pi r}{T} = \frac{qBr}{m} \Rightarrow T = \frac{2\pi m}{qB}$$

***(ii)* Kinetic energy of charged particle:**

$$KE = \frac{1}{2}mv^2 \qquad \Rightarrow \qquad \frac{1}{2}m\frac{q^2B^2r^2}{m^2} = \frac{q^2B^2r^2}{2m}$$

Q. 4. You are given a low resistance R_1 a high resistance R_2 and a moving coil galvanometer. Suggest how would you use these to have an instrument that will be able to measure

(i) Current
(ii) Potential difference.

Ans. (i) To measure current we shall connect low resistance R_1 in parallel with the coil of moving coil galvanometer. This arrangement is called ammeter.

(ii) To measure the potential difference we shall connect high resistance R_2 in series with the coil of galvanometer. This arrangement is called voltmeter.

Q. 5. If a particle of charge q is moving with velocity v along X-axis and the magnetic field B is acting along Y-axis, use the expression $\vec{F} = q(\vec{v} \times \vec{B})$ **to find the direction of force** $\vec{F}$ **acting on it.**

Ans.

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

$$\text{Given } \vec{v} = v\,i,\ \vec{B} = B\,\hat{j}$$

$$\therefore \quad \vec{F} = q(v\hat{i} \times (B\hat{j}) = \text{qvB}\ \hat{k}$$

That is, force is acting along Z-axis.

Q. 6. The velocities of two α-particles A and B entering a uniform magnetic field are in the ratio 4 : 1. On entering the field they move in different circular paths. Give the ratio of the radii of curvature of the paths of the particles.

Ans.

$$\text{Radius of circular path } r = \frac{\text{mv}}{\text{qB}} \ \ i.e.\ \ r \propto v$$

$$\therefore \quad \frac{r_A}{r_B} = \frac{v_A}{v_B} = \frac{4}{1}$$

Q. 7. An ammeter and a milliammeter are converted from the same galvanometer. Out of the two, which current measuring instrument has a higher resistance?

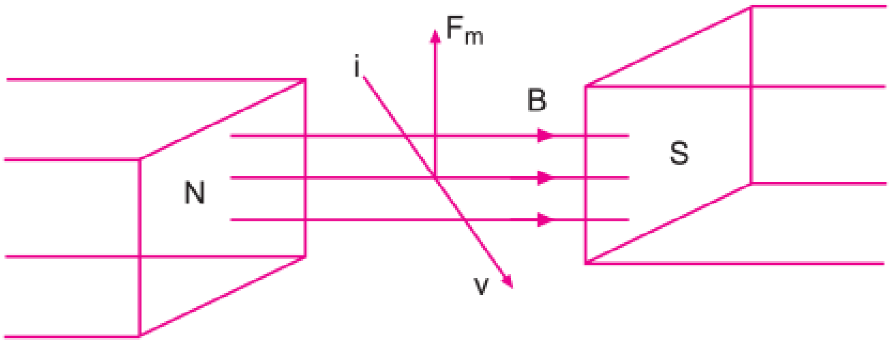
Ans. $$\text{Shunt resistance, } S = \frac{I_g}{I - I_g}G \approx \frac{I_g}{I}G$$

Clearly, smaller the value of range, larger is the shunt resistance. Obviously, milliammeter will have a larger shunt resistance and hence it will have a higher resistance.

$$\frac{1}{R_A} = \frac{1}{G} + \frac{1}{S}$$

Higher the S, higher the R_A for given G.

Q. 8. A charged particle enters into a uniform magnetic field and experiences an upward force as indicated in the figure. What is the charge sign on the particle? [HOTS]



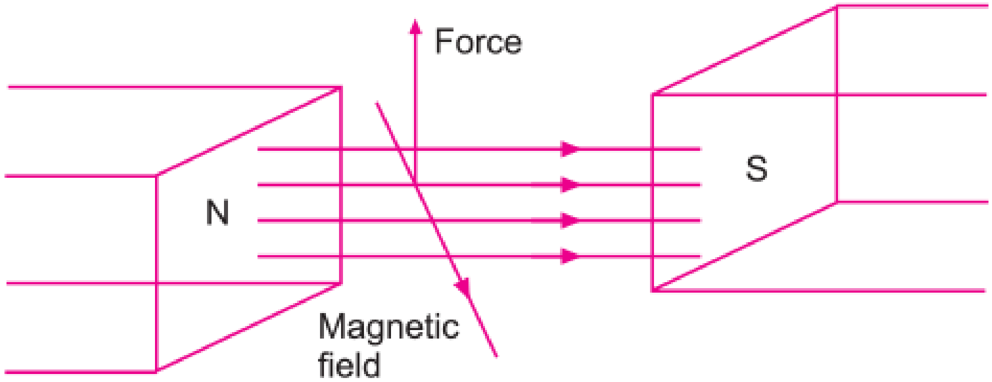
Ans. Positive Charge: By Fleming left hand rule the direction of current is along positive Z-axis. By vector method

$$\vec{F}_m = q\vec{v} \times \vec{B}$$

$$F_m\ \hat{j} = q\,v\,\hat{k} \times B\,\hat{i}$$

$$F_m\ \hat{j} = \mathrm{qvB}\ \hat{j}$$

This shows that q is positive.



Q. 9. A given galvanometer is to be converted into (i) an ammeter (ii) a milliammeter (iii) a voltmeter. In which case will the required resistance be (i) least (ii) highest and why? [HOTS]

Ans. The required resistance has least value in the case of an ammeter and maximum value in the case of a voltmeter.

This is due to the reason that the shunt resistance required to convert a galvanometer into ammeter or milliammeter has the value

$$S = \frac{I_g}{I - I_g} \times R_g$$

Thus, the shunt required in the case of milliammeter has higher value.

Similarly, since the voltmeter should have a high resistance, the value of required resistance should be highest in the case of a voltmeter. This is connected in series with the coil of the galvanometer.