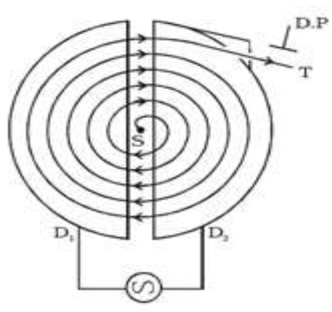
INDIAN SCHOOL MUSCAT

SENIOR SECTION

3 and 5 mark question and answers in Magnetism and Magnetic effects of current for Class XII

1. Draw a neat diagram of Cyclotron. State its principle. Explain the theory of cyclotron.



Principle: Cyclotron works on the principle that a charged particle moving normal to a magnetic field experiences magnetic Lorentz force due to which the particle moves in a circular path and its kinetic energy increases by acceleration due to high frequency AC.

Theory

When the particle moves along a circle of radius r with a velocity v, the magnetic Lorentz force provides the necessary centripetal force.

$$Bqv = \frac{mv^2}{r}$$

$$\frac{v}{r} = \frac{Bq}{m} = \text{constant} \quad \ldots(1)$$

The time taken to describe a semi-circle

$$t = \frac{\pi r}{v} \quad \ldots(2)$$

Substituting equation (1) in (2),

$$t = \frac{\pi m}{Bq} \quad ...(3)$$

It is clear from equation (3) that the time taken by the ion to describe a semi-circle is independent of (i) the radius (r) of the path and (ii) the velocity (v) of the particle.
Hence, period of rotation T = 2t

$$T = \frac{2\pi m}{Bq} = \text{constant} \quad ...(4)$$

So, in a uniform magnetic field, the ion traverses all the circles in exactly the same time. The frequency of rotation of the particle,

$$\upsilon = \frac{1}{T} = \frac{Bq}{2\pi m} \quad ...(5)$$

If the high frequency oscillator is adjusted to produce oscillations of frequency as given in equation (5), resonance occurs.
2. Derive the expression for maximum kinetic energy of a positive charge in a cyclotron
When the particle moves along a circle of radius r with a velocity v, the magnetic Lorentz force provides the necessary centripetal force.

$$Bq\upsilon = \frac{m\upsilon^2}{r}$$

$$\frac{\upsilon}{r} = \frac{Bq}{m} = \text{constant} \quad .....(1)$$

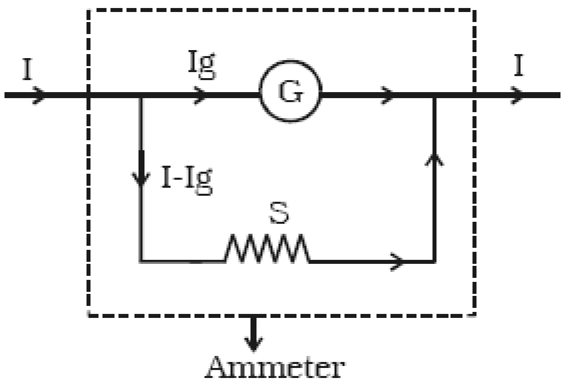
$$\upsilon = \frac{qBR}{m} \quad ......(2)$$

Is the maximum velocity , where v is the velocity, R is the radius of the trajectory at exit, and equals the radius of a dee.
Hence, the kinetic energy of the ions is,

$$\frac{1}{2}m\upsilon^2 = \frac{q^2B^2R^2}{2m}$$

3. Explain with relevant theory how will you convert a galvanometer into an ammeter?

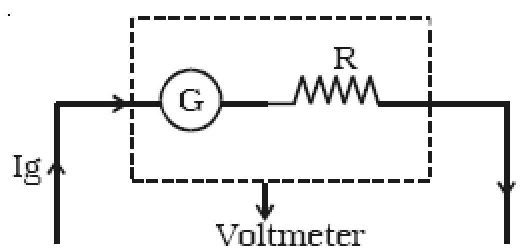
A galvanometer is a device used to detect the flow of current in an electrical circuit.
Being a very sensitive instrument, a large current cannot be passed through the galvanometer, as it may damage the coil.
A galvanometer is converted into an ammeter by connecting a low resistance S called shunt resistance in parallel with it.



As a result, when large current flows in a circuit, only a small fraction of the current passes through the galvanometer and the remaining larger portion of the current passes through the shunt. Thus shunt resistance protects galvanometer.

4. Explain with relevant theory how will you convert a galvanometer into a voltmeter?
Voltmeter is an instrument used to measure potential difference between the two ends of a current carrying conductor. A galvanometer can be converted into a voltmeter by connecting a high resistance R in series with it.

The scale is calibrated in volt. The value of the resistance connected in series decides the range of the voltmeter.



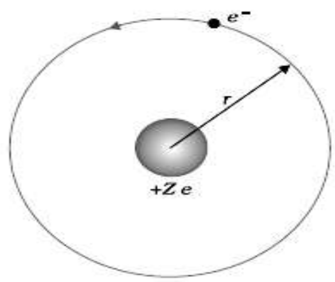
Let the Galvanometer resistance = G
The current required to produce full scale deflection in the galvanometer = Ig
Range of voltmeter = V
Resistance to be connected in series = R
Since R is connected in series with the galvanometer, the current through the galvanometer,
V = Ig (R+G)

$$R = \frac{V}{I_g} - G$$

The effective resistance of the voltmeter is R_v
$R_v = G + R$
R_v is very large, and hence a voltmeter is connected **in parallel** in a circuit as it draws the least current from the circuit. So that pd across the part of the circuit is equal to voltmeter reading.

An **ideal voltmeter** is one which has infinite resistance.

5. Derive an expression for magnetic moment of an electron revolving around the nucleus and define (i) gyromagnetic ratio. (ii) Bohr magneton



In the Bohr model, the electron (a negatively charged particle) revolves around a positively charged nucleus .The electron of charge (–e) revolves around a stationary heavy nucleus of charge +Ze. This constitutes a current I,

$$I = \frac{e}{T}$$

$$T = \frac{2\pi r}{v}$$

substituting for T in I we have

$$I = ev/2\pi r$$

A magnetic moment μ_l , associated with this circulating current in magnitude is,

$\boldsymbol{\mu_l = I\pi r^2 = evr/2}$. The direction of this magnetic moment is into the plane of the paper. Multiplying and dividing the right-hand side of the above expression by the electron mass m_e,

$$\mu_l = \frac{e}{2m_e}(m_e v r)$$

$$= \frac{e}{2m_e} l$$

l is the magnitude of the angular momentum of the electron about the central nucleus ("orbital" angular momentum). Vectorially

$$\mu_l = -\frac{e}{2m_e}\mathbf{l}$$

The negative sign indicates that the angular momentum of the electron is opposite in direction to the magnetic moment. If we had taken a particle with charge (+q), the angular momentum and magnetic moment would be in the same direction.
The ratio

$$\frac{\mu_l}{l} = \frac{e}{2m_e}$$

is called the **gyromagnetic ratio** and is a constant. Its value is 8.8×10^{10} C /kg   for an electron.

T is the time period of revolution. Let r be the orbital radius of the electron, and v the orbital speed. Then Bohr hypothesized that the angular momentum assumes a discrete set of values, namely,

$$l = \frac{nh}{2\pi}$$

where n is a natural number, n = 1, 2, 3, ... and h is a constant named after Max Planck (Planck's constant) with a value $h = 6.626 \times 10^{-34}$ J s.
For n =1 in the above equation,

$$(\mu_l)_{\min} = \frac{e}{4\pi m_e} h$$

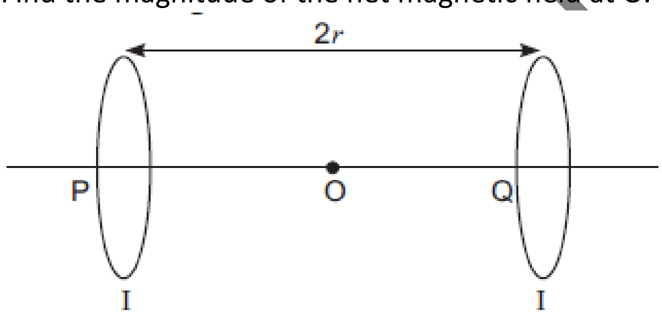
$$= \frac{1.60 \times 10^{-19} \times 6.63 \times 10^{-34}}{4 \times 3.14 \times 9.11 \times 10^{-31}}$$

$$= 9.27 \times 10^{-24}\ \mathrm{Am}^2$$

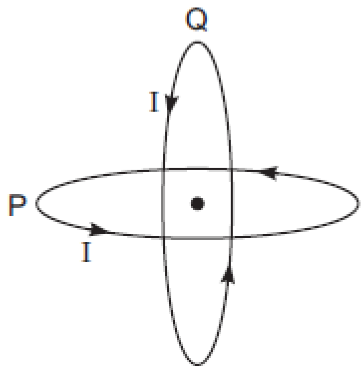
This value is called the **Bohr magneton.** It is defined as the magnetic moment of an electron in first orbit.

Questions 6 and 7 for practice .

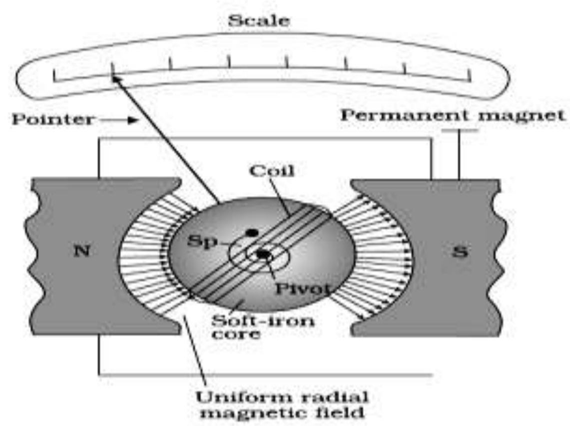
6. Two identical circular loops, P and Q, each of radius r and carrying equal currents are kept in the parallel planes having a common axis passing through O. The direction of current in P is clockwise and in Q is anti-clockwise as seen from O which is equidistant from the loops P and Q. Find the magnitude of the net magnetic field at O.



7. Two identical circular wires P and Q each of radius R and carrying current 'I' are kept in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils.



8. With a neat diagram explain the theory of a moving coil galvanometer. Mention the use of a) radial field b) cylindrical soft iron core.



The hemispherical magnetic poles produce a radial magnetic field in which the plane of the coil is parallel to the magnetic field in all its positions. The expression for torque becomes
$T = MB\sin\theta = MB$ as $\theta = 90°$ in a radial field.

There is a cylindrical soft iron core which not only makes the field radial but also increases the strength of the magnetic field.

Theory

When a current flows through the coil, a torque acts on it. This torque is given by

$$\tau = NI\,AB\sin\theta$$
$$= NIAB$$

where the symbols have their usual meaning. Since the field is radial by design, we have taken $\sin\theta = 1$ in the above expression for the torque.

The magnetic torque NIAB tends to rotate the coil. A spring Sp provides a counter torque $k\phi$ that balances the magnetic torque NIAB; resulting in a
steady angular deflection ϕ. In equilibrium

$$k\phi = NI\,AB$$

where k is the torsional constant of the spring; i.e. the restoring torque per unit twist.
The deflection ϕ is indicated on the scale by a pointer attached to the spring.

$$\phi = \left(\frac{NAB}{k}\right) I$$

Current sensitivity = ϕ / I
is the ratio of deflection per unit current.

9. Define current sensitivity and mention the factors on which it depends.
Current sensitivity = ϕ / I is the ratio of deflection per unit current.

$$\frac{\phi}{I} = \frac{NAB}{k}$$

The **current sensitivity** of a galvanometer can be **increased** by
(i) increasing the number of turns
(ii) increasing the magnetic induction
(iii) increasing the area of the coil
(iv) decreasing the couple per unit twist of the suspension wire.
This explains why phosphor-bronze wire is used as the suspension wire , since it has small couple per unit twist.

10 . Define voltage sensitivity and factors on which it depends.
The voltage sensitivity of a galvanometer is defined as the deflection per unit voltage.

$\phi/V = \phi/IG = NAB/kG$ G galvanometer resistance .
The **voltage sensitivity** of a galvanometer can be **increased** by
i) increasing the magnetic induction
(ii) increasing the area of the coil
(iii) decreasing the couple per unit twist of the suspension wire.

Increasing the number of turns has no effect on voltage sensitivity because as N increase G also increases so voltage sensitivity remains constant.