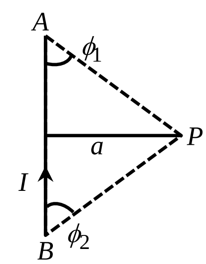
Blue Print (As per PU Board)

Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
Moving Charges & Magnetism	–	–	1	1	8

One mark questions

1. **Can a stationary charge produce a magnetic field?**
   Answer: A charge can produce a magnetic field only when it is moving. A stationary charge cannot produce a magnetic field.
2. **Give a general expression for the magnetic flux density at a point around the midpoint of a straight conductor or finite length**
   Answer: $B=\frac{\mu_0}{4\pi}\frac{I}{a}[\sin\phi_1+\sin\phi_2]$ where ϕ_1 and ϕ_2 are the angles subtended at the point P by the lines joining the point and the extreme ends A and B of the conductor.



3. **What is magnetic flux density?**
   Answer: The number of magnetic field lines passing through unit area of a surface in a direction normal to the surface is called magnetic flux density.

Two marks questions

4. **What is meant by "magnetic dipole moment of a current loop". Write its SI unit**
   Answer: A current loop produces a magnetic field and hence it acts like a magnet. The magnetic moment associated with a current loop is called its magnetic dipole moment and it is measured by the product of current and area of the loop.
   $M = IA$
   $= I\left(\pi r^2\right)$ where r is the radius of the loop. (1 mark)
   $M=\pi r^2 I$. The SI unit of M is A m^2. (1 mark)

5. **Give any two differences between ammeter and voltmeter.**
   Answer: (1 mark for each point)

	Ammeter		Voltmeter
1	It is a device used to measure current	1	It is a device used to measure the p.d between two points in a circuit
2	It is always connected in series in an electrical circuit	2	It is always connected in parallel in an electrical circuit

6. **A galvanometer has resistance G and requires a current I_g for full scale deflection. How do you convert it into (i) an ammeter (ii) a voltmeter**
   Answer: (i) A galvanometer can be converted into an ammeter by connecting a low resistance (shunt) in parallel with it.

The resistance of the shunt $S=\frac{I_gG}{\left(I-I_g\right)}$; $I \propto I_g$ (1 mark)

(ii) A galvanometer can be converted into a voltmeter by connecting a high resistance in series with it.

$R=\frac{V}{I_g}-G$; $I_g \propto V$ (1 mark)

Three marks questions

7. Obtain an expression for torque acting on a rectangular current loop in a uniform magnetic field in the plane of the loop. (The uniform magnetic field B is applied in the plane of the loop.)

Answer: Consider a rectangular loop $PQRT$ having length l and breadth b. Let a current IA be passed through the loop. Let m denote the magnetic moment of the current loop. When the current passes through the side PQ of the coil, it experiences a force $F_1 = BIl$ Newtons in a direction perpendicular to the plane of the paper directed away from it. When the current flows through the side RT of the coil, it experiences the same force

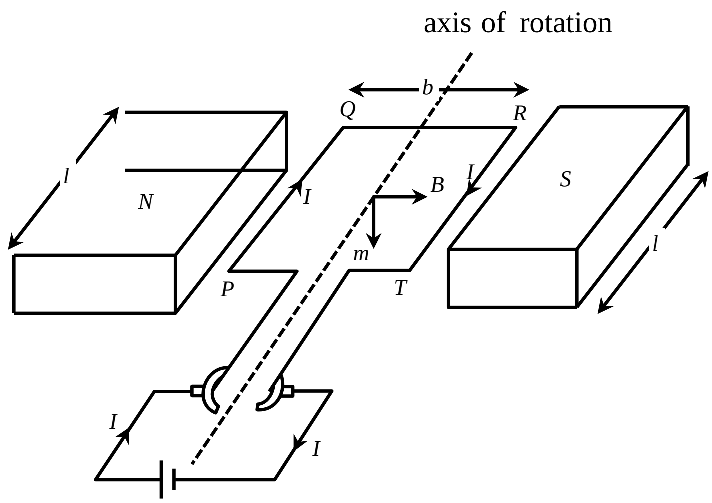


Fig (1 mark)

$F_2 = BIl$ but in the opposite direction. Hence the current loop is subjected to the action of two equal unlike parallel forces which form a torque.

The net force acting on the current loop is zero.

But there is a torque acting on the loop due to the pair of forces F_1 and F_2. The magnitude of this torque is given by $T = F_1 \cdot \frac{b}{2} + F_2 \cdot \frac{b}{2}$

$= BIl \cdot \frac{b}{2} + BIl \cdot \frac{b}{2}$

$= BI\left(lb\right)$

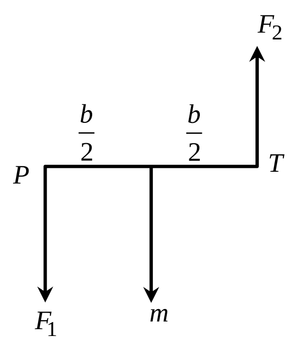
But $lb = A =$ Area of the rectangle

$\therefore T = BIA$

$= \left(IA\right)B$

But $IA = m =$ magnetic moment of the loop.

$T = mB$

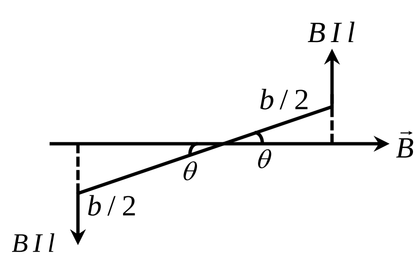


(1 mark)

In this case both $\vec{m}$ and $\vec{B}$ are vectors perpendicular to each other. The effect of this torque is to rotate the coil. According to the figure, the coil has to rotate in the anticlockwise direction.

In general, if the normal to the plane of the coil makes an angle θ with the direction of the applied magnetic field $T = mB\sin\theta$

$T = \vec{m} \times \vec{B}$



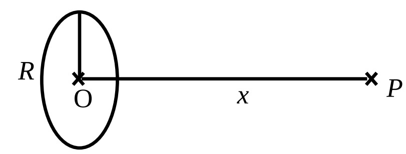
(1 mark)

8. Obtain an expression for magnetic field in terms of magnetic dipole moment associated with a circular current loop.
OR
Show that a circular current loop can be associated with a magnetic dipole.

Answer: We know that the magnetic field at a point on the axis of a current loop is
$B=\left(\frac{\mu_0}{4\pi}\right)\frac{2\pi IR^2}{\left(R^2+x^2\right)^{\frac{3}{2}}}$ (1 mark)

Where $I=$ current passing through the loop
$R=$ Radius of the loop
$x=$ Distance of the point on the axis from the centre of the loop
If the point is at a very large distance from the centre of the loop, $x >>> R$
In this case $\left(x^2+R^2\right)$ may be approximated to x^2

$$B=\frac{\mu_0}{4\pi}\frac{2\pi IR^2}{\left(x^2\right)^{\frac{3}{2}}}$$



$$B=\frac{\mu_0}{4\pi}\left(\frac{2\pi IR^2}{x^3}\right)$$

$$B=\frac{\mu_0}{4\pi}\left[\frac{2I\left(\pi R^2\right)}{x^3}\right]$$

But $\pi R^2=A=$ (area of the circular loop)
$I\left(\pi R^2\right)=IA=\vec{m}=$ Magnetic moment of the loop

$\therefore\ B=\frac{\mu_0}{4\pi}\frac{2\vec{m}}{x^3}$ (1 mark)

This is analogous to the expression for the magnetic field at a point on the axis of a short dipole
$E=\frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{x^3}$ (1 mark)

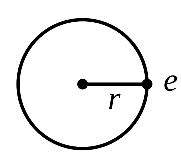
Hence a circular current loop can be associated with an electric dipole.

9. Derive an expression for magnetic dipole moment of a revolving electron.

Answer: Consider an electron (of charge e) revolving round the nucleus in a circular orbit of radius r. Let v be the orbital velocity of the electron. Due to the orbital motion of the electron an electric current I is produced. Let T be the time period of revolution. So the current produced is given by $I=\frac{\text{charge}}{\text{time}}$

$I=\frac{\mathrm{e}}{\mathrm{T}}$ … (1)

$$\mathrm{T}=\frac{\text{Distance travelled by the electron in one revolution}}{\text{orbital velocity of the electron}}$$



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

Substituting this in (1), we get

$I=\frac{\mathrm{e}}{\left(\frac{2\pi r}{v}\right)}$ (1 mark)

$I=\left(\frac{\mathrm{e}v}{2\pi r}\right)$ … (2)

By virtue of this current, the electron revolving round the nucleus in a circular loop is equivalent to a current carrying conducting loop. The magnetic moment of this loop is given by $\mu = I\text{A}$ where A is the area of the orbit

$\therefore\ \mu = \left(\frac{\text{ev}}{2\pi r}\right)\text{A}$ (1 mark)

Put $\text{A} = \pi r^2$

$\therefore\ \mu = \left(\frac{\text{ev}}{2\pi r}\right)\cdot \pi r^2$

$\mu = \frac{\text{ev}r}{2}$ … (3)

According to Bohr's theory, the angular momentum of the electron is given by $l = mvr$

$\therefore\ vr = \frac{\ell}{\text{m}}$

Substituting this in (3)

$\mu = \frac{e\ell}{2\,\text{m}}$ (1 mark)

The direction of $\vec{\mu}_l$ is opposite to that of $\vec{\ell}$ ($\because$ electron is a negatively charged particle)

Five marks questions

10. Derive an expression for the deflecting couple in a moving coil. Hence derive an expression for current sensitivity.

Answer: Consider a rectangular coil $PQRT$ of length $PT = l$ and breadth $PQ = b$, having n number of turns. The area of the face of the coil is A. The coil is suspended in a magnetic field of strength B tesla, the field lines are in the plane of the paper. Let a current IA be passed through the coil from T to P. Applying Fleming's left hand thumb rule, we find that the side PT of the coil experiences a force BIl newton's perpendicular to the plane of the paper directed into it. But when the current flows from S to R, the coil experiences the same force but in a direction perpendicular to the plane of the paper directed away from it. Hence the coil is subjected to the action of two equal unlike parallel forces which constitute a couple. The moment of this couple is given by C_d = one of the force $\times \perp^r$ distance between them

$= (BIl) \times b$

$= BI \times (lb)$

$lb = A =$ area of the face of the coil

$\therefore\ C_d = BIA$

This is the couple for 1 turn of the coil. For n turns of the coil, $C_D = (BIA)n$

$\therefore\ C_D = BIAn$ … (1) (1 mark)

The effect of this couple is to rotate the coil. This is called deflecting couple. As the coil rotates, the suspension wire twists this is called torsion. This twisting of the coil is also due to a couple called torsional couple. This is called restoring couple. (C_R)

For equilibrium of the coil, $C_D = C_R$ … (2) (1 mark)

The restoring couple is directly proportional to the angle θ through which the coil deflects.

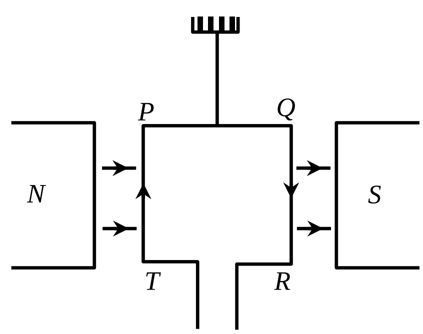
Hence $C_R \propto \theta$

$C_R = \tau\theta$ (1 mark)

Where τ is a constant called couple/unit twist.

It depends on the material of the suspension wire.

Now $C_D = C_R$



$\therefore\ BIAn = \tau\theta$ (1 mark)

$\frac{\theta}{I} = \frac{Ban}{\tau}$

The deflection produced per unit current is called current sensitivity. (1 mark)

11. Derive an expression for the magnetic field produced by a circular coil at any point on the axial line of a the coil.

Answer: Consider a circular coil having n number of turns each of radius r. Let a current I A be passed through the coil. Consider a point P on the axis at distance x from the centre of the coil. Consider one turn of the coil. This can be considered to be divided into an even number of current elements of identical length dl, such that for every current element AB in the upper half of the coil, there is a corresponding current element CD in the lower half of the coil. The magnetic fields produced by any current element acts in a direction perpendicular to the line joining the current element and the point P. Hence we get a number of magnetic fields acting in different directions. To find the resultant magnetic field, we have to resolve them

(i) along the axis of the coil $dB\sin\theta$ (1 mark)

(ii) at right angles to the axis of the coil $dB\cos\theta$

The magnetic fields produced by AB and EF are resolved into the respective components as shown in the figure.

The components $dB\cos\theta$ and $dB\cos\theta$ cancel each other. The magnetic fields $dB\sin\theta$ and $dB\sin\theta$ act get added up. The resultant field produced by AB and EF is given by $dB\sin\theta + dB\sin\theta = 2dB\sin\theta$.

The resultant magnetic field produced by one turn of the coil is given by $\sum 2dB\sin\theta$ (1 mark)

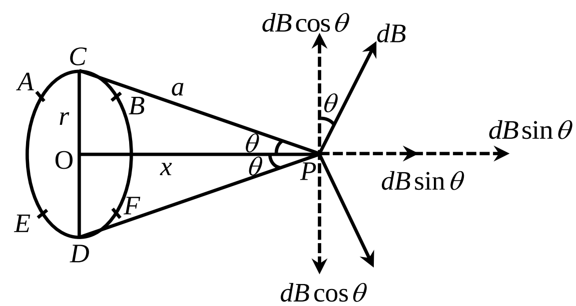
The summation is carried over one half of the circumference of the coil only.

$\because\ dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\alpha}{a^2}$

$\alpha = 90°$

$\therefore\ dB = \frac{\mu_0}{4\pi}\frac{Idl}{a^2}$

fig.(1 mark)



So magnetic field produced by one turn of the coil is $B_1 = 2\frac{\mu_0}{4\pi}\sum\frac{Idl\sin\theta}{a^2}$ (1 mark)

$B_1 = \frac{\mu_0}{2\pi}\frac{I\sin\theta}{a^2}\cdot\sum dl$

$\sum dl = \pi r$

$\therefore\ B_1 = \frac{\mu_0}{2\pi}\frac{I\sin\theta}{a^2}(\pi r)$

$= \frac{\mu_0 Ir}{2a^2}\sin\theta$

But $\sin\theta = \frac{r}{a}$ $[\text{In } \Delta COP]$

$\therefore\ B_1 = \frac{\mu_0 Ir^2}{2a^3}$

The magnetic field produced by n turns of the coil $= n\times B_1$

$B = n\times\frac{\mu_0 Ir^2}{2a^3}$

But $a^2 = \left(r^2 + x^2\right)$

and $a = \left(r^2 + x^2\right)^{\frac{1}{2}}$

$\therefore B = \dfrac{\mu_0 n I r^2}{2\left(r^2 + x^2\right)^{\frac{3}{2}}}$ (1 mark)

12. Obtain an expression for the magnetic force on a current carrying conductor.

Answer: Consider a conductor of length l in the plane of the paper to be placed in a magnetic field $\vec{B} \perp^r$ to the plane of the paper directed into it. Let θ be the angle between the two vectors

Let $A =$ cross sectional area of the conductor

$I =$ current passing through the conductor

$n =$ Free electron density of the material of the conductor

$v_d =$ Drift velocity of electrons inside the conductor

Let q be the total quantity of charge transported across the length of the conductor

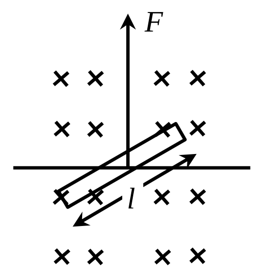
$q = n(Al)e$ (1 mark)

Since the charged particles (electrons) are moving at an angle θ with the direction of the magnetic field B with velocity v_d, the force experienced by them is given by

$\vec{F} = q\vec{v}_d \times \vec{B}$ (1 mark)

$= (n \cdot Ale)\vec{v}_d \times \vec{B}$

$= (ne\vec{v}_d)Al \times \vec{B}$ (1 mark)



But $ne\vec{v}_d = \vec{j} =$ current density fig (1 mark)

$\therefore \vec{F} = \vec{j}Al \times \vec{B}$

But $\left|\vec{j}A\right| = I$

$\therefore \vec{F} = I\vec{l} \times \vec{B}$

or $F = BIl\sin\theta$ (1 mark)