IMPORTANT QUESTIONS CLASS – 12 PHYSICS
CHAPTER – 5 MAGNETISM AND MATTER

1. A particle of mass m and charge q moving with a uniform speed normal to a uniform magnetic field B describes a circular path of radius & Derive expressions for (1) Radius of the circular path (2) time period of revolution (3) Kinetic energy of the particle?

Ans. A particle of mass (m) and change (q) moving with velocity υ normal to $\vec{B}$ describes a circular path if

$(\therefore \theta = 90^0)$

$$\frac{mv^2}{r} = qBv\sin\theta$$

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

$$\Rightarrow \boxed{r = \frac{mv}{Bq}} ----(1)$$

Since Time period of Revolution

During circular path = $\frac{\text{Circumference of circle}}{velocity}$

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

$$\therefore v = \frac{Bqr}{m} \text{ from eg.}(1)$$

=> ()

=> T = $\frac{2\pi r \times m}{Bqr}$

$$T = \frac{2\pi m}{Bq} ----(2)$$

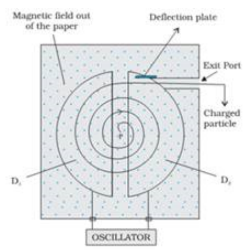
Kinetic energy K.E = $\frac{1}{2}$ mv^2

=> KE = $\frac{1}{2} m \left(\frac{Bqr}{m}\right)^2$

$$KE = \frac{B^2q^2r^2}{2m} ---(3)$$

2. Write an expression for the force experienced by the charged particle moving in a uniform magnetic field B With the help of labeled diagram explain the working of cyclotron? Show that cyclotron frequency does not depend upon the speed of the particle?

Ans. Force experienced by the charged particle moving at right angles to uniform magnetic field $\vec{B}$ with velocity $\vec{v}$ is given by $\vec{F}$ = q ($\vec{v} \times \vec{B}$) Initially Dee D_1 is negatively charged and Dee D_2 is positively charged so, the positive ion will get accelerated towards Dee D_1 since the magnetic field is uniform and acting at right angles to the plane of the Dees so the ion completes a circular path in D_1 when ions comes out into the gap, polarity of the Dee's gets reversed used the ion is further accelerated towards Dee D_2 with greater speed and cover a bigger semicircular path. This process is separated time and again and the speed of the ion becomes faster till it reaches the periphery of the dees where it is brought out by means of a deflecting plate and is made to bombard the target.



Since F = qVBsin90° provides the necessary centripetal force to the ion to cover a circular path so we can say

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

=> r = $\frac{mv}{Bq}$ ----- (1)

$$\frac{2\pi r}{v} = \frac{2\pi v m}{Bqv} = \frac{2\pi m}{Bq}$$

Time period =

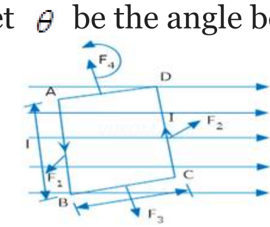
V = $\frac{1}{T} = \frac{Bq}{2\pi m}$

=> frequency is independent of velocity

3. (a) Obtain an expression for the torque acting on a current carrying circular loop.

(b) What is the maximum torque on a galvanometer coil 5 cm 12 cm of 600 turns when carrying a current of 10^{-5} A. in a field where flux density is?

Ans. ABCD is a rectangular loop of length (L), breadth (b) and area (A). Let I be the Current flowing in the anti clockwise direction. Let θ be the angle between the normal to the loop and magnetic field $\vec{B}$



Force acting on arm AB of the loop

$$\vec{F}_1 = I(\vec{L} \times \vec{B})(outwards)$$

Force on arm CD

$$\vec{F}_2 = I(\vec{L} \times \vec{B})(inwards)$$

Force on arm BC

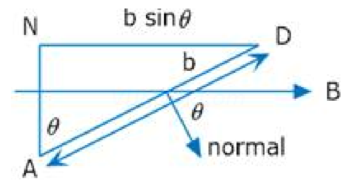
$$\vec{F}_3 = I(\vec{b} \times \vec{B})(downwards)$$

Force on arm DA

$$\vec{F}_4 = I(\vec{b} \times \vec{B})(upwards)$$

Since $F_3 and\ F_4$ are equal and opposite and also acts along the same line, hence they cancel each other.

$F_1 and\ F_2$ are also equal and opposite but their line of action is different, so they form a couple and makes the rectangular loop rotate anti clockwise.



Thus τ = either force $\times \perp$ distance

$$\tau = I(\bar{L} \times \bar{B}) \times DN$$

$$\tau = I(\bar{L} \times \bar{B}) \times b \sin\theta$$

$$\tau = I\ LB \sin 90^\circ\ b \sin\theta$$

$$\tau = I\ A\ B\ \sin\theta$$

$$\tau = MB \sin\theta\ (\because M = NIA)$$

$$\Rightarrow \tau_{max} = NIAB$$

For loop of N turns

$\tau = NIAB \sin\theta$

$\vec{\tau} = \overline{M} \times \vec{B}$

Where M is magnet

ic moment of the loop.

$\tau = NIAB \sin\theta$

Torque will be maximum when θ = 90^0

$(\because Sin 90^\circ = 1)$

$$\tau_{max} = 600 \times 10^{-5} \times (0.10)(60 \times 10^{-4})$$

$$\tau_{max} = 3.6 \times 10^{-6} Nm$$

4. The current sensitivity of a moving coil galvanometer increases by 20% when its resistance is increased by a factor of two. Calculate by what factor, the voltage sensitivity changes?

Ans. Current sensitivity $\frac{\alpha}{I} = \frac{nBA}{k} ------(i)$

Voltage sensitivity $\frac{\alpha}{V} = \frac{nBA}{kR} ------(ii)$

Resistance of a galvanometer increases when n and A are changed
Given R' = 2R
Then n = n' and A = A'
New current sensitivity

$$\frac{\alpha'}{I'} = \frac{n'A'B}{k} ------(iii)$$

New voltage sensitivity

$$\frac{\alpha'}{V} = \frac{\alpha'}{I'R'} = \frac{n'A'B}{2kR} -----(iv)$$

$$Since \frac{\alpha'}{I'} = \frac{120}{100}\frac{\alpha}{I} ------(v)$$

From (i) and (iii) $$\frac{n'A'B}{R} = \frac{\alpha}{I}\frac{120}{100}$$

$$\frac{n'A'\cancel{B}}{\cancel{k}} = \frac{nA\cancel{B}}{\cancel{k}}\frac{120}{100}$$

n'A'= $\frac{6}{5}nA$

Using equation (iv)

$$\frac{\alpha'}{V} = \frac{6}{5}\frac{nAB}{2kR}$$

$$\frac{\alpha'}{V} = \frac{3nAB}{5kR}$$

$$\frac{\alpha'}{V} = \frac{3}{5}\frac{\alpha}{V}$$

Thus voltage sensitivity decreases by a factor of $\frac{3}{5}$.

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5. (a) Show how a moving coil galvanometer can be converted into an ammeter?
(b) A galvanometer has a resistance 30 and gives a full scale deflection for a current of 2mA. How much resistance in what way must be connected to convert into?
(1) An ammeter of range 0.3A
(2) A voltammeter of range 0.2V.

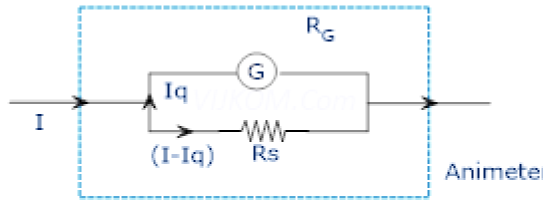
Ans. (a) A galvanometer can be converted into an ammeter by connecting a low resistance called shunt parallel to the galvanometer.

$$IgR_G = (I - Ig)\ R_S$$

Since G and R_S are in parallel voltage across then is same

⇒

$$Rs = \left(\frac{Ig}{I - Ig}\right) R_G$$



(b) (1) I = 0.3A G = 30 Ω Ig = 2mA = $2 \times 10^{-3} A$

Sheent (S) = $\dfrac{IgG}{I - Ig}$

$$S = \frac{2 \times 10^{-3} \times 30}{(0.3 - 2 \times 10^{-3})}$$

S = 0.2 Ω

(2) G = 30 π , Ig = 2mA = $2 \times 10^{-3} A$, V = 0.2V

Shunt Resistance (R) $\left(\dfrac{V}{Ig} - G\right)$

$$R = \left(\frac{0.2}{2 \times 10^{-3}} - 30\right)$$

R = 70 Ω

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6. A monoenergetic (18 keV) electron beam initially in the horizontal direction is subjected to a horizontal magnetic field of 0.04 G normal to the initial direction. Estimate the up or down deflection of the beam over a distance of 30 cm (*me*=). [Note: *Data* in this exercise are so chosen that the answer will give you an idea of the effect of earth's magnetic field on the motion of the electron beam from the electron gun to the screen in a TV set.]

Ans. Energy of an electron beam, *E*= 18 keV = $18 \times 10^3 eV$

Charge on an electron, *e*= $1.6 \times 10^{-19} C$

E= $18 \times 10^3 \times 1.6 \times 10^{-19} J$

Magnetic field, *B* = 0.04 G

Mass of an electron, *me*= $9.11 \times 10^{-19} kg$

Distance up to which the electron beam travels, *d* = 30 cm = 0.3 m

We can write the kinetic energy of the electron beam as:

$$E = \frac{1}{2} mv^2$$

$$v = \sqrt{\frac{2E}{m}}$$

$$= \sqrt{\frac{2 \times 18 \times 10^3 \times 1.6 \times 10^{-19} \times 10^{-15}}{9.11 \times 10^{-31}}}$$

The electron beam deflects along a circular path of radius, *r*.

The force due to the magnetic field balances the centripetal force of the path.

$$= 0.795\times10^{8}\ m/s$$

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

$$\times r = \frac{mv}{Be}$$

Let the up and down deflection of the electron beam be $x = r(1-\cos\theta)$

$$= \frac{9.11\times10^{-31}\times0.795\times10^{8}}{0.4\times10^{-4}\times1.6\times10^{-19}} = 11.3m$$

Where,

θ= Angle of declination

$$\sin\theta = \frac{d}{r}$$

$$= \frac{0.3}{11.3}$$

$$\theta = \sin^{-1}\frac{0.3}{11.3} = 1.521^{0}$$

Therefore, the up and down deflection of the beam is 3.9 mm.

$$and\ x = 11.3(1-\cos10521^{0})$$

$$= 0.0039m = 3.9mm$$

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7. A sample of paramagnetic salt contains atomic dipoles each of dipole moment . The sample is placed under a homogeneous magnetic field of 0.64 T, and cooled to a temperature of 4.2 K. The degree of magnetic saturation achieved is equal to 15%. What is the total dipole moment of the sample for a magnetic field of 0.98 T and a temperature of 2.8 K? (Assume Curie's law)

Ans. Number of atomic dipoles, *n*= 2.0×10^{24}

Dipole moment of each atomic dipole, *M*= $1.5\times10^{-23}JT^{-1}$

When the magnetic field, B_1 = 0.64 T

The sample is cooled to a temperature, T_1 = 4.2°K

Total dipole moment of the atomic dipole, $M_{tot} = n\times M$

= $2\times10^{24}\times1.5\times10^{-23}$

= $30\ JT^{-1}$

Magnetic saturation is achieved at 15%.

Hence, effective dipole moment,

$$M_1 = \frac{15}{100}\times30 = 4.5JT^{-1}$$

When the magnetic field, B_2 = 0.98 T

Temperature, T_2 = 2.8°K

Its total dipole moment = M_2

According to Curie's law, we have the ratio of two magnetic dipoles as:

$$\frac{M_2}{M_1} = \frac{B_2}{B_1} \times \frac{T_1}{T_2}$$

$$\therefore M_2 = \frac{B_2 T_1 M_1}{B_1 T_2}$$

$$= \frac{0.98 \times 4.2 \times 4.5}{2.8 \times 0.64} = 10.336 JT^{-1}$$

Therefore, $10.336 JT^{-1}$ is the total dipole moment of the sample for a magnetic field of 0.98 T and a temperature of 2.8 K.

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8. A telephone cable at a place has four long straight horizontal wires carrying a current of 1.0 A in the same direction east to west. The earth's magnetic field at the place is 0.39 G, and the angle of dip is. The magnetic declination is nearly zero. What are the resultant magnetic fields at points 4.0 cm below the cable?

Ans. Number of horizontal wires in the telephone cable, n= 4

Current in each wire, = 1.0 A

Earth's magnetic field at a location, H= 0.39 G = $0.39 \times 10^{-4} T$

Angle of dip at the location, $\delta = 35°$

Angle of declination, $\theta \sim 0^0$

For a point 4 cm below the cable:

Distance, r = 4 cm = 0.04 m

The horizontal component of earth's magnetic field can be written as:

$$H_h = H\cos\delta - B$$

Where,

B= Magnetic field at 4 cm due to current I in the four wires

$$4 = \times \frac{\mu_0 1}{2\pi r}$$

μ_0 = Permeability of free space = $4n \times 10^{-7} Tm A^{-1}$

$$\times B = 4 \times \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 0.04}$$

= 0 $.2 \times 10^{-4} T$ = 0.2 G

$\therefore H_h$

$$= 0.39\, cos\, 35° - 0.2$$

=

$$0.39 \times 0.819 - 0.2 \approx 0.12 G$$

The vertical component of earth's magnetic field is given as:

Hv= Hsin δ

$$= 0.39\, sin\, 35° = 0.22\, G$$

The angle made by the field with its horizontal component is given as:

$$\theta = \tan^{-1} \frac{H_V}{H_v}$$

The resultant field at the point is given as:

s

For a point 4 cm above the cable:

Horizontal component of earth's magnetic field:

= 0.39 cos 35° + 0.2 = 0.52 G

Vertical component of earth's magnetic field:

$H_v = H\sin\delta$ = 0.39

Angle, = 22.9°

And resultant field:

$$= \tan^{-1}\frac{0.22}{0.12} = 61.39^0$$

$$H_1 = \sqrt{(H_v)^2 + (H_k)^2}$$

$$= \sqrt{(0.22)^2 + (0.12)^2} = 0.25G$$

$$sin\ 35° = 0.22\ G$$

$$\theta \tan^{-1}\frac{H_V}{H_v} = \tan^{-1}\frac{0.22}{0.52}$$

$$H_2 = \sqrt{(H_v)^2 + (H_h)^2}$$

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9. Answer the following questions:

(a) Explain qualitatively on the basis of domain picture the irreversibility in the magnetisation curve of a ferromagnet.

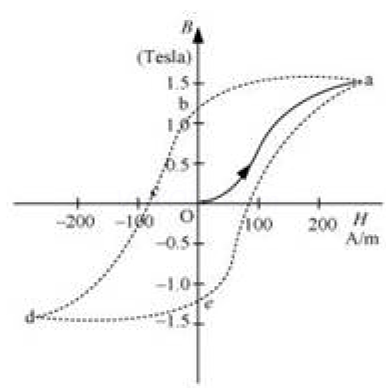
(b) The hysteresis loop of a soft iron piece has a much smaller area than that of a carbon steel piece. If the material is to go through repeated cycles of magnetisation, which piece will dissipate greater heat energy?

(c) 'A system displaying a hysteresis loop such as a ferromagnet, is a device for storing memory?' Explain the meaning of this statement.

(d) What kind of ferromagnetic material is used for coating magnetic tapes in a cassette player, or for building 'memory stores' in a modern computer?

(e) A certain region of space is to be shielded from magnetic fields. Suggest a method.

Ans. The hysteresis curve (*B*–*H* curve) of a ferromagnetic material is shown in the following figure.



(a) It can be observed from the given curve that magnetisation persists even when the external field is removed. This reflects the irreversibility of a ferromagnet.

(b) The dissipated heat energy is directly proportional to the area of a hysteresis loop. A carbon steel piece has a greater hysteresis curve area. Hence, it dissipates greater heat energy.

(c) The value of magnetisation is memory or record of hysteresis loop cycles of magnetisation. These bits of

information correspond to the cycle of magnetisation. Hysteresis loops can be used for storing information.
(d) Ceramic is used for coating magnetic tapes in cassette players and for building memory stores in modern computers.
(e) A certain region of space can be shielded from magnetic fields if it is surrounded by soft iron rings. In such arrangements, the magnetic lines are drawn out of the region.

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10. Answer the following questions:
(a) Why does a paramagnetic sample display greater magnetisation (for the same magnetising field) when cooled?
(b) Why is diamagnetism, in contrast, almost independent of temperature?
(c) If a to roid uses bismuth for its core, will the field in the core be (slightly) greater or (slightly) less than when the core is empty?
(d) Is the permeability of a ferromagnetic material independent of the magnetic field? If not, is it more for lower or higher fields?
(e) Magnetic field lines are always nearly normal to the surface of a ferromagnetic at every point. (This fact is analogous to the static electric field lines being normal to the surface of a conductor at every point.) Why?
(f) Would the maximum possible magnetisation of a paramagnetic sample be of the same order of magnitude as the magnetization of a ferromagnet?
Ans. (a) Owing to therandom thermal motion of molecules, the alignments of dipoles get disrupted at high temperatures. On cooling, this disruption is reduced. Hence, a paramagnetic sample displays greater magnetisation when cooled.
(b) The induced dipole moment in a diamagnetic substance is always opposite to the magnetising field. Hence, the internal motion of the atoms (which is related to the temperature) does not affect the diamagnetism of a material.
(c) Bismuth is a diamagnetic substance. Hence, a toroid with a bismuth core has a magnetic field slightly greater than a toroid whose core is empty.
(d) The permeability of ferromagnetic materials is not independent of the applied magnetic field. It is greater for a lower field and vice versa.
(e) The permeability of a ferromagnetic material is not less than one. It is always greater than one. Hence, magnetic field lines are always nearly normal to the surface of such materials at every point.
(f) The maximum possible magnetisation of a paramagnetic sample can be of the same order of magnitude as the magnetisation of a ferromagnet. This requires high magnetising fields for saturation.
