Blue Print (As per PU Board)

Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
Magnetism & Matter	–	1	–	1	2

Two marks questions

1. **What is meant by (a) geographic meridian and (b) magnetic meridian?**

Answer:

(a) A vertical plane containing the longitudinal circle and the axis of rotation of the earth is called geographic meridian. (1 mark)

(b) A vertical plane containing the axis of a freely suspended magnet at a given place is called magnetic meridian. [Horizontal component of earth's magnetic field] (1 mark)

2. **(a) What is meant by magnetic declination?**
(b) What is meant by magnetic inclination or dip?

Answer:

(a) The angle between the geographic meridian and magnetic meridian is called the angle of declination at the given place. (1 mark)

(b) The inclination of dip of the earth's magnetic field at the given place is defined as the angle between the true horizontal line and the direction of the earth's magnetic field at that place. (1 mark)

3. **Define (a) magnetic permeability and (b) magnetic susceptibility of a substance.**

Answer:

(a) Magnetic permeability is defined as the ratio of the magnetic flux density (induction) to the magnetising field.

$$\mu = \frac{B}{H}$$ (1 mark)

(b) Magnetic susceptibility is defined as the ratio of intensity of magnetisation to the intensity of the applied magnetic field.

$$\chi = \frac{I}{H}$$ (1 mark)

4. **(a) What are ferromagnetic substances?** **(P)**
(b) Give an example for a ferromagnetic substance.

Answer:

(a) Ferromagnetic substances are those that are attracted to a magnet with a very strong force. They move from weaker points in the field to points where the field is strong. (1 mark)

(b) Iron, Steel ….etc. Alloys of Iron like Alnico …etc. Salts of iron (1 mark)

Three marks questions

5. **Write an expression for magnetic field at (i) a point on the axial line and (ii) a point on the equatorial line of a bar magnet. What is the ratio of the magnetic fields in the two cases.**

Answer:

(i) Magnetic field in the axial line of a bar magnet (B_A)

Let $\vec{m}$ = Magnetic moment of the magnet.

r = Distance of the point from the centre of the magnet

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

(ii) Magnetic field on the equatorial line of the magnet

$$\vec{B}_B = \frac{\mu_0}{4\pi}\frac{\vec{m}}{r^3}$$ (1 mark)

(iii) $\frac{B_A}{B_B} = 2:1$ (1 mark)

6. Distinguish between diamagnetic and ferromagnetic substances considering their susceptibility and relative permeability (3 marks)

Answer:

	Diamagnetic Substances	Paramagnetic Substances	Ferro magnetic Substances
Relative Permeability	Less than 1	Greater than 1	Greater than 1 and very high
Susceptibility χ	$-ve$	$+ve$, but low	$+ve$ and very high
Variation of susceptibility with temperature	χ is independent of temperature	$\chi \propto \frac{1}{\text{T}}$	$\chi \propto \frac{1}{T - T_c}$ T_c = Curie point

7. A circular coil of 16 turns and radius $10\,\text{cm}$ carrying a current of $0.75\,\text{A}$ rests with its plane normal to an external field of magnitude $5.0\times10^{-2}\,\text{T}$. The coil is free to turn about an axis in its plane perpendicular to the field direction. When the coil is turned slightly and released, it oscillates about its stable equilibrium position with a frequency $2.0\,\text{s}^{-1}$. What is the moment of inertia of the coil about its axis of rotation? (3 marks)

Answer: $N = 16$

$r = 10\,\text{cm} = 10^{-1}\,\text{m}$

$B = 5\times10^{-2}\,\text{T}$

$f = 2s^{-1}$ or $T = \frac{1}{2}s = 0.5\,s$

$I = ?$

Magnetic moment $= m = NiA$

$= 16\times0.75\times\pi r^2$

$= 12\times3.14\times\left(10^{-1}\right)^2$

$m = 37.68\times10^{-2}\,JT^{-1}$ (1 mark)

$T = 2\pi\sqrt{\frac{I}{MB}}$ (1 mark)

(Squaring) $T^2 = 4\pi^2\frac{I}{MB}$

$$I = \frac{T^2MB}{4\pi^2} = \frac{(0.5)^2\times37.68\times10^{-2}\times5\times10^{-2}}{4\times(3.14)^2}$$

$I = 1.2\times10^{-4}\,\text{kg}\,\text{m}^2$ (1 mark)

8. A short bar magnet has a magnetic moment of $0.48\,\text{J}\,\text{T}^{-1}$. Give the direction and magnitude of the magnetic field produced by the magnet at a distance of $10\,\text{cm}$ from the centre of the magnet on (a) the axis and (b) the equatorial line of the magnet. (3 marks)

Answer: $m = 0.48\,\text{J}\,\text{T}^{-1}$

$r = 10\,\text{cm} = 10^{-1}\,\text{m}$

(a) On the axis $B_A = \frac{\mu_0}{4\pi}\frac{2m}{d^3}$ (1 mark)

$$B_A = \frac{10^{-7} \times 2 \times 0.48}{\left(10^{-1}\right)^3}$$

$= 0.96 \times 10^{-4}$ J along $S - N$ direction (1 mark)

(b) $B_B = \frac{B_A}{2} = \frac{0.96 \times 10^{-4}}{2}$

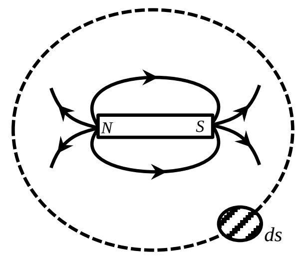
$B_B = 0.48 \times 10^{-4}$ T along $N - S$ direction (1 mark)

9. State and explain Gauss' law in magnetism. (3 marks)

Answer: The net magnetic flux passing normally outward through any closed surface is zero.

$\phi_m = \oint \vec{B} \cdot d\vec{S} = 0$ (1 mark)

Consider a bar magnet. The field lines surrounding the magnet are shown. Let us surround the magnet by a closed surface. Let dS be a small elementary area of the surface.



The net magnetic flux over the entire Gaussian surface is

$\phi = \oint B \cos\theta \, dS$

(1 mark)

This consists of two parts:

(i) $\phi_1 = +\phi_B$ which is entering into the surface

(ii) $\phi_2 = -\phi_B$ which is leaving the surface.

Net magnetic flux= $\phi = \phi_1 + \phi_2$

$= \phi_B - \phi_B$

$\therefore \oint B \cos\theta \, dS = 0$ (1 mark)

Five marks questions

10. A compass needle free to turn in a horizontal plane is placed at the centre of a circular coil of 30 turns and radius 12 cm. The coil is in a vertical plane making an angle of 45° with the magnetic meridian. When the current in the coil is 0.35 A, the needle points west to east.

(a) Determine the horizontal component of the earth's magnetic field at the location.

(b) The current in the coil is reversed and the coil rotated about its vertical axis by an angle of 90° in the anticlockwise direction looking from above. Predict the direction of the needle. Take magnetic declination to be zero. **(5 marks)**

Answer:

(a) $n = 30$

$r = 12\,\text{cm} = 12 \times 10^{-2}$ m

$B = \frac{\mu_0 n I}{2r}$ (1 mark)

$= \frac{4\pi \times 10^{-7} \times 30 \times 0.35}{2 \times 12 \times 10^{-2}}$

$= \frac{4 \times 22 \times 30 \times 0.35}{7 \times 24} \times 10^{-5}$

$= 5.5 \times 10^{-5} T = 0.55 \times 10^{-4} T = 0.55 G$ (1 mark)

$B_H = B \cos\theta$ (1 mark)

$= 0.55 \times \cos 45°$

$= 0.39 G$ (1 mark)

(b) When the current in the coil is reverser, the direction of deflection of the needle is reversed, the direction of deflection of the needle is reversed, it will now point east to west. (1 mark)

11. A monoenergetic $(18\,\text{keV})$ electron beam initially in the horizontal direction is subjected to a horizontal magnetic field of $0.04G$ normal to the initial direction. Estimate the up or down linear deflection of the bean over a distance of $30\,\text{cm}$. (Mass of the electron $=9.11\times10^{-31}\,\text{kg}$) (5 marks)

Answer: The electron moves in a circle. The centripetal force necessary for the circular motion of the electron is provided by the magnetic force. $\frac{mv^2}{R}=qvB$ (1 mark)

$\therefore\; R=\frac{mv^2}{qvB}$

$=\frac{mv}{qB}$

$R=\frac{p}{qB}$ …(1)

But $p=\sqrt{2mE}$ where E= energy of the electron

$q=e=$ Charge of the electron

$E=18\,\text{keV}$

$=18\times10^3\,e\text{V}$

$=18\times10^3\times1.6\times10^{-19}\,J$

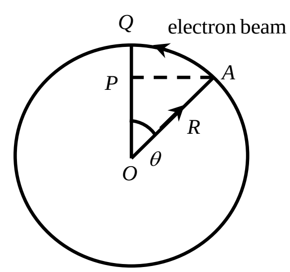
$=28.8\times10^{-16}\,J$

$R=\frac{\sqrt{2mE}}{eB}$ (1 mark)

$=\frac{\sqrt{2\times9.11\times10^{-31}\times28.8\times10^{-16}}}{1.6\times10^{-19}\times4\times10^{-5}}$

$=\frac{72.44\times10^{-24}}{6.4\times10^{-24}}$

$=11.3\text{cm}$



(1 mark)

$\theta=\frac{s}{R}=\frac{0.3}{11.3}$

$\theta=0.0265\approx\sin\theta$

$\cos\theta=\sqrt{1-\sin^2\theta}$

$=\sqrt{1-(0.0265)^2}$

$=0.99964$

Linear deflection $PQ=R(1-\cos\theta)$

$=11.3[1-0.99964]$

$=11.3[0.00036]$

$=0.004\,\text{m}$

$=4\,\text{mm}$ (1 mark)

$PQ=OQ-OP$

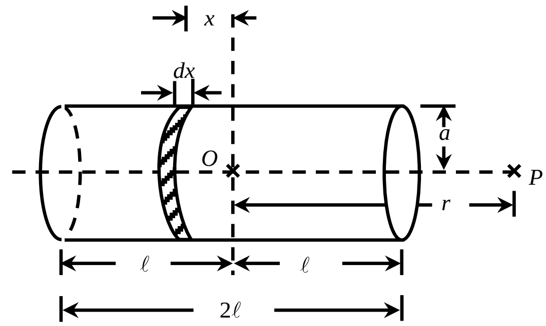
$=R-R\cos\theta$ (1 mark)

$=R(1-\cos\theta)$

12. Explain how a bar magnet can be considered as an equivalent solenoid. **(5 marks)**

Answer:

Consider a solenoid of length $2l$ and radius of cross section $'a'$ as shown in the figure. Let n be the number of turns per metre length of this solenoid. Let I be the current passing through the solenoid. Consider a point P on the axis of the solenoid at distance r from its centre. Consider a small circular element of thickness dx of this solenoid at distance x from the centre. The magnetic field produced by this element is



(1 mark)

$$dB = \frac{\mu_0 n I a^2}{\left[2(r-x)^2 + a^2\right]^{\frac{3}{2}}} dx$$ (1 mark)

[∵ number of turns in a length $dx = n\,dx$]

To calculate the magnetic field produced by the entire solenoid, we have to integrate this expression from $-l$ to $+l$.

$$B = \int_{-l}^{+l} \frac{\mu_0 n I a^2}{\left[2(r-x)^2 + a^2\right]^{\frac{3}{2}}} dx$$ (1 mark)

When $r >> a$, we can ignore a

$(r-x) \approx r$

$$B = \frac{\mu_0 n I a^2}{2r^3} \int_{-l}^{+l} dx$$

$$B = \frac{\mu_0 n I a^2}{2r^3}[2l]$$ (1 mark)

$$B = \frac{\mu_0}{4\pi}\left[\frac{2(n \times 2l) \times I \times \pi a^2}{r^3}\right]$$

$(n \times 2l)$ = Total number of turns in a length $'2l'$ of the solenoid

$(n \times 2l) \times I \times (\pi a^2) = m =$ Magnetic moment of the solenoid

$$B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$$

This will be the same expression which we would have obtained in the case of a short bar magnet at a point on the axial line at distance r from its centre. Thus a bar magnet can be considered as an equivalent solenoid. (1 mark)