19

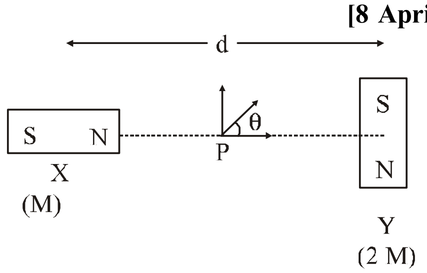
Magnetism and Matter

TOPIC 1 Magnetism, Gauss's Law, Magnetic Moment, Properties of Magnet

1. A small bar magnet placed with its axis at 30° with an external field of 0.06 T experiences a torque of 0.018 Nm. The minimum work required to rotate it from its stable to unstable equilibrium position is : **[Sep. 04, 2020 (I)]**
   (a) 6.4×10^{-2} J (b) 9.2×10^{-3} J
   (c) 7.2×10^{-2} J (d) 11.7×10^{-3} J

2. A circular coil has moment of inertia 0.8 kg m^2 around any diameter and is carrying current to produce a magnetic moment of 20 Am^2. The coil is kept initially in a vertical position and it can rotate freely around a horizontal diameter. When a uniform magnetic field of 4 T is applied along the vertical, it starts rotating around its horizontal diameter. The angular speed the coil acquires after rotating by 60° will be : **[Sep. 04, 2020 (II)]**
   (a) 10 rad s^{-1} (b) 10π rad s^{-1}
   (c) 20π rad s^{-1} (d) 20 rad s^{-1}

3. Two magnetic dipoles X and Y are placed at a separation *d*, with their axes perpendicular to each other. The dipole moment of Y is twice that of X. A particle of charge *q* is passing through their midpoint P, at angle $\theta = 45°$ with the horizontal line, as shown in figure. What would be the magnitude of force on the particle at that instant? (*d* is much larger than the dimensions of the dipole) **[8 April 2019 II]**



   (a) $\left(\frac{\mu_0}{4\pi}\right)\frac{M}{\left(\frac{d}{2}\right)^3} \times qv$ (b) 0
   (c) $\sqrt{2}\left(\frac{\mu_0}{4\pi}\right)\frac{M}{\left(\frac{d}{2}\right)^3} \times qv$ (d) $\left(\frac{\mu_0}{4\pi}\right)\frac{2M}{\left(\frac{d}{2}\right)^3} \times qv$

4. A magnet of total magnetic moment $10^{-2}\hat{i}$ A-m^2 is placed in a time varying magnetic field, $B\hat{i}$ $(\cos\omega t)$where B = 1 Tesla and ω = 0.125 rad/s. The work done for reversing the direction of the magnetic moment at t = 1 second, is: **[10 Jan. 2019 I]**
   (a) 0.01 J (b) 0.007 J
   (c) 0.028 J (d) 0.014 J

5. A magnetic dipole in a constant magnetic field has : **[Online April 8, 2017]**
   (a) maximum potential energy when the torque is maximum
   (b) zero potential energy when the torque is minimum.
   (c) zero potential energy when the torque is maximum.
   (d) minimum potential energy when the torque is maximum.

6. A magnetic dipole is acted upon by two magnetic fields which are inclined to each other at an angle of 75°. One of the fields has a magnitude of 15 mT. The dipole attains stable equilibrium at an angle of 30° with this field. The magntidue of the other field (in mT) is close to : **[Online April 9, 2016]**
   (a) 1 (b) 11 (c) 36 (d) 1060

7. A 25 cm long solenoid has radius 2 cm and 500 total number of turns. It carries a current of 15 A. If it is equivalent to a magnet of the same size and magnetization $\vec{M}$ (magnetic moment/volume), then $|\vec{M}|$ is : **[Online April 10, 2015]**
   (a) 30000π Am^{-1} (b) 3π Am^{-1}
   (c) 30000 Am^{-1} (d) 300 Am^{-1}

8. A bar magnet of length 6 cm has a magnetic moment of 4 J T^{-1}. Find the strength of magnetic field at a distance of 200 cm from the centre of the magnet along its equatorial line. **[Online May 7, 2012]**
   (a) 4×10^{-8} tesla (b) 3.5×10^{-8} tesla
   (c) 5×10^{-8} tesla (d) 3×10^{-8} tesla

9. A thin circular disc of radius *R* is uniformly charged with density $\sigma > 0$ per unit area. The disc rotates about its axis with a uniform angular speed ω. The magnetic moment of the disc is **[2011 RS]**

(a) $\pi R^4 \sigma\omega$ (b) $\frac{\pi R^4}{2}\sigma\omega$

(c) $\frac{\pi R^4}{4}\sigma\omega$ (d) $2\pi R^4 \sigma\omega$

10. A magnetic needle is kept in a non-uniform magnetic field. It experiences **[2005]**

(a) neither a force nor a torque
(b) a torque but not a force
(c) a force but not a torque
(d) a force and a torque

11. The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2s. The magnet is cut along its length into three equal parts and these parts are then placed on each other with their like poles together. The time period of this combination will be **[2004]**

(a) $2\sqrt{3}$ s (b) $\frac{2}{3}$ s (c) 2 s (d) $\frac{2}{\sqrt{3}}$ s

12. A magnetic needle lying parallel to a magnetic field requiers W units of work to turn it through 60^0. The torque needed to maintain the needle in this position will be **[2003]**

(a) $\sqrt{3}$W (b) W (c) $\frac{\sqrt{3}}{2}$W (d) 2W

13. The magnetic lines of force inside a bar magnet **[2003]**

(a) are from north-pole to south-pole of the magnet
(b) do not exist
(c) depend upon the area of cross-section of the bar magnet
(d) are from south-pole to north-pole of the Magnet

TOPIC 2 The Earth Magnetism, Magnetic Materials and their properties

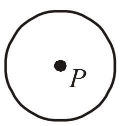
14. An iron rod of volume 10^{-3} m^3 and relative permeability 1000 is placed as core in a solenoid with 10 turns/cm. If a current of 0.5 A is passed through the solenoid, then the magnetic moment of the rod will be : **[Sep. 05, 2020 (II)]**

(a) 50×10^2 Am^2 (b) 5×10^2 Am^2
(c) 500×10^2 Am^2 (d) 0.5×10^2 Am^2

15. A paramagnetic sample shows a net magnetisation of 6 A/m when it is placed in an external magnetic field of 0.4 T at a temperature of 4 K. When the sample is placed in an external magnetic field of 0.3 T at a temperature of 24 K, then the magnetisation will be : **[Sep. 04, 2020 (II)]**

(a) 1 A/m (b) 4 A/m
(c) 2.25 A/m (d) 0.75 A/m

16. A perfectly diamagnetic sphere has a small spherical cavity at its centre, which is filled with a paramagnetic substance. The whole system is placed in a uniform magnetic field $\vec{B}$. Then the field inside the paramagnetic substance is : **[Sep. 03, 2020 (II)]**

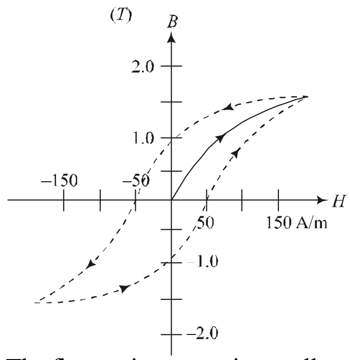


(a) $\vec{B}$
(b) zero
(c) much large than $|\vec{B}|$ and parallel to $\vec{B}$
(d) much large than $|\vec{B}|$ but opposite to $\vec{B}$

17. Magnetic materials used for making permanent magnets (P) and magnets in a transformer (T) have different properties of the following, which property best matches for the type of magnet required? **[Sep. 02, 2020 (I)]**

(a) T : Large retentivity, small coercivity
(b) P : Small retentivity, large coercivity
(c) T : Large retentivity, large coercivity
(d) P : Large retentivity, large coercivity

18.



The figure gives experimentally measured B vs. H variation in a ferromagnetic material. The retentivity, co-ercivity and saturation, respectively, of the material are: **[7 Jan. 2020 II]**

(a) 1.5 T, 50 A/m and 1.0 T
(b) 1.5 T, 50 A/m and 1.0 T
(c) 150 A/m, 1.0 T and 1.5 T
(d) 1.0 T, 50 A/m and 1.5 T

19. A paramagnetic material has 10^{28} atoms/m^3. Its magnetic susceptibility at temperature 350 K is 2.8×10^{-4}. Its susceptibility at 300 K is: **[12 Jan. 2019 II]**

(a) 3.267×10^{-4} (b) 3.672×10^{-4}
(c) 3.726×10^{-4} (d) 2.672×10^{-4}

20. A paramagnetic substance in the form of a cube with sides 1 cm has a magnetic dipole moment of 20×10^{-6} J/T when a magnetic intensity of 60×10^3 A/m is applied. Its magnetic susceptibility is: **[11 Jan. 2019 II]**

(a) 3.3×10^{-2} (b) 4.3×10^{-2}
(c) 2.3×10^{-2} (d) 3.3×10^{-4}

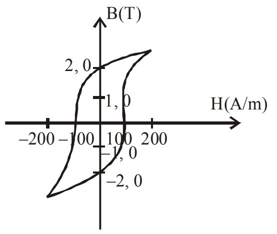
21. At some location on earth the horizontal component of earth's magnetic field is 18×10^{-6} T. At this location, magnetic needle of length 0.12 m and pole strength 1.8 Am is suspended from its mid-point using a thread, it makes 45° angle with horizontal in equilibrium. To keep this needle horizontal, the vertical force that should be applied at one of its ends is: **[10 Jan. 2019 II]**

(a) 3.6×10^{-5} N (b) 1.8×10^{-5} N
(c) 1.3×10^{-5} N (d) 6.5×10^{-5} N

22. A bar magnet is demagnetized by inserthing it inside a solenoid of length 0.2 m, 100 turns, and carrying a current of 5.2 A. The coercivity of the bar magnet is: **[9 Jan. 2019 I]**

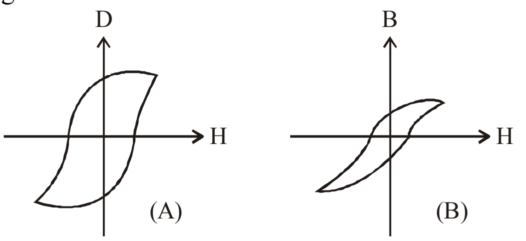
(a) 285 A/m (b) 2600 A/m
(c) 520 A/m (d) 1200 A/m

23. The B-H curve for a ferromagnet is shown in the figure. The ferromagnet is placed inside a long solenoid with 1000 turns/cm.. The current that should be passed in the solenoid to demagnetise the ferromagnet completely is: **[Online April 15, 2018]**



(a) 2 mA (b) 1 mA (c) 40 μA (d) 20 μA

24. Hysteresis loops for two magnetic materials A and B are given below :



These materials are used to make magnets for elecric generators, transformer core and electromagnet core. Then it is proper to use : **[2016]**

(a) A for transformers and B for electric generators.
(b) B for electromagnets and transformers.
(c) A for electric generators and trasformers.
(d) A for electromagnets and B for electric generators.

25. A fighter plane of length 20 m, wing span (distance from tip of one wing to the tip of the other wing) of 15m and height 5m is lying towards east over Delhi. Its speed is 240 ms^{-1}. The earth's magnetic field over Delhi is 5×10^{-5}T with the declination angle ~0° and dip of θ such that $\sin\theta = \frac{2}{3}$. If the voltage developed is V_B between the lower and upper side of the plane and V_W between the tips of the wings then V_B and V_W are close to : **[Online April 10, 2016]**

(a) V_B = 40 mV; V_W = 135 mV with left side of pilot at higher voltage
(b) V_B = 45 mV; V_W = 120 mV with right side of pilot at higher voltage
(c) V_B = 40 mV; V_W = 135 mV with right side of pilot at higher voltage
(d) V_B = 45 mV; V_W = 120 mV with left side of pilot at higher voltage

26. A short bar magnet is placed in the magnetic meridian of the earth with north pole pointing north. Neutral points are found at a distance of 30 cm from the magnet on the East – West line, drawn through the middle point of the magnet. The magnetic moment of the magnet in Am^2 is close to: (Given $\frac{\mu_0}{4\pi} = 10^{-7}$ in SI units and B_H =Horizontal component of earth's magnetic field = 3.6 × 10^{-5} tesla) **[Online April 11, 2015]**

(a) 14.6 (b) 19.4 (c) 9.7 (d) 4.9

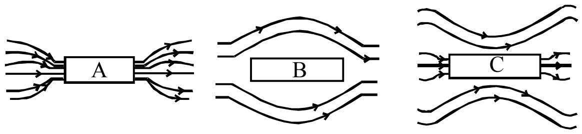
27. The coercivity of a small magnet where the ferromagnet gets demagnetized is 3×10^3 Am^{-1}. The current required to be passed in a solenoid of length 10 cm and number of turns 100, so that the magnet gets demagnetized when inside the solenoid, is: **[2014]**

(a) 30 mA (b) 60 mA (c) 3 A (d) 6 A

28. An example of a perfect diamagnet is a superconductor. This implies that when a superconductor is put in a magnetic field of intensity B, the magnetic field B_s inside the superconductor will be such that: **[Online April 19, 2014]**

(a) $B_s = -B$ (b) $B_s = 0$
(c) $B_s = B$ (d) $B_s < B$ but $B_s \neq 0$

29. Three identical bars A, B and C are made of different magnetic materials. When kept in a uniform magnetic field, the field lines around them look as follows:



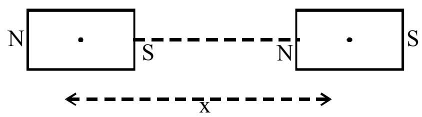
Make the correspondence of these bars with their material being diamagnetic (D), ferromagnetic (F) and paramagnetic (P): **[Online April 11, 2014]**

(a) $A \leftrightarrow D, B \leftrightarrow P, C \leftrightarrow F$
(b) $A \leftrightarrow F, B \leftrightarrow D, C \leftrightarrow P$
(c) $A \leftrightarrow P, B \leftrightarrow F, C \leftrightarrow D$
(d) $A \leftrightarrow F, B \leftrightarrow P, C \leftrightarrow D$

30. The magnetic field of earth at the equator is approximately 4×10^{-5} T. The radius of earth is 6.4×10^6 m. Then the dipole moment of the earth will be nearly of the order of: **[Online April 9, 2014]**

(a) 10^{23} A m^2 (b) 10^{20} A m^2
(c) 10^{16} A m^2 (d) 10^{10} A m^2

31. The mid points of two small magnetic dipoles of length d in end-on positions, are separated by a distance x, (x >> d). The force between them is proportional to x^{-n} where n is: **[Online April 9, 2014]**



(a) 1 (b) 2 (c) 3 (d) 4

32. Two short bar magnets of length 1 cm each have magnetic moments 1.20 Am^2 and 1.00 Am^2 respectively. They are placed on a horizontal table parallel to each other with their N poles pointing towards the South. They have a common magnetic equator and are separated by a distance of 20.0 cm. The value of the resultand horizontal magnetic induction at the mid-point O of the line joining their centres is close to (Horizontal component of earth.s magnetic induction is 3.6× 10.5Wb/m^2) **[2013]**

(a) 3.6 × 10.5 Wb/m^2 (b) 2.56 × 10.4 Wb/m^2
(c) 3.50 × 10.4 Wb/m^2 (d) 5.80 × 10.4 Wb/m^2

33. The earth's magnetic field lines resemble that of a dipole at the centre of the earth. If the magnetic moment of this dipole is close to 8×10^{22} Am^2, the value of earth's magnetic field near the equator is close to (radius of the earth = 6.4×10^6 m) **[Online April 25, 2013]**

(a) 0.6 Gauss (b) 1.2 Gauss
(c) 1.8 Gauss (d) 0.32 Gauss

34. Relative permittivity and permeability of a material ε_r and μ_r, respectively. Which of the following values of these quantities are allowed for a diamagnetic material? **[2008]**

(a) $\varepsilon_r = 0.5, \mu_r = 1.5$ (b) $\varepsilon_r = 1.5, \mu_r = 0.5$
(c) $\varepsilon_r = 0.5, \mu_r = 0.5$ (d) $\varepsilon_r = 1.5, \mu_r = 1.5$

35. Needles N_1, N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance respectively. A magnet when brought close to them will **[2006]**

(a) attract N_1 and N_2 strongly but repel N_3
(b) attract N_1 strongly, N_2 weakly and repel N_3 weakly
(c) attract N_1 strongly, but repel N_2 and N_3 weakly
(d) attract all three of them

36. The materials suitable for making electromagnets should have **[2004]**

(a) high retentivity and low coercivity
(b) low retentivity and low coercivity
(c) high retentivity and high coercivity
(d) low retentivity and high coercivity

37. A thin rectangular magnet suspended freely has a period of oscillation equal to T. Now it is broken into two equal halves (each having half of the original length) and one piece is made to oscillate freely in the same field. If its period of oscillation is T', the ratio $\frac{T'}{T}$ is **[2003]**

(a) $\frac{1}{2\sqrt{2}}$ (b) $\frac{1}{2}$
(c) 2 (d) $\frac{1}{4}$

38. Curie temperature is the temperature above which **[2003]**

(a) a ferromagnetic material becomes paramagnetic
(b) a paramagnetic material becomes diamagnetic
(c) a ferromagnetic material becomes diamagnetic
(d) a paramagnetic material becomes ferromagnetic

TOPIC 3 Magnetic Equipment

39. A ring is hung on a nail. It can oscillate, without slipping or sliding (i) in its plane with a time period T_1 and, (ii) back and forth in a direction perpendicular to its plane, with a period T_2. The ratio $\frac{T_1}{T_2}$ will be : **[Sep. 05, 2020 (II)]**

(a) $\frac{2}{\sqrt{3}}$ (b) $\frac{2}{3}$
(c) $\frac{3}{\sqrt{2}}$ (d) $\frac{\sqrt{2}}{3}$

40. A magnetic compass needle oscillates 30 times per minute at a place where the dip is 45°, and 40 times per minute where the dip is 30°. If B_1 and B_2 are respectively the total magnetic field due to the earth and the two places, then the ratio B_1/B_2 is best given by : **[12 April 2019 I]**

(a) 1.8 (b) 0.7 (c) 3.6 (d) 2.2

41. A hoop and a solid cylinder of same mass and radius are made of a permanent magnetic material with their magnetic moment parallel to their respective axes. But the magnetic moment of hoop is twice of solid cylinder. They are placed in a uniform magnetic field in such a manner that their magnetic moments make a small angle with the field. If the oscillation periods of hoop and cylinder are T_h and T_c respectively, then: **[10 Jan. 2019 II]**

(a) $T_h = T_c$ (b) $T_h = 2\,T_c$
(c) $T_h = 1.5\,T_c$ (d) $T_h = 0.5\,T_c$

42. A magnetic needle of magnetic moment 6.7×10^{-2} Am^2 and moment of inertia 7.5×10^{-6} kg m^2 is performing simple harmonic oscillations in a magnetic field of 0.01 T. Time taken for 10 complete oscillations is : **[2017]**

(a) 6.98 s (b) 8.76 s
(c) 6.65 s (d) 8. 89 s

Hints & Solutions

1. **(c)** Here, $\theta = 30°$, $\tau = 0.018$ N-m, $B = 0.06$ T

Torque on a bar magnet :

$$\tau = MB\sin\theta$$

$$0.018 = M \times 0.06 \times \sin 30°$$

$$\Rightarrow 0.018 = M \times 0.06 \times \frac{1}{2} \Rightarrow M = 0.6 \text{ A-m}^2$$

Position of stable equilibrium ($\theta = 0°$)

Position of unstable equilibrium ($\theta = 180°$)

Minimum work required to rotate bar magnet from stable to unstable equilibrium

$$\Delta U = U_f - U_i = -MB\cos 180° - (-MB\cos 0°)$$

$$W = 2MB = 2 \times 0.6 \times 0.06$$

$$\therefore W = 7.2 \times 10^{-2} \text{J}$$

2. **(a)** Given,

Moment of inertia of circular coil, $I = 0.8$ kg m^2

Magnetic moment of circular coil, $M = 20$ Am^2

Rotational kinetic energy of circular coil,

$$\text{KE} = \frac{1}{2} I\omega^2$$

Here, ω = angular speed of coil

Potential energy of bar magnet = – $MB\cos\phi$

From energy conservation

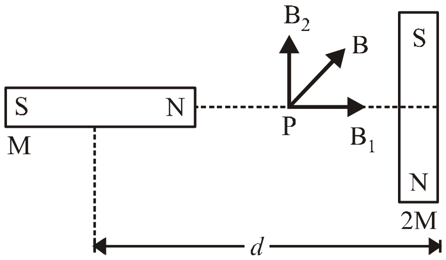
$$\frac{1}{2} I\omega^2 = U_{\text{in}} - U_f = -MB\cos 60° - (-MB)$$

$$\Rightarrow \frac{MB}{2} = \frac{1}{2} I\omega^2$$

$$\Rightarrow \frac{20 \times 4}{2} = \frac{1}{2}(0.8)\omega^2$$

$$\Rightarrow 100 = \omega^2 \Rightarrow \omega = 10 \text{ rad}$$

3. **(b)** $B_1 = \frac{\mu_0}{4\pi} \frac{2K}{(d/2)^3}$



and $B_2 = \frac{\mu_0}{4\pi} \frac{2M}{(d/2)^3}$

$$\therefore \quad \tan\theta = \frac{B_2}{B_1} = \frac{\frac{\mu_0}{4\pi}\frac{2M}{(d/2)^3}}{\frac{\mu_0}{4\pi}\frac{2M}{(d/2)^3}} = 1$$

or $\theta = 45°$

The resultant field is 45° from B_1. The angle between $\vec{B}$ and $\vec{v}$ zero, so force on the particle is zero.

4. **(c)**

Work done, W = 2 m·B

= 2 × 10^{-2} × 1 cos (0.125)

= 0.02 J

5. **(c)** Potential energy of dipole,

U = – pE cos θ

Torque experienced by dipole

τ = pE sin θ

Torque will be maximum (τ_{max}) when $\theta = 90°$ then potential energy U = 0

6. **(b)** We know that, magnetic dipole moment

$M = NiA\cos\theta$ i.e., $M \propto \cos\theta$

When two magnetic fields are inclined at an angle of 75° the equilibrium will be at 30°, so

$$\cos\theta = \cos(75° - 30°) = \cos 45° = \frac{1}{\sqrt{2}}$$

$$\frac{x}{\sqrt{2}} = \frac{15}{2} \therefore x \approx 11$$

7. **(c)** $\vec{M}$ (mag. moment/volume) = $\frac{NiA}{A\ell}$

$$= \frac{Ni}{\ell} = \frac{(500)15}{25 \times 10^{-2}} = 30000 \text{ Am}^{-1}$$

8. **(c)** Along the equatorial line, magnetic field strength

$$B = \frac{\mu_0}{4\pi} \frac{M}{\left(r^2 + \ell^2\right)^{3/2}}$$

Given: $M = 4JT^{-1}$

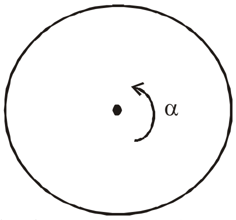
$r = 200$ cm = 2 m

$$\ell = \frac{6\text{cm}}{2} = 3 \text{ cm} = 3 \times 10^{-2} \text{ m}$$

$$\therefore B = \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{4}{\left[2^2 + \left(3 \times 10^{-2}\right)^2\right]^{3/2}}$$

Solving we get, $B = 5 \times 10^{-8}$ tesla

9. **(c)** $\frac{q}{2m} = \frac{\text{Magnetic dipole moment}}{\text{Angular momentum}}$



∴ Magnetic dipole moment (M)

$$M = \frac{q}{2m}.\left(\frac{mR^2}{2}\right).\omega \ = \frac{1}{4}\sigma.\pi R^4\omega.$$

10. **(d)** A magnetic needle kept in non uniform magnetic field experience a force and torque due to unequal forces acting on poles.

11. **(b)** Initially, time period of magnet

$$T = 2\pi\sqrt{\frac{I}{MB}} = 25 \quad \text{where } I = \frac{1}{12}m\ell^2$$

When the magnet is cut into three pieces the pole strength will remain the same and

Moment of inertia of each part,

$$(I') = \frac{1}{12}\left(\frac{m}{3}\right)\left(\frac{\ell}{3}\right) \times 3 = \frac{I}{9}$$

We have, Magnetic moment (M)

= Pole strength (m) × ℓ

∴ New magnetic moment,

$$M' = m \times \left(\frac{\ell}{3}\right) \times 3 = m\ell = M$$

New time period, $T' = 2\pi\sqrt{\frac{I'}{M'B}}$

$$= 2\pi\sqrt{\frac{I}{9MB}} \qquad \Rightarrow T' = \frac{T}{\sqrt{9}} = \frac{2}{3}s.$$

12. **(a)** Workdone to turn a magnetic needle from angle θ_1 to θ_2 is given by

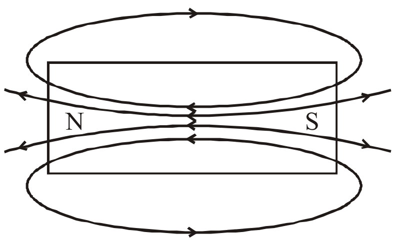
$$W = MB(\cos\theta_1 - \cos\theta_2)$$

$$\therefore W = MB(\cos 0° - \cos 60°)$$

$$= MB\left(1 - \frac{1}{2}\right) = \frac{MB}{2}$$

$$\therefore \text{ Torque, } \tau = MB\sin\theta = MB\sin 60° = \sqrt{3}\frac{MB}{2} = \sqrt{3}W$$

13. **(d)** The magnetif field lines of bar magnet form closed lines. As shown in the figure, the magnetic lines of force are directed from south to north inside a bar magnet. Outside the bar magnet magnetic field lines directed from north to south pole.



14. **(b)** Given,

Volume of iron rod, $V = 10^{-3}\ m^3$

Relative permeability, $\mu_r = 1000$

Number of turns per unit length, $n = 10$

Magnetic moment of an iron core solenoid,

$$M = (\mu_r - 1) \times NiA$$

$$\Rightarrow M = (\mu_r - 1) \times Ni\frac{V}{l} \Rightarrow M = (\mu_r - 1) \times \frac{N}{l}iV$$

$$\Rightarrow M = 999 \times \frac{10}{10^{-2}} \times 0.5 \times 10^{-3} = 499.5 \approx 500.$$

15. **(d)** For paramagnetic material. According to curies law

$$\chi \propto \frac{1}{T}$$

For two temperatures T_1 and T_2

$$\chi_1 T_1 = \chi_2 T_2$$

But $\chi = \frac{I}{B}$

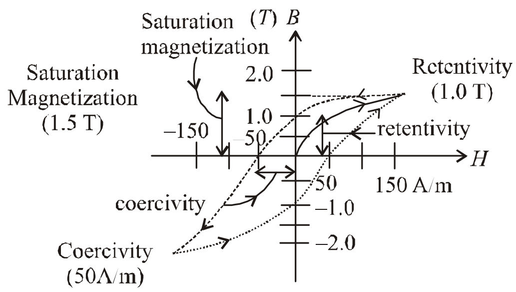
$$\therefore \frac{I_1}{B_1}T_1 = \frac{I_2}{B_2}T_2$$

$$\Rightarrow \frac{6}{0.4} \times 4 = \frac{I_2}{0.3} \times 24 \Rightarrow I_2 = \frac{0.3}{0.4} = 0.75 \text{ A/m}$$

16. **(b)** When magnetic field is applied to a diamagnetic substance, it produces magnetic field in opposite direction so net magnetic field inside the cavity of sphere will be zero. So, field inside the paramagnetic substance kept inside the cavity is zero.

17. **(d)** Permanent magnets (P) are made of materials with large retentivity and large coercivity. Transformer cores (T) are made of materials with low retentivity and low coercivity.

18. **(d)**



19. **(a)** According to Curie law for paramagnetic substance,

$$\chi \propto \frac{1}{T_C} \Rightarrow \frac{\chi_1}{\chi_2} = \frac{T_{C_2}}{T_{C_1}}$$

$$\frac{2.8 \times 10^{-4}}{\chi_2} = \frac{300}{350}$$

$$\chi_2 = \frac{2.8 \times 350 \times 10^{-4}}{300} = 3.266 \times 10^{-4}$$

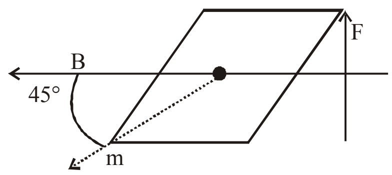
20. **(d)** Magnetic susceptibility,

$$\chi = \frac{I}{H}$$

where, $I = \frac{\text{Magnetic moment}}{\text{Volume}} = \frac{20\times10^{-6}}{10^{-6}} = 20\ N/m^2$

Now, $\chi = \frac{20}{60\times10^3} = \frac{1}{3}\times10^{-3} = 3.3\times10^{-4}$

21. **(d)** using, $MB\sin\theta = F\,\ell\,\sin\theta\ (\tau)$



$MB\sin 45° = F\frac{\ell}{2}\sin 45°$

$F = 2MB = 2\times1.8\times18\times10^{-6} = 6.5\times10^{-5}N$

22. **(b)** Corecivity, $H = \frac{B}{\mu_0}$ and $B = \mu_0 ni\left(n = \frac{N}{\ell}\right)$

or, $H = \frac{N}{\ell}i = \frac{100}{0.2}\times5.2 = 2600$ A/m

23. **(b)** Given Number of turns,
$n = 1000$ turns/cm $= 1000\times100$ turns/m
Coercivity of ferromagnet, $H = 100$ A/m
Current to demagnetise the ferromagnet, $I = ?$
Using, $H = nI$
or, $100 = 10^5\times I$

$\therefore\ I = \frac{100}{10^5} = 1$ mA

24. **(b)** Graph [A] is for material used for making permanent magnets (high coercivity)
Graph [B] is for making electromagnets and transformers.

25. **(d)** $V_B = VB_H l = 240\times5\times10^{-5}\cos(\theta)\times5 = 44.7$ mv
By right hand rule, the charge moves to the left of pilot.

26. (c) Here, r = 30cm = 0.3cm

we know $\frac{\mu_0 M}{4\pi r^3} = B_H = 3.6\times10^{-5}$

$\Rightarrow M = \frac{3.6\times10^{-5}}{10^{-7}}(0.3)^3$

Hence, $M = 9.7\ Am^2$

27. **(c)** Magnetic field in solenoid $B = \mu_0 ni$

$\Rightarrow \frac{B}{\mu_0} = ni$

(Where n = number of turns per unit length)

$\Rightarrow \frac{B}{\mu_0} = \frac{Ni}{L} \Rightarrow 3\times10^3 = \frac{100i}{10\times10^{-2}}$

$\Rightarrow i = 3A$

28. **(b)** Magnetic field inside the superconductor is zero. Diamagnetic substances are repelled in external magnetic field.

29. **(b)** Diamagnetic materials are repelled in an external magnetic field.
Bar B represents diamagnetic materials.

30. **(a)** Given, $B = 4\times10^{-5}$ T
$R_E = 6.4\times10^6$ m
Dipole moment of the earth M = ?

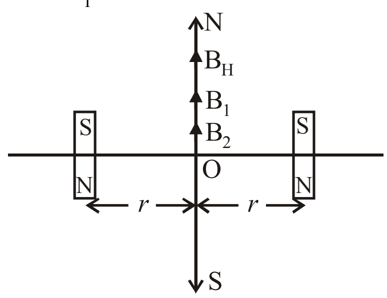
$B = \frac{\mu_0}{4\pi}\frac{M}{d^3}$

$4\times10^{-5} = \frac{4\pi\times10^{-7}\times M}{4\pi\times\left(6.4\times10^6\right)^3}$

$\therefore\ M \cong 10^{23}\ Am^2$

31. **(d)** In magnetic dipole
Force $\propto \frac{1}{r^4}$
In the given question,
Force $\propto x^{-n}$
Hence, n = 4

32. **(b)** **Given :** $M_1 = 1.20\ Am^2$



$M_2 = 1.00\ Am^2;\ r = \frac{20}{2}cm = 0.1m$

$B_{net} = B_1 + B_2 + B_H$

$B_{net} = \frac{\mu_0}{4\pi}\frac{(M_1+M_2)}{r^3} + B_H$

$= \frac{10^{-7}(1.2+1)}{(0.1)^3} + 3.6\times10^{-5} = 2.56\times10^{-4}\ wb/m^2$

33. **(a)** Given $M = 8\times10^{22}\ Am^2$
$d = R_e = 6.4\times10^6 m$

Earth's magnetic field, $B = \frac{\mu_0}{4\pi}\cdot\frac{2M}{d^3}$

$= \frac{4\pi\times10^{-7}}{4\pi}\times\frac{2\times8\times10^{22}}{(6.4\times10^6)^3} \cong 0.6$ Gauss

34. **(b)** For a diamagnetic material, the value of μ_r is slightly less than one. For any material, the value of $\in_r$ is always greater than 1.

35. **(b)** Ferromagnetic substance has magnetic domains whereas paramagnetic substances have magnetic dipoles which get attracted to a magnetic field. Ferromagnetic material magnetised strongly in the direction of magnetism field, Hence, N_1 will be attracted paramagnetic substance attract weekly in the direction of field. Hence, N_2 will weakly attracted. Diamagnetic substances do not have magnetic dipole but in the presence of external magnetic field due to their orbital motion of electrons these substances are repelled. Hence, N_3 will be repelled.

36. **(b)** Electromagnet should be amenable to magnetisation & demagnetization.

$\therefore$ Materials suitable for making electromagnets should have low retentivity and low coercivity should be low.

37. **(b)** The time period of a rectangular magnet oscillating in earth's magnetic field is given by $T = 2\pi\sqrt{\frac{I}{MB_H}}$

where I = Moment of inertia of the rectangular magnet

M = Magnetic moment

B_H = Horizontal component of the earth's magnetic field

Initially, the time period of the magnet

$$T = 2\pi\sqrt{\frac{I}{MB_H}} \quad \text{where } I = \frac{1}{12}M\ell^2$$

Case 2

Magnet is cut into two identical pieces such that each piece has half the original length.

Then $T' = 2\pi\sqrt{\frac{I'}{M'B_H}}$

Moment of inertia of each part

$$I' = \frac{1}{12}\left(\frac{M}{2}\right)\left(\frac{\ell}{2}\right)^2 = \frac{I}{8} \text{ and } M' = \frac{M}{2}$$

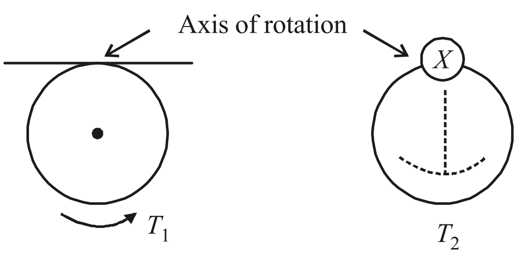
$$\therefore \frac{T'}{T} = \sqrt{\frac{I'}{M} \times \frac{M}{I}} = \sqrt{\frac{I/8}{M/2} \times \frac{M}{I}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

38. **(a)** The temperature above which a ferromagnetic substance becomes paramagnetic is called Curie's temperature.

39. **(a)** Let I_1 and I_2 be the moment of inertia in first and second case respectively.

$$I_1 = 2MR^2$$

$$I_2 = MR^2 + \frac{MR^2}{2} = \frac{3}{2}MR^2$$



Time period, $T = 2\pi\sqrt{\frac{I}{mgd}}$

$T \propto I$

$$\therefore \frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{2MR^2}{\frac{3}{2}MR^2}} = \frac{2}{\sqrt{3}}$$

40. **(Bonus)** We have, $T = 2\pi\sqrt{\frac{I}{MB_x}}$

$$\therefore \frac{T_1^2}{T_2^2} = \frac{Bx_2}{Bx_1}$$

$$\text{or } \left(\frac{2}{1.5}\right)^2 = \frac{B_2\cos 45°}{B_1\cos 30°} = \frac{B_2 \times 2}{\sqrt{2} \times B_1 \times \sqrt{3}}$$

$$\left(\frac{4}{3}\right)^2 = \frac{B_2}{B_1} \times \frac{2}{\sqrt{6}}$$

$$\therefore \frac{B_1}{B_2} = \frac{9}{8\sqrt{6}} = 0.46$$

41. **(a)** Using, time /oscillation period,

$$T = 2\pi\sqrt{\frac{I}{MB}}$$

Where, M = magnetic moment, I moment of inertia and B = magnetic field

$$T_h = 2\pi\sqrt{\frac{mR^2}{(2MB)}}$$

$$T_c = 2\pi\sqrt{\frac{1/2mR^2}{MB}}$$

Clearly, $T_h = T_c$

42. **(c)** Given : Magnetic moment, $M = 6.7 \times 10^{-2}\,Am^2$

Magnetic field, B = 0.01 T

Moment of inertia, $I = 7.5 \times 10^{-6}$ Kgm^2

Using, $T = 2\pi\sqrt{\frac{I}{MB}}$

$$= 2\pi\sqrt{\frac{7.5 \times 10^{-6}}{6.7 \times 10^{-2} \times 0.01}} = \frac{2\pi}{10} \times 1.06\,s$$

Time taken for 10 complete oscillations

$t = 10T = 2\pi \times 1.06$

$= 6.6568 \approx 6.65$ s