PHYSICS

Class XII

Chapter 5- Magnetism and Matter

1 Mark Questions

Questions 1.
The permeability of a magnetic material is 0.9983. Name the type of magnetic materials it represents.
Answer:
It represents diamagnetic materials.

Question 2.
The susceptibility of a magnetic material is 1.9×10^{-5}. Name the type of magnetic materials it represents.
Answer:
It represents Paramagnetic substance.

Question 3.
The susceptibility of a magnetic material is -4.2×10^{-6}. Name the type of magnetic materials it represents.
Answer:
It represents diamagnetic substances.

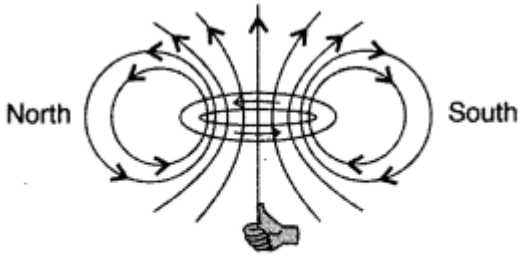
Question 4.
Where on the surface of Earth is the angle of dip 90°?
Answer:
At the magnetic poles, the angle of dip is 90° on the surface of Earth.

Question 5.
Where on the surface of Earth is the angle of dip zero?
Answer:
At the magnetic equator, the angle of dip is 0°.

Question 6.
Where on the surface of Earth is the vertical component of Earth's magnetic field zero?
Answer:
At the Magnetic equator the vertical component of Earth's magnetic field is zero.

Question 7.
The horizontal component of the earth's magnetic field at a place is B and angle of dip is 60°. What is the value of vertical component of earth's magnetic field at equator?
Answer:
$B_H = B \cos \delta$
$B_V = B_H \tan \delta = B \tan 60° = B \times \sqrt{3} = \sqrt{3}B$
∴ At equator, $B_V = 0$ (zero).

Question 8.
Current flows through a circular loop. Depict the north and south pole of its equivalent magnetic dipole.
Answer:
Direction of the magnetic field lines is given by right hand thumb rule.



Magnetic field lines

Question 9.
A straight wire extending from east to west falls with a speed v at right angles to the horizontal component of the Earth's magnetic field. Which end of the wire would be at the higher electrical potential and why?
Answer:
West end of the wire must be at higher electric potential. According to Fleming's Right Hand rule, "the direction of induced emf is from West to East".

Question 10.
What are permanent magnets? Give one example.
Answer:
Substances which at room temperature retain their ferromagnetic property for a long period of time are called permanent magnets.
Example: Steel, alinco

Question 11.
Which of the following substances are diamagnetic?
Bi, Al, Na, Cu, Ca and Ni
Answer:
Bi and Cu

Question 12.
Which of the following substances are para-magnetic ?
Bi, Al, Cu, Ca, Pb, Ni
Answer:
Al and Ca are para-magnetic.

Question 13.
Is the steady electric current the only source of magnetic field? Justify your answer.
Answer:
No. Steady current is not the only source of magnetic field. Magnets are also source of magnetic field. Unsteady current will also be source of varying magnetic field.

Question 14.
Where on the surface of Earth is the vertical com-ponent of Earth's magnetic field zero?
Answer:
At the Equator the vertical component of the Earth's magnetic field is zero.

Question 15.
Where on the surface of Earth is the horizontal component of Earth's magnetic field zero?
Answer:
At poles of Earth the horizontal component of Earth's magnetic field is zero.

Question 16.
Where on the surface of Earth is the Earth's magnetic field perpendicular to the surface of the Earth?
Answer:
At poles of the Earth. The Earth's magnetic field is perpendicular to the surface of the Earth.

Question 17.
The motion of copper plate is damped when it is allowed to oscillate between the two poles of a magnet. What is the cause of this damping?
Answer:
The cause of this damping is eddy current.

Question 18.
Relative permeability of a material, $\mu_r = 0.5$. Identify the nature of the magnetic material and write its relation to magnetic susceptibility.
Answer:

1. Diamagnetic material
2. $\mu_r = 1 + X_m$

2 Mark Questions

Question 1.
Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify?
Answer:
(i) Magnetic susceptibility (χm) : It is the property of a material which determines how easily it can be magnetised when kept in a magnetising field.
Also, it is the ratio of intensity of magnetisation (I) produced in the material to the intensity of magnetising field (H)

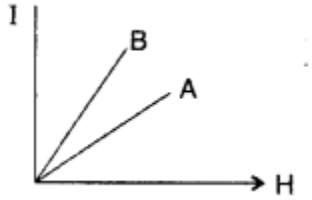
$$\chi_m = \frac{I}{H}$$

(ii) Positive susceptibility : para-magnetic material
Example: Al, Ca.

Negative susceptibility : diamagnetic material
Example: Bi, Cu.

(iii) Negative susceptibility signifies that the material is diamagnetic in nature.

Question 2.
The figure shows the variation of intensity of magnetisation versus the applied magnetic field intensity, H, for two magnetic materials A and B :



(a) Identify the materials A and B.
(b) Why does the material B, has a larger susceptibility than A, for a given field at constant temperature?
Answer:

$$(a)\ \text{As}\ \chi_m = \frac{I}{H}$$

Slope of the line gives magnetic susce¬ptibilities.
For magnetic material B, it is giving higher +ve value.
So material is 'ferromagnetic'.
For magnetic material A, it is giving lesser +ve value than 'B'.
So material is 'paramagnetic'.

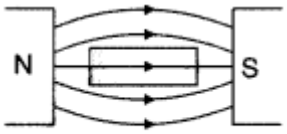
(b) Larger susceptibility is due to characteristic 'domain structure'. More number of mag¬netic moments get aligned in the direction of magnetising field in comparision to that for paramagnetic materials for the same value of magnetising field.

Question 3.
(i) Write two characteristics of a material used for making permanent magnets.
(ii) Why is core of an electromagnet made of ferromagnetic materials?
Answer:
(i) Two characteristics of a material used for making permanent magnets are :
(a) High retentivity so that it produces a strong magnetic field.
(b) High coercivity so that its magnetisation is not destroyed by strong magnetic fields, temperature variations or minor mechanical damage.

(ii) The core of electromagnet is made of ferromagnetic materials because they have high initial permeability so that magnetisation is large even for a small magnetising field and low resistivity to reduce losses due to eddy currents.

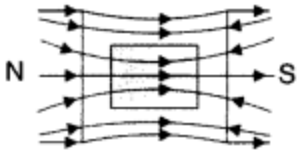
Question 3.
Draw magnetic field lines when a
(i) diamagnetic,

(ii) paramagnetic substance is placed in an external magnetic field.
Which magnetic property distinguishes this behaviour of the field lines due to the two substances?
Answer:
(i) When a diamagnetic material is placed in an external magnetic field.



Diamagnetic

(ii) When a paramagnetic material is placed in an external magnetic field.



Paramagnetic

Magnetic susceptibility distinguishes this behaviour of the field lines due to the two substances.

Question 4.
A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip down at 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place.
Answer:

Given : $\delta = 60°$, $H = 0.4$ G, $R = ?$

As $H = R \cos \delta$

$$R = \frac{H}{\cos \delta} = \frac{0.4}{\cos 60°} \quad \therefore R = \frac{0.4}{1/2} = \mathbf{0.8\ G}$$

Question 5.
The susceptibility of a magnetic material is -2.6×10^{-5}. Identify the type of magnetic material and state its two properties.
Answer:
Magnetic material is diamagnetic, because susceptibility of a magnetic material is in negative.
Properties are :

1. In a non-uniform magnetic field, it tends to move slowly from stronger to weaker parts of the field.
2. A freely suspended diamagnetic rod aligns itself perpendicular to the field.
3. They expel magnetic field lines.
4. Such substances are repelled by a magnet. [any two]

Question 26.
The susceptibility of a magnetic material is 2.6×10^{-5}. Identify the type of magnetic material and state its two properties.
Answer:

The material is paramagnetic.
Its two properties are :

1. They are feebly attracted by magnets.
2. In a non-uniform magnetic field, they tend to move slowly from weaker to stronger parts of the field.

Question 7.
The relative magnetic permeability of a magnetic material is 800. Identify the nature of magnetic material and state its two properties.
Answer:
Substance is ferromagnetic.
Its properties are :

1. They are strongly attracted by magnets.
2. In a non-uniform magnetic field, they tend to move quickly from weaker to stronger parts of the field.

Question 8.
A circular coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.
Answer:

Magnetic moment $= NIA = N_1 I\pi r^2$ | $N_1.2\pi R = N_2.2\pi(R/2)$, $N_2 = 2N_1$

When radius of another coil $= R/2$

Then Magnetic moment of new coil

$$= N_2 I \times \pi\left(\frac{R}{2}\right)^2 = N_2 I \times \pi\frac{R^2}{4}$$

$$\therefore \quad \frac{\text{Magnetic moment of new coil}}{\text{Magnetic moment of original coil}}$$

$$= \frac{2N_1 I \times \pi R^2/4}{N_1 I \times \pi R^2} = \frac{1}{2} \qquad \therefore \textbf{ Ratio = 1 : 2}$$

4 Marks Questions

Question 1.
A circular coil of N turns and diameter 'd' carries a current 'I'. It is unwound and rewound to make another coil of diameter '2d', current T remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.
Answer:
Magnetic moment of the coil is given by M = NIA

$$1^{st} \text{ case} : M_1 = N_1 I\pi \frac{d_1^2}{4},$$

$$2^{nd} \text{ case} : M_2 = N_2 I\pi \frac{d_2^2}{4}$$

But as given, I[st] coil is rewound to make new coil.

$$\text{So, } N_1(2\pi r_1) = N_2(2\pi r_2) \text{ or } N_1 d_1 = N_2 d_2$$

$$\text{from given condition } d_2 = 2d_1$$

$$\Rightarrow \quad N_1 d_1 = N_2(2d_1) \qquad \Rightarrow N_1 = 2N_2$$

Ratio of M_1 and M_2 will be,

$$\frac{M_1}{M_2} = \frac{N_1 I\pi d_1^2/4}{N_2 I\pi d_2^2/4} = \frac{2N_2 \times d_1^2}{N_2(2d)^2} = \frac{2}{4} = \frac{1}{2}$$

$$\therefore \quad \mathbf{M_1 : M_2 = 1 : 2}$$

Question 2.
(a) How does a diamagnetic material behave when it is cooled to very low temperatures?
(b) Why does a paramagnetic sample display greater magnetisation when cooled? Explain.
Answer:
(a) When diamagnetic material is cooled to very low temperature then it exhibits both perfect conductivity and perfect diamagnetism.
(b) This is because at lower temperature, the tendency to disrupt the alignment of dipoles (due to magnetising field) decreases on account of reduced random thermal motion.

Question 3.
State two characteristic properties distinguishing the behaviour of paramagnetic and diamagnetic materials.
Answer:

	Paramagnetic	Diamagnetic
(i)	Susceptibility is small and positive, i.e., $0 < \chi m < \varepsilon$ (where e is a small number) for paramagnetic	Susceptibility is small and negative, i.e., $-1 \leq \chi m$ for diamagnetic.
(ii)	Paramagnetic materials are feebly attracted by magnets	Diamagnetic materials are feebly repelled by magnets

Question 4.
State two characteristic properties distinguish¬ing the behaviour of diamagnetic and ferromagnetic materials.
Answer:

Diamagnetic material	Ferromagnetic material
(i) Relative magnetic permeability of dia-magnetic substances is always less than unity, i.e.,$\mu r < 1$. *(ii)* The susceptibility of diamagnetic substances has a small -	Relative magnetic permeability of ferro-magnetic materials is very large (= 10^3 to 10^5).The susceptibility of ferromagnetic materials is very large.

ve value : $\mu r < 1 \Rightarrow -1 \leq \chi m \leq 0$	$\chi m > 1$

Question 5.
Write two characteristic properties each to select materials suitable for
(i) permanent magnets and
(ii) electromagnets.
Answer:
Properties of a material—
(a) For making a permanent magnet:

1. High retentivity
2. High coercivity
3. High permeability

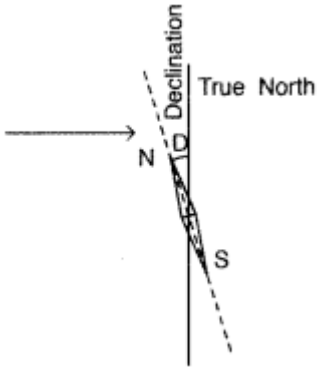
(b) For making an electromagnet:

1. High permeability .
2. Low retentivity
3. Low coercivity

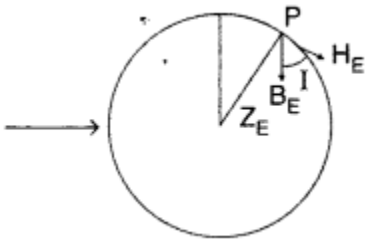
7 Mark Questions

Question 44.
Define the following using suitable diagrams :
(i) magnetic declination and
(ii) angle of dip. In what direction will a compass needle point when kept at the
(i) poles and
(ii) equator?
Answer:
Magnetic declination:

Angle between magnetic meridian and geographical meridian



Angle of dip : It is the angle which the magnetic needle makes with the horizontal in the magnetic meridian.



1. Direction of compass needle is vertical to the earth's surface at poles.
2. Parallel to the earth's surface at equator.

Question 2.
(a) A small compass needle of magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period.

(b) A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of

1. **horizontal component of earth's magnetic field and**
2. **angle of dip at the place.**

Answer:
(a) This is done by placing a small compass needle of known magnetic moment m and moment of inertia I and allowing it to

oscillate in the magnetic field $\vec{B}$.

The torque on the needle is, $\vec{\tau} = \vec{M} \times \vec{B}$
In magnitude $\tau = mB \sin\theta$. Here τ is restoring torque and θ is the angle between m and B.
$\therefore$ In equilibrium, $I\alpha = -mB \sin\theta$ $[\tau = I\alpha]$
where [α is angular acceleration]

$$I \frac{d^2\theta}{dt^2} = -mB \sin\theta \Rightarrow I \frac{d^2\theta}{dt^2} = -mB\,\theta$$

$$\left[\alpha = \frac{d^2\theta}{dt^2}\right]$$

or $$\frac{d^2\theta}{dt^2} = \frac{-mB}{I}\theta$$

This represents a simple harmonic motion.
The square of the angular frequency is $\omega^2 = \frac{mB}{I}$ and the time period is

$$\boxed{T = 2\pi\sqrt{\frac{I}{mB}}}$$

(b) Since, the compass needle is oriented vertically

1. Horizontal component of earth's magnetic field will be zero.
2. The value of angle of dip at that place will be 90°.

Fill in the Blanks

1. A horse-shoe magnet is an example of _____.**(Artificial magnet)**

2. A freely suspended magnet aligns in which direction---------- **(North-south)**

3. Which among the following materials display higher magnetic susceptibility----------**(Ferromagnetic material)**

4. A permanent magnet has the capacity to attract----------**(Only** ferromagnetic substances)

5. The SI unit of magnetic flux is----------**(Weber)**

6. Susceptibility is positive for----------**(Ferromagnetic material)**

7. The magnetic dipole moment of a magnetic dipole is given by the formula _____.**(M = m × 2I)**

Multiple choice questions

1. The earth behaves as a magnet with magnetic field pointing approximately from the geographic
(a) North to South
(b) South to North
(c) East to West
(d) West to East

Answer: b

2. The strength of the earth's magnetic field is
(a) constant everywhere.
(b) zero everywhere.
(c) having very high value.
(d) vary from place to place on the earths surface.

Answer: d

3. Which of the following is responsible for the earth's magnetic field?
(a) Convective currents in earth's core
(б) Diversive current in earth's core.
(c) Rotational motion of earth.
(d) Translational motion of earth.

Answer: a

4. Which of the following independent quantities is not used to specify the earth's magnetic field?
(a) Magnetic declination (θ).
(b) Magnetic dip (δ).
(c) Horizontal component of earth's field (B_H).
(d) Vertical component of earth's field (B_V).

Answer: d

5. Let the magnetic field on earth be modelled by that of a point magnetic dipole at the centre of earth. The angle of dip at a point on the geographical equator is
(a) always zero
(b) positive, negative or zero
(c) unbounded
(d) always negative

Answer: b

6. The angle of dip at a certain place where the horizontal and vertical components of the earth's magnetic field are equal is
(a) 30°
(b) 75°
(c) 60°
(d) 45°

Answer: d

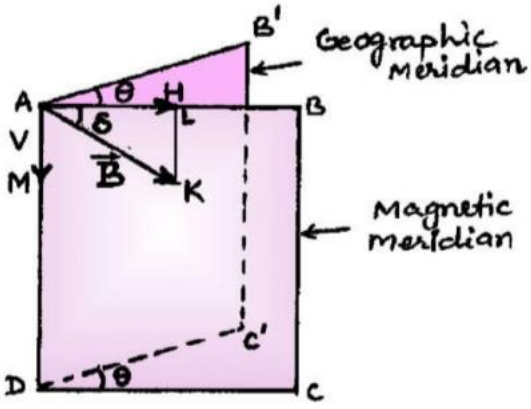
7. The vertical component of earth's magnetic field . at a place is √3 times the horizontal component the value of angle of dip at this place is
(a) 30°
(b) 45°
(c) 60°
(d) 90°

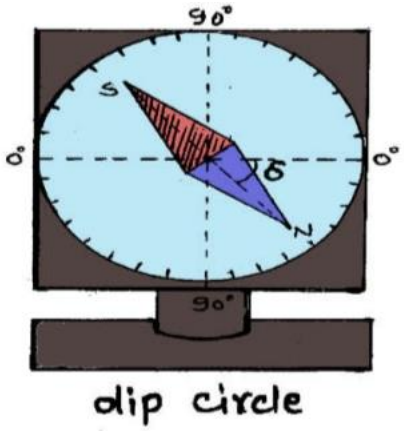
Answer: c

8. At a given place on earth's surface the horizontal component of earth's magnetic field is $2 \times 10^{3-5}$ T and resultant magnetic field is $4 \times 10^{3-5}$ T. The angle of dip at this place is
(a) 30°
(b) 60°
(c) 90°
(d) 45°

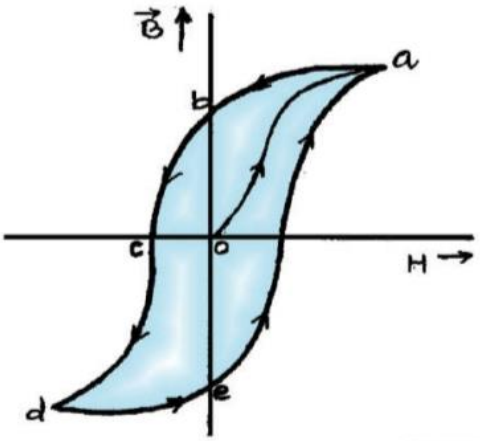
Answer: b

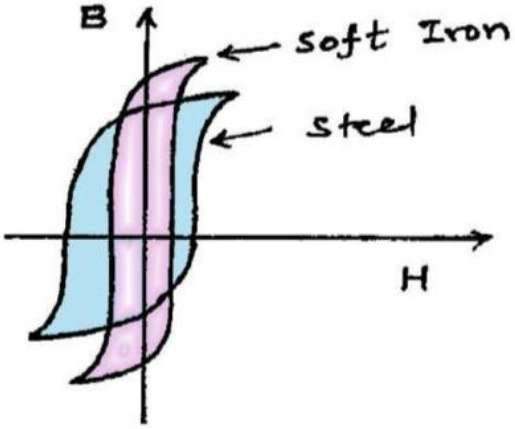
Diagrams

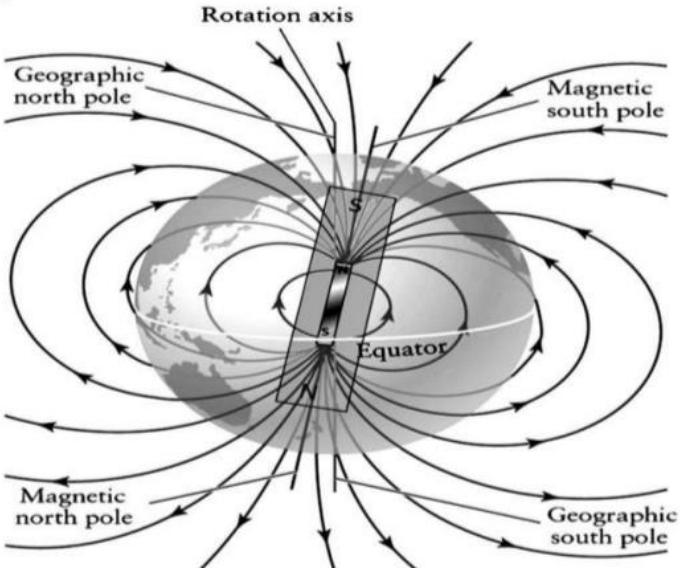




Hysteresis Curve







SUMMARY

- Magnetic materials tend to point in the north – south direction.
- Like magnetic poles repel and unlike ones attract.
- Magnetic poles cannot be isolated.
- When a bar magnet of dipole moment $\vec{m}$ is placed in a uniform magnetic field $\vec{B}$, then,
  a) The force on it is zero
  b) The torque on it is $\vec{m} \times \vec{B}$
  c) Its potential energy is $-\vec{m}.\vec{B}$

  where we choose the zero of energy at the orientation when $\vec{m}$ is perpendicular to $\vec{B}$.
- Consider a bar magnet of size l and magnetic moment $\vec{m}$, at a distance r from its mid – point, where r >>l, the magnetic field $\vec{B}$ due to this bar is,

$$\vec{B} = \frac{\mu_0 \vec{m}}{2\pi r^3} \quad \text{(along axis)}$$

$$= \frac{\mu_0 \vec{m}}{4\pi r^3} \quad \text{(along equator)}$$

- **Gauss's Law for Magnetism:**
  It states that the net magnet flux through any closed surface is zero

$$\phi_B = \sum_{\substack{all\ area \rightarrow \\ elements \Delta s}} \vec{B}.\Delta\vec{S} = 0$$

- **Poles:**
  a) The pole near the geographic north pole of the earth is called the north magnetic pole.
  b) The pole near the geographic south – pole is called the south magnetic pole.
  c) The magnitude of the magnetic field on the earth's surface = 4 x 10^{-5} T.
- **Elements of the Earth's Magnetic Field:**
  Three quantities are needed to specify the magnetic field of the earth on its surface,
  a) The horizontal component
  b) The magnetic declination
  c) The magnetic dip.

  These are known as the elements of the earth's magnetic field.
- **Magnetic Intensity:**
  Consider a material placed in an external magnetic field $\vec{B}_0$. The magnetic intensity is,

$$\vec{H} = \frac{\vec{B}_0}{\mu_0}$$

  If the magnetization $\vec{M}$ of the material is its dipole moment per unit volume, then the magnetic field $\vec{B}$ in the material will be,

$$\vec{B} = \mu_0 (\vec{H} + \vec{M})$$

For a linear material,

$$\vec{M} = \chi \vec{H}$$

So that,

$$\vec{B} = \mu \vec{H}$$

Where χ is the magnetic susceptibility of the material and μ_r is the relative magnetic permeability.

- **Relationship between** $\mu, \mu_0 and \mu_r$ **:**

  The magnetic permeability area, μ is related as,

  $$\mu = \mu_0 \mu_r$$

  $$\mu_r = 1 + \chi$$

- **Classification of Magnetic Materials:**

  Magnetic materials are broadly classified as,

  a) Diamagnetic
  b) Paramagnetic
  c) Ferromagnetic

- **Magnetic Susceptibility of the Material for Magnetic Materials:**

  a) For diamagnetic materials χ is negative and small.
  b) For paramagnetic materials χ is positive and small.
  c) For ferromagnetic materials χ lies between $\vec{B}$ and $\vec{H}$

- **Permanent Magnets:**

  Substances which retain their ferromagnetic property for a long period of time at room temperature are called permanent magnets.