

## Chapter: 8

### Magnetism

#### Short Response Questions

**1. Can two magnetic field lines intersect each other? Justify your answer.**

No, two magnetic field lines cannot intersect each other. If they did, it would mean that the magnetic field has two directions at the same point, which is impossible. A magnetic field at any point has a unique direction, and the lines represent the path along which a magnetic force acts. Therefore, if two lines intersect, it would contradict the definition of a magnetic field.

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**2. A freely suspended magnet always points along north-south direction. Why?**

A freely suspended magnet aligns itself along the north-south direction because of the Earth's magnetic field. The Earth behaves like a giant magnet with a magnetic south pole near the geographic north pole and a magnetic north pole near the geographic south pole. The north pole of the suspended magnet is attracted to the Earth's magnetic south pole, while the south pole of the magnet is attracted to the Earth's magnetic north pole. This alignment minimizes the potential energy, causing the magnet to orient in the north-south direction.

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**3. What is the neutral zone or field-free region of the magnetic field?**

The neutral zone or field-free region in a magnetic field is an area where the magnetic field strength is effectively zero. This can occur when two like poles of a magnet are placed close together, causing their magnetic fields to cancel each other out. It is commonly observed between two magnets that are positioned with like poles facing each other, where the field lines repel each other, creating a region with no magnetic field.

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**4. Is there any material which does not have any magnetic behavior? Justify your answer.**

Yes, some materials do not exhibit any magnetic behavior. These are known as non-magnetic materials. Non-magnetic materials, such as wood, plastic, and rubber, do not have any unpaired electrons or aligned atomic magnetic moments. Therefore, they do not respond to a magnetic field. Their atomic structure does not allow for the creation of a net magnetic field, and as a result, they neither attract nor repel magnets.

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**5. A proton is also a charged particle and spins like an electron. Why its effect is neglected in the study of magnetism?**

Although a proton is a charged particle and spins like an electron, its magnetic effect is generally neglected in the study of magnetism because the proton's magnetic moment is much smaller than that of an electron. Protons are also significantly heavier than electrons, and their motion or spin contributes much less to the magnetic field of a material compared to electrons. The contribution of electron spin and orbital motion is far more significant in generating a material's magnetic properties.

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**6. What is the geomagnetic reversal phenomenon? Explain.**

Geomagnetic reversal refers to the phenomenon where Earth's magnetic field periodically flips, with the magnetic north and south poles switching places. This reversal is not sudden but occurs over thousands of years. The cause is believed to be changes in the movement of molten iron in the Earth's outer core, which generates the magnetic field. The process of geomagnetic reversal is recorded in the alignment of magnetic minerals in rocks, which shows that Earth's magnetic field has reversed many times in the planet's history.

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**7. Why the Earth spins about its geographical axis instead of its magnetic axis? Explain.**

Earth spins around its geographical axis because it is a consequence of the conservation of angular momentum from the formation of the planet. The geographical axis is the line around which Earth rotates due to the initial conditions of Earth's formation and the gravitational forces from the Sun and Moon. The magnetic axis, on the other hand, is determined by the Earth's magnetic field, which is generated by the motion of molten iron in the outer core. These axes are not coincident because the magnetic field is influenced by dynamic processes within the Earth's interior, which differ from the factors governing rotational motion.

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**8. Why the Earth's geographical and magnetic axes are not coincident? Explain.**

The geographical and magnetic axes of Earth are not coincident due to the complex nature of Earth's magnetic field, which is generated by the movement of molten iron in the outer core. The magnetic field is not perfectly aligned with the rotational axis because of irregularities in the flow of these molten materials. This results in the magnetic poles being slightly offset from the geographic poles, with an inclination angle of about  $11.3^\circ$  between the two axes.

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**9. What is the difference between paramagnetic and ferromagnetic materials?**

The primary difference between paramagnetic and ferromagnetic materials lies in their response to a magnetic field. Paramagnetic materials, such as aluminum and tungsten,

are weakly attracted to a magnetic field and do not retain any magnetization once the external field is removed. On the other hand, ferromagnetic materials, like iron, cobalt, and nickel, are strongly attracted to a magnetic field and can retain their magnetization even after the external field is removed, making them permanent magnets.

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### 10. At what factors the strength of the magnetic field of an electromagnet depends?

The strength of the magnetic field of an electromagnet depends on several factors:

1. The amount of current flowing through the coil ( $I$ ) – The greater the current, the stronger the magnetic field.
2. The number of turns of wire in the coil ( $n$ ) – More turns increase the strength of the magnetic field.
3. The permeability of the material around the coil ( $\mu$ ) – Materials with high permeability, like iron, concentrate the magnetic field, increasing its strength.
4. The length of the solenoid ( $L$ ) – A shorter solenoid produces a stronger magnetic field.

The strength of the magnetic field can be calculated using the formula:

$$B = \mu \cdot n \cdot I$$

where  $B$  is the magnetic field strength,  $\mu$  is the permeability,  $n$  is the number of turns per unit length, and  $I$  is the current.

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### 11. Draw magnetic field lines of two solenoids placed near each other i) facing same poles to each other ii) facing opposite poles to each other.

For drawing:

1. **Solenoids facing same poles to each other:** The magnetic field lines will repel each other between the solenoids, creating a weaker field in the space between them.
2. **Solenoids facing opposite poles to each other:** The magnetic field lines will attract each other, resulting in a stronger magnetic field between the solenoids.

The field lines will be bent towards each other in case of opposite poles, while they will curve away from each other when like poles face each other.

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## Long Response Questions

## 1. Define and explain magnetism.

### Definition and Introduction

Magnetism is a physical phenomenon associated with the motion of electric charges. It is responsible for the force that certain materials exert on others. Magnetism arises primarily due to the motion of electrons in atoms, both their orbital motion around the nucleus and their spin around their axis. It can be observed when materials like iron, nickel, and cobalt exhibit magnetic properties.

### Magnetic Field and Its Nature

A magnetic field is a region around a magnet within which it exerts a force on other magnets and magnetic materials. Magnetic fields are visualized using magnetic field lines, which emerge from the north pole and curve back into the south pole. The strength of the field depends on the proximity to the source of the magnetic field. It is measured in tesla (T).

### Example

Earth itself behaves like a giant magnet, with its magnetic poles located near the geographic poles. This field extends far into space, protecting the Earth from solar radiation and cosmic rays.

### Mathematical Derivation

The force  $F$  between two magnetic poles is given by:

$$F = \frac{\mu_0 m_1 m_2}{4\pi r^2}$$

Where:

- $\mu_0$  is the permeability of free space,
- $m_1$  and  $m_2$  are the magnetic pole strengths,
- $r$  is the distance between the poles.

### Applications

Magnetism is used in various applications like electric motors, transformers, and magnetic resonance imaging (MRI) machines, which rely on the principles of magnetism to function.

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## 2. What is the domain theory of magnetism? Explain.

### Definition and Introduction

The domain theory of magnetism explains how magnetism arises in materials. According to this theory, a material is made up of many small regions called magnetic domains, where the magnetic moments (spins of electrons) are aligned in the same direction. In

unmagnetized materials, the domains are randomly oriented, and their magnetic effects cancel out.

### Magnetization Process

When an external magnetic field is applied, the domains align in the direction of the field, resulting in a net magnetization of the material. The more the domains align, the stronger the material's overall magnetic field.

### Diagram and Explanation

In the diagram above:

- (a) shows the random orientation of domains in an unmagnetized material,
- (b) shows the alignment of domains in a magnetized material.

### Mathematical Derivation

The magnetization  $M$  in a material can be defined as:

$$M = \frac{N \cdot m}{V}$$

Where:

- $N$  is the number of aligned magnetic dipoles,
- $m$  is the magnetic moment of each dipole,
- $V$  is the volume of the material.

### Applications

The domain theory helps in understanding permanent magnets and how materials like iron, cobalt, and nickel retain magnetism after being magnetized. This theory is also used to explain phenomena like hysteresis in magnetic materials.

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## 3. Explain magnetic field strength and magnetic shielding.

### Magnetic Field Strength

Magnetic field strength refers to the intensity of the magnetic field at a given point and is measured in tesla (T). It is determined by the number of magnetic field lines passing through a given area. The strength of a magnetic field is influenced by the current passing through a conductor or the magnetic properties of the material.

### Formula for Magnetic Field Strength

For a solenoid, the magnetic field strength  $B$  is given by:

$$B = \mu \cdot n \cdot I$$

Where:

- $B$  is the magnetic field strength,
- $\mu$  is the permeability of the material,
- $n$  is the number of turns per unit length of the solenoid,
- $I$  is the current flowing through the solenoid.

### **Magnetic Shielding**

Magnetic shielding is the process of blocking or reducing the effect of external magnetic fields. This can be achieved by using materials with high magnetic permeability, such as iron or lead. The principle behind shielding is that these materials absorb and redirect magnetic field lines, preventing them from affecting sensitive equipment.

### **Applications**

Magnetic shielding is used in devices such as MRI machines, power transformers, and electronic devices to ensure their proper functioning in a magnetic environment.

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## **4. Explain the magnetic field of a bar magnet and that of a solenoid, also compare them.**

### **Magnetic Field of a Bar Magnet**

A bar magnet has two distinct poles: a north pole (N) and a south pole (S). The magnetic field lines emerge from the north pole and curve toward the south pole. The field is strongest at the poles and weakest at the midpoint. The field can be visualized by placing iron filings around the magnet, which will align along the field lines.

### **Magnetic Field of a Solenoid**

A solenoid is a coil of wire through which current flows. When current passes through the solenoid, it generates a magnetic field that resembles the field of a bar magnet, with well-defined north and south poles. The field inside the solenoid is uniform and parallel, whereas the field outside is similar to the dipolar field of a bar magnet.

### **Comparison**

- The field inside a solenoid is uniform and strong, while the field of a bar magnet is weaker and non-uniform.
- The magnetic field of a solenoid can be varied by changing the current or the number of coils, whereas the magnetic field of a bar magnet is fixed.
- A solenoid's magnetic field can be concentrated with a ferromagnetic core, such as iron, while a bar magnet cannot be adjusted similarly.

### Applications

Solenoids are widely used in electromagnets, electric motors, and transformers, while bar magnets are used in compasses and magnetic storage devices.

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### 5. Define induced magnetism. Also explain some of the methods for induced magnetism.

#### Definition of Induced Magnetism

Induced magnetism refers to the phenomenon where a material that is not magnetized becomes a magnet when exposed to a magnetic field. This occurs due to the alignment of magnetic domains within the material when placed in an external magnetic field.

#### Methods for Induced Magnetism

3. **Stroking Method:** A permanent magnet is stroked along a metal bar, aligning the domains in the bar in the direction of the magnet. After stroking, the bar becomes magnetized.
4. **Hammering Method:** A metal bar is placed in a magnetic field and gently hammered. The external field causes the domains in the metal to align, magnetizing the bar.
5. **Heating Method:** Heat can be used to demagnetize a material. When a material is heated, the movement of domains is increased, causing misalignment and reducing magnetization. However, some materials can become magnetized due to heating, a phenomenon known as thermo-magnetism.

### Applications

Induced magnetism is commonly used in the manufacturing of temporary magnets and electromagnets. It is also a key principle behind the operation of devices such as electric motors and transformers.

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