CHAPTER

5 MAGNETISM AND MATTER

Syllabus

- *Current loop as a magnetic dipole and its magnetic dipole moment, magnetic dipole moment of a revolving electron, bar magnet as an equivalent solenoid, magnetic field lines; earth's magnetic field and magnetic elements.*

Revision Notes

Magnetic Dipole

Current loop as a magnetic dipole and its magnetic dipole moment

- Magnetic dipole is a small magnet of microscopic dimensions similar to flow of electric charge around a loop.
- Magnetic dipole moment is the strength of magnetic dipole that measures dipole's ability to align itself with external magnetic field.
- Magnetic dipole moment, known as magnetic moment, is the maximum amount of torque generated by magnetic force on dipole which appears per unit value of surrounding magnetic field in vacuum.
- Magnetic field produced at large distance *r* from the centre of circular loop along its axis will be

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

where, I = Current in the loop, A = Area

- Magnetic moment of current loop is the product of current and loop area,

$$M = I \times A$$

- A current loop may experience a torque in a constant magnetic field,

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

Magnetic dipole moment of revolving electron

- For an electron of charge e revolving around a nucleus of charge Ze at an orbit of radius r, with velocity v and magnetic moment μ_1, the orbital magnetic moment will be

$$\mu_1 = -\frac{em_e vr}{2m_e}$$

But angular momentum of electron,

$$L = m_e vr$$

Magnetism & Matter

Trace the Mind Map
- First Level
- Second Level
- Third Level

Dipole moment

- **Circular Loop**: Current loop of area $A = \pi r^2$ carrying current i may be replaced by a magnetic dipole of dipole moment, $\mu = md = iA$
- **Revolving electron**:
  - $|\vec{\mu}| = iA = \frac{ev}{2\pi r} \times \pi r^2$
  - $= evr/2$
  - $\vec{\mu} = \frac{-e}{2m_e}\vec{L}$
  - $\mu = md$
  - m = Magnetic charge or pole strength
  - d = Separation between poles
  - r = Radius of circular orbit
  - e = Charge on electron
  - v = Speed of electron;
  - L = Angular momentum
  - m_e = Mass of electron
- **Solenoid**:
  - $\mu = NIA$,
  - N = Number of turns
  - I = Current
  - A = Area

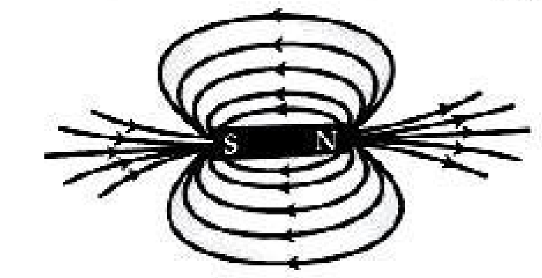
Earth's magnetic field

Earth is a natural source of magnetic field having geometric north and geometric south pole

- **Declination**: Angle between magnetic meridian and geographical meridian.
- **Inclination or dip (δ)**: Angle made by Earth's magnetic field with horizontal in the magnetic direction, $\delta_{equator} = 0$, $\delta_{pole} = 90°$
- **Horizontal component**:
  - $B_H = B\cos\theta$
  - B_H (at pole) = 0
  - B_H (at equator) is maximum

Magnetic field lines

Continuous imaginary lines which represent the direction of magnetic field.



Magnetic substance

- **Para-magnetism**: Tendency to increase the magnetic field due to magnetization, *e.g. Al, Mn* (c_m low and $-ve$, $\mu_r > 1$)
- **Diamagnetism**: Tendency of strong magnetization in the direction of magnetic field. *e.g. Fe, Co, Ni*, ($\mu_r, \chi_m >> 1$)
- **Ferromagnetism**: Tendency to magnetise in a direction opposite to direction of magnetic field *e.g. Bi, Cu, Hg, Ni.* ($\mu_r, \chi_m < 1$)

Electromagnets

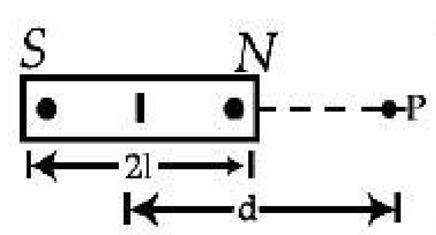
Magnet in which the magnetic field is produced by an electric current. Magnetic field disappears when current is turned off.

Magnetic terms

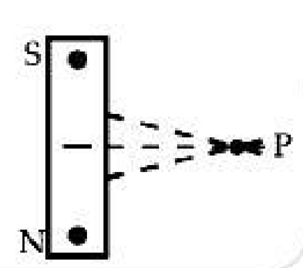
- **Magnetic intensity**: $H = \frac{B_0}{\mu}$
- **Magnetic permeability**: $\mu = \mu_0(1 + c_m)$
- **Magnetic Susceptibility**: $\chi = \frac{I}{H}$
- **Intensity of magnetization**: $I = \frac{M}{V}$
- **Time period oscillating bar magnet**: $T = 2\pi\sqrt{\frac{I}{MB}}$

Bar magnet

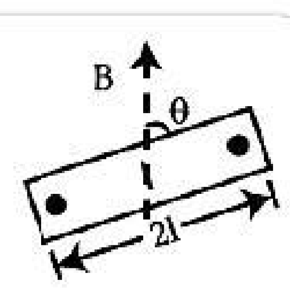
- **Magnetic field intensity**
  - End–on–position
    - $= \frac{\mu_0}{4\pi}\frac{2M}{d^3}$
    - $M = 2ml$
    - $d >>> l$



  - Broadside Position,
    - $B = \frac{\mu_0}{4\pi}\frac{M}{(d^2 + l^2)^{3/2}}$
    - For $d >>> l$,
    - $B = \mu_0 M / 4\pi d^3$



- **Potential energy of a Field-Magnet System**: $U_\theta = U_\theta - U_{90°} = -MB\cos\theta = -\vec{M}.\vec{B}$ we take P.E. at θ = 90° to be zero
- **Torque**:
  - $\vec{\tau} = \vec{M} \times \vec{B} = MB\sin\theta$
  - $M = 2ml$
  - B = Magnetic field



$$\therefore \qquad \mu_l = -\frac{e}{2m_e}L$$

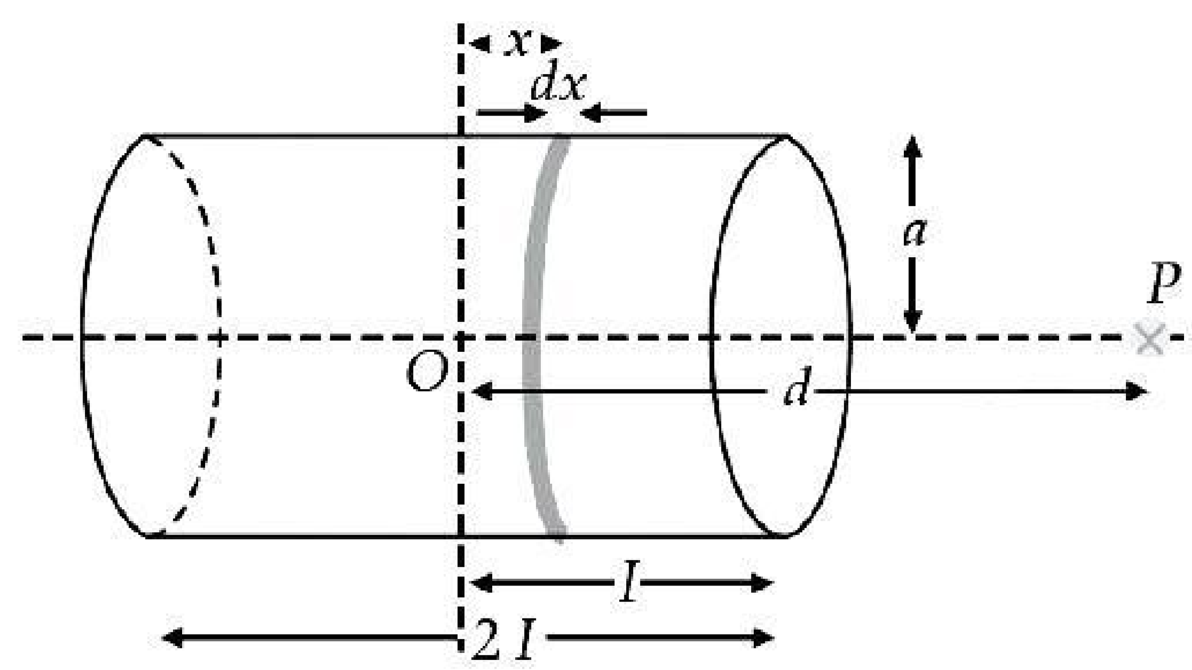
Here (–) sign shows that angular momentum's direction is opposite to the magnetic moment's direction.

Magnetic field of a Solenoid, Earth's Magnetism & Magnetic properties of Materials

Bar magnet as an equivalent solenoid

- If a solenoid of length $2l$, radius a with current I having n number of turns per unit length, then the magnetic moment of solenoid,

$$M\ (= NIA),\ B = \frac{\mu_0 2M}{4\pi d^3}$$



- Magnetic moment of a bar magnet is equal to magnetic moment of an equivalent solenoid that produces same magnetic field.

Gauss' Law for Magnetic Fields

- Gauss' Law for magnetism applies to the magnetic flux through a closed surface.
- It shows that no magnetic monopoles exist and total flux through closed surface will be zero.
- The Gauss's law for magnetic fields in integral form is given by

$$\phi = \int \vec{B}.\vec{dA} = 0$$

Earth's Magnetism

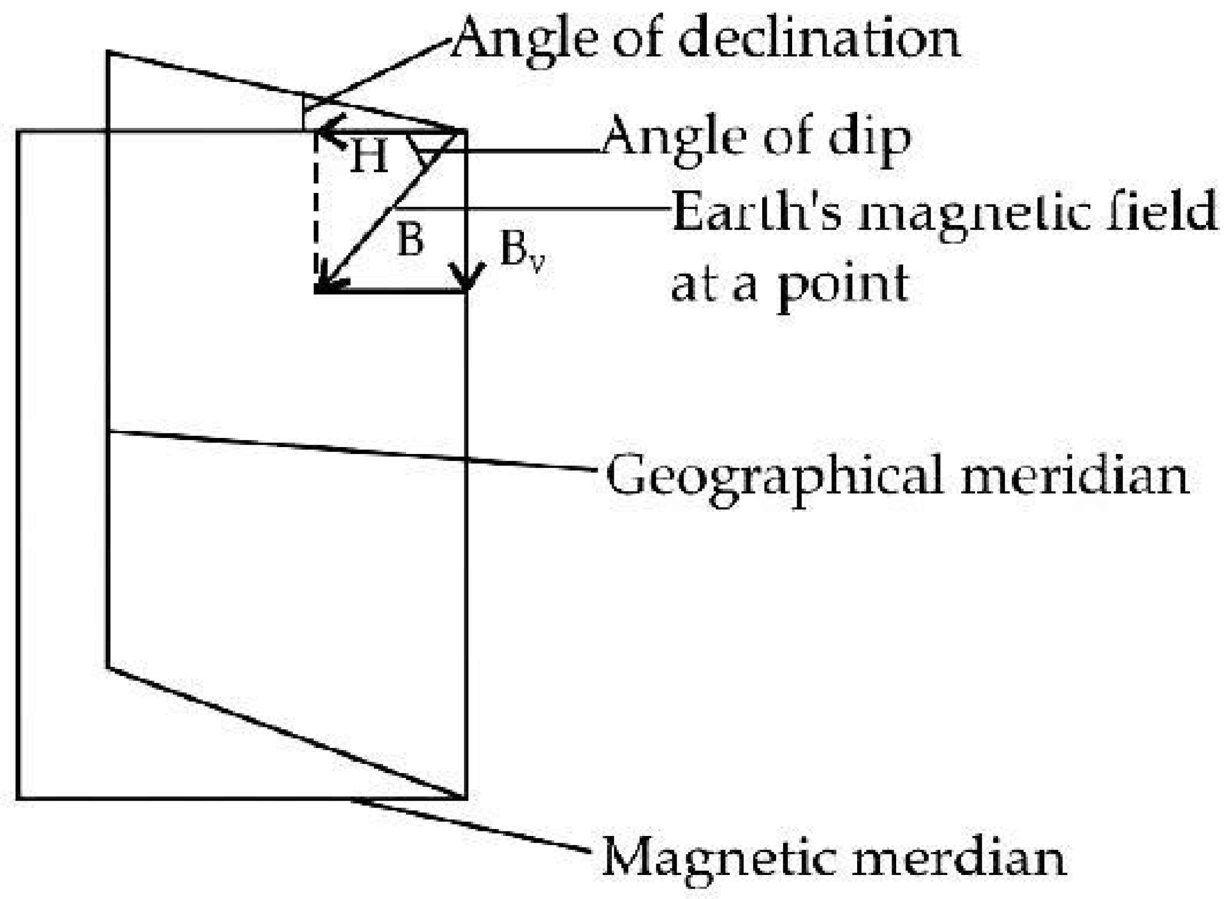
- Earth shows magnetic properties. This is evident from the following facts:
  - A freely suspended needle stays in north - south direction.
  - Availability of neutral points. At neutral points, magnetic field due to suspended magnet is equal and opposite to the horizontal component of Earth's magnetic field.
- The source of Earth's magnetism is still undefined, though certain theories have good scientific justifications like ions revolving with Earth.

Characteristics of Earth's Magnetism

- Earth's south pole and north pole are defined by Sun's direction. These are known as geographical north and south poles. Magnetic north and south poles are the points where the magnetic needle becomes perpendicular to earth's surface. Hence, there are two systems of directions.
- Due to two systems of directions, we can draw two meridians. (Plane joining geographic North and South pole is geographic meridian and plane joining magnetic North and South pole is magnetic meridian)

Elements of earth's magnetic field

- **Angle of Declination:** At any place on Earth, the acute angle between magnetic meridian and the geographical meridian is called the angle of declination.
- **Angle of Dip:** The angle of dip at any place is the angle between Earth's magnetic field intensity B with horizontal in the magnetic meridian at that place.



- **Horizontal Component of Earth's Magnetic field:** The horizontal component of Earth's magnetic field H is in the horizontal direction in the magnetic meridian.

$$B_H \text{ or } H = B\cos\theta$$
$$B_V = B\sin\theta$$

Where θ is angle of Dip, $$\tan\theta = \frac{B_V}{B_H}$$

We find the earth's magnetic field B at any place by measuring its horizontal component. Hence,

$$B = \frac{H}{\cos\theta} \text{ and } B_V = H\tan\theta$$

- There is variation in magnetic field between place to place depending upon angle of Dip, angle of declination and horizontal component of Earth, Hence, these are known as elements of Earth's magnetic field.

Mnemonics

Concept: Four characteristics of magnetic field lines:

Mnemonics: **I** love **new** stories Tina found new **Cookies.**

Interpretation:

(i) **I**maginary Lines

(ii) **E**xtended North to South pole

(iii) **T**angent gives (magnetic) field direction

(iv) **N**ever Cross each other

Know the Formulae

- Magnetic field due to short dipole at distance '*d*' on axial line:

$$B_{axial} = \frac{\mu_0 2M}{4\pi d^3}$$

- Magnetic field due to short dipole at distance '*d*' on equatorial line:

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

STAND ALONE MCQs (1 Mark each)

Q. 1. A toroid of n turns, mean radius R and cross-sectional radius a carries current I. It is placed on a horizontal table taken as x-y plane. Its magnetic moment m

(A) is non-zero and points in the z-direction by symmetry.

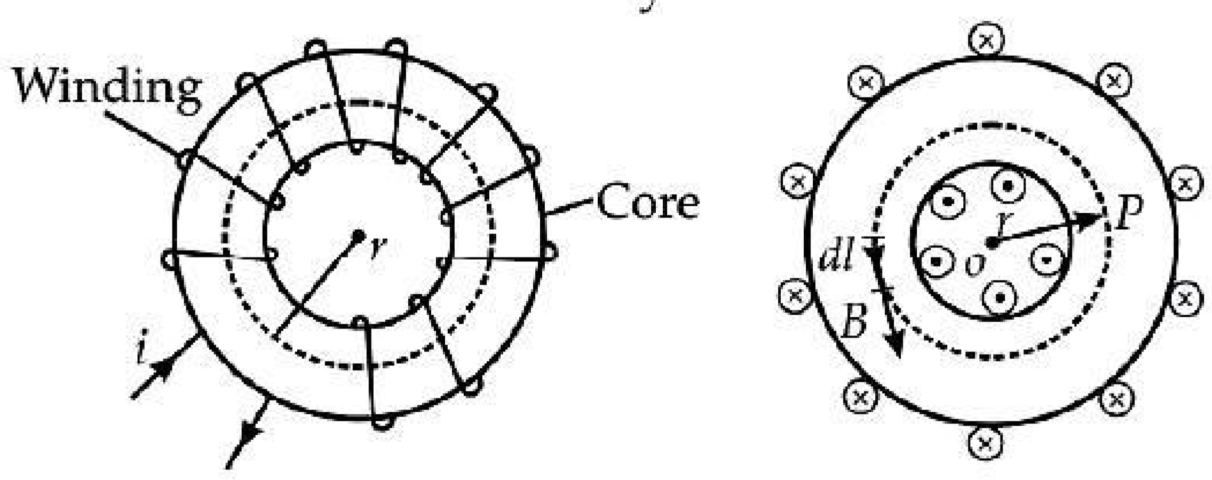
(B) points along the axis of the toroid ($m = m_\phi$).

(C) is zero, otherwise there would be a field falling as $\frac{1}{r^3}$ at large distances outside the toroid.

(D) is pointing radially outwards.

Ans. Option (C) is correct.

Explanation: As we know that a toroid can be considered as a ring shaped closed solenoid. So that it is like an endless cylindrical solenoid.



So, the magnetic field is only confined inside the body of a toroid in the form of concentric magnetic lines of force.

For any point inside, the empty space surrounded by toroid and outside the toroid, the magnetic field B is zero because the net current enclosed in these spaces is zero. So that, the magnetic moment of toroid is zero. In general, if we take **r** as a long distance outside the toroid, the $m \propto \frac{1}{r^3}$ but this case is not possible here.

Q. 2. Consider the two idealized systems : (i) a parallel plate capacitor with large plates and small separation and (ii) a long solenoid of length L, R, radius of cross-section. In (i), E is ideally treated as a constant between plates and zero outside. In (ii), magnetic field is constant inside the solenoid and zero outside. These idealized assumptions, however, contradict fundamental laws as below :

(A) Case (i) contradicts Gauss's law for electrostatic fields.

(B) Case (ii) contradicts Gauss's law for magnetic fields.

(C) Case (i) agrees with $\oint_s E.dl = 0$

(D) Case (ii) contradicts $\oint H.dl = I_{en}$

Ans. Option (B) is correct.

Explanation: According to Gauss's law of electrostatic field,

$$\oint E.ds = \frac{q}{\varepsilon_0}$$

So it does not contradict for electrostatic field as the electric field lines do not form continuous path.

According to Gauss's law of magnetic field, $\oint B.ds = 0$

It is clear that it contradicts for magnetic field because there is magnetic field inside the solenoid, and no field outside the solenoid carrying current, but the magnetic field lines form the closed paths.

Q. 3. A rod of length L, along east-west direction is dropped from a height H. If B be the magnetic field due to Earth at that place and angle of dip is θ, then the magnitude of the induced e.m.f. across two ends of the rod when the rod reachs the Earth is

(A) BLH cos θ (B) BL cos θ × $(2gH)^{1/2}$

(C) BL cos θ / $(2gH)^{1/2}$ (D) None of the above

Ans. Option (B) is correct.

Explanation: Horizontal component of magnetic field = B cos θ

Velocity of the rod = $(2\ gH)^{1/2}$

Induced e.m.f. = BLv = BL cos θ × $(2\ gH)^{1/2}$

Q. 4. A coil of N turns and radius R carries a current I. It is unwound and rewound to make a square coil of side a having same number of turns (N). Keeping the current I same, the ratio of the magnetic moments of the circular coil and the square coil is

(A) $\pi\frac{R^2}{a^2}$ (B) $\pi\frac{a^2}{R^2}$

(C) $\frac{R^2}{a^2}$ (D) None of the above

Ans. Option (A) is correct.

Explanation: $\frac{M_{square}}{M_{circular}} = \frac{NIA_{square}}{NIA_{circular}} = \pi R^2 / a^2$

Q. 5. A magnetic dipole moment is a vector quantity directed from:

(A) South to North (B) North to South

(C) East to West (D) West to East

Ans. Option (A) is correct.

Explanation: Magnetic dipole moment vector is directed from South pole to north pole.

Q. 6. Time period of oscillation of a magnetic needle is

(A) $T = \sqrt{\frac{I}{MB}}$ (B) $T = 2\pi\sqrt{\frac{I}{MB}}$

(C) $T = 2\pi\sqrt{\frac{MB}{I}}$ (D) $T = \pi\sqrt{\frac{MB}{I}}$

Ans. Option (B) is correct.

Explanation: Time period of oscillation of a magnetic needle is $T = 2\pi\sqrt{\frac{I}{MB}}$

Q. 7. A magnetic needle is kept in a non-uniform magnetic field experiences

(A) a force as well as a torque

(B) a torque but not a force

(C) a force and a torque

(D) a force but not a torque

Ans. Option (A) is correct.

> *Explanation:* Field being non-uniform, the poles of the needle will experience non-uniform forces. Hence, the needle experiences a force as well as a torque.

Q. 8. The magnetic field of Earth can be modelled by that of a point dipole placed at the centre of the Earth. The dipole axis makes an angle of 11.3° with the axis of Earth. At Mumbai, declination is nearly zero. Then,

(A) the declination varies between 11.3° W to 11.3° E.

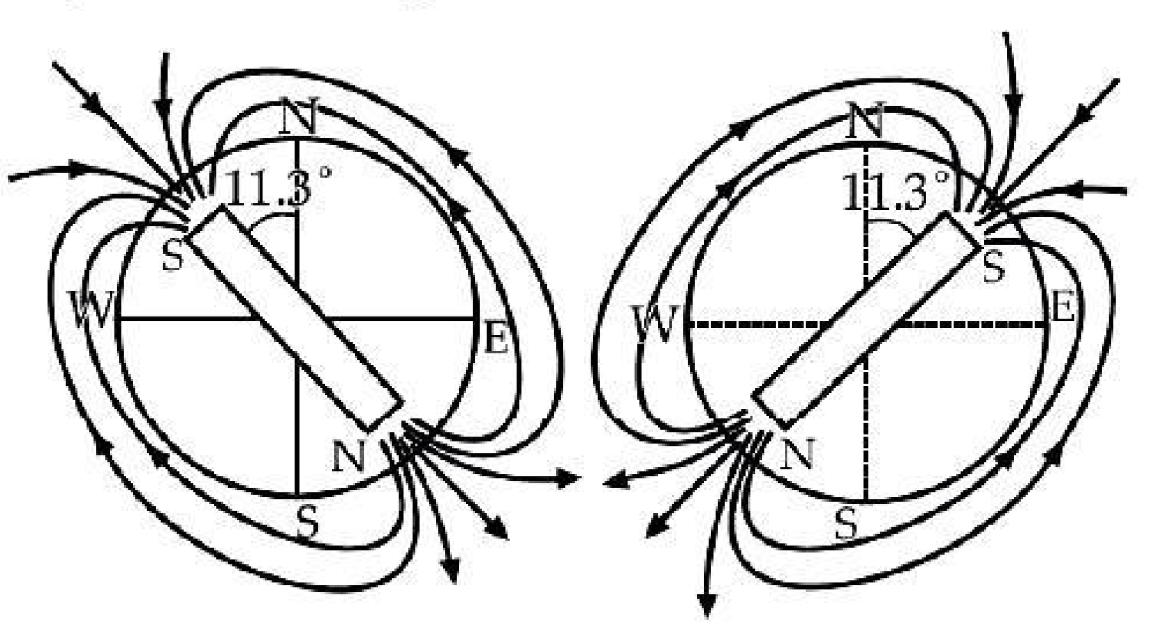
(B) the least declination is 0°.

(C) the plane defined by dipole axis and Earth axis passes through Greenwich.

(D) declination averaged over Earth must be always negative.

Ans. Option (A) is correct.

> *Explanation:* The magnetic field lines of the Earth resemble that of a hypothetical magnetic dipole located at the centre of the Earth.
> The axis of the dipole does not coincide with the axis of rotation of the Earth and it is tilted at some angle (angle of declination).
> In this situation, the angle of declination is approximately 11.3° with respect to the later. So, there is two possibilities arises as shown :



> So that the declination varies between 11.3° W to 11.3° E.

Q. 9. 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

(A) is always zero.

(B) is always positive

(C) is always negative

(D) can be positive or negative or zero.

Ans. Option (D) is correct.

> *Explanation:* Angle of inclination or dip is the angle between the direction of intensity of total magnetic field of the Earth and a horizontal line in the magnetic meridian.
> If the total magnetic field of the Earth is modelled by a point magnetic dipole at the centre, then it is in the same plane of geographical equator, thus the angle of dip on the geographical equator will be different at different points. It may be positive or negative or may be zero at some points.

Q. 10. Relative permeability of a magnetic material is 0.5. The material is

(A) diamagnetic.

(B) ferromagnetic.

(C) paramagnetic.

(D) not a magnetic material.

Ans. Option (A) is correct.

> *Explanation:* Relative permeability of diamagnetic magnetic material is less than 1.

Q. 11. Which of the following relation is correct?

(A) $B = B_V \times B_H$ **(B)** $B = B_V / B_H$

(C) $B = B_V + B_H$ **(D)** $B = \sqrt{B_V^2 + B_H^2}$

Ans. Option (D) is correct.

> *Explanation:* $B_H = B \cos \theta$
> $B_V = B \sin \delta$
> $\therefore \quad B = \sqrt{B_V^2 + B_H^2}$

Q. 12. Ratio of total intensity of magnetic field at equator to poles is

(A) 1:1 **(B)** 1:2

(C) 2:1 **(D)** None of the above

Ans. Option (A) is correct.

> *Explanation:* $B_H = B \cos \theta$
> $B_V = B \sin \delta$
> At equator, $\delta = 0°$.
> So, $B_H = B, B_V = 90°$
> At poles, $\delta = 90°$.
> So, $B_H = B, B_V = B$
> So, the ratio of total intensity of magnetic field at equator to poles is 1 : 1.

Q. 13. Which of the following is most suitable for the core of an electromagnet?

(A) Soft iron **(B)** Steel

(C) Alnico **(D)** Copper

Ans. Option (A) is correct.

> *Explanation:* Soft Iron gets magnetized faster but loses its magnetism as soon as the current stops flowing in solenoid. Hence soft iron is said to have high susceptibility but low retentivity. This property of soft iron makes it suitable for core of electromagnets where we need strong but temporary magnetism as long as current is flowing.

Q. 14. A ferromagnetic substance is heated above its curie temperature. Which of the following statements is correct?

(A) Ferromagnetic domains get perfectly arranged.
(B) Ferromagnetic domains get randomly arranged.
(C) Ferromagnetic domains are not at all influenced.
(D) Ferromagnetic material transforms into diamagnetic substance.

Ans. Option (B) is correct.

> *Explanation:* On heating above Curie temperature, Ferromagnetic domains get randomly arranged and it transforms into paramagnetic substance.

ASSERTION AND REASON BASED MCQs (1 Mark each)

Directions : In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.

(A) Both A and R are true and R is the correct explanation of A
(B) Both A and R are true but R is NOT the correct explanation of A
(C) A is true but R is false
(D) A is false and R is true

Q. 1. Assertion (A): The magnetic field configuration with 3 poles is not possible.

Reason (R): No torque acts on a bar magnet itself due to its own field.

Ans. Option (B) is correct.

> *Explanation:* Magnetic poles exist in pairs. So assertion is true.
> The bar magnet does not exert a torque on itself in its own magnetic field. Torque is proportional to cross product of $\vec{M}$ and $\vec{B}$. The angle between $\vec{M}$ and $\vec{B}$ being 0, the cross product is 0. So, there will be no torque. So reason is also true.
> But R cannot explain A.

Q. 2. Assertion (A): Magnetic poles cannot be separated by breaking a bar magnet into two pieces.

Reason (R): When a magnet is broken into two pieces, the magnetic moment will be reduced to half.

Ans. Option (B) is correct.

> *Explanation:* Magnetic poles always exist in pairs even in atomic level. So assertion is true.
> When a magnet is broken into two pieces, the pole strength remains same; only the length becomes half. So, the magnetic moment becomes half. So, the reason is also true.
> But R is not the proper explanation of A.

Q. 3. Assertion (A): The basic difference between magnetic lines of force and electric lines of force is electric lines of force are discontinuous and magnetic lines of force are continuous.

Reason (R): Magnetic lines of force exist in a magnet but no electric lines of force exist in a charged body.

Ans. Option (A) is correct.

> *Explanation:* Let us consider an electric dipole. The electric lines of force exist outside only and not inside the dipole.
>
> Let us take a magnetic dipole. The magnetic lines of force exist outside as well as inside the dipole.
>
> So, it can be said that magnetic lines of force are continuous and electric lines of force are discontinuous.
>
> So assertion and reason both are true and reason explains the assertion too.

Q. 4. Assertion (A): Gauss theorem is not applicable in magnetism.

Reason (R): Magnetic monopole does not exist.

Ans. Option (A) is correct.

Explanation: Gauss's theorem of magnetism is different from that for electrostatics because electric charges may not exist in pair but magnetic poles always exist in pair. So assertion is true.

Magnetic monopole does not exist. Magnetic poles always exist in pair. So reason is also true and reason clearly explains the assertion.

Q. 5. Assertion (A): A compass needle when placed at Earth's magnetic pole rotates in vertical plane.

Reason (R): The Earth has only horizontal component of its magnetic field at the poles.

Ans. Option (D) is correct.

Explanation: Magnetic needle can rotate in horizontal plane only. But at poles, there is no horizontal component of Earth's magnetic field. So, the needle will remain horizontal and will point in any direction. Hence the assertion is false.

At poles, Earth has only vertical components of its magnetic field. Hence, the reason is also false.

Q. 6. Assertion (A): Compass needle points the magnetic north-south direction.

Reason (R): The magnetic meridian of the earth merges with the axis of rotation of earth.

Ans. Option (D) is correct.

Explanation: Compass needle points the magnetic north-south direction. So the assertion is true.

Earth's magnetic meridian is along its axis through magnetic north-south direction. Earth's axis of rotation is along its geographic north-south direction. The angle between these two axes is 11.3°. Hence, the reason is also false.

Q. 7. Assertion (A): Ferromagnetic substances become paramagnetic beyond Curie temperature.

Reason (R): Domains are destroyed at high temperature.

Ans. Option (A) is correct.

Explanation: From Curie Weiss law,

$$\chi = \frac{C}{T - T_C}$$

As temperature increases beyond Curie temperature, susceptibility decreases and the ferromagnetic substances become paramagnetic. So, the assertion is true.

Paramagnetic substance has no magnetic domain. At a very high temperature, the domains of ferromagnetic substance get destroyed and the substance transforms into paramagnetic substance. So, the reason is also true and properly explains the assertion.

Q. 8. Assertion (A): Gauss's law of magnetism is different from Gauss's law of electrostatics.

Reason (R): Isolated electric charge can exist but isolated magnetic pole cannot exist.

Ans. Option (A) is correct.

Explanation: In electrostatics, Gauss's law:

$$- \int \vec{E}.d\vec{A} = \frac{q}{\varepsilon_0}$$

Gauss's law of magnetism:

$$\int \vec{B}.d\vec{A} = 0$$

Gauss's law of magnetism is different from Gauss's law of electrostatics. Hence, the assertion is true.

Electric charge may or may not exist in pair. But magnetic poles always exist in pair. No magnetic monopole exists. This is the reason why Gauss's law of magnetism is different from Gauss's law of electrostatics. So, the reason is also true and explains the assertion.

CASE-BASED MCQs

Attempt any 4 sub-parts out of 5. Each sub-part carries 1 mark.

I. Read the following text and answer the following questions on the basis of the same:

Earth's magnetism: Earth's magnetic field is caused by a dynamo effect. The effect works in the same way as a dynamo light on a bicycle. Magnets in the dynamo start spinning when the bicycle is pedaled, creating an electric current. The electricity is then used to turn on the light. This process also works in reverse. If you have a rotating electric current, it will create a magnetic field. On Earth, flowing of liquid metal in the outer core of the planet generates electric currents. The rotation of Earth on its axis causes these electric currents to form a magnetic field which extends around the planet. The average magnetic field strength in the

Earth's outer core was measured to be 25 Gauss, 50 times stronger than the magnetic field at the surface. The magnetic field is extremely important for sustaining life on Earth. Without it, we would be exposed to high amounts of radiation from the Sun and our atmosphere would be free to leak into space. This is likely what happened to the atmosphere on Mars. As Mars doesn't have flowing liquid metal in its core, it doesn't produce the same dynamo effect. This left the planet with a very weak magnetic field, allowing for its atmosphere to be stripped away by solar winds, leaving it uninhabitable. Based upon the study of lava flows throughout the world, it has been proposed that the Earth's magnetic field reverses at an average interval of approximately 300,000 years. However, the last such event occurred some 780,000 years ago.

Q. 1. Which of the followings is the reason for Earth's magnetism ?

(A) Rotation of electric current

(B) Rotation of Earth

(C) Attraction due to other celestial bodies

(D) Solar flares

Ans. Option (A) is correct.

> ***Explanation:*** On Earth, flowing of liquid metal in the outer core of the planet generates electric currents. The rotation of Earth on its axis causes these electric currents to form a magnetic field which extends around the planet.

Q. 2. Electric current in the Earth's body is generated due to:

(A) movement of charged particle in the atmosphere.

(B) flowing of liquid metal in the outer core.

(C) electric discharges during thunderstorm.

(D) its revolution round the Sun.

Ans. Option (A) is correct.

> ***Explanation:*** On Earth, flowing of liquid metal in the outer core of the planet generates electric currents.

Q. 3. Which planet has no own magnetic field ?

(A) Jupiter **(B)** Neptune

(C) Mars **(D)** Mercury

Ans. Option (C) is correct.

> ***Explanation:*** As Mars doesn't have flowing liquid metal in its core, it doesn't produce dynamo effect. So, it has very weak or almost no magnetic field.

Q. 4. Average magnetic field strength in the Earth's outer core is:

(A) 5 Gauss **(B)** 25 Gauss

(C) 500 Gauss **(D)** Cannot be measured

Ans. Option (B) is correct.

> ***Explanation:*** The average magnetic field strength in the Earth's outer core was measured to be 25 Gauss.

Q. 5. Which of the following statements is true ?

(A) Earth's magnetic field is due to electric current induced in the ionosphere.

(B) The average magnetic field strength in the Earth's outer core is equal to the magnetic field at the surface.

(C) Earth's magnetic field reverses at an average interval of approximately 3,00,000 years.

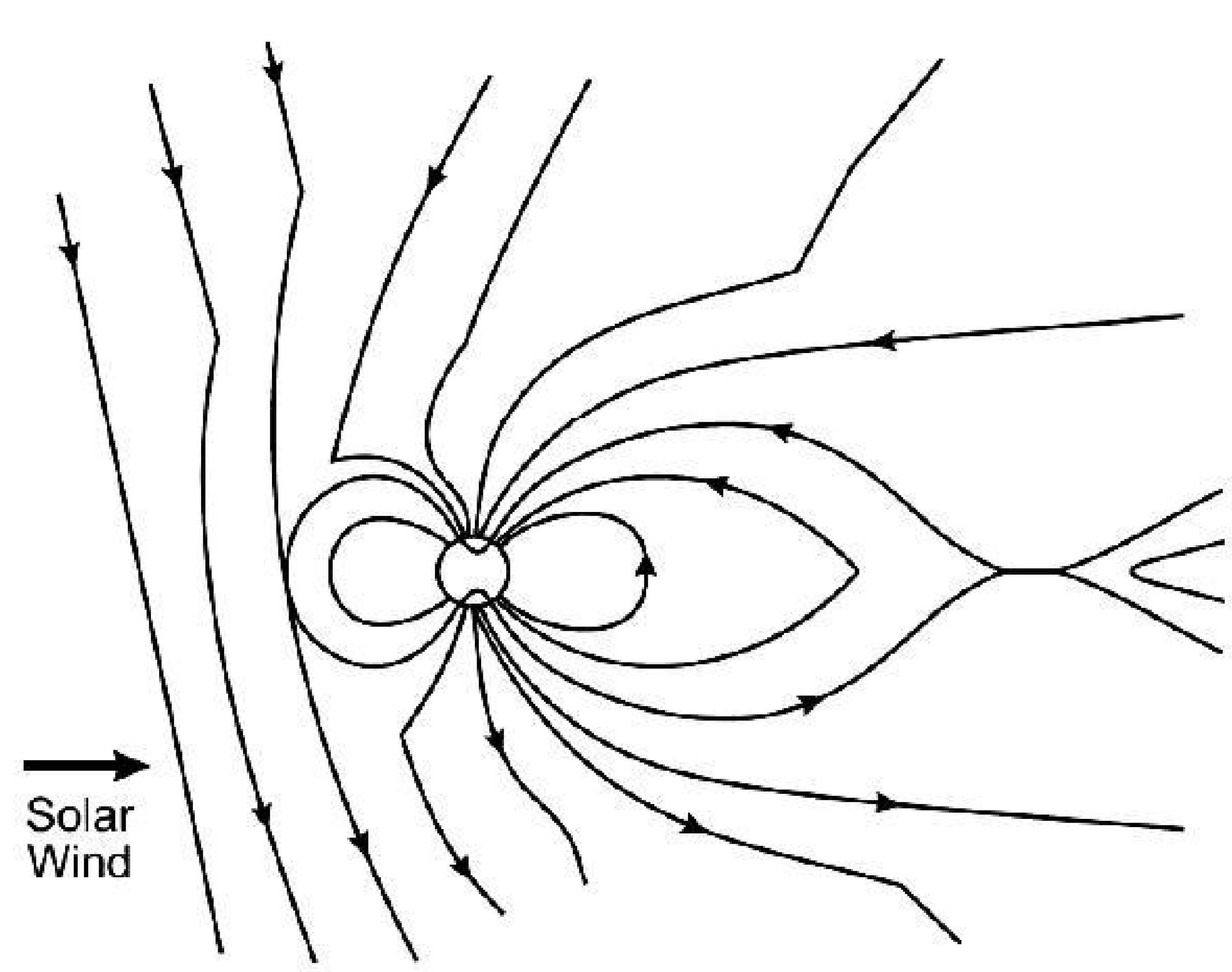
(D) Angle of dip is same at every point of the surface of Earth.

Ans. Option (C) is correct.

> ***Explanation:*** Based upon the study of lava flows throughout the world, it has been proposed that the Earth's magnetic field reverses at an average interval of approximately 300,000 years.

II. Read the following text and answer the following questions on the basis of the same:

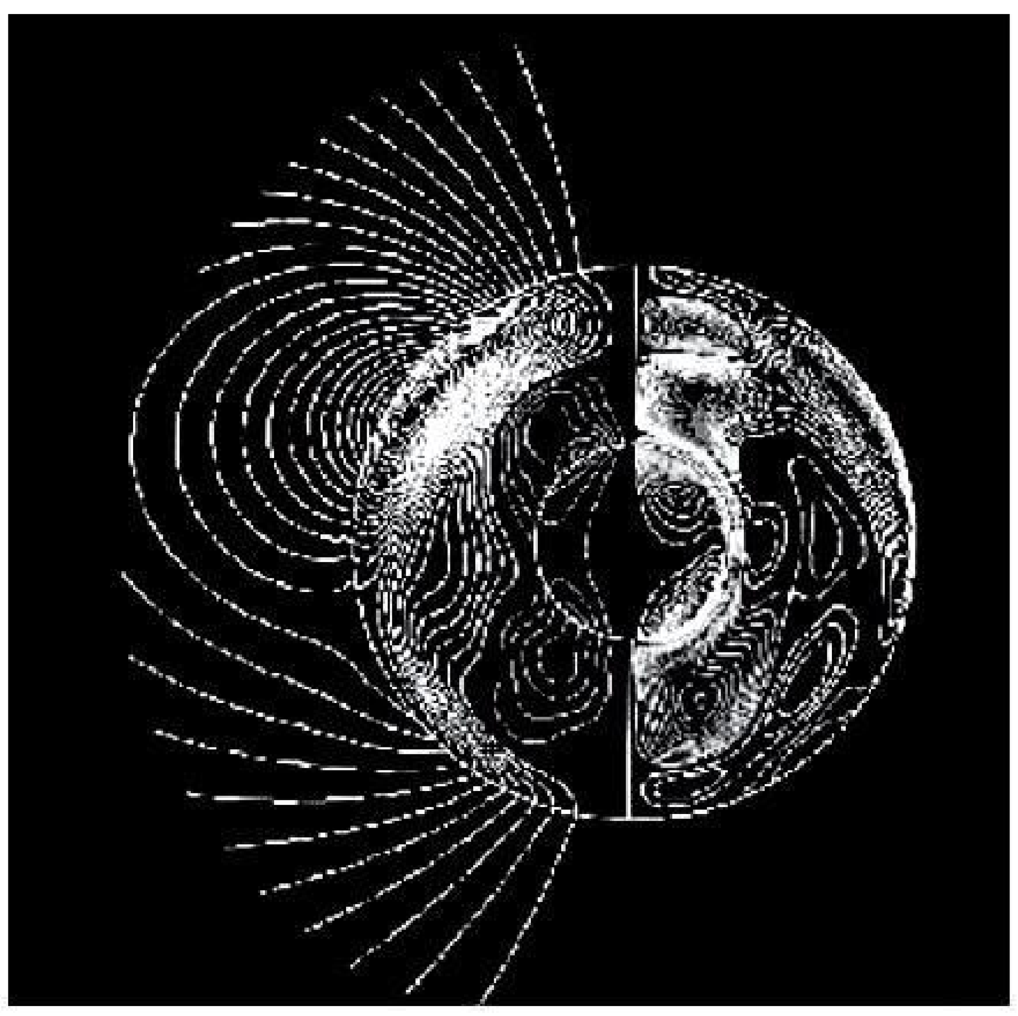
If we move into space and study the Earth's invisible magnetic field, it wouldn't really look like a bar magnet at all. Earth's magnetic field gets stretched out into a comet-like shape with a tail of magnetism that stretches millions of miles behind the earth, opposite to the Sun. The Sun has a wind of gas that pushes the earths field from the left to the right in the picture.



The core of the Earth is an electromagnet. Although the crust is solid, the core of the Earth is surrounded by a mixture of molten iron and nickle.

The magnetic field of Earth is caused by currents of electricity that flow in the molten core. These currents are hundreds of miles wide and flow at thousands of miles per hour as the Earth rotates. The powerful magnetic field passes out through the core of the Earth, passes through the crust and enters space. This picture shows the solid inner core region (inner circle) surrounded by a molten outer core (the area between the two circles). The currents flow in the outer core, travel outwards through the rest of the earth's interior.

If the Earth rotated faster, it would have a stronger magnetic field.



By the time the field has reached the surface of Earth, it has weakened a lot, but it is still strong enough to keep your compass needles pointed towards one of its poles. All magnets have two poles: a North Pole and a South Pole. The magnetic poles of earth are not fixed on the surface, but wander quite a bit. The pole in the Northern Hemisphere seems to be moving northwards in geographic latitude by about 10 kilometres per year by an average.

Q. 1. Earth's magnetic field has a:

(A) shape of the magnetic field of a bar magnet.
(B) shape of the magnetic field of a horseshoe magnet.
(C) shape of a sphere.
(D) None of the above

Ans. Option (D) is correct.

> *Explanation:* Earth's magnetic field gets stretched out into a comet-like shape with a tail of magnetism that stretches millions of miles behind the Earth, opposite from the Sun.

Q. 2. Core of the Earth is:

(A) an electromagnet. **(B)** a permanent magnet.
(C) a unipolar magnet. **(D)** None of these

Ans. Option (A) is correct.

> *Explanation:* The core of the Earth is an electromagnet. Although the crust is solid, the core of the Earth is surrounded by a mixture of molten iron and nickle. The magnetic field of Earth is caused by currents of electricity that flow in the molten core.

Q. 3. The magnetic poles of Earth are:

(A) fixed on the surface
(B) wander throughout the Earth's surface
(C) wander about 1000 kilometres per year on an average.
(D) wander about 10 kilometres per year on an average.

Ans. Option (D) is correct.

> *Explanation:* The magnetic poles of Earth are not fixed on the surface, but wander quite a bit. The pole in the Northern Hemisphere seems to be moving northwards in geographic latitude by about 10 kms per year on an average.

Q. 4. Earth's magnetic field may increase if:

(A) it rotates on its axis faster.
(B) its direction of rotation is changed.
(C) it revolves round the Sun faster.
(D) All of the above

Ans. Option (A) is correct.

> *Explanation:* If the Earth rotated faster, it would have a stronger magnetic field.

Q. 5. The Earth's magnetism is due to:

(A) induction of Sun's magnetism.
(B) current produced by the movement of molten metals.
(C) sea current.
(D) revolution of the Earth round the Sun.

Ans. Option (B) is correct.

> *Explanation:* The Earth crust is solid, the core of the Earth is surrounded by a mixture of molten iron and nickle. The magnetic field of Earth is caused by currents of electricity that flow in the molten core. These currents are hundreds of miles wide and flow at thousands of miles per hour as the Earth rotates.

III. Read the following text and answer the following questions on the basis of the same:

Super magnet

The term super magnet is a broad term and encompasses several families of rare-earth magnets that include seventeen elements in the periodic table; namely scandium, yttrium, and the fifteen lanthanides. These elements can be magnetized, but have Curie temperatures below room temperature. This means that in their pure form, their magnetism only appears at low temperatures. However, when they form compounds with transition metals such as iron, nickel, cobalt, etc. Curie temperature rises well above room temperature and they can be used effectively at higher temperatures as well. The main advantage they have over conventional magnets is that their greater strength allows for smaller, lighter magnets to be used.

Super magnets are of two categories:

(i) *Neodymium magnet:* These are made from an alloy of neodymium, iron, and boron. This material is currently the strongest known type of permanent magnet. It is typically used in the construction of head actuators in computer hard drives and has many electronic applications, such as electric motors, appliances, and magnetic resonance imaging (MRI).

(ii) *Samarium-cobalt magnet*: These are made from an alloy of samarium and cobalt. This second-strongest type of rare Earth magnet is also used in electronic motors, turbo-machinery, and because of its high temperature range tolerance may also have many applications for space travel, such as cryogenics and heat resistant machinery.

Rare-earth magnets are extremely brittle and also vulnerable to corrosion, so they are usually plated or coated to protect them from breaking, chipping, or crumbling into powder.

Since super magnets are about 10 times stronger than ordinary magnets, safe distance should be maintained otherwise these may damage mechanical watch, CRT monitor, pacemaker, credit cards, magnetically stored media etc.

These types of magnets are hazardous for health also. The greater force exerted by rare-earth magnets creates hazards that are not seen with other types of magnet. Magnets larger than a few centimeters are strong enough to cause injuries to body parts pinched between two magnets or a magnet and a metal surface, even causing broken bones.

Neodymium permanent magnets lose their magnetism 5% every 100 years. So, in the truest sense Neodymium magnets may be considered as a permanent magnet.

Q. 1. Curie point of pure rare Earth elements is

(A) very high.

(B) below room temperature.

(C) 0 K.

(D) varies from element to element.

Ans. Option (B) is correct.

> ***Explanation:*** Rare-Earth elements which can be magnetized have Curie temperatures below room temperature. This means that in their pure form, their magnetism only appears at low temperatures.

Q. 2. Neodymium and Samarium are

(A) diamagnetic.

(B) paramagnetic.

(C) ferromagnetic.

(D) not magnetic materials.

Ans. Option (C) is correct.

Q. 3. Super magnets are about _____ time stronger than ordinary magnets.

(A) 10 **(B)** 100

(C) 1000 **(D)** 10000

Ans. Option (A) is correct.

Q. 4. To raise the Curie point of rare Earth elements.

(A) they are coated with gold.

(B) compounds are formed with transition metals.

(C) they are oxidized.

(D) None of the above

Ans. Option (B) is correct.

> ***Explanation:*** When rare-Earth elements form compounds with transition metals such as iron, nickel, cobalt, etc. Curie temperatures thus rise well above room temperature.

Q. 5. Neodymium permanent magnets lose their magnetism ____ % every 100 years.

(A) 50 **(B)** 0.5

(C) 10 **(D)** None of the above

Ans. Option (B) is correct.

> ***Explanation:*** Neodymium permanent magnets lose their magnetism 5% every 100 years. So, in the truest sense. Neodymium magnets may be considered as a permanent magnet.