#458237

Topic: Earth's Magnetism

Answer the following questions regarding earth's magnetism:

(a) A vector needs three quantities for its specification. Name the three independent quantities conventionally used to specify the earth's magnetic field.

(b) The angle of dip at a location in southern India is about 18^o. Would you expect a greater or smaller dip angle in Britain?

(c) If you made a map of magnetic field lines at Melbourne in Australia, would the lines seem to go into the ground or come out of the ground?

(d) In which direction would a compass free to move in the vertical plane point to, if located right on the geomagnetic north or south pole?

(e) The earth's field, it is claimed, roughly approximates the field due to a dipole of magnetic moment $8 \times 10^{22} J\,T^{-1}$ located at its centre. Check the order of magnitude of this number in some way.

(f) Geologists claim that besides the main magnetic N-S poles, there are several local poles on the earth's surface oriented in different directions. How is such a thing possible a all?

Solution

(a) The three quantities used to specify the earth's magnetic field are-

1. Horizontal component of earth's magnetic field
2. The magnetic declination
3. The angle of dip

(b) The dip increases from equator to the poles. Since Britain is farther from equator than Southern India, the dip angle is greater in Britain.

(c) It is hypothetically considered as a huge bar magnet with north pole of the bar magnetic at the geographic south pole and vice versa. Thus magnetic field lines at Melbourne(southern hemisphere) would appear to come out of the ground.

(d) Since the magnetic field at the poles is exactly vertical, and the compass is free to move in a vertical plane, it will point out of the ground in south pole, and into the ground a the north pole.

(e) Here $M = 8 \times 10^{22} JT^{-1}$

Let us calculate magnetic field intensity of a short magnetic dipole, which $d = R = 6400km$

$B = \frac{\mu_0}{4\pi}\frac{M}{d^3} = 0.31 \times 10^{-4}T = 0.31Gauss$

This value is a good approximation with observed values of earth's magnetic field.

(f) The earth's magnetic field is only approximately a dipole field. Therefore local N-S poles may exist in different orientations. This is possible due to deposits of magnetized minerals.

#458240

Topic: Energy

A short bar magnet of magnetic moment $m = 0.32\ JT^{-1}$ is placed in a uniform magnetic field of $0.15T$. If the bar is free to rotate in the plane of the field, which orientation would correspond to its (a) stable, and (b) unstable equilibrium? What is the potential energy of the magnet in each case?

Solution

(a) In stable equilibrium, the bar magnet is aligned along the magnetic field,i.e., $\theta = 0°$.

Potential energy=$-mBcos\theta = -4.8 \times 10^{-2}J$

(b) In unstable equilibrium, the bar magnet is aligned reversed to magnetic field, i.e., $\theta = 180°$.

Potential energy=$-mBcos\theta = 4.8 \times 10^{2}J$

#458241

Topic: Magnets

A closely wound solenoid of 800 turns and area of cross section $2.5 \times 10^{-4}m^2$ carries a current of $3.0\ A$. Explain the sense in which the solenoid acts like a bar magnet. What its associated magnetic moment?

Solution

Given: $n = 800, A = 2.5 \times 10^{-4} m^2, I = 3.0A$

A magnetic field develops along the axis of the solenoid. Therefore current carrying solenoid acts like a bar magnet.

$m = nIA = 800 \times 3 \times 2.5 \times 10^{-4} JT^{-1}$

$= 0.6 JT^{-1}$ along the axis of solenoid.

#458243

Topic: Energy

A bar magnet of magnetic moment $1.5 JT^{-1}$ lies aligned with the direction of a uniform magnetic field of 0.22 T.

(a) What is the amount of work required by an external torque to turn the magnet so as to align its magnetic moment: (i) normal to the field direction, (ii) opposite to the field direction?

(b) What is the torque on the magnet in cases (i) and (ii)?

Solution

Here $m = 1.5 J/T, B = 0.22T$

(a)

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

(i)

$\theta_1 = 0°$(along the field)

$\theta_2 = 90°$(perpendicular to the field)

$W = -0.33(0-1)J = 0.33\ J$

(ii)

$\theta_1 = 0°, \theta_2 = 180°$

$W = -1.5 \times 0.22(cos180° - cos0°) = 0.66\ J$

(b)

Torque $= mBsin\theta$

(i)

$\theta = 90°$

$\implies \tau = 0.33\ Nm$

(ii)

$\tau = mBsin180°$

$= 0Nm$

#458246

Topic: Earth's Magnetism

A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip pointing down at 22^o with the horizontal. The horizontal component of th earth's magnetic field at the place is known to be 0.35 G. Determine the magnitude of the earth's magnetic field at the place.

Solution

$\theta = 22°$

$H = 0.35G$

$H = Rcos\theta$

$\implies R = \frac{H}{cos\theta} = \frac{0.35G}{cos22°} = 0.38G$

#458247

Topic: Earth's Magnetism

At a certain location in Africa, a compass points 12^o west of the geographic north. The north tip of the magnetic needle of a dip circle placed in the plane of magnetic meridian points 60^o above the horizontal. The horizontal component of the earth's field is measured to be 0.16 G. Specify the direction and magnitude of the earth's field at the location.

Solution

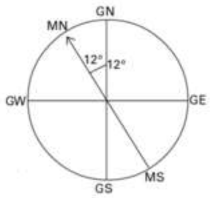
Here declination=12° west.

dip angle =60°, $H = 0.16gauss = 0.16 \times 10^{-4}T$

$H = Rcos\theta$

$\implies R = \frac{H}{cos\theta} = \frac{0.16 \times 10^{-4}}{cos60^{\circ}} = 0.32 \times 10^{-4}T$

The earth's magnetic field lies in a vertical plane 12° west of geographic meridian at an angle of 60° above the horizontal.



#458248

Topic: Magnetic field

A short bar magnet has a magnetic moment of $0.48JT^{-1}$. Give the direction and magnitude of the magnetic field produced by the magnet at a distance of 10 cm from the centre of the magnet on (a) the axis, (b) the equatorial lines (normal bisector) of the magnet.

Solution

Here $M = 0.48JT^{-1}, d = 10cm = 0.1m$

(a)

On axis,

$B = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = 10^{-7} \times \frac{2 \times 0.48}{0.1^3} = 0.96 \times 10^{-4}T$

Direction is away from magnet on the axis on the North-side and towards the magnet on the axis on the South-side

(b) On the equatorial line of the magnet

$B = \frac{\mu_0}{4\pi}\frac{M}{d^3} = 0.48 \times 10^{-4}T$along N-S direction.

Direction at equatorial line is same as direction from north pole to south pole.

#458249

Topic: Magnetic field

A short bar magnet placed in a horizontal plane has its axis aligned along the magnetic north-south direction. Null points are found on the axis of the magnet at 14 cm from the centre of the magnet. The earth's magnetic field at the place is 0.36 G and the angle of dip is zero. What is the total magnetic field on the normal bisector of the magnet at the same distance as the null-point (i.e., 14 cm) from the centre of the magnet? (At null points, field due to a magnet is equal and opposite to the horizontal component of earth's magnetic field.)

Solution

At null point(and along the axis), earth's magnetic field and bar's magnetic field are opposite in direction.

On equatorial line, bar's magnetic field is opposite in direction to its field on the axis. Hence, on equatorial line, the two fields add up.

As the null points are on the axis of the bar magnet, therefore,

$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = H$

On the equatorial line of magnet at same distance(d), field due to the magnet is

$B_2 = \frac{\mu_0}{4\pi}\frac{M}{d^3} = \frac{B_1}{2} = \frac{H}{2}$

Therefore total magnetic field at this point on equatorial line is

$B = B_2 + H = \frac{3H}{2} = \frac{3}{2} \times 0.36G = 0.54G$

#458250

Topic: Magnetic field

If the bar magnet is turned around by 180^{o}, where will the new null points be located?

Solution

When a bar magnet is turned by 180^0, then the null points are obtained on the equatorial line. So, magnetic field on the equatorial line at a distance d' is given by

$B' = \frac{\mu_0 M}{4\pi d'^3} = H$---------------------------(1)

As the magnetic field is equal to the horizontal component of the earth magnetic field.

As we know that, magnetic field

$B_1 = \frac{\mu_0 2M}{4\pi d^3} = H$------------------------- (2)

From both (1) and (2) we have

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

$d'^3 = \frac{d^3}{2} = \frac{14^3}{2}$

$d' = 11.1cm$

Thus, the null points are located on the equatorial line at a distance of $11.1cm$

#458251

Topic: Magnetic field

A short bar magnet of magnetic moment $5.25 \times 10^{-2} JT^{-1}$ is placed with its axis perpendicular to the earth's field direction. At what distance from the centre of the magnet, tl resultant field is inclined at 45^o with earth's field on (a) its normal bisector and (b) its axis. Magnitude of the earth's field at the place is given to be 0.42 G. Ignore the length of tl magnet in comparison to the distances involved.

Solution

$M = 5.25 \times 10^{-2} JT^{-1}$

Earth's field=$B_E = 0.42 \times 10^{-4} T$

(a) At a point P at a distance r on normal bisector, field due to the magnet is

$\vec{B_2} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$along PA (or N-S)

The resultant field $\vec{R}$ would be inclined at 45° to the earth's field along PQ only when $\left|\vec{B_2}\right| = \left|\vec{B_E}\right|$

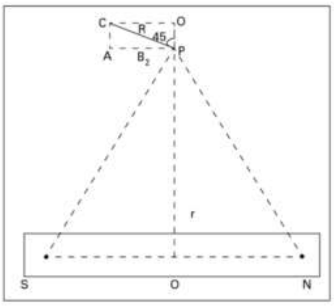
$\implies r = 0.05m = 5cm$

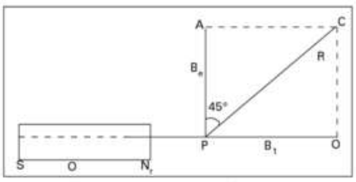
(b) When point P lies on the axis of magnet such that OP=r , field due to magnet is

$\vec{B_1} = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$ along PO, earth's magnetic field is along $\vec{PA}$. The resultant vector $\vec{R}$ would be inclined at 45° to earth's field only when,

$\left|\vec{B_1}\right| = \left|\vec{B_E}\right|$

Solving, $\implies r = 6.3cm$





#458252

Topic: Terms Used in Magnetism

Answer the following questions:

(a) Why does a paramagnetic sample display greater magnetisation (for the same magnetising field) when cooled?

(b) Why is diamagnetism, in contrast, almost independent of temperature?

(c) If a toroid uses bismuth for its core, will the field in the core be (slightly) greater or (slightly) less than when the core is empty?

(d) Is the permeability of a ferromagnetic material independent of the magnetic field? If not, is it more for lower or higher fields?

(e) Magnetic field lines are always nearly normal to the surface of a ferromagnet at every point. (This fact is analogous to the static electric field lines being normal to the surfac of a conductor at every point.) Why?

(f) Would the maximum possible magnetisation of a paramagnetic sample be of the same order of magnitude as the magnetisation of a ferromagnet?

Solution

(a) This is because at lower temperatures, the tendency to disrupt the alignment of dipoles(due to magnetizing field) decreases on account of reduced random thermal motion

(b) In a diamagnetic sample, each molecule is not a magnetic dipole in itself.Therefore random thermal motion of molecules does not affect the magnetism of the specimen. Th is why diamagnetism is independent of temperature.

(c) As bismuth is diamagnetic, therefore the field in the core would be slightly less than when the core is empty.

(d) No, permeability of ferromagnetic material is not independent of magnetic field. As is clear from hysteresis curve, μ is greater for lower fields.

(e) Magnetic field lines are always nearly normal to the surface of a ferromagnet at every point. The proof of this important fact is based on the boundary conditions of magneti fields (B and H) at the interface of two media.

(f) The maximum possible magnetisation of a paramagnetic sample can be of the same order of magnitude as the magnetisation of a ferromagnet. For this, a high magnetising fields for saturation will be required.

#458253
Topic: Terms Used in Magnetism

Answer the following questions:

(a) Explain qualitatively on the basis of domain picture the irreversibility in the magnetisation curve of a ferromagnet.

(b) The hysteresis loop of a soft iron piece has a much smaller area than that of a carbon steel piece. If the material is to go through repeated cycles of magnetisation, which piece will dissipate greater heat energy?

(c) 'A system displaying a hysteresis loop such as a ferromagnet, is a device for storing memory? Explain the meaning of this statement.

(d) What kind of ferromagnetic material is used for coating magnetic tapes in a cassette player, or for building 'memory stores' in a modern computer?

(e) A certain region of space is to be shielded from magnetic fields. Suggest a method.

Solution

(a) Since in a ferromagnetic substance the magnetic properties are due to alignment of domains, therefore on withdrawing the magnetizing field the original domain formation does not take place.

(b) Carbon steel piece, because heat lost per cycle is proportional to the area of hysteresis loop.

(c) Magnetization of a ferromagnet is not a single-valued function of magnetizing field. Its value for a particular field depends both on the field and also on the history of magnetization. In other words, the value of magnetization is a record of 'memory' of its cycle of magnetization. If information bits can be made to correspond to these cycles, th system with such a hysteresis loop can act as a device for storing information.

(d) Ceramic(specially treated barium iron-oxides) also called ferites.

(e) Surround the region by soft-iron rings. Magnetic field lines will be drawn into the rings, and the enclosed space will be free of magnetic field. But this shielding is only approximate, unlike the perfect electric shielding of a cavity in a conductor placed in an external electric field.

#458256
Topic: Earth's Magnetism

A telephone cable at a place has four long straight horizontal wires carrying a current of 1.0 A in the same direction east to west. The earth's magnetic field at the place is 0.39 G, and the angle of dip is 35^o. The magnetic declination is nearly zero. What are the resultant magnetic fields at points 4.0 cm below the cable?

Solution

Total magnetic field at the point due to the four wires=$4\times\dfrac{\mu_0 I}{2\pi r}=0.2G$

By fleming's right hand rule, the direction of above field is North to South.

Horizontal component of earth's magnetic field at this point$=0.39cos35^{\circ}G$ from South to North

Thus net horizontal field at this point=$0.39cos35^{\circ}G-0.2=0.12G$

Vertical field due to earth at this point=$Bsin35^{\circ}=0.22G$

Thus net magnetic field at the point=$\sqrt{0.12^2+0.22^2}G=0.25G$

#458258
Topic: Magnetic Moment

A magnetic dipole is under the influence of two magnetic fields. The angle between the field directions is 60^o, and one of the fields has a magnitude of $1.2 \times 10^{-2}T$. If the dipole comes to stable equilibrium at an angle of 15^o with this field, what is the magnitude of the other field?

Solution

In stable equilibrium, net torque $\tau = MBsin\theta = 0$

thus $MB_1 sin\theta_1 = MB_2 sin\theta_2$

$\implies 1.2 \times 10^{-2} \times sin15^\circ = B_2 sin(60-15)^\circ = B_2 sin45^\circ$

$\implies B_2 = 4.4 \times 10^{-3}T$