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Class: 12
Subject: Physics
Topic: Moving charges and magnetism
No. of Questions: 30

1. A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field B at the centre of the coil?

Sol.

Number of turns on the circular coil, $n = 100$

Radius of each turn, $r = 8.0\ cm = 0.08\ m$

Current flowing in the coil, $I = 0.4\ A$

Magnitude of the magnetic field at the centre of the coil is given by the relation,

$|B| = \frac{\mu_0}{4\pi}\frac{2\pi nI}{r}$ Where, μ_0 = Permeability of free space $= 4\pi \times 10^{-7} T$ m A^{-1}

$|B| = \frac{4\pi\times10^{-7}}{4\pi} \times \frac{2\pi\times100\times0.4}{0.08} = 3.14 \times 10^{-4}$ T

Hence, the magnitude of the magnetic field is 3.14×10^{-4} T.

2. A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude and direction of B at a point 2.5 m east of the wire.

Sol.

Current in the wire, $I = 50\ A$

A point is 2.5 m away from the East of the wire.

$\therefore$ Magnitude of the distance of the point from the wire, $r = 2.5\ m$.

Magnitude of the magnetic field at that point is given by the relation, $\text{B} = \frac{\mu_0 2I}{4\pi r}$

Where,

μ_0 = Permeability of free space $= 4\pi \times 10^{-7} T\ m\ A^{-1}$

$$B = \frac{4\pi \times 10^{-7} \times 2 \times 50}{4\pi \times 2.5}$$

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$= 4 \times 10^{-6}$ T

The point is located normal to the wire length at a distance of 2.5 m. The direction of the current in the wire is vertically downward. Hence, according to the Maxwell's right hand thumb rule, the direction of the magnetic field at the given point is vertically upward.

3. A closely wound solenoid 80 cm long has 5 layers of windings of 400 turns each. The diameter of the solenoid is 1.8 cm. If the current carried is 8.0 A, estimate the magnitude of B inside the solenoid near its centre.

Sol.

Length of the solenoid, $l = 80$ cm $= 0.8$ m

There are five layers of windings of 400 turns each on the solenoid.

∴ Total number of turns on the solenoid, $N = 5 \times 400 = 2000$

Diameter of the solenoid, D = 1.8 cm = 0.018 m

Current carried by the solenoid, $I = 8.0\ A$

Magnitude of the magnetic field inside the solenoid near its centre is given by the relation,

$B = \frac{\mu_0 N I}{l}$ Where, μ_0 = Permeability of free space = $4\pi \times 10^{-7}$ T m A^{-1}

$$B = \frac{4\pi \times 10^{-7} \times 2000 \times 8}{0.8}$$

$= 8\pi \times 10^{-3} = 2.512 \times 10^{-2}$ T

Hence, the magnitude of the magnetic field inside the solenoid near its centre is 2.512×10^{-2} T.

4. In a chamber, a uniform magnetic field of 6.5 G (1 G = 10^{-4}T) is maintained. An electron is short into the field with a speed of 4.8×10^{6} m s^{-1} normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbits. (e = 1.6×10^{-19} C, m_e = 9.1×10^{-31} kg)

Sol.

Magnetic field strength, B = 6.5 G = 6.5×10^{-4} T

Speed of the electron, v = 4.8×10^{6} m/s

Charge on the electron, e = 1.6×10^{-19} C

Mass of the electron, $m_e = 9.1 \times 10^{-31}$ kg

Angle between the shot electron and magnetic field, $\theta = 90^o$

Magnetic force exerted on the electron in the magnetic field is given as:

$F = evB\ sin\theta$

This force provides centripetal force to the moving electron. Hence, the electron starts moving in a circular path of radius r.

Hence, centripetal force exerted on the electron,

$$F_c = \frac{mv^2}{r}$$

In equilibrium, the centripetal force exerted on the electron is equal to the magnetic force i.e.,

$$F_c = F$$

$$\frac{mv^2}{r} = evB\ sin\theta$$

$$r = \frac{mv}{B\ e \sin\theta}$$

Hence, the radius of the circular orbit of the electron is 4.2 cm.

5. Answer the following questions:
A magnetic field that varies in magnitude from point to point but has a constant direction (east to west) is set up in a chamber. A charged particle enters the chamber and travels un-deflected along a straight path with constant speed. What can you say about the initial velocity of the particle?
A charged particle enters an environment of a strong and non-uniform magnetic field varying from point to point both in magnitude and direction, and comes out of it following a complicated trajectory. Would its final speed equal the initial speed if it suffered no collisions with the environment?

Sol.

The initial velocity of the particle is either parallel or anti-parallel to the magnetic field. Hence, it travels along a straight path without suffering any deflection in the field.

Yes, the final speed of the charged particle will be equal to its initial speed. This is because magnetic force can change the direction of velocity, but not its magnitude.

6. An electron travelling west to east enters a chamber having a uniform electrostatic field in north to south direction. Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflecting from its straight line path.
   Sol.

   An electron travelling from West to East enters a chamber having a uniform electrostatic field in the North-South direction. This moving electron can remain un-deflected if the electric force acting on it is equal and opposite of magnetic field. Magnetic force is directed towards the South. According to Fleming's left hand rule, magnetic field should be applied in a vertically downward direction.

7. An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 k V, enters a region with uniform magnetic field of 0.15 T. Determine trajectory of the electron if the field (a) is transverse to its initial velocity, (b) makes an angle of 30^o with the initial velocity.

   Sol.

   Magnetic field strength, B = 0.15 T

   Charge on the electron, e = 1.6×10^{-19} C

   Mass of the electron, m = 9.1×10^{-31} kg

   Potential difference, V = 2.0 kV = 2×10^3 V

   Thus, kinetic energy of the electron = eV

$$\Rightarrow eV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2eV}{m}} \qquad ....(1)$$

Where,

v =velocity of the electron

Magnetic force on the electron provides the required centripetal force of the electron. Hence, the electron traces a circular path of radius r.

Magnetic force on the electron is f given by the relation,

B ev

Centripetal force $= \frac{mv^2}{r}$

$\therefore$ Bev $= \frac{mv^2}{r}$

$r = \frac{mv}{Be}$ .....(2)

From equation (1) and (2), we get

$r = \frac{m}{Be}\left[\frac{2eV}{m}\right]^{\frac{1}{2}}$

$= \frac{9.1\times10^{-31}}{0.15\times1.6\times10^{-19}} \times \left(\frac{2\times1.6\times10^{-19}\times2\times10^{3}}{9.1\times10^{-31}}\right)^{\frac{1}{2}}$

$= 100.55 \times 10^{-5}$

$= 1.01 \times 10^{-3}$m

$= 1$ mm

Hence, the electron has a circular trajectory of radius 1.0 mm normal to the magnetic field.

When the field makes an angle $\theta\ of\ 30^o$ with initial velocity, the initial velocity will be,

$v_1 = v\ sin\theta$

From equation (2), we can write the expression for new radius as:

$r_1 = \frac{mv_1}{Be}$

$= \frac{mv\ sin\theta}{Be}$

$= \frac{9.1\times10^{-31}}{0.15\times1.6\times10^{-19}} \times \left[\frac{2\times1.6\times10^{-19}\times2\times10^{3}}{9\times10^{-31}}\right]^{\frac{1}{2}} \times \sin 30^o$

$= 0.5 \times 10^{-3}$m

$= 0.5$ mm

Hence, the electron has a helical trajectory of radius 0.5 mm along the magnetic field's direction.

8. A circular coil of 20 turns and radius 10 cm is placed in a uniform magnetic field of 0.10 T normal to the plane of the coil. If the current in the coil is 5.0 A, what is the total torque on the coil, total force on the coil and average force on each electron in the coil due to the magnetic field?
(The coil is made of copper wire of cross-sectional area 10^{-5} m^2, and the free electron density in copper is given to be about 10^{29} m^{-3}.)

Sol.
Number of turns on the circular coil, n = 20
Radius of the coil, r = 10 cm = 0.1 m
Magnetic field strength, B = 0.10 T
Current in the coil, $I = 5.0$ A
The total torque on the coil is zero because the field is uniform.
The total force on the coil is zero because the field is uniform.
Cross-sectional are of copper coil, A = 10^{-5} m^2
Number of free electrons per cubic meter in copper, N = 10^{29} $/m^3$
Charge on the electron, e = 1.6×10^{-19} C
Magnetic force, F = Bev_d
Where,
V_d= Drift velocity of electrons

$= \frac{I}{NeA}$

$\therefore F = \frac{Bel}{NeA}$

$= \frac{0.10 \times 5.0}{10^{29} \times 10^{-5}} = 5 \times 10^{25}\ N$

Hence, the average force on each electron is 5×10^{-25} N.

9. A galvanometer coil has a resistance of 12 Ω and the metre shows full scale deflection for a current of 3 mA. How will you convert the metre into a voltmeter of range 0 to 18 V?
Sol.
Resistance of the galvanometer coil, G = 12Ω
Current for which there is full scale deflection, $I_g = 3\ mA = 3 \times 10^{-3}\ A$
Range of the voltmeter is 0, which needs to be converted to 18 V.
$\therefore V = 18\ V$
Let a resistor of resistance R be connected in series with the galvanometer to convert it into a voltmeter. This resistance is given as:

$R = \frac{V}{I_g} - G$

$= \frac{18}{3 \times 10^{-3}} - 12 = 6000 - 12 = 5988\Omega$

Hence, a resistor of resistance 5988 Ω is to be connected in series with the galvanometer.

10. A galvanometer coil has a resistance of 15 Ω and the metre shows full scale deflection for a current of 4 mA. How will you convert the metre into an ammeter of range 0 to 6 A?

Sol.

Resistance of the galvanometer coil, G = 15 Ω

Current for which the galvanometer shows full scale deflection,

$$I_g = 4\,mA = 4 \times 10^{-3}\,A$$

Range of the ammeter is 0, which needs to be converted to 6 A.

∴ Current, $I = 6\,A$

A shunt resistor of resistance S is to be connected in parallel with the galvanometer to convert it into an ammeter. The value of S is given as:

$S = \frac{I_g G}{I - I_g}$

$= \frac{4\times10^{-3}\times15}{6-4\times10^{-3}}$

$S = \frac{6\times10^{-2}}{6-0.004} = \frac{0.06}{5.996}$

$\approx 0.01\Omega = 10\text{m}\Omega$

Hence, a 10 mΩ shunt resistor is to be connected in parallel with the galvanometer.

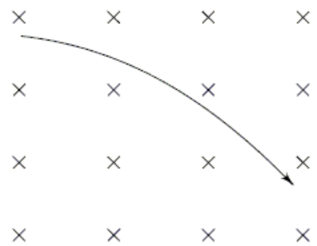
11. The direction of the force experienced by a charged particle moving with a velocity v in a uniform magnetic field B is

A. parallel to v and perpendicular to B
B. parallel to B and perpendicular to v
C. parallel to both v and B
D. perpendicular to both v and B

Right Answer Explanation:

Since **F** = (**v** × **B**), so the correct choice is (4).

12. A particle is projected into a uniform magnetic field acting perpendicular to the plane of the paper. The field points into the paper, indicated by x which represents the tail of the field vector. The trajectory shown could be that of



A. neutron
B. proton
C. alpha particle
D. electron

Right Answer Explanation:
Applying the Fleming's left hand rule and noting the charge on an electron is negative, i.e. F = – e (v × B), it follows that the particle is an electron, which is choice (4).

13. In the region around a charge at rest, there is

A. electric field only
B. magnetic field only
C. neither electric nor magnetic field
D. electric as well as magnetic field

Right Answer Explanation:
In the region around a charge at rest, there is electric field only.

14. A magnetic needle is kept in a non-uniform magnetic field. It experiences

A. a force as well as a torque
B. a force but no torque
C. a torque but no force
D. neither a force nor a torque

Right Answer Explanation:
A magnetic needle is kept in a non-uniform magnetic field. It experiences a torque but no force.

15. A proton (mass = 1.7 $\times$ 10^{-27} kg) moves with a speed of 5 $\times$ 10^5 m/s in a direction perpendicular to a magnetic field of 0.17 T. The acceleration of the proton is

A. zero
B. 2 $\times 10^{12}$ ms^{-2}
C. 4 $\times 10^{12}$ ms^{-2}
D. 8 $\times 10^{12}$ ms^{-2}
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Right Answer Explanation:
Force F = qvB

$$\therefore \text{Acceleration} = \frac{F}{m} = \frac{qvB}{m}$$

$$= \frac{1.6\times10^{-19}\times5.0\times10^{5}\times0.17}{1.7\times10^{-17}}$$

$$= 8\times10^{12}\ ms^{-2}$$

Hence, the correct choice is (4).

16. The vertical component of the earth's magnetic field is zero at the

A. magnetic poles
B. magnetic equator
C. geographic poles
D. 45° latitude

Right Answer Explanation:
The vertical component of the earth's magnetic field is zero at the magnetic equator.

17. The angle of dip is 90° at the

magnetic poles
magnetic equator
geographic poles
90° latitude

Right Answer Explanation:
The angle of dip is 90° at the magnetic poles.

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18. The relative permeability of iron is of the order of

A. zero
B. 1
C. 10^{-4}
D. 10^{3}

Right Answer Explanation:
The relative permeability of iron is of the order of 10^3

19. A bar magnet of magnetic moment 2.0 JT^{-1} lies aligned with the direction of a uniform magnetic field of 0.25 T. What is the work done to turn the magnet so as to align its magnetic moment opposite to the field direction?

A. 0.25 J
B. 0.5 J
C. 0.75 J
D. J

Right Answer Explanation:
Potential energy when $\theta = 180^o$ (i.e. M opposite to B) is

$U'' = -MB\cos 180^o = MB$

$\therefore$ Work done $= U'' - U_o = MB - (-MB)$

$= 2\,MB = 2 \times 2.0 \times 0.25 = 1.0$ J

Hence, the correct choice is (4).

20. A toroidal solenoid has 3000 turns and a mean radius of 10 cm. It has a soft iron core of relative permeability 2000. What is the magnitude of the magnetic field in the core when a current of 1 A is passed through the solenoid?

A. 0.012 T
B. 0.12 T
C. 1.2 T
D. 12 T

Right Answer Explanation:
The magnetic field in the core is given by

$B = \mu nI$

where μ is the permeability of soft iron and n is the number of turns per unit length of the solenoid.
Now

$$\mu_r = \frac{\mu}{\mu_0} \text{ and } n = \frac{3000}{2\pi r} = \frac{3000}{2\pi \times 0.1}$$

$$\therefore \quad B = \mu_r \mu_0 \, n\, I$$

$$= 2000 \times 4\pi \times 10^{-7} \times \frac{3000}{2\pi \times 0.1} \times 1 = 12\,T$$

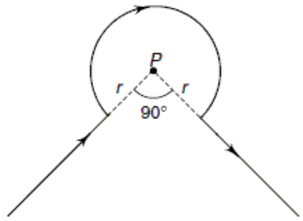
Hence, the correct choice is (4).

21. A small piece of a material is repelled by a strong magnet. The material is

A. paramagnetic
B. ferromagnetic
C. diamagnetic
D. non-magnetic

Right Answer Explanation:
A small piece of a material is repelled by a strong magnet. The material is diamagnetic.

22. The wire shown in figure carries a current of 32 A. If r = 3.14 cm, the magnetic field at point P will be



A. 1.6 $\times$ 10^{-4} T
B. 3.2 $\times$ 10^{-4} T
C. 4.8 $\times$ 10^{-4} T
D. 6.4 $\times$ 10^{-4} T

Right Answer Explanation:
The straight portions of the wire do not contribute because the point P is along them. The field at P is due to 3/4th of the loop of radius r. Thus

$$B = \frac{3}{4}\left(\frac{\mu_0 I}{2r}\right)$$

$$= \frac{3}{4} \times \frac{4\pi \times 10^{-7} \times 32}{2 \times 3.14 \times 10^{-2}} = 4.8 \times 10^{-4}\,T$$

Hence the correct choice is (3).

23. A proton of mass 1.67×10^{-27} kg and charge 1.6×10^{-19} C is projected with a speed of 2×10^6 ms^{-1} at an angle of 60^o to the x -axis. If a uniform magnetic field of 0.014 T is applied along the y -axis, the path of the proton is

A. a circle of radius 0.1 m and time period $2\pi \times 10^{-7}$ s
B. a circle of radius 0.2 m and time period $\pi \times 10^{-7}$ s
C. a helix of radius 0.1 m and time period $2\pi \times 10^{-7}$ s
D. a helix of radius 0.2 m and time period $4\pi \times 10^{-7}$ s

Right Answer Explanation:
A proton of mass 1.67×10^{-27} kg and charge 1.6×10^{-19} C is projected with a speed of 2×10^6 ms^{-1} at an angle of 60^o to the x -axis. If a uniform magnetic field of 0.014 T is applied along the y -axis, the path of the proton is a helix of radius 0.1 m and time period $2\pi \times 10^{-7}$ s

24. A loosely wound helix made of stiff wire is mounted vertically with the lower end just touching a dish of mercury. When a current from the battery is started in the coil through the mercury, then

A. the wire oscillates
B. the wire continues making contact
C. the wire breaks contact just when the current is passed
D. the mercury will expand by heating due to passage of current

Right Answer Explanation:
When a current is passed through the helix, the neighbouring coils of the helix attract each other due to which it contracts. As a result the contact is broken and the coils will recover their original state under the influence of a restoring force. The contact is made again and the process continues. Thus the wire oscillates. Hence, the correct choice is (1).

25. A coil having N turns is wound tightly in the form of a spiral with inner and outer radii a and b respectively. When a current I passes through the coil, the magnetic field at the centre is

A. $\frac{\mu_0 NI}{b}$
B. $\frac{2\mu_0 NI}{a}$
C. $\frac{\mu_0 NI}{2(b-a)} \ln \frac{b}{a}$
D. $\frac{\mu_0 NI}{2(b-a)} \ln \frac{a}{b}$

Right Answer Explanation:
The correct choice is (3).

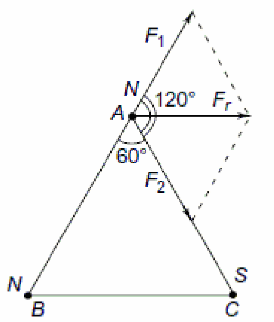
26. Two poles of the same strength attract each other with a force of magnitude F when placed at two corners of an equilateral triangle. If a north pole of the same strength is placed at the third vertex, it experiences a force of magnitude

A. $\sqrt{3}$ F
B. F
C. $\sqrt{2}$ F
D. 2 F

Right Answer Explanation:
Refer to figure. Let the north pole be placed at B and the south pole at C so that they attract with a force F. The north pole placed at the third vertex A is repelled with a force F_1 by the north pole at B and attracted with a force F_2 towards the south pole at C. Since all pole strengths are equal, $F_1 = F_2 = F$. The resultant force experienced by the north pole at A is given by

$$F_r^2 = F_1^2 + F_2^2 + 2F_1 F_2 \cos(120°)$$
$$= F^2 + F^2 + 2F^2 \times \left(-\frac{1}{2}\right) = F^2$$

or $F_r = F$, which is choice (2). $(\because F_1 = F_2 = F)$



27. An electron moves with a speed of 2 × 10^5 ms^{-1} along the positive x-direction in a magnetic field B = $(\hat{i} - 4\hat{j} - 3\hat{k})$ tesla. The magnitude of the force (in Newton) experienced by the electron is (the charge on electron = 1.6 × 10^{-19} C)

A. 1.18 × 10^{-13}
B. 1.28 × 10^{-13}
C. 1.6 × 10^{-13}
D. 1.72 × 10^{-13}

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Right Answer Explanation:

Given $v = (2 \times 10^5\ \hat{\mathbf{i}})\ \text{ms}^{-1}$. The force vector is given by

$$F = q(\mathbf{v} \times \mathbf{B})$$
$$= q\{2 \times 10^5\ \mathbf{i} \times (\hat{\mathbf{i}} - 4\hat{\mathbf{j}} - 3\hat{k})\}$$
$$= 2 \times 10^5 \times q\,(-4\hat{k} + 3\hat{\mathbf{j}})$$

Therefore, the y and z components of the force are

$$F_y = 6 \times 10^5 \times q$$

and $$F_z = -8 \times 10^5 \times q$$

$\therefore$ Magnitude of force $= \sqrt{F_y^2 + F_z^2}$

$$= q\sqrt{(6 \times 10^5)^2 + (-8 \times 10^5)^2}$$
$$= q \times 10 \times 10^5$$
$$= 1.6 \times 10^{-19} \times 10 \times 10^5$$
$$= 1.6 \times 10^{-13}\ \text{N}$$, which is choice (3).

28. Two short bar magnets of magnetic moments ‘M’ each are arranged at the opposite corners of a square of side ‘d’, such that their centres coincide with the corners and their axes are parallel. If the like poles are in the same direction, the magnetic field at any of the other corners of the square is

A. $\frac{\mu_0}{4\pi} \cdot \frac{M}{d^3}$

B. $\frac{\mu_0}{4\pi} \cdot \frac{2M}{d^3}$

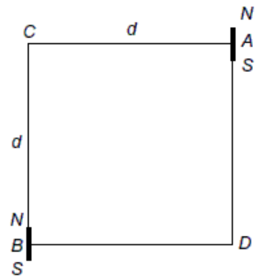
C. $\frac{\mu_0}{4\pi} \cdot \frac{M\sqrt{5}}{d^3}$

D. $\frac{\mu_0}{4\pi} \cdot \frac{3M}{d^3}$

Right Answer Explanation:

Refer to figure. Let us find the net magnetic field at corner C of the square ABCD. For the magnet at corner B, the point C is on the axial line at a distance d from the centre of the magnet. For a short magnet, the magnetic field at C is given by

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



For the magnet at corner A, the point C is on the equatorial line at a distance d from its centre. For a short magnet, the magnetic field at C due to this magnet is given by

$$B_2 = \frac{\mu_0}{4\pi}\cdot\frac{M}{d^3}$$

Since their like poles are in the same directions, so the net magnetic field at C is

$$B = B_1 - B_2$$

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

29. A straight section PQ of a circuit lies along the x–axis from x = $-\frac{a}{2}$ to x = $\frac{a}{2}$ and carries a current I.
The magnetic field due to the section PQ at point x = + a will be

A. proportional to a
B. proportional to a^2
C. proportional to $\frac{1}{a}$
D. equal to zero

Right Answer Explanation:
The point x = + a lies along the line of the straight section PQ of the circuit. Hence, the magnetic field at point x = a is zero.

30. A bar magnet of magnetic moment 2.0 JT^{-1} lies aligned with the direction of a uniform magnetic field of 0.25 T. What is the amount of work required to turn the magnet, so as to align its magnetic moment perpendicular to the field direction?

A. 0.125 J
B. 0.25 J
C. 0.5 J
D. J

Right Answer Explanation:
0.5 J