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?

Answer :

The magnitude of the magnetic field at the centre of a circular coil of radius r carrying current I is given by,

$$|B| = \frac{\mu_0 I}{2r}$$

For 100 turns, the magnitude of the magnetic field will be,

$$|B| = 100 \times \frac{\mu_0 I}{2r}$$

$$|B| = 100 \times \frac{4\pi \times 10^{-7} \times 0.4}{2 \times 0.08}$$ (current=0.4A, radius = 0.08m, permeability of free space = $4\pi \times 10^{-7} TmA^{-1}$)

$$= 3.14 \times 10^{-4} T$$

2. A long straight wire carries a current of 35 A. What is the magnitude of the field B at a point 20 cm from the wire?

Answer:

The magnitude of the magnetic field at a distance r from a long straight wire carrying current I is given by,

$$|B| = \frac{\mu_0 I}{2\pi r}$$

In this case

$$|B| = \frac{4\pi \times 10^{-7} \times 35}{2\pi \times 0.2} = 3.5 \times 10^{-5} T$$ (current=35A, distance= 0.2m, permeability of free space = 4 $\pi \times 10^{-7}$ TmA $^{-1}$)

3. 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.

Answer:

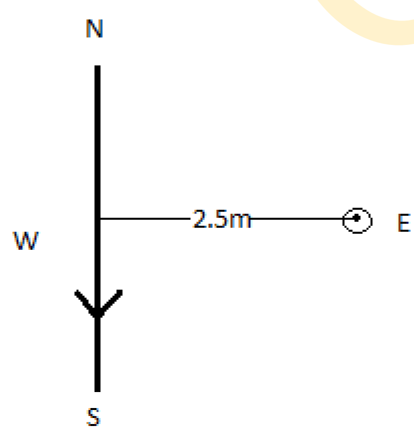
The magnitude of the magnetic field at a distance r from a long straight wire carrying current I is given by,

$$|B| = \frac{\mu_0 I}{2\pi r}$$

In this case

$$|B| = \frac{4\pi \times 10^{-7} \times 50}{2\pi \times 2.5}$$ (current=50A, distance= 2.5m, permeability of free space = 4 $\pi \times 10^{-7}$ TmA $^{-1}$)

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



The current is going from the North to South direction in the horizontal plane and the point lies to the East of the wire. Applying Maxwell's right-hand thumb rule we can see that the direction of the magnetic field will be vertically upwards.

4. A horizontal overhead power line carries a current of 90 A in east to west direction. What is the magnitude and direction of the magnetic field due to the current 1.5 m below the line?

Answer:

The magnitude of the magnetic field at a distance r from a long straight wire carrying current I is given by,

$$|B| = \frac{\mu_0 I}{2\pi r}$$

In this case (current=35A, distance= 0.2m, permeability of free space = $4\pi \times 10^{-7}$ TmA^{-1})

$$|B| = \frac{4\pi \times 10^{-7} \times 90}{2\pi \times 1.5} = 1.2 \times 10^{-5} T$$

The current in the overhead power line is going from the East to West direction and the point lies below the power line. Applying Maxwell's right-hand thumb rule we can see that the direction of the magnetic field will be towards the South.

5. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8 A and making an angle of 30° with the direction of a uniform magnetic field of 0.15 T?

Answer:

The magnetic force on an infinitesimal current-carrying conductor in a magnetic field is given by $d\vec{F} = Id\vec{l} \times \vec{B}$ where the direction of vector dl is in the direction of flow of current.

For a straight wire of length l in a uniform magnetic field, the Force equals to

$$\vec{F} = \int_0^l I\vec{dl} \times \vec{B}$$
$$|\vec{F}| = BIlsin\theta$$

In the given case the magnitude of force per unit length is equal to

$|F| = 0.15 \times 8 \times \sin 30^{\circ}$ ($I=8A$, $B=0.15$ T, $\theta = 30^{\circ}$)

$= 0.6$ Nm $^{-1}$

6. A 3.0 cm wire carrying a current of 10 A is placed inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be 0.27 T. What is the magnetic force on the wire?

Answer:

For a straight wire of length l in a uniform magnetic field, the Force equals to

$$\vec{F} = \int_0^l I\vec{dl} \times \vec{B}$$
$$|\vec{F}| = BIlsin\theta$$

In the given case the magnitude of the force is equal to

$|F| = 0.27 \times 10 \times 0.03 \times \sin 90^{\circ}$ ($I=10A$, $B=0.27$ T, $\theta = 90^{\circ}$)

$= 0.081$ N

The direction of this force depends on the orientation of the coil and the current-carrying wire and can be known using the Flemings Left-hand rule.

7. Two long and parallel straight wires A and B carrying currents of 8.0 A and 5.0 A in the same direction are separated by a distance of 4.0 cm. Estimate the force on a 10 cm section of wire A.

Answer:

The magnitude of magnetic field at a distance r from a long straight wire carrying current I is given by,

$$|B| = \frac{\mu_0 I}{2\pi r}$$

In this case the magnetic field at a distance of 4.0 cm from wire B will be

$$|B| = \frac{4\pi \times 10^{-7} \times 5}{2\pi \times 0.04}$$ (I=5 A, r=4.0 cm)

$$= 2.5 \times 10^{-5} T$$

The force on a straight wire of length l carrying current I in a uniform magnetic field B is given by

$F = BIl sin\theta$, where θ is the angle between the direction of flow of current and the magnetic field.

The force on a 10 cm section of wire A will be

$F = 2.5 \times 10^{-5} \times 8 \times 0.1 \times sin 90^{\circ}$ (B=2.5 T, I=8 A, l = 10 cm, θ =90 º)

$$F = 2 \times 10^{-5} N$$

8. 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.

Answer:

The magnitude of the magnetic field at the centre of a solenoid of length l, total turns N and carrying current I is given by

$B = \frac{\mu_o N I}{l}$, where μ_o is the permeability of free space.

In the given question N= number of layers of winding $\times$ number of turns per each winding

N=5 $\times$ 400=2000

I=8.0 A

l=80 cm

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

$$B = 2.51 \times 10^{-2} T$$

9. A square coil of side 10 cm consists of 20 turns and carries a current of 12 A. The coil is suspended vertically and the normal to the plane of the coil makes an angle of 30° with the direction of a uniform horizontal magnetic field of magnitude 0.80 T. What is the magnitude of torque experienced by the coil?

Answer:

The magnitude of torque experienced by a current-carrying coil in a magnetic field is given by

$$\tau = nBIAsin\theta$$

where n = number of turns, I is the current in the coil, A is the area of the coil and θ is the angle between the magnetic field and the vector normal to the plane of the coil.

In the given question n = 20, B=0.8 T, A=0.1 $\times$ 0.1=0.01 m^2, I=12 A, θ =30 ^{o}

$$\tau = 20 \times 0.8 \times 12 \times 0.01 \times sin30^o$$

=0.96 Nm

The coil, therefore, experiences a torque of magnitude 0.96 Nm.

10 (a) Two moving coil meters, M_1 and M_2 have the following particulars:

-

(The spring constants are identical for the two meters).
Determine the ratio of current sensitivity of M_2 and M_1

Answer:

The torque experienced by the moving coil M_1 for a current I passing through it will be equal to $\tau = B_1 A_1 N_1 I$

The coil will experience a restoring torque proportional to the twist ϕ

$$\phi k = B_1 A_1 N_1 I$$

The current sensitivity is therefore $\frac{B_1 A_1 N_1}{k}$

Similarly, for the coil M_2, current sensitivity is $\frac{B_2 A_2 N_2}{k}$

Their ratio of current sensitivity of coil M_2 to that of coil M_1 is, therefore, $\frac{B_2 A_2 N_2}{B_1 A_1 N_1}$

$$= \frac{0.5 \times 1.8 \times 10^{-3} \times 42}{0.25 \times 3.6 \times 10^{-3} \times 30} = 1.4$$

10.(b) Two moving coil meters, M_1 and M_2 have the following particulars:

-

(The spring constants are identical for the two meters).

Determine the ratio of voltage sensitivity of M_2 and M_1

Answer:

The torque experienced by the moving coil M $_1$ for a current I passing through it will be equal to $\tau = B_1 A_1 N_1 I$

The coil will experience a restoring torque proportional to the twist ϕ

$\phi k = B_1 A_1 N_1 I$

we know V=IR

Therefore, $\phi k = \frac{B_1 A_1 N_1 V}{R_1}$

Voltage sensitivity of coil M $_1$ = $\frac{B_1 A_1 N_1}{k R_1}$

Similarly for coil M $_2$ Voltage sensitivity = $\frac{B_2 A_2 N_2}{k R_2}$

Their ratio of voltage sensitivity of coil M $_2$ to that of coil M $_1$

$$= \frac{B_2 A_2 N_2 R_1}{B_1 A_1 N_1 R_2}$$

$$= 1.4 \times \frac{10}{14}$$

$= 1$

11) In a chamber, a uniform magnetic field of $6.5G(1G = 10^{-4}T)$ is maintained. An electron is shot into the field with a speed of $4.8 \times 10^{6} ms^{-1}$ normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbit. $(e = 1.5 \times 10^{-19}C, m_e = 9.1 \times 10^{-31}kg)$

Answer:

The magnetic force on a moving charged particle in a magnetic field is given by $\vec{F_B} = q\vec{V} \times \vec{B}$

Since the velocity of the shot electron is perpendicular to the magnetic field, there is no component of velocity along the magnetic field and therefore the only force on the electron will be due to the magnetic field and will be acting as a centripetal force causing the electron to move in a circular path. (if the initial velocity of the electron had a component along the direction of the magnetic field it would have moved in a helical path)

Magnetic field(B)= $6.5G(1G = 10^{-4}T)$

Speed of electron(v)= $4.8 \times 10^{6} ms^{-1}$

Charge of electron= $-1.6 \times 10^{-19}C$

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

The angle between the direction of velocity and the magnetic field = 90 °

Since the force due to the magnetic field is the only force acting on the particle,

$$\frac{mV^2}{r} = q\vec{V} \times \vec{B}$$
$$\frac{mV^2}{r} = |qVBsin\theta|$$
$$r = |\frac{mV}{qBsin\theta}|$$

$$r = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2cm$$

12) In Exercise 4.11 obtain the frequency of revolution of the electron in its circular orbit. Does the answer depend on the speed of the electron? Explain

Answer:

In exercise 4.11 we saw $r = \frac{eB}{mv}$

Time taken in covering the circular path once(time period (T))= $\frac{2\pi r}{v} = \frac{2\pi m}{eB}$

Frequency, $\nu = \frac{1}{T} = \frac{eB}{2\pi m}$

From the above equation, we can see that this frequency is independent of the speed of the electron.

$$\nu = \frac{1.6 \times 10^{-19} \times 4.8 \times 10^6}{2\pi \times 9.1 \times 10^{-31}} = 18.2MHz$$

13 (a) A circular coil of 30 turns and radius 8.0 cm carrying a current of 6.0 A is suspended vertically in a uniform horizontal magnetic field of magnitude 1.0 T. The field lines make an angle of 60° with the normal of the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil from turning.

Answer:

Number of turns in the coil(n)=30

The radius of the circular coil(r)=8.0 cm

Current flowing through the coil=6.0 A

Strength of magnetic field=1.0 T

The angle between the field lines and the normal of the coil=60 ^{o}

The magnitude of the counter-torque that must be applied to prevent the coil from turning would be equal to the magnitude of the torque acting on the coil due to the magnetic field.

$$\tau = nBIAsin\theta$$
$$\tau = 30 \times 1 \times 6 \times \pi \times (0.08)^2 \times sin60^o$$

=3.13 Nm

A torque of magnitude 3.13 Nm must be applied to prevent the coil from turning.

13 b) Would your answer change, if the circular coil in (a) were replaced by a planar coil of some irregular shape that encloses the same area? (All other particulars are also unaltered.)

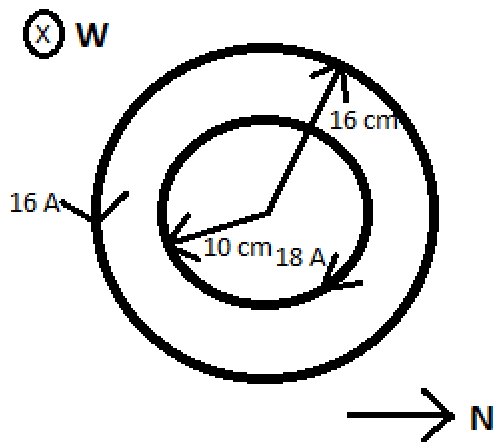
Answer:

From the relation $\tau = nBIAsin\theta$ we can see that the torque acting on the coil depends only on the area and not its shape, therefore, the answer won't change if the circular coil in (a) were replaced by a planar coil of some irregular shape that encloses the same area.

NCERT solutions for moving charges and magnetism additional exercise:

14) Two concentric circular coils X and Y of radii 16 cm and 10 cm, respectively, lie in the same vertical plane containing the north to south direction. Coil X has 20 turns and carries a current of 16 A; coil Y has 25 turns and carries a current of 18 A. The sense of the current in X is anticlockwise, and clockwise in Y, for an observer looking at the coils facing west. Give the magnitude and direction of the net magnetic field due to the coils at their centre.

Answer:



Using the right-hand thumb rule we can see that the direction of the magnetic field due to coil X will be towards the east direction and that due to coil Y will be in the West direction.

We know the magnetic field at the centre of a circular loop of radius r carrying current I is given by

$$B = \frac{\mu_o I}{2r}$$

$$B_x = \frac{n_x \mu_o I_x}{2r_x}$$

$$B_x = \frac{20 \times 4\pi \times 10^{-7} \times 16}{2 \times 0.16}$$

$B_x = 4\pi \times 10^{-4} T$ (towards East)

$$B_y = \frac{n_y \mu_o I_y}{2r_y}$$
$$B_y = \frac{25 \times 4\pi \times 10^{-7} \times 18}{2 \times 0.1}$$

$B_y = 9\pi \times 10^{-4} T$ (towards west)

The net magnetic field at the centre of the coils,

$B_{net} = B_y - B_x$

$= 1.57 \times 10^{-3}$ T

The direction of the magnetic field at the centre of the coils is towards the west direction.

15) A magnetic field of $100G (1G = 10^{-4}) T$ is required which is uniform in a region of linear dimension about 10 cm and area of cross-section about $10^{-3} m^2$ The maximum current-carrying capacity of a given coil of wire is 15 A and the number of turns per unit length that can be wound round a core is at most $1000 \ turns \ m^{-1}$. Suggest some appropriate design particulars of a solenoid for the required purpose. Assume the core is not ferromagnetic.

Answer:

Strength of the magnetic field required is $100G (1G = 10^{-4}) T$

$$B = \mu_o n I$$
$$nI = \frac{B}{\mu_o}$$
$$= \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}}$$

nI $= 7957.74 \approx 8000$

Therefore keeping the number of turns per unit length and the value of current within the prescribed limits such that their product is approximately 8000 we can produce the required magnetic field.

e.g. n=800 and I=10 A.

16.(a) For a circular coil of radius R and N turns carrying current I, the magnitude of the magnetic field at a point on its axis at a distance x from its centre is given by,

$$B = \frac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$$

Show that this reduces to the familiar result for the field at the centre of the coil.

Answer:

For a circular coil of radius R and N turns carrying current I, the magnitude of the magnetic field at a point on its axis at a distance x from its centre is given by,

$$B = \frac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$$

For finding the field at the centre of coil we put x=0 and get the familiar result

$$B = \frac{\mu_0 I N}{2R}$$

16. (b) For a circular coil of radius R and N turns carrying current I, the magnitude of the magnetic field at a point on its axis at a distance x from its centre is given by,

$$B = \frac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$$

Consider two parallel co-axial circular coils of equal radius R, and number of turns N, carrying equal currents in the same direction, and separated by a distance R. Show that the field on the axis around the mid-point between the coils is uniform over a distance that is small as compared to R, and is given by,

$B = 0.72\frac{\mu_0 NI}{R}$ approximately.

Answer:

Let a point P be at a distance of l from the midpoint of the centres of the coils.

The distance of this point from the centre of one coil would be R/2+l and that from the other would be R/2-l.

The magnetic field at P due to one of the coils would be

$$B_1 = \frac{\mu_0 IR^2 N}{2((R/2+l)^2 + R^2)^{3/2}}$$
.

The magnetic field at P due to the other coil would be

$$B_2 = \frac{\mu_0 IR^2 N}{2((R/2-l)^2 + R^2)^{3/2}}$$

Since the direction of current in both the coils is same the magnetic fields B_1 and B_2 due to them at point P would be in the same direction

$B_{net} = B_1 + B_2$

Since l<<R we can ignore term l^2/R^2

$$B_{net} = \frac{\mu_0 IN}{2R} \times (\frac{4}{5})^{3/2} \left[1 + \frac{6l}{5R} + 1 - \frac{6l}{5R}\right]$$

$$B_{net} = \frac{\mu_0 IN}{2R} \times (\frac{4}{5})^{3/2} \times 2$$

$$B_{net} = 0.715\frac{\mu_0 IN}{R} \approx 0.72\frac{\mu_0 IN}{R}$$

Since the above value is independent of l for small values it is proved that about the midpoint the Magnetic field is uniform.

17.(a) A toroid has a core (non-ferromagnetic) of inner radius 25 cm and outer radius 26 cm, around which 3500 turns of a wire are wound. If the current in the wire is 11 A, what is the magnetic field outside the toroid

Answer:

Outside the toroid, the magnetic field will be zero.

17.(b) A toroid has a core (non-ferromagnetic) of inner radius 25 cm and outer radius 26 cm, around which 3500 turns of a wire are wound. If the current in the wire is 11 A, what is the magnetic field inside the core of the toroid?

Answer:

The magnetic field inside the core of a toroid is given by

$$B = \frac{\mu_o NI}{l}$$

Total number of turns(N)=3500

Current flowing in toroid =11 A

Length of the toroid, l=

(r $_1$ =inner radius=25 cm, r $_2$ =outer radius=26 cm)

$$B = \frac{4\pi \times 10^{-7} \times 3500 \times 11}{0.51\pi} = 0.031T$$

17.(c) A toroid has a core (non-ferromagnetic) of inner radius 25 cm and outer radius 26 cm, around which 3500 turns of a wire are wound. If the current in the wire is 11 A, what is the magnetic field in the empty space surrounded by the toroid?

Answer:

The magnetic field in the empty space surrounded by the toroid is zero.

18. (a) 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 undeflected along a straight path with constant speed. What can you say about the initial velocity of the particle?

Answer:

The charged particle is not deflected by the magnetic field even while having a non zero velocity, therefore, its initial velocity must be either parallel or anti-parallel to the magnetic field i.e. It's velocity is either towards the east or the west direction.

18 b) 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?

Answer:

Yes, its final speed will be equal to the initial speed if it has not undergone any collision as the work done by the magnetic field on a charged particle is always zero because it acts perpendicular to the velocity of the particle.

18 c) 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.

Answer:

The electron would experience an electrostatic force towards the north direction, therefore, to nullify its force due to the magnetic field must be acting on the electron towards the south direction. By using Fleming's left-hand rule we can see that the force will be in the north direction if the magnetic field is in the vertically downward direction.

Explanation:

The electron is moving towards the east and has a negative charge therefore $q\vec{V}$ is towards the west direction, Force will be towards south direction if the magnetic field is in the vertically downward direction as $\vec{F} = q\vec{V} \times \vec{B}$

19 (a) An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 kV, enters a region with uniform magnetic field of 0.15 T. Determine the trajectory of the electron if the field is transverse to its initial velocity

Answer:

(a) The electron has been accelerated through a potential difference of 2.0 kV.

Therefore K.E of electron = $1.6 \times 10^{-19} \times 2000 = 3.2 \times 10^{-16} J$

Since the electron initially has velocity perpendicular to the magnetic field it will move in a circular path.

The magnetic field acts as a centripetal force. Therefore,

19. (b) An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 kV, enters a region with uniform magnetic field of 0.15 T. Determine the trajectory of the electron if the field makes an angle of 30° with the initial velocity.

Answer:

The electron has been accelerated through a potential difference of 2.0 kV.

Therefore K.E of electron = $1.6 \times 10^{-19} \times 2000 = 3.2 \times 10^{-16}$ J

The component of velocity perpendicular to the magnetic field is

$$v_p = v sin30^o$$
$$v_p = 1.33 \times 10^7 \ ms^{-1}$$

The electron will move in a helical path of radius r given by the relation, r=5m

r=5 × 10 $^{-4}$ m

r=0.5 mm

The component of velocity along the magnetic field is

$$v_t = vcos30^o$$
$$v_t = 2.31 \times 10^7\ ms^{-1}$$

The electron will move in a helical path of pitch p given by the relation,

p=5.45 × 10 $^{-3}$ m

p=5.45 mm

The electron will, therefore, move in a helical path of radius 5 mm and pitch 5.45 mm.

20 A magnetic field set up using Helmholtz coils (described in Exercise 4.16) is uniform in a small region and has a magnitude of 0.75 T. In the same region, a uniform electrostatic field is maintained in a direction normal to the common axis of the coils. A narrow beam of (single species) charged particles all accelerated through 15 kV enters this region in a direction perpendicular to both the axis of the coils and the electrostatic field. If the beam remains undeflected when the electrostatic field is $9.0 \times 10^{-5} Vm^{-1}$, make a simple guess as to what the beam contains. Why is the answer not unique?

Answer:

$$qE = qvB$$
$$E = vB \quad \text{(i)}$$

Let the beam consist of particles having charge q and mass m.

After being accelerated through a potential difference V its velocity can be found out by using the following relation,

$$\frac{1}{2}mv^2 = qV$$

$$v = \sqrt{\frac{2qV}{m}} \quad \text{(ii)}$$

Using the value of v from equation (ii) in (i) we have

21. (a) A straight horizontal conducting rod of length 0.45 m and mass 60 g is suspended by two vertical wires at its ends. A current of 5.0 A is set up in the rod through the wires. What magnetic field should be set up normal to the conductor in order that the tension in the wires is zero?

Answer:

In order for the tension in the wires to be zero the force due to the magnetic field must be equal to the gravitational force on the rod.

$$mg = BIl$$

mass of rod=0.06 g

length of rod=0.45m

the current flowing through the rod=5 A

$$B = \frac{mg}{Il}$$
$$B = \frac{0.06 \times 9.8}{5 \times 0.45}$$
$$B = 0.261\ T$$

A magnetic field of strength 0.261 T should be set up normal to the conductor in order that the tension in the wires is zero

21.(b) A straight horizontal conducting rod of length 0.45 m and mass 60 g is suspended by two vertical wires at its ends. A current of 5.0 A is set up in the rod through the wires. What will be the total tension in the wires if the direction of current is reversed keeping the magnetic field same as before?
(Ignore the mass of the wires.) $g = 9.8ms^{-2}$

Answer:

If the direction of the current is reversed the magnetic force would act in the same direction as that of gravity.

Total tension in wires(T)=Gravitational force on rod + Magnetic force on rod

$$T = mg + BIl$$

$$T = 0.06 \times 9.8 + 0.261 \times 5 \times 0.45$$

$$T = 1.176\ N$$

The total tension in the wires will be 1.176 N.

22. The wires which connect the battery of an automobile to its starting motor carry a current of 300 A (for a short time). What is the force per unit length between the wires if they are 70 cm long and 1.5 cm apart? Is the force attractive or repulsive?

Answer:

Since the distance between the wires is much smaller than the length of the wires we can calculate the Force per unit length on the wires using the following relation.

$$F = \frac{\mu_o I_1 I_2}{2\pi d}$$

Current in both wires=300 A

Distance between the wires=1.5 cm

Permeability of free space=4 $\pi \times 10^{-7}$ TmA^{-1}

$$F = \frac{4\pi \times 10^{-7} \times 300 \times 300}{2\pi \times 0.015}$$

F=1.2 Nm^{-1}

23.(a) A uniform magnetic field of 1.5 T exists in a cylindrical region of radius10.0 cm, its direction parallel to the axis along east to west. A wire carrying current of 7.0 A in the north to south direction passes through this region. What is the magnitude and direction of the force on the wire if, the wire intersects the axis,

Answer:

The length of wire inside the magnetic field is equal to the diameter of the cylindrical region=20.0 cm=0.2 m.

Magnetic field strenth=1.5 T.

Current flowing through the wire=7.0 A

The angle between the direction of the current and magnetic field=90 ^{o}

Force on a wire in a magnetic field is calculated by relation,

$$F = BIl sin\theta$$
$$F = 1.5 \times 7 \times 0.2$$

F=2.1 N

This force due to the magnetic field inside the cylindrical region acts on the wire in the vertically downward direction.

23.(b) A uniform magnetic field of 1.5 T exists in a cylindrical region of radius10.0 cm, its direction parallel to the axis along east to west. A wire carrying current of 7.0 A in the north to south direction passes through this region. What is the magnitude and direction of the force on the wire if, the wire is turned from N-S to northeast-northwest direction,

Answer:

Magnetic field strenth=1.5 T.

Current flowing through the wire=7.0 A

The angle between the direction of the current and magnetic field=45 ^{o}

The radius of the cylindrical region=10.0 cm

The length of wire inside the magnetic field, $l = \frac{2r}{sin\theta}$

Force on a wire in a magnetic field is calculated by relation,

$$F = BIl sin\theta$$

$$F = 1.5 \times 7 \times \frac{2 \times 0.1}{sin45^o} \times sin45^o$$

F=2.1 N

This force due to the magnetic field inside the cylindrical region acts on the wire in the vertically downward direction.

This force will be independent of the angle between the wire and the magnetic field as we can see in the above case.

Note: There is one case in which the force will be zero and that will happen when the wire is kept along the axis of the cylindrical region.

23 c) A uniform magnetic field of 1.5 T exists in a cylindrical region of radius10.0 cm, its direction parallel to the axis along east to west. A wire carrying current of 7.0 A in the north to south direction passes through this region. What is the magnitude and direction of the force on the wire if, the wire in the N-S direction is lowered from the axis by a distance of 6.0 cm?

Answer:

The wire is lowered by a distance d=6cm.

In this case, the length of the wire inside the cylindrical region decreases.

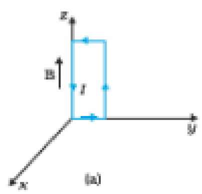
Let this length be l.

$$F = BIlsin\theta$$
$$F = 1.5 \times 7 \times 0.16$$

F=1.68 N

This force acts in the vertically downward direction.

24.(a) A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in Fig. 4.28? What is the force on each case? Which case corresponds to stable equilibrium?



Answer:

The magnetic field is

$$\vec{B} = 3000\ G\hat{k} = 0.3\ T\hat{k}$$

Current in the loop=12 A

Area of the loop = length $\times$ breadth

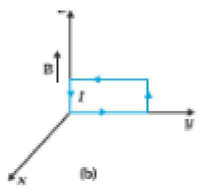
A=0.1 $\times$ 0.05

A=0.005 m^2

$$\vec{A} = 0.005\ m^2\hat{i}$$

The torque on the loop has a magnitude of 0.018 Nm and acts along the negative-y direction. The force on the loop is zero.

24.(b) A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in Fig. 4.28? What is the force on each case? Which case corresponds to stable equilibrium?



Answer:

The magnetic field is

$\vec{B} = 3000\ G\hat{k} = 0.3\ T\hat{k}$

Current in the loop=12 A

Area of the loop = length $\times$ breadth

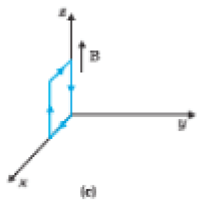
A=0.1 $\times$ 0.05

A=0.005 m^2

$\vec{A} = 0.005\ m^2\hat{i}$ (same as that in the last case)

The torque on the loop has a magnitude of 0.018 Nm and acts along the negative-y direction. The force on the loop is zero. This was exactly the case in 24. (a) as well.

24 (c). A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in Fig. 4.28? What is the force on each case? Which case corresponds to stable equilibrium?



(c)

Answer:

The magnetic field is

$$\vec{B} = 3000\ G\hat{k} = 0.3\ T\hat{k}$$

Current in the loop=12 A

Area of the loop = length × breadth

A=0.1 × 0.05

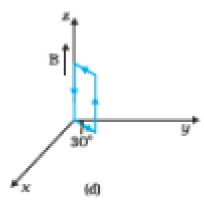
A=0.005 m ^{2}

$$\vec{A} = -0.005\ m^2\hat{j}$$

The torque on the loop has a magnitude of 0.018 Nm and acts along the negative-x-direction.

The force on the loop is zero.

24 (d) . A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in Fig. 4.28? What is the force on each case? Which case corresponds to stable equilibrium?



Answer:

The magnetic field is

$$\vec{B} = 3000\ G\hat{k} = 0.3\ T\hat{k}$$

Current in the loop=12 A

Area of the loop = length $\times$ breadth

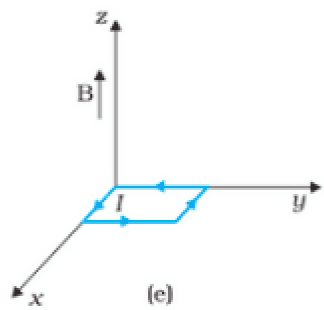
A=0.1 $\times$ 0.05

A=0.005 m ^{2}

$$\vec{A} = 0.005\ m^2(-\frac{\hat{i}}{2} + \frac{\sqrt{3}}{2}\hat{j})$$

The torque on the loop has a magnitude of 0.018 Nm and at an angle of 240 ^{o} from the positive x-direction. The force on the loop is zero.

24. (e) A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in Fig. 4.28? What is the force on each case? Which case corresponds to stable equilibrium?



Answer:

The magnetic field is

$$\vec{B} = 3000\ G\hat{k} = 0.3\ T\hat{k}$$

Current in the loop=12 A

Area of the loop = length $\times$ breadth

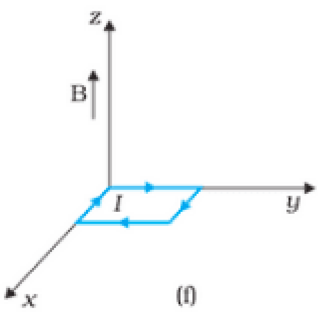
A=0.1 $\times$ 0.05

A=0.005 m^2

$$\vec{A} = 0.005\ m^2\hat{k}$$

Since the area vector is along the direction of the magnetic field the torque on the loop is zero. The force on the loop is zero.

24 (f) A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in Fig. 4.28? What is the force on each case? Which case corresponds to stable equilibrium?



Answer:

The magnetic field is

$$\vec{B} = 3000\ G\hat{k} = 0.3\ T\hat{k}$$

Current in the loop=12 A

Area of the loop = length $\times$ breadth

A=0.1 $\times$ 0.05

A=0.005 m ^{2}

$$\vec{A} = -0.005\ m^2\hat{k}$$

Since the area vector is in the opposite direction of the magnetic field the torque on the loop is zero. The force on the loop is zero.

The force on the loop in all the above cases is zero as the magnetic field is uniform

25. (a) 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,

Answer:

As we know the torque on a current-carrying loop in a magnetic field is given by the following relation

$$\vec{\tau} = I\vec{A} \times \vec{B}$$

It is clear that the torque, in this case, will be 0 as the area vector is along the magnetic field only.

25. (b) 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, total force on the coil.

Answer:

The total force on the coil will be zero as the magnetic field is uniform.

25 (c) 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 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 $10^{29}m^{-3}$.)

Answer:

The average force on each electron in the coil due to the magnetic field will be $eV_d B$ where V_d is the drift velocity of the electrons.

The current is given by

$$I = neAV_d$$

where n is the free electron density and A is the cross-sectional area.

$$V_d = \frac{I}{neA}$$

$$V_d = \frac{5}{10^{29} \times 1.6 \times 10^{-19} \times 10^{-5}}$$

$$Vd = 3.125 \times 10^{-5} ms^{-1}$$

The average force on each electron is

$$F = eV_dB$$

$$F = 1.6 \times 10^{-19} \times 3.125 \times 10^{-5} \times 00.1$$

$$F = 5 \times 10^{-25} N$$

26. A solenoid 60 cm long and of radius 4.0 cm has 3 layers of windings of 300 turns each. A 2.0 cm long wire of mass 2.5 g lies inside the solenoid (near its centre) normal to its axis; both the wire and the axis of the solenoid are in the horizontal plane. The wire is connected through two leads parallel to the axis of the solenoid to an external battery which supplies a current of 6.0 A in the wire. What value of current (with an appropriate sense of circulation) in the windings of the solenoid can support the weight of the wire? $g = 9.8ms^{-2}$

Answer:

The magnetic field inside the solenoid is given by

$$B = \mu_0 nI$$

n is number of turns per unit length

$$n = \frac{3 \times 300}{0.6}$$

n=1500 m^{-1}

Current in the wire I_w = 6 A

Mass of the wire m = 2.5 g

Length of the wire l = 2 cm

The windings of the solenoid would support the weight of the wire when the force due to the magnetic field inside the solenoid balances weight of the wire

$$BI_wl = mg$$

Therefore a current of 108.37 A in the solenoid would support the wire.

27. A galvanometer coil has a resistance of 12Ω 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?

Answer:

The galvanometer can be converted into a voltmeter by connecting an appropriate resistor of resistance R in series with it.

At the full-scale deflection current(I) of 3 mA the voltmeter must measure a Voltage of 18 V.

The resistance of the galvanometer coil G = 12Ω

$I \times (R + G) = 18V$

$$R = \frac{18}{3 \times 10^{-3}} - 12$$

$R = 6000 - 12$

$= 5988\Omega$

The galvanometer can be converted into a voltmeter by connecting a resistor of resistance 5988Ω in series with it.

28. A galvanometer coil has a resistance of 15Ω 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?

Answer:

The galvanometer can be converted into an ammeter by connecting an appropriate resistor of resistance R in series with it.

At the full-scale deflection current(I) of 4 mA, the ammeter must measure a current of 6 A.

The resistance of the galvanometer coil is G = 15Ω

Since the resistor and galvanometer coil are connected in parallel the potential difference is the same across them.

$IG = (6 - I)R$

$$R = \frac{IG}{6 - I}$$

$$R = \frac{4 \times 10^{-3} \times 15}{6 - 4 \times 10^{-3}}$$

$R \approx 0.01\Omega$

The galvanometer can be converted into an ammeter by connecting a resistor of resistance 0.01Ω in parallel with it.