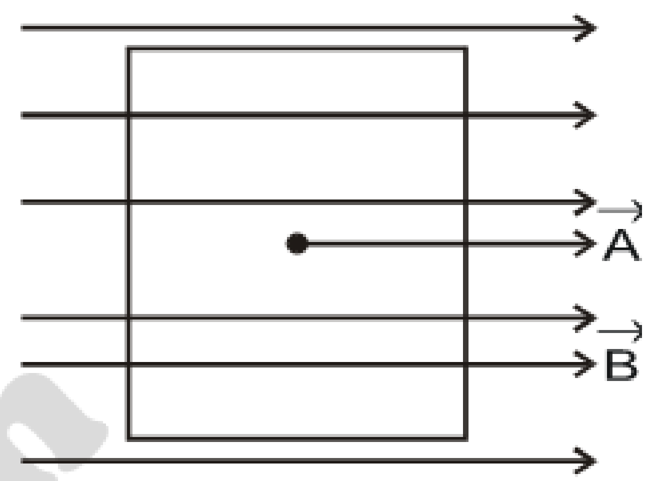
SHORT QUESTIONS

14.1 A plane conducting loop is located in a uniform magnetic field that is directed along the x-axis. For what orientation of the loop is the flux a maximum? For what orientation is the flux a minimum?

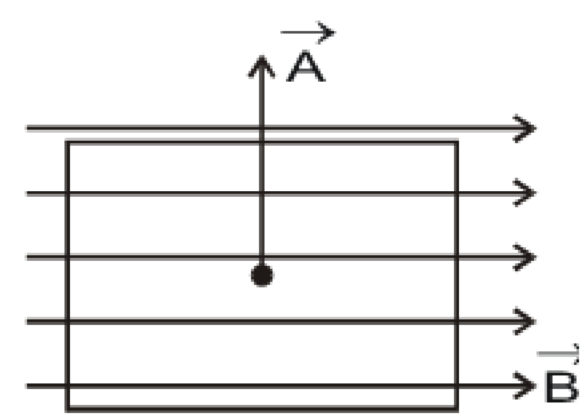
Ans. (i) When a conducting loop is held perpendicular to the magnetic field (vector area is parallel to the magnetic field) then $\theta = 0°$.



$$\text{So,}\quad \phi = \vec{B}\cdot\vec{A}$$
$$= BA\cos\theta = BA\cos 0°$$
$$= BA$$

Hence flux will be maximum when plane of conducting loop is held perpendicular to the field.

(ii) When the conducting loop is held parallel to the magnetic field (vector area is perpendicular to the field) then $\theta = 90°$.



$$\text{So,}\quad \phi = \vec{B}\cdot\vec{A}$$
$$= BA\cos\theta$$
$$= BA\cos 90°$$
$$\phi = 0$$

Hence flux will be minimum when plane of the conducting loop is held parallel to the field.

14.2 A current in a conductor produces a magnetic field, which can be calculated using Ampere's law. Since current is defined as the rate of flow of charge, what can you conclude about the magnetic field due to stationary charges? What about moving charges?

Ans. A stationary charge cannot produce any magnetic field but it produces only the electric field. Where as a moving charge can produce a magnetic field around the path of its motion similar to the magnetic field produced around the current carrying conductor.

14.3 Describe the change in the magnetic field inside a solenoid carrying a steady current I, if (a) the length of the solenoid is doubled but the number of turns remains the same and (b) the number of turns is doubled, but the length remains the same.

Ans. We know that the expression for the magnetic field produced by a solenoid is given by

$$B = \mu_0 nI$$

But $$n = \frac{N}{L}$$

$$B = \mu\frac{NI}{L} \qquad \ldots\ldots \text{(i)}$$

(a) Let B' be the magnetic field when the length of the solenoid is doubled i.e., $L' = 2L$ and the number of turns, remains same.

Then $B' = \dfrac{\mu_0 NI}{2L}$

$$B' = \frac{1}{2} \times \frac{\mu_0 NI}{L}$$

i.e., $B' = \dfrac{\mu_0 NI}{L}$

$$B' = \frac{1}{2} \times B$$

Then $B' = \dfrac{B}{2}$

Hence the magnetic field becomes half if the length of solenoid becomes double but the number of turns remain, same.

(b) Let B' be the magnetic field when the number of turns is doubled i.e., $N' = 2N$ and the length remains same.

Then $B' = \dfrac{\mu_0 (2N)I}{L}$

$$B' = 2\frac{\mu_0 NI}{L}$$

Since $\dfrac{\mu_0 NI}{L} = B$

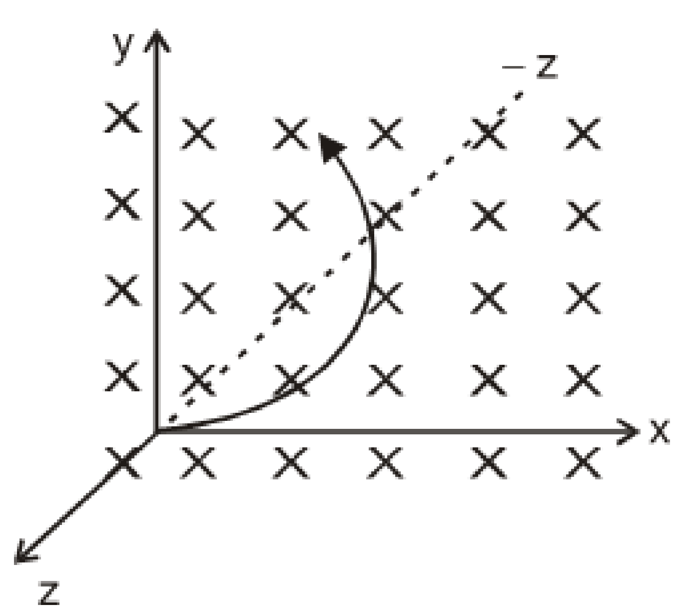
$$B' = 2B$$

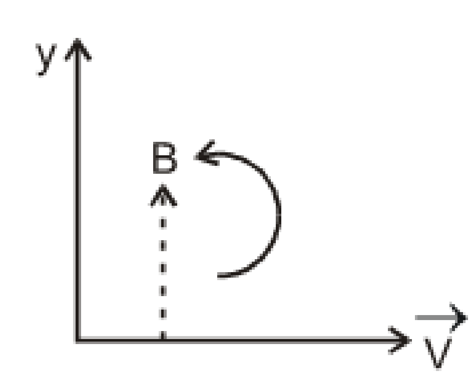
Hence the magnetic field becomes double if the number of turns of the solenoid becomes doubled but length remains same.

14.4 At a given instant, a proton moves in the positive x-direction in a region where there is magnetic field in the negative z-direction. What is the direction of the magnetic force? Will the proton continue to move in the positive x-direction? Explain.

Ans. According to right hand rule, the direction of magnetic force is along y-axis. Because $\vec{F} = e(\vec{V} \times \vec{B})$

No, the proton will not continue to move in the positive x-direction but it will deflect towards y-axis and circulate in xy-plane.





14.5 Two charged particles are projected into a region where there is a magnetic field perpendicular to their velocities. If the charges are deflected in opposite directions, what can you say about them?

Ans. When the charge particles are projected across the magnetic field, experiences a force. This magnetic force on the charge particle tends to deflects the particles into a curved path. If the charge particles are deflected opposite to each other, then the particles are oppositely charged. That is, if one particle positively charged then other must be negatively charged.

14.6 Suppose that a charge q is moving in a uniform magnetic field with a velocity V. Why is there no work done by the magnetic force that acts on the charge?

Ans. The magnetic force on the charged particle moving in a magnetic field is given by

$$\vec{F}_m = q(\vec{V} \times \vec{B})$$

Due to the magnetic force, the charge particle will moves in a circular path. In circular path, the force $\vec{F}_m$ is perpendicular to the velocity $\vec{V}$. Hence magnetic force has done no work, i.e.,

$$W = \vec{F} . \vec{d}$$

$$W = Fd \cos\theta$$

But $\theta = 90°$ (The angle b/w $\vec{F}$ and $\vec{V}$ is 90°)

So, $W = Fd \,Cos90°$

$W = 0$

So there is no work done by the magnetic force. This means that magnetic force is only a deflecting force.

14.7 If a charged particle moves in a straight line through some region of space, can you say that the magnetic field in the region is zero?

Ans. ***Case I:*** Yes the charge particle moves in a straight line if there is no external magnetic field.

Case II: No because the charge particle may be moving parallel or antiparallel to the externally applied magnetic field.

i.e., $\theta = 0°$ or $\theta = 180°$

As $F = qvB \sin\theta$

Since $\sin 0° = 0$

and $\sin 180° = 0$

Therefore $F = 0$

As there is no magnetic field acting on the charge particle so it will move in a straight line.

14.8 Why does the picture on a TV screen become distorted when a magnet is brought near the screen?

Ans. The picture on TV screen is due to the motion of charged particle (electron). As a magnet is brought close to the TV screen, the path of electron is disturbed due to the magnetic force acting on them they deflect and not hitting on the target. Hence the picture on TV screen is distorted.

14.9 Is it possible to orient a current loop in a uniform magnetic field such that the loop will not tend to rotate? Explain.

Ans. A current carrying loop when placed in a magnetic field experiences a torque.

i.e., $\tau = BINA \cos\alpha$

Where α is the angle between magnetic field $\vec{B}$ and plane of the loop.

When the plane of the loop is at right angle to the magnetic field i.e., $\alpha = 90°$.

$$\tau = BINA \cos 90°$$

$$\tau = 0$$

Hence the value of torque is zero so the loop will not tend to rotate.

14.10 How can a current loop be used to determine the presence of a magnetic field in a given region of space?

Ans. When a current carrying loop is placed in a uniform magnetic field, at different orientations a torque is produced in a loop. If the loop is deflected in that region then we can say that magnetic field is present due to torque otherwise not.

14.11 How can you use a magnetic field to separate isotopes of chemical element?

Ans. The isotopes of an element are projected perpendicular to the uniform magnetic field. Then they follow different circular path due to difference in their masses in **mass spectrograph apparatus**. So according to formula for e/m of

$$\frac{e}{m} = \frac{V}{rB}$$

$$r = \frac{mV}{eB}$$

where $\frac{V}{eB}$ is constant so

$$r \propto m$$

So isotopes of different masses will have different radii and thus they can be separated by a magnetic field.

14.12 What should be the orientation of a current carrying coil in a magnetic field so that torque acting upon the coils is (a) maximum (b) minimum?

Ans. The torque acting on rectangular coil of area A, magnetic field B, and current I, when placed in a magnetic field is given by

$$\tau = BINA \cos \alpha$$

where α is the angle between plane of coil and magnetic field.

(a) When the plane of the coil is parallel to the magnetic field, i.e., $\alpha = 0°$

$$\tau = BINA \cos 0$$

$$\tau = BINA$$

So the torque will be maximum.

(b) When the plane of the coil is perpendicular to the magnetic field i.e., $\alpha = 90°$. So,

$$\tau = BINA \cos 90°$$

$$\tau = 0$$

So the torque acting upon the coil is minimum.

14.13 A loop of wire is suspended between the poles of a magnet with its plane parallel to the pole faces. What happens if a direct current is put through the coil? What happens if an alternating current is used instead?

Ans. As plane of the coil is parallel to the pole faces i.e., plane of the coil is perpendicular to the magnetic field i.e., $\alpha = 90°$.

So, $\tau = BINA \cos 90°$

$\tau = 0$

Hence for both A.C and D.C, the coil will not tend to rotate.

14.14 Why the resistance of an ammeter should be very low?

Ans. In order to measure the current ammeter is always connected in series therefore the its resistance should be very low so that it does not disturb the circuit.

14.15 Why the voltmeter should have a very high resistance?

Ans. In order to measure the potential differences voltmeter is always connected in parallel to the circuit. Therefore, its resistance should be very large so that it does not draw any current through the circuit.

PROBLEMS WITH SOLUTIONS

PROBLEM 14.1

Find the value of the magnetic field that will cause a maximum force of 7.0×10^{-3} N on a 20.0 cm straight wire carrying a current of 10.0 A.

Data

Maximum force = F = 7.0×10^{-3} N

Length of conductor = L = 20.0 cm = 0.2 m

Current = I = 10.0 A

To Find

Value of magnetic field = B = ?

SOLUTION

Using $F = ILB \sin \alpha$

For maximum force $\alpha = 90°$

$$\boxed{F = BIL}$$

$$B = \frac{F}{IL} = \frac{7.0 \times 10^{-3}}{10.0 \times 0.2}$$

$$= 3.5 \times 10^{-3} \text{ tesla}$$

Result

Value of magnetic field = B = 3.5×10^{-3} tesla

PROBLEM 14.2

How fast must a proton move in magnetic field of 2.50×10^{-3} T such that the magnetic force is equal to its weight?

Data

Magnetic field = B = 2.50×10^{-3}

To Find

Speed of proton = V = ?

SOLUTION

By formula

$$F = q(\vec{V} \times \vec{B})$$

$$F = qVB \sin \theta \quad \text{But} \quad \theta = 90^o$$

$$F = qVB$$

Since the magnetic force is equal to the weight of the proton so

$$qVB = mg$$

$$\boxed{V = \frac{mg}{qB}}$$

But mass of proton = $m = 1.67 \times 10^{-27}$ kg

Charge on proton = $q = 1.6 \times 10^{-19}$ C

Therefore;

$$V = \frac{1.67 \times 10^{-27} \times 9.8}{1.6 \times 10^{-19} \times 2.50 \times 10^{-3}}$$

$$= 4.09 \times 10^{-27+19+3}$$

$$= 4.09 \times 10^{-5} \text{ m/s}$$

Result

Speed of proton = $V = 4.09 \times 10^{-5}$ m/s

PROBLEM 14.3

A velocity selector has a magnetic field of 0.30 T. If a perpendicular electric field of 10,000 Vm^{-1} is applied, what will be the speed of the particle that will pass through the selector?

Data

Magnetic field = $B = 0.30$ T

Electric field = $E = 10,000$ V/m

To Find

Speed of particle = $V = ?$

SOLUTION

As we know that the magnitude of the electric force is

$$F_e = qE$$

And the magnitude of the magnetic force is

$$F_m = qVB$$

Therefore in velocity particle selector method

$$F_m = F_e$$

$$qVB = q E$$

$$VB = E$$

$$\boxed{V = \frac{E}{B}}$$

$$V = \frac{10000}{0.30}$$

$$= 3.3 \times 10^{4} \text{ m/s}$$

Result

Speed of particle = $V = 3.3 \times 10^4$ m/s

PROBLEM 14.4

A coil of 0.1m × 0.1m and of 200 turns carrying a current of 1.0 mA is placed in a uniform magnetic field of 0.1 T. Calculate the maximum torque that acts on the coil?

Data

Number of turns = N = 200

Area of cross-section = A = 0.1×0.1

= $0.01\ m^2$

Current = I = 1.0 mA

= I = 1.0×10^{-3} A

Magnetic field = B = 0.1 T

To Find

Maximum torque acting = τ = ?

SOLUTION

By formula

$$\tau = BIN\,A \cos\alpha$$

For maximum torque, $\alpha = 0°$

So $\cos 0° = 1$

Therefore;

$$\tau = BIN\,A$$

$$\tau = 0.1 \times 1.0 \times 10^{-3} \times 200 \times 0.01$$

$$= 0.2 \times 10^{-3}$$

$$= 2.0 \times 10^{-4}\ N.m$$

Result

Maximum torque acting = τ = 2.0×10^{-4} N.m

PROBLEM 14.5

A power line 10.0 m high carries a current 200 A. Find the magnetic field of the wire at the ground.

Data

Height of power line = h = r = 10 m

Current = I = 200 A

To Find

Magnetic field = B = ?

SOLUTION

As we know that

$$2\pi rB = \mu . I$$

But $\mu_o = 4\pi \times 10^{-7}$ wb/mA

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

$$B = \frac{4\pi \times 10^{-7} \times 200}{2\times 3.14 \times 10}$$

$$= \frac{800 \times 10^{-7}}{20}$$

$$= 40 \times 10^{-7}$$

$$B = 4.0 \times 10^{-6}\ T$$

Result

Magnetic field $= B = 4.0 \times 10^{-6}$ T

PROBLEM 14.6

You are asked to design a solenoid that will give a magnetic field of 0.10 T, the current must not exceed 10.0 A. Find the number of turns per unit length that the solenoid should have?

Data

Magnetic field $= B = 0.10$ T

Current $= I = 10.0$ A

To Find

The number of turns per unit length $= n = ?$

SOLUTION

By formula

$$\boxed{B = \mu_o nI}$$

$$n = \frac{B}{\mu_o I}$$

$$= \frac{0.10}{4\pi \times 10^{-7} \times 10.0}$$

$$n = 7.96 \times 10^{-4+7}$$

$$n = 7.9 \times 10^{3}$$

Result

Number of turns per unit length $= n = 7.96 \times 10^{3}$

PROBLEM 14.7

What current should pass through a solenoid that is 0.5 m long with 10,000 turns of copper wire so that it will have a magnetic field of 0.4 T?

Data

Length of solenoid = L = 0.5 m

Number of turns = N = 10,000

Magnetic field = B = 0.4 T

To Find

Current from the solenoid = I = ?

SOLUTION

By formula

$$B = \mu_o n I$$

But $$n = \frac{N}{L}$$

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

$$\boxed{I = \frac{B\,L}{\mu_o\,N}}$$

$$I = \frac{0.4 \times 0.5}{4\pi \times 10^{-7} \times 10000}$$

$$= \frac{0.2}{12.56 \times 10^{-7+4}}$$

$$= 0.0159 \times 10^{3}$$

$$= 15.9 \text{ Amp}$$

$$I = 16 \text{ Amp}$$

Result

Current from the solenoid = I = 16 Amp

PROBLEM 14.8

A galvanometer having an internal resistance R_g = 15.0 Ω gives full scale deflection with current I_g = 20.0 mA. It is to be converted into an ammeter of range 10.0 A. Find the value of shunt resistance R_s.

Data

Resistance of galvanometer = R_g = 15.0 Ω

Current for full scale deflection = I_g = 20.0 mA

= 0.02 A

Range current = I = 10.0 A

To Find

Shunt resistance = R_s = ?

SOLUTION

By formula

$$\boxed{R_s = \frac{I_g R_g}{I - I_g}}$$

$$R_s = \frac{0.02 \times 15.0}{10.0 - 0.02}$$

$$= \frac{0.3}{9.98}$$

$$R_s = 0.030\ \Omega$$

Result

Shunt resistance = R_s = 0.030 Ω

PROBLEM 14.9

The resistance of a galvanometer is 50.0 Ω and reads full-scale deflection with a current of 2.0 mA. Show that a diagram how to convert this galvanometer into voltmeter reading 200 V full scale.

Data

Resistance of galvanometer = R_g = 50.0 Ω

Current for full scale = I_g = 2.0 mA

= 0.002 A

Range voltage = V = 200 volt

To Find

High resistance = R_h = ?

SOLUTION

By formula

$$\boxed{R_h = \frac{V}{I_g} - R_g}$$

$$= \frac{200}{0.002} - 50.0$$

$$= 100{,}000 - 50.0$$

$$R_h = 99950\ \Omega$$

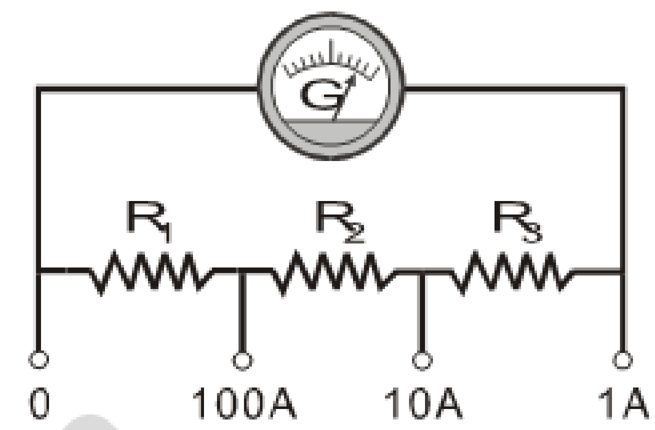
Result

High Resistance = R_h = 99950 Ω

PROBLEM 14.10

The resistance of a galvanometer coil is 10.0 Ω and reads full-scale with a current of 1.0 mA. What should be the values of resistance R_1, R_2 and R_3 to convert this galvanometer into a multirange ammeter of 100, 10.0 and 1.0 A as shown in the figure?

Data



Resistance of galvanometer $= R_g = 10.0\ \Omega$

Current for full scale $= I_g = 1.0$ mA $= 0.001$ A

Range current $= I_1 = 100$ A

$I_2 = 10.0$ A

$I_3 = 1.0$ A

To Find

Shunt Resistance for $I_1 = R_1 = ?$

Shunt Resistance for $I_2 = R_2 = ?$

Shunt Resistance for $I_3 = R_3 = ?$

SOLUTION

By formula

$$\boxed{R_s = \frac{I_g R_g}{I - I_g}}$$

For 1st resistance R_1

$$\boxed{R_1 = \frac{I_g R_g}{I_1 - I_g}}$$

$$= \frac{0.001 \times 10.0}{100 - 0.001}$$

$$= \frac{0.01}{99.99}$$

$$R_1 = 0.0001\ \Omega$$

For 2nd resistance

$$\boxed{R_2 = \frac{I_g R_g}{I_2 - I_g}}$$

$$= \frac{0.001 \times 10.0}{10.0 - 0.001}$$

$$= \frac{0.01}{9.999}$$

$$R_2 = 0.001\ \Omega$$

For 3rd resistance

$$\boxed{R_3 = \frac{I_g R_g}{I_3 - I_g}}$$

$$= \frac{0.001 \times 10.0}{1.0 - 0.001}$$

$$= \frac{0.01}{0.999}$$

$$R_3 = 0.01\ \Omega$$

Result

Shunt Resistance for I_1 = R_1 = $0.0001\ \Omega$

Shunt Resistance for I_2 = R_2 = $0.001\ \Omega$

Shunt Resistance for I_3 = R_3 = $0.01\ \Omega$