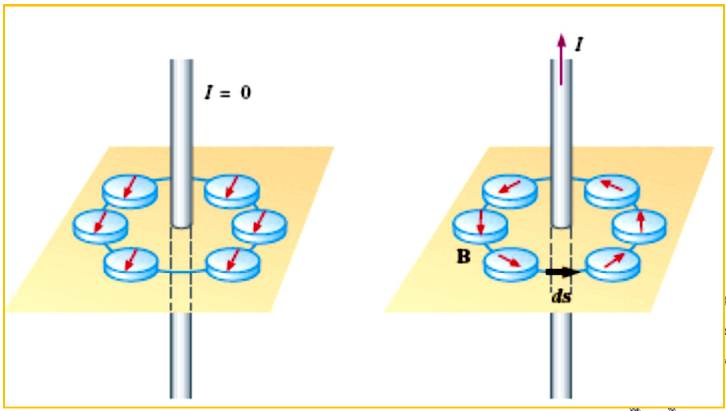
ELECTROMAGNETISM

Q # 1. Describe the properties of magnetic field due to current in a long straight conductor.

Ans. When the heavy current is passed through a straight conductor:



i. A magnetic field is set up in the region surrounding a current carrying wire.
ii. The lines of force are circular and their direction depends upon the direction of current.
iii. The magnetic field lasts only as long as the current is flowing through the wire.
iv. The direction of magnetic lines of force can be find out by right hand rule described below:

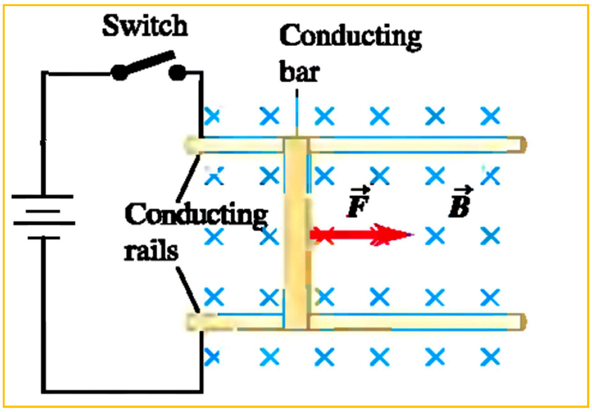
"If the wire is grasped in fist of right hand with the thumb pointing in the direction of current, the finger of the hand will circle the wire in the direction of magnetic field."

Q # 2. Derive the expression of force on a current carrying conductor in a uniform magnetic force.

Ans. If a current carrying conductor is placed in an external magnetic field, the magnetic field of conductor will interact with the external magnetic field, as the result of which the conductor may experience a force.

Consider a rod of copper of length L that is capable of moving on the pair of copper rails. The whole arrangement is placed between the poles pieces of a horseshoe magnet so that the copper rod is subjected to a magnetic field B directed vertically upward.

When a current I is passed through the copper rod from battery, the current carrying conductor will experience magnetic force and moves on the rails. The magnitude of magnetic force depends upon the following factors:



i. The magnetic force is directly proportional to the current flowing through conductor.

$$F \propto I$$

ii. The force is directly proportional to the length of the conductor inside the magnetic field.

$$F \propto L$$

iii. The force is directly proportional to the strength of applied magnetic field.

$$F \propto B$$

iv. The magnetic force on current carrying conductor is directly proportional to $\sin\theta$, where θ is the angle between conductor and the field.

$$F \propto \sin\theta$$

Combining all these factors,

$$F \propto ILB\sin\theta$$

$$F = kILB\sin\theta$$

Where k is the constant of proportionality. If we follow SI units, the value of k is 1. Thus in SI units

$$F = ILB\sin\theta$$

If L vector is in the direction f current flow, then in vector form:

$$\mathbf{F} = I(\mathbf{L}\times\mathbf{B})$$

This is expression of magnetic force on a current carrying conductor in a uniform magnetic field.

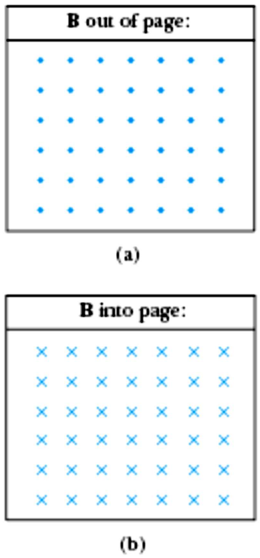


Figure 29.6 (a) Magnetic field lines coming out of the paper are indicated by dots, representing the tips of arrows coming outward. (b) Magnetic field lines going into the paper are indicated by crosses, representing the feathers of arrows going inward.

Q # 3. Define the term Magnetic Field Strength.

Ans. The force acting on one meter length of conductor placed at right angle to the magnetic field when 1 A current is passing through it. In SI units the unit of magnetic field strength is tesla ($1T = 1\,NA^{-1}m^{-1}$).

Q # 4. What do you know about magnetic flux?

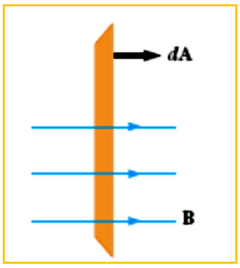
Ans. The number of magnetic lines of force passing through certain area element is called magnetic flux. The magnetic flux Φ_B through the plane element of vector area **A** in the uniform magnetic field **B** is given by the dot product of **B** and **A**.

$$\Phi_B = \mathbf{B}.\mathbf{A}$$

$$\Phi_B = BA\cos\theta$$

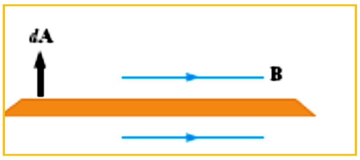
Where θ is the angle between the magnetic field strength **B** and vector area **A**. Magnetic flux is a scalar quantity and its SI unit is NmA^{-1} which is called weber (Wb).

Special cases



Case 1. When the field is directed along the normal to the area, so θ is zero and the flux is maximum:

$$\Phi_B = \mathbf{B}.\mathbf{A} = BA\cos 0 = BA$$



Case 2. When the field is parallel t the plane of the area, the angle between the field and normal to the area is 90^0, i.e., $\theta = 90^0$, so the flux through the area in this position is zero.

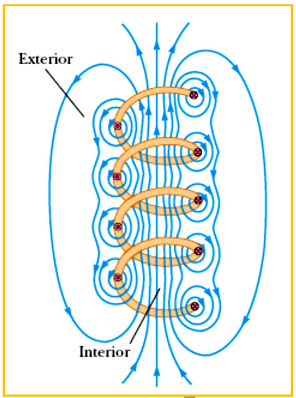
$$\Phi_B = \mathbf{B}.\mathbf{A} = BA\cos 90^0 = 0$$

Case 3. For the case of curved surface placed in a non-uniform magnetic field, the curved surface is divided into small surface elements. Each element being assumed plane and the flux through the whole curved surface is calculated by the sum of the contributions from all the elements of the surface.

Q # 5. Define the term flux density.

Ans. The magnetic induction B is the flux per unit area of a surface perpendicular to B, hence it is also called as flux density. Its unit is $Wb\,m^{-2}$.

Q # 6. State the Ampere's Law. Apply it to find out the magnetic field strength inside a current carrying solenoid.



Ans. Consider a close circular path enclosing a current carrying conductor. This closed path is referred as Amperean path. Divide this path into small elements of length like $\Delta\mathbf{L}$. Let $\mathbf{B}$ be the value of flux density at the site of $\Delta\mathbf{L}$. If θ is the angle between $\mathbf{B}$ and $\Delta\mathbf{L}$, then $B\cos\theta$ represents the component of $\mathbf{B}$ along $\Delta\mathbf{L}$. Thus $\mathbf{B}.\Delta\mathbf{L}$ represents product of length of element $\Delta\mathbf{L}$ and the component of $\mathbf{B}$ along $\Delta\mathbf{L}$.

Ampere's law states that

"*The sum of the quantities $\mathbf{B}.\Delta\mathbf{L}$ for all path elements into which the complete loop has been divided equals μ_0 times the total current enclosed by the loop*"

The Ampere's law can be described mathematically as:

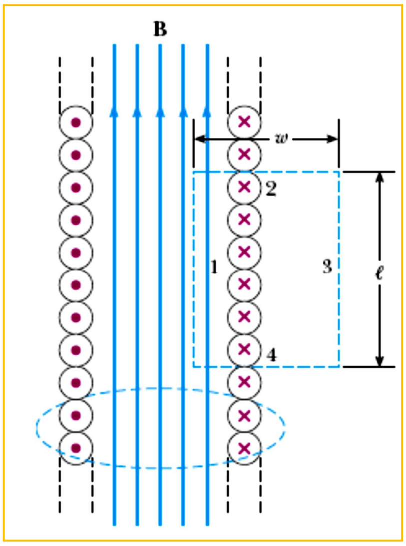
$$(\mathbf{B}.\Delta\mathbf{L})_1 + (\mathbf{B}.\Delta\mathbf{L})_2 + (\mathbf{B}.\Delta\mathbf{L})_3 + \dots\dots + (\mathbf{B}.\Delta\mathbf{L})_r + \dots\dots (\mathbf{B}.\Delta\mathbf{L})_N = \mu_0 I$$

Or

$$\sum_{r=1}^{N}(\mathbf{B}.\Delta\mathbf{L})_r = \mu_0 I$$

Where $(\mathbf{B}.\Delta\mathbf{L})_r$ is the value of $\mathbf{B}.\Delta\mathbf{L}$ along the **r th** element and N is the total number of elements into which loop has been divided.

Magnetic Field Strength Due To Current Carrying Solenoid



When current passes through a solenoid, it behaves like bar magnet. Suppose that the magnetic field inside a long solenoid is uniform and much strong whereas outside the solenoid.

We want to find out the magnetic field strength B inside the solenoid by applying Ampere circuital law. For this we consider a rectangular Amperean loop. We divide the loop into four elements of lengths $ab = l_1$, $bc = l_2$, $cd = l_3$ and $da = l_4$.

Applying Ampere's law, we have:

$$\sum_{r=1}^{4}(\mathbf{B}.\Delta\mathbf{L})_r = \mu_0 \times current\ enclosed$$

$$(\mathbf{B}.\Delta\mathbf{L})_1 + (\mathbf{B}.\Delta\mathbf{L})_2 + (\mathbf{B}.\Delta\mathbf{L})_3 + (\mathbf{B}.\Delta\mathbf{L})_4 = \mu_0 \times current\ enclosed \quad \text{-------} \quad (1)$$

- The length element $ab = l_1$ lies inside the solenoid, where the field is uniform and is parallel to l_1:

  $(\mathbf{B}.\Delta\mathbf{L})_1 = B\, l_1 \cos 0^0 = B\, l_1$
- For the element $cd = l_3$, that lies outside the solenoid, the field $\mathbf{B}$ is zero, so

  $(\mathbf{B}.\Delta\mathbf{L})_3 = 0$
- For elements $bc = l_2$ and $da = l_4$, $\mathbf{B}$ is perpendicular to length elements, so

  $(\mathbf{B}.\Delta\mathbf{L})_2 = (\mathbf{B}.\Delta\mathbf{L})_4 = 0$

The equation (1) becomes:

$$B\, l_1 = \mu_0 \times current\ enclosed$$

If n is the number of turns per unit length of the solenoid, the rectangular surface will intercept nl_1 turns, each carrying current I. So the current enclosed by the loop is $nl_1 I$. Thus Ampere's law gives

$$B\, l_1 = \mu_0 \times nl_1 I$$

$$B = \mu_0 nI$$

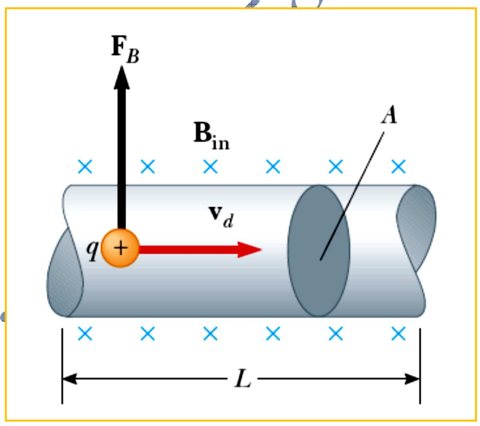
Direction of Magnetic field strength inside Solenoid

The direction of magnetic field strength B can be find out by right hand rule which states:

Hold the solenoid in the right hand with figures curling in the direction of current, the thumb will point in the direction of the field.

Q # 7. Find out the expression of magnetic force on a moving charge in a magnetic field.

Ans. Consider the portion of wire, carrying current I, is placed in an external magnetic field of strength **B**. The magnetic force on the current carrying conductor is given by the expression:



$$\mathbf{F}_L = I\,(\mathbf{L} \times \mathbf{B}) \quad \text{----------} \quad \mathbf{(1)}$$

Let

n = Number of free electrons per unit

AL = Volume of the conductor

nAL = Number of free electrons in the conductor

v = Speed of the charge carrier

Then the carrier entering the left face of the segment takes the time $\Delta t = {}^{L}/_{v}$ to reach the right face. If

q = Charge on a charge carrier

Then $nALq = \Delta Q$ = Total charge flowing in conductor in time $\Delta t = {}^{L}/_{v}$

So, the current through conductor is:

$$I = \frac{q}{t} = \frac{nALq}{L/v} = nAqv$$

The equation (1) becomes:

$$\mathbf{F}_L = nAqv\,(\mathbf{L} \times \mathbf{B})$$

$$= nAqv\,(L\hat{L} \times \mathbf{B}) \quad \text{----------} \quad \mathbf{(2)}$$

It is clear from the figure that the direction of the segment **L** is the same as the direction of the velocity of the charge carriers **v**. If $\hat{L}$ is a unit vector along the direction of segment **L** and $\hat{v}$ is along the velocity **v**, then

$$\hat{L} = \hat{v}$$

Substituting the value in equation (2), we have:

$$\mathbf{F}_L = nAqv\,(L\hat{v} \times \mathbf{B})$$

$$= nAqL\,(v\hat{v} \times \mathbf{B})$$

$$= nALq\,(\mathbf{v} \times \mathbf{B})$$

As nAL is the total number of charge carriers in the segment **L,** so the force **F** experienced by a single charge carrier is:

$$\mathbf{F} = \frac{\mathbf{F}_L}{nAL} = q\,(\mathbf{v} \times \mathbf{B})$$

Thus the force experience by a single charge carrier moving with velocity **v** in the magnetic field strength **B** is:

$$\mathbf{F} = q\,(\mathbf{v} \times \mathbf{B})$$

Q # 8. What do you know about the Lorentz force?

When a charge particle q is moving with velocity $\mathbf{v}$ in a region where there is electric field $\mathbf{E}$ and magnetic field $\mathbf{B}$, then the vector sum of electric force $q\mathbf{E}$ and magnetic force $q\,(\mathbf{v} \times \mathbf{B})$ is called the Lorentz force $\mathbf{F}$. Mathematically, it is described as:

$$\mathbf{F} = \mathbf{F_e} + \mathbf{F_b}$$

$$\mathbf{F} = q\mathbf{E} + q\,(\mathbf{v} \times \mathbf{B})$$

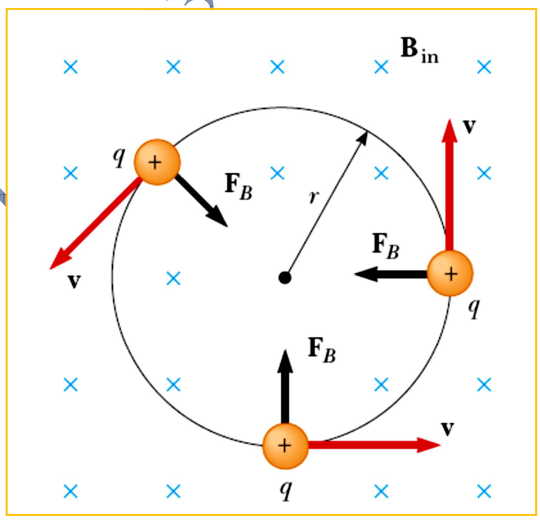
It is important to note that only the electric force does work, while no work is done by the magnetic force which is simply a deflecting force.

Q # 9. Derive the expression to find out e/m of an electron.

Ans. Let a narrow beam of electrons moving with a constant speed v be projected at right angles to a known magnetic field $\mathbf{B}$. The magnetic force experienced by the beam of electron will be:

$$\mathbf{F} = -e\,(\mathbf{v} \times \mathbf{B})$$

The direction of the force will be perpendicular to both $\mathbf{v}$ and $\mathbf{B}$. As the electron is experiencing a force that acts at right angle to velocity, so it will change the direction of velocity. Thus the electrons are subjected to a constant force $F = evB$ at the right angle to the direction of motion. Under the action of this force, the electrons will move in the circle as shown in the figure.



As the electron moves in the circle, the necessary magnetic force $\frac{mv^2}{r}$ is provided by the magnetic force $F = evB$. Thus we have:

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

$$\frac{e}{m} = \frac{v}{Br} \quad \text{----------} (1)$$

This equation shows that if the values of v and r is known, e/m of the electron is determined.

- To find out the value of r, a glass tube is filled with a gas such as hydrogen at low pressure. The glass tube is placed in a region of uniform magnetic field of known value. As the electrons are shot into this tube, they begin to move along a circle under the action of magnetic force. As the electron move, they collide with the atoms of gas. This excites the atoms due to which they emit light and their path becomes visible as a circular ring of light. The diameter of ring can be easily measured.
- In order to measure the velocity v of electrons, we should know the potential difference through which the electrons are accelerated before entering into magnetic field. If V is this potential difference, the energy gained by the electrons during their acceleration is Ve. This appears as kinetic energy of electrons:

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

$$v = \sqrt{\frac{2Ve}{m}}$$

Substituting the value of v in equation (1), we get:

$$\frac{e}{m} = \frac{1}{Br}\sqrt{\frac{2Ve}{m}}$$

$$\sqrt{\frac{e}{m}} = \frac{1}{Br}\sqrt{2V}$$

Squaring both sides:

$$\frac{e}{m} = \frac{2V}{B^2r^2}$$

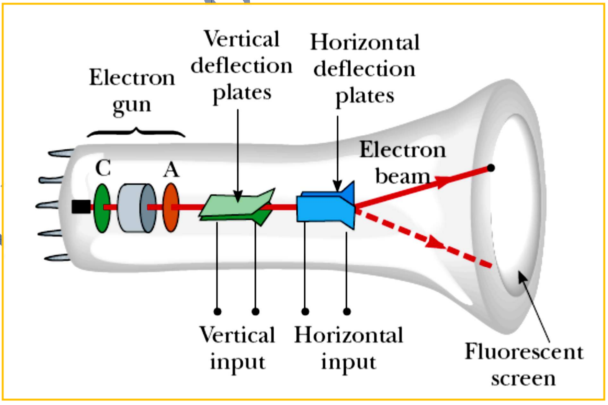
This is the required expression to find the $^{e}/_{m}$ of electron.

Q # 10. What do you know about cathode ray oscilloscope (CRO)? Also describe the construction, working and applications of CRO.

Ans. Cathode ray oscilloscope is a high speed graph plotting device. It is called cathode ray oscilloscope because it traces the desired waveform with a beam of electrons which are also called cathode rays.

Principle

Its works by deflecting the beam of electrons as they pass through uniform electric field between the two sets of parallel plates. The deflected beam then falls on fluorescent screen where it makes a visible spot. It can display the graphs of functions which rapidly vary with time.



Construction

The beam of electrons is provided by an electron gun which consists of an indirectly heated cathode, a grid and anode. The filament heats the cathode C which emits electrons. The anode A which is at high positive potential with respect to cathode, accelerate as well as focus the electronic beam to the fixed spot on the screen.

The two set of defecting plates are usually referred as horizontal and vertical deflection plates. A voltage applied between the horizontal plates deflects the beam horizontally on the screen and the voltage applied across vertical deflects the beam vertically on the screen.

Working

The voltage that is provided across horizontal plates is usually provided by a circuit that is built in the CRO. It is known as sweep or time base generator whose output waveform is a saw tooth voltage of period T.

If a sinusoidal voltage is applied across the y plates when, simultaneously, time base voltage is impressed across horizontal plates, will now spread out and appear as sinusoidal trace on the screen.

Uses of CRO

The CRO is used for displaying the waveform of a given voltage. Once the waveform is displayed, we can measure the voltage, its frequency and phase. Information about the phase difference between two voltages can be obtained by simultaneously displaying their waveforms.

Q # 11. Find out expression of torque on a current carrying coil.

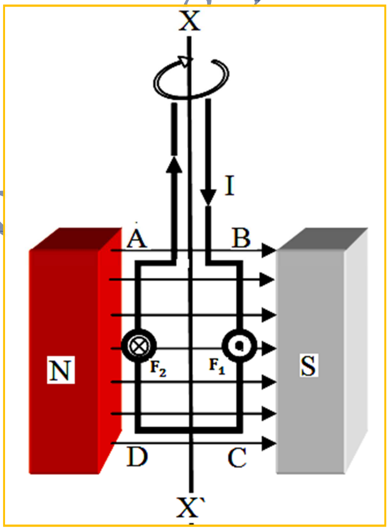
Ans. Consider a rectangular coil carrying current I. The coil is capable of rotation about an axis XX\`. Suppose it is placed in uniform magnetic field **B** with its plane along the field.

The force on current carrying conductor placed in magnetic field is describe by the expression $F = ILB\sin\theta$, where θ is the angle between conductor and the field.

- In case of the sides AB and CD of the coil, the angle θ is zero or 180^0, so the force on these sides will be zero.
- In case of sides DA and BC, the angle θ is 90^0 and the force on these sides will be:

$$F_1 = F_2 = ILB$$

Where L is the length of these sides, F_1 is the force on the side DA and F_2 on BC.



Therefore, the forces $\mathbf{F_1}$ and $\mathbf{F_2}$ being equal and opposite form a couple which tends to rotate it about an axis.

The torque τ of the couple is given by the expression:

$$\tau = (Force)(Moment\ Arm)$$

$$\tau = (ILB)(a) = IBLa \quad ---------- \quad (1)$$

where a is the moment arm of the couple and is equal to the length of side AB or CD. La is the area of the coil. The equation (1) becomes:

$$\tau = IBA \quad ---------- \quad (2)$$

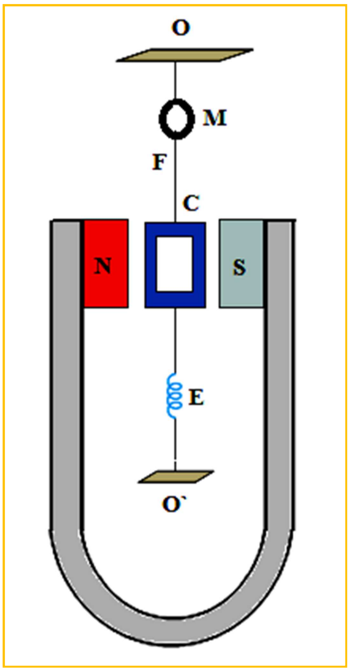
The equation (2) gives the value of torque when the field **B** is in the plane of the coil. However, if the field makes an angle α with the plane of the coil, the moment arm will become $a\cos\alpha$. So,

$$\tau = IBLa\cos\alpha$$

$$\tau = IBA\cos\alpha$$

Q # 12. What do you know about galvanometer? Also describe its construction and working.

Ans. A galvanometer is an electrical instrument used to detect the passage of current.



Principle

Its working depends upon the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque which can be described by the formula:

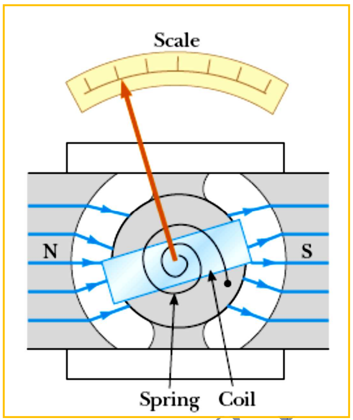
$$\tau = NIAB\cos\alpha$$

Where N is the number of turns in the coil, A is its area, I is the current passing through it, B is the magnetic field in which the coil is placed and α is the angle which the plane of the coil makes with B.

Due to action of the torque, the coil rotates and thus it detects the current.

Construction

A rectangular coil C is suspended between concaved shaped N and S poles of horseshoe magnet with the help of a fine metallic suspension wire. The suspension wire F is also used as one current lead to the coil. The other terminal of the coil is connected to a loosely wound spiral E which serve as the second current lead. The pole pieces of the magnet are made concave to make the field radial and stronger.



Working

When the current is passed through the coil, it is acted upon by a couple which tends to rotate the coil. This couple is known as deflecting couple and is given by $NIAB\cos\alpha$. As the coil is placed in radial magnetic field in which the plane of the coil is always parallel to the firld , so α is always zero. This makes $\cos\alpha = 1$ and thus,

$$Deflecting\ Couple = NIAB$$

As the coil turns under the action of deflecting couple, the suspension wire is twisted which gives rise to a torsional couple. It tends to untwist the suspension and restore the coil to its original position. This couple is known as restoring couple. The restoring couple of the suspension wire is proportional to the angle of deflection θ as long as the suspension wire obeys Hook's law. Thus

$$Restoring\ Torque = c\theta$$

Where constant c is called torsional couple and is defined as the couple of untwist.
Under the effect of these two couples, coil comes to rest when

$$Deflecting\ Torque = Restoring\ Torque$$

$$NIAB = c\theta$$

$$I = \frac{c}{NAB}\theta \quad ---------- \quad (1)$$

Thus $I \ \alpha \ \theta$ since $\frac{c}{NAB} = constant.$

Thus the current passing through the coil is directly proportional to the angle of deflection.

Sensitivity of Galvanometer

Sensitivity of the galvanometer is the measure of the ability of galvanometer to detect small amount of current. It is obvious from equation (1) that a galvanometer can be made more sensitive if $\frac{c}{NAB}$ is made small. Thus, to increase the sensitivity of galvanometer, c may be decreased or B, A and N may be increased.

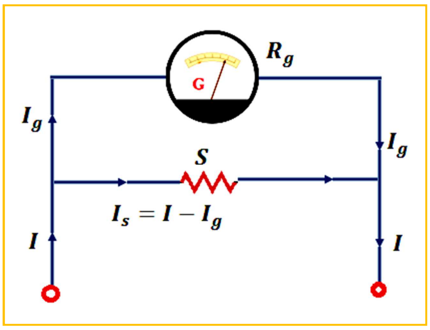
Dead Beat Galvanometer

The galvanometer in which the coil comes to rest quickly after current passed through it or the current is stopped from flowing through it, is called stable or a dead beat galvanometer.

Q # 13. Describe the working of an ammeter.

Ans. An ammeter is an electrical instrument which is used to measure the current in amperes. An ammeter can be constructed by connecting a low value bypass resistance (called shunt) to a galvanometer.

Consider a galvanometer of resistance R_g which gives full scale deflection when current I_g is passed through it. The potential difference V_g that causes the current I_g to pass through galvanometer is given by



$$V_g = I_g R_g$$

We want to find out the expression of shunt (bypass) resistant R_s that is needed to convert the galvanometer to ammeter which can measure maximum current I.

The shunt resistance is of such a value so that the current I_g pass through galvanometer and the remaining current $(I - I_g)$ passes through shunt.

As the shunt resistance is parallel to the galvanometer, the potential difference across the galvanometer is equal to the potential difference across the shunt.

$$V_g = V_s$$

$$I_g R_g = (I - I_g) R_s$$

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

This is the expression to find out the shunt resistance, that is connected in parallel to convert galvanometer into ammeter.

Q # 14. Find out expression of resistance that is connected in series with galvanometer to convert it into voltmeter.

Ans. A voltmeter is an electrical device which measures the potential difference in volts between two points in an electric circuit.

To construct a voltmeter, a very high resistance is connected in series with galvanometer. Consider a galvanometer of resistance R_g which gives full scale deflection when current I_g is passed through it.

In order to make a voltmeter of the range of V volts, the value of high should be such that full scale deflection is obtained when it is connected across V volts. If the current I_g passes through the circuit, then by applying Ohm's law:

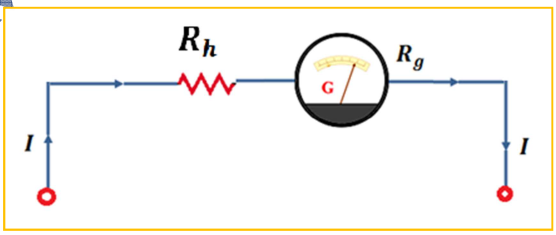
$$V = V_g + V_R$$

$$\Rightarrow V = I_g R_g + I_g R_h$$

$$\Rightarrow V = I_g (R_g + R_h)$$

$$\Rightarrow \frac{V}{I_g} = R_g + R_h$$

$$\Rightarrow \boldsymbol{R_h} = \frac{V}{I_g} - R_g$$



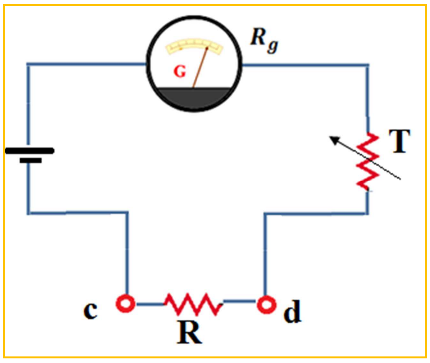
This is the expression to find out the resistance that is connected in series to convert galvanometer into ammeter.

Q # 15. Describe the construction and working of Ohmmeter.

Ans. It is a useful device for rapid measurement of resistance. It consists of a galvanometer, and adjustable resistance of known value and a cell connected in series as shown on the figure.

To convert a galvanometer into ohmmeter, the scale of galvanometer is calibrated using the following procedure:

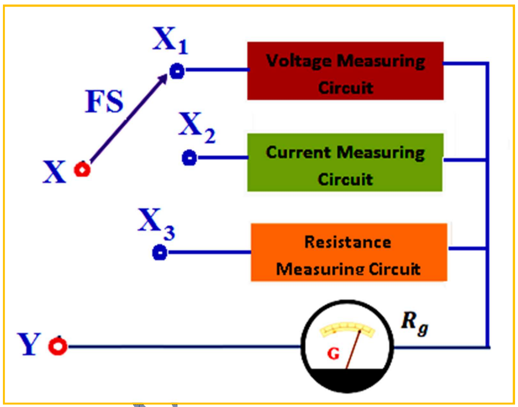
- The series resistance R_s is so adjusted that when the terminals c and d are short circuited $(R = 0)$, the galvanometer gives full scale deflection. So the extreme graduation of the usual scale of the galvanometer is marked 0 for resistance measurement.



- When the terminals c and d are not joined, no current passes through galvanometer and its deflection is zero. Thus zero of the scale is marked as infinity ohms.
- When R is not infinite, the galvanometer deflects to some intermediate point depending on the value of R and hence the galvanometer scale can he calibrated to read the resistance directly.

Q # 16. Write down the working of AVO meter in detail.

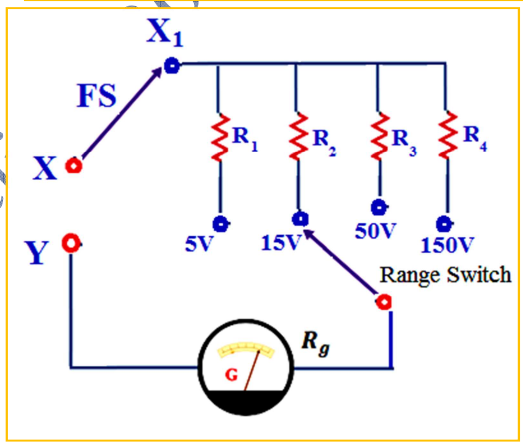
It is an instrument which can measure the current in amperes, potential difference in volts and resistance in ohms. It actually employs a single galvanometer which by the help of a switch is converted into multi-ranged ammeter, voltmeter and ohmmeter according to the requirement of the user.



Here X and Y are the main terminals of AVO meter which is connected with the circuit in which the measurement is required. FS is the function selector switch which connects the galvanometer with relevant measuring circuit.

Voltage Measuring Part of AVO Meter

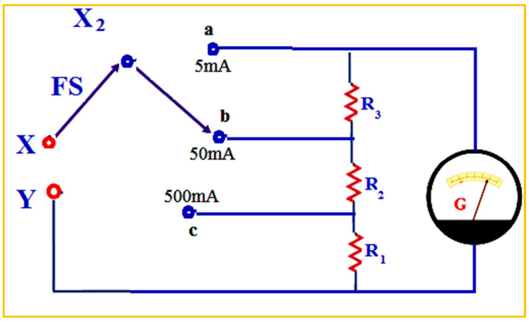
The voltage measuring part of AVO Meter is actually a multi-ranged voltmeter. It consist of a number of resistances each of which can be connected in series with the moving coil galvanometer with the help of a switch called the range switch. The value of each resistance depends upon the range of the voltmeter which it controls.



Current Measuring Part of AVO Meter

The current measuring part of AVO meter is actually is a multi-ranged ammeter. It consist of a number of low resistance connected in parallel with the galvanometer. The values to these resistances depend upon the range of the ammeter.

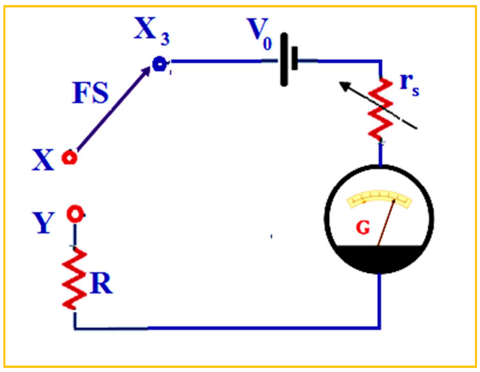
The circuit also has a range selection switch SR which is used to select a particular range of current.



Resistance Measuring Part of AVO Meter

The resistance measuring part of AVO meter is in fact a multi-range ohmmeter. Circuit for each range of this meter consist of a battery of emf V_0 and a variable resistance R_s connected in series with galvanometer of resistance R_g.

Before measuring an unknown resistance by an ohmmeter, it is first zeroed which means that we short circuit the terminals X, Y and adjust to r, to produce full scale deflection.



Digital Multimeter

Another useful device to measure resistance, current and voltage is an electronic instrument called digital multimeter. It is a digital version of an AVO meter. It has become very popular testing device because the digital values are displayed automatically with decimal point, polarity and the unit for $V, A\ or\ \Omega$.

These meters are generally easier to use because they eliminate the human error that often occur in reading the dial of an ordinary AVO meter.

EXERCISE SHORT QUESTIONS

Q # 1. A plane conducting loop is located in a uniform magnetic field that is directed along the x-axis. For what orientations of the loop, is the flux maximum? For what orientation, is the flux minimum?

Ans. The magnetic flux through a conducting loop can be find out by the expression:

$$\Delta\varphi = \mathbf{B}.\mathbf{A} = BA\cos\theta$$

Here **B** is the magnetic field strength and A is vector area whose direction is perpendicular to the plane of the loop.

Case 1. When vector area of the conducting loop is in the direction of magnetic field strength i.e., $\theta = 0°$, then the magnetic flux:

$$\Delta\varphi = \mathbf{B}.\mathbf{A} = BA\cos 0° = BA \qquad \text{as } \cos 0° = 1$$

Thus the magnetic flux through the coil is maximum, when the vector area of the conducting loop is parallel to magnetic field strength.

Case 2. When vector area of the conducting loop is perpendicular to magnetic field strength i.e., $\theta = 90°$, then the magnetic flux:

$$\Delta\varphi = \mathbf{B}.\mathbf{A} = BA\cos 90° = BA \qquad \text{as } \cos 90° = 0$$

Thus the magnetic flux through the coil is minimum, when the vector area of the conducting loop is perpendicular to magnetic field strength.

Q # 2. A current in a conductor produce 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 charges cannot produce any magnetic field. In case of stationary charges, the rate of flow of charges is zero(i.e. current = 0), so there will be no magnetic field.

As the moving charges produce current, so the magnetic field produced around the path of its motion similar to the magnetic field produced around a current carrying conductor.

Q # 3. Describe the charge in the magnetic field inside a solenoid carrying 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 are doubled, but the length remains the same.

Ans. The magnetic field strength **B** inside a current carrying conductor can be find out by the expression:

$$B = \mu_0 nI \quad \text{-----------} \ (1)$$

Where I is the current flowing through conductor and n is the number of turns per unit length i.e., $n = \frac{N}{L}$. Thus

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

(a) When Length of solenoid is doubled by keeping the number of turns constant, then magnetic field strength:

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

Thus on doubling the length of solenoid by keeping the turns constant, the magnetic field strength becomes one half of its original value.

(b) When number of turns of solenoid is doubled by keeping the length of solenoid constant, then magnetic field strength:

$$B'' = \frac{\mu_0 (2N) I}{L} \Longrightarrow B'' = 2B$$

Thus on doubling the number of turns of solenoid by keeping its length constant, the magnetic field strength becomes doubled of its original value.

Q # 4. At a given instant, a proton moves in the positive x-direction in the 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. As the proton is moving in the positive x-direction and magnetic field is directed into the plane of paper, then the magnetic force on proton can be find out using expression:

$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$$

According to right hand rule, the magnetic force is directed along y-axis.

No, the proton will not continue to move in the positive x-direction. Since the magnetic force is acting at the right angle to motion of conductor, therefore it will move along a circular path in xy-plane.

Q # 5. Two charged particles are projected into a region where there is a magnetic field perpendicular to their velocities. If the charge are deflected in opposite directions, what can you say about them?

Ans. When a charge particle is projected in a magnetic field, it will experience the magnetic force given by:

$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$$

The magnetic force is a deflecting force. Thus if the charged particles are deflected in opposite direction, then particles are oppositely charged. i.e., one particle is positively charged and the other is negatively charged.

Q # 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 a charge particle will act normal to the direction of motion of the particle, so the work done by the force is given by:

$$W = \mathbf{F}.\mathbf{d} = Fd\cos\theta$$

Where θ is the angle between the magnetic force and displacement of charge particle. For present case: $\theta = 90°$. Therefore:

$$W = Fd\cos 90° = 0$$

Thus we can say that magnetic force is a deflecting force and it cannot do any work.

Q # 7. If a charge particle moves in a straight line through some region of space, can you say that the magnetic field in the region is zero.

Ans. The magnitude of magnetic force on a charge particle can be expressed as:

$$F = qvB\sin\theta$$

Where θ is the angle between **B** and **v**. So if the particle moves in a straight line through some region of space then it means that the charge particle is not experiencing magnetic force which might be due to one of the following reasons:

- **i.** Magnetic field strength B in the region is zero
- **ii.** Magnetic field is parallel or anti-parallel to the direction of motion.

Q # 8. Why does the picture on a TV screen become distorted when a magnet is brought near the screen?

Ans. The picture on a TV is formed when moving electrons strike the florescent screen. As magnet is brought close to the TV screen, the path of electrons is distorted due to the magnetic force on them. So the picture on the screen of TV is distorted.

Q # 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 magnetic field will experience a torque given by:

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

Where B is the magnetic field strength, I is current flowing through coil, N is number of turns in a coil, A is the area of the coil and α is the angle between plane of the coil and magnetic field.

It is clear from expression that when plane of the coil makes and angle of 90° with magnetic field, the torque on the coil will be zero. In this condition, the coil will not tend to rotate.

Q # 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, a torque is produced in the loop is given by:

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

If the loop is deflected in a given region, then it confirms the presence of magnetic field, otherwise not.

Q # 11. How can you use a magnetic field to separate isotopes of chemical element?

Ans. If the ions of isotopes of an element are projected in a magnetic field of known strength B, the ions move in circular path of radius r. The e/m of the ion is given by the expression:

$$\frac{e}{m} = \frac{v}{Br} \Rightarrow r = \frac{v}{B} \times \frac{m}{e}$$

If v, B and e of the ions are constant, then

$$r \propto m$$

So the ions of different mass will have different radii of curvature and hence they can be separated in magnetic field.

Q # 12. What should be the orientation of a current carrying coil in a magnetic field so that torque acting upon the coil is (a) maximum (b) minimum?

Ans. A current carrying loop when placed in magnetic field will experience a torque given by:

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

Where B is the magnetic field strength, I is current flowing through coil, N is number of turns in a coil, A is the area of the coil and α is the angle between plane of the coil and magnetic field.

(a) When plane of the coil is parallel to magnetic field, $\alpha = 0$ and the torque acting on the coil will be maximum given by: $\tau = BINA\cos 0° = BINA$

(b) When plane of the coil is perpendicular to magnetic field, $\alpha = 90°$ and the torque acting on the coil will be minimum, given by: $\tau = BINA\cos 90° = 0$.

Q # 13. A loop of wire is suspended between the pools 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. When direct current is passed through he coil of wire, a torque acts on the coil which rotates the coil.

However, when alternating current is passed through the coil, the direction of current is reversed after every half cycle of the coil. So the coil oscillates in the magnetic field instead of rotating.

Q # 14. Why the resistance of an ammeter should be very low?

Ans. An ammeter is connected in series with a circuit to measure the current. It is connected in series so that total current passing through the circuit should pass through it. If the resistance of the ammeter will be large, it will alter the current of the circuit to great extent and the measurement of current will not be accurate.

Q # 15. Why the voltmeter should have a very high resistance?

Ans. A voltmeter is connected in parallel to the resistor to measure potential difference across it. It should have very high resistance so that practically, a very little current should pass through it and the current of the circuit should almost remain constant, so that it might measure the potential difference across a resistor accurately.

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