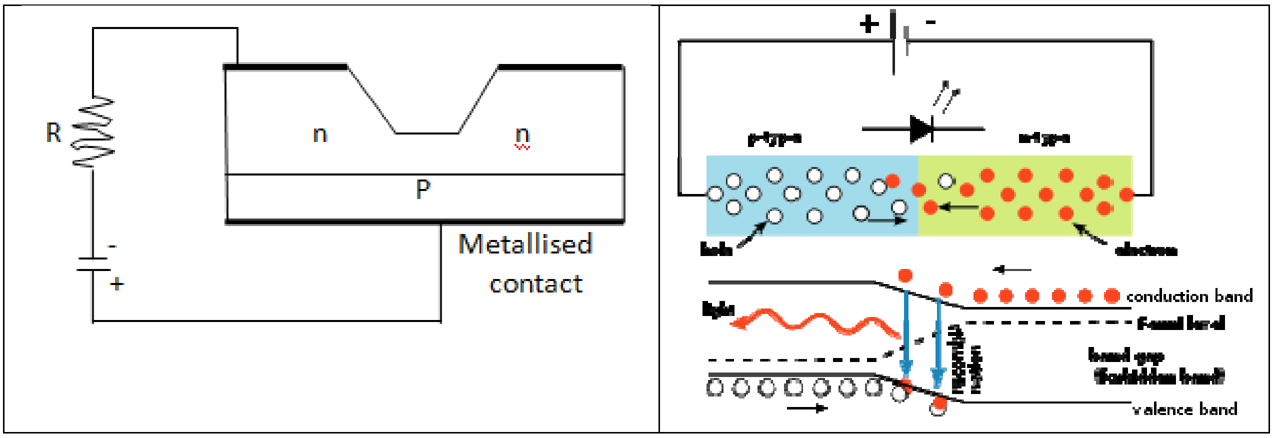
Q27. Explain, with the help of a schematic diagram, the principle and working of a Light Emitting Diode. What criterion is kept in mind while choosing the semiconductor material for such a device? Write any two advantages of Light Emitting Diode over conventional incandescent lamps.

Answer: A light-emitting diode (LED) is a two-lead semiconductor light source. It is a basic pn-junction (forward biased) diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.



In a forward biased p-n junction, the electrons of the n-region and holes of p-region are pushed towards the junction where electron-hole recombination taken place. As the electrons are in higher conduction band on n-side and holes are in lower valence band on p-side, the energy difference appears in the form of heat or light radiation during the process of recombination.

Based on the requirement of wavelength of light required to be emitted from LED suitable semiconductor is chosen.

Advantages:

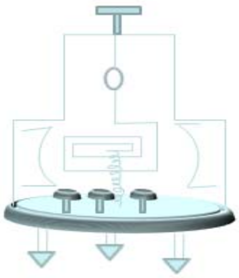
(I) LEDs emit more lumens per watt than incandescent light bulbs. Efficiency of LED's are high in comparision to bulbs or tubes..

(II) It takes micro seconds to warm up and lifetime of LED is very high 35,000 to 50,000 hrs.

Q28. Draw a labeled diagram of a moving coil galvanometer. State the principle on which it works.

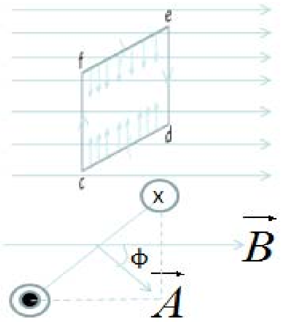
Deduce an expression for the torque acting on a rectangular current carrying loop kept in a uniform magnetic field. Write two factors on which the current sensitivity of a moving coil galvanometer depends.

Answer:



Principle :(Based on the principle of the force of interaction between the current carrying conductor and a magnetic field) A coil is suspended in a magnetic field. The current to be measured is passed through the coil. The current through the coil produces a magnetic field which interacts with the given magnetic field in which the coil is suspended. Due to the interaction the coil gets deflected and measuring the angle of rotation current can be calculated.

A circular or rectangular coil of about 10 to 15 turns of a fine insulated copper or aluminium wire is suspended from a torsion head T, by means of quartz fibre in between the concave pole pieces of a strong magnet. The lower end of the coil is attached to a light springs which brings the coil back to its original position when the current is stopped. The suspension wire and the spring are connected with two terminal screws at the base which acts as the leads of current. The whole thing is enclosed in a metal box provided with glass face and is supported on leveling screws. The angle of rotation of the coil is measured by lamp & scale arrangement, reflection takes place from the tiny mirror M attached with the suspension wire.



Theory : Given n = the number of turns in the coil

l & b = the length of each vertical & horizontal side of the coil respectively (assuming) the coil to be rectangular

i = the current flowing through the coil.

B = the induction vector of the magnetic field in which the coil is suspended.

We know that the force experienced by the current carrying conductor placed in a magnetic field is

$\vec{F} = i(\vec{l} \times \vec{B}) \to (1)$

Force on each wire 'de' and 'fc'

$|\vec{F}| = ibB\sin(90 - \phi) = ibB\sin\phi$

where ϕ = angle between the normal to the plane of the coil and the direction of the magnetic field.

The direction of the force on the wires 'de' & 'fc' are in the plane of the coil along the downward and upward direction respectively and hence cancel out.

The force on the two vertical wires 'cd' and 'ef' by using equation(1) are found to have magnitude

$F = ilB\sin 90^0 = ilb$

Applying the right hand curl rule for vector product the directions of the force are as shown in the figure. These two forces being equal in magnitude, opposite in direction parallel and non co-planer constitute a couple.

Moment of the couple $\Gamma = ilB \times OC$

$\Gamma = ilBb\sin\phi = i(lb)B\sin\phi = iAB\sin\phi$

Since there are n turns in the coil the total torque experienced by the current carrying coil in the magnetic field

$\Gamma = \text{niABsin}\phi$

Due to this torque the coil rotates a restoring couple due to the torsion rigidity sets in and when the restoring couple equals to the deflecting couple the coil comes to equilibrium

Let c = torsional couple per unit twist of the suspension wire

θ = the angle through which the coil rotate in the position of equilibrium

Restoring couple $= c\theta \rightarrow (1)$

From equation(2) and (3): $\text{nAiBsin}\phi = c\theta$

$$i = \frac{c}{nAB}\frac{\theta}{\sin\phi} \rightarrow (4)$$

By using concave pole pieces the magnetic field is made radial so that for any position of coil ϕ is always 90^0.

$\sin\phi = \sin 90^0 = 1$

$$\therefore i = \frac{c}{nAB}\theta \rightarrow (5)$$

Since c, n, A & B are all constant

$i \propto \theta$

The current sensitivity of a moving coil galvanometer depends on

(I) Number of turns in the galvanometer coil.
(II) Torsional constant of the suspension fibre.

Or,

State Biot-Savart law. Use it to derive an expression for the magnetic field at the center of a circular loop of radius R carrying a steady current I. Sketch the magnetic field lines for such a current carrying loop.

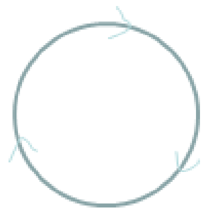
Answer: **Biot-Savart Law :** It states that the magnetic field $d\vec{B}$ due to a current element *dl* carrying a steady current I at a point P at a distance r from the current element is

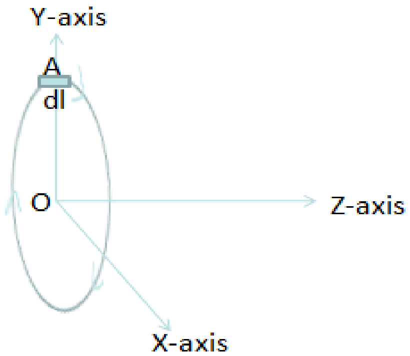
$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{r}}{r^3}$$

$$\Rightarrow dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

Where θ is the angle between the direction of the current and the line joining the current element.

Magnetic Field at the center of the circular Coil/Loop Carrying Current:





We have a circular coil of many turns a current flows through the coil . We have to find the magnetic field at the centre of the coil due to the current through the coil.

Given

i = current flowing through the coil

a =radius of the coil

n = number of turns in the coil

Let us choose a right handed system of mutually perpendicular axes X,Y and Z as follows. The plane of the coil is represented by Y-Z plane and X-axis is perpendicular to the plane of the coil at O.

Let us consider an element of the coil at A of length dl. The axis of the element is along Z-axis i.e. dl is along Z-axis using Biot's law the magnetic field at O due to the current element at A

$$db = \frac{\mu_0}{4\pi}\frac{i}{r^2}\left(\vec{dl}\times\hat{r}\right) \rightarrow (1)$$

Where r = a = radius of the coil

$\hat{r}$ = a unit vector along Y axis

Taking the magnitude of equation(1)

$$\left|\vec{db}\right| = db = \frac{\mu_0}{4\pi}\frac{i}{a^2}dl\times 1\times\sin 90^0 = \frac{\mu_0}{4\pi}\frac{idl}{a^2} \rightarrow (2)$$

Applying the right handed curl rule for vector product the direction of the magnetic field is along X axis in the figure.If we consider the element at different points along the coil it is found that for every position of the element the direction of the magnetic field at the centre O along X-axis. Since the direction of the magnetic field at O is same for every position of the element hence vector addition reduces to scalar addition and resultant magnetic field at O can be obtained by integrating equation(2)

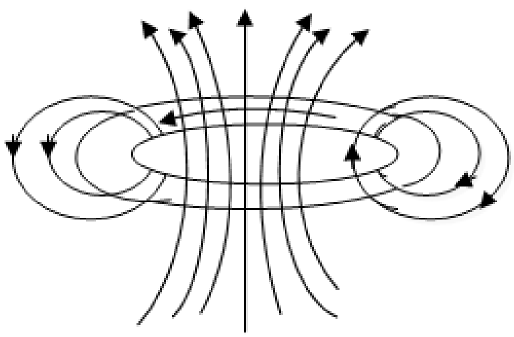
$$B = \int dB = \int \frac{\mu_0}{4\pi}\frac{idl}{a^2} = \frac{\mu_0}{4\pi}\frac{i}{a^2}\int dl = \frac{\mu_0}{4\pi}\frac{i}{a^2}(2\pi a \times n) = \frac{\mu_0}{2}\frac{ni}{a} \rightarrow (3)$$

$$\int dl = \text{the total length of the coil} = (2\pi a)n$$

Equation (3) gives the magnitude of the magnetic field at the centre of the circular coil carrying current.

Direction of Magnetic field:

The direction of the magnetic field at the centre which is found to be along X axis can be stated as follows :



" Curl the finger of right hand in the direction of current in the coil the thumb gives the direction of the magnetic field"