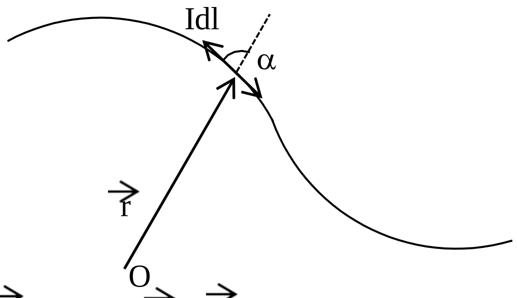
Magnetic effect of current,Magnetic Force , ElectromagneticInduction & inductance

Magnetic effect of current :

1. ***What is Biot – Savart law. Find an expression for magnetic field at a point due to long straight current carrying conductor. Or, Derive expression for magnetic field at the center of the circularcoil.***

Ans: Biot – Savart law establish a relation between electric current and magnetic field due to the current. According to Biot – Savart law the magnetic field at any point due to currentelement.



$\vec{dB} = \mu_o/4\pi[\vec{r} \cdot I\,\vec{dl}/r^3]$

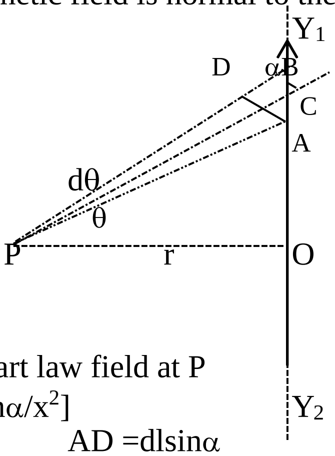
$dB = \mu_o/4\pi[I\,dl\,\sin\alpha/r^2]$

Where Idl = current element.

α= angle between Idl and r.

$\vec{r}$ = position vector of the current element.

The direction of the magnetic field is normal to the plane of $\vec{r}$ and $\vec{Idl}$.



Y_1Y_2 is along straight wire carryingcurrentI and P is apoint at perpendicular distancer.

ABiscurrent element AB atdistance PC = x at angle θ.

According to Biot – Savart law field at P

$dB = \mu_o/4\pi[Idl\sin\alpha/x^2]$

In △ABD $\sin\alpha = AD/AB$ AD =dlsinα

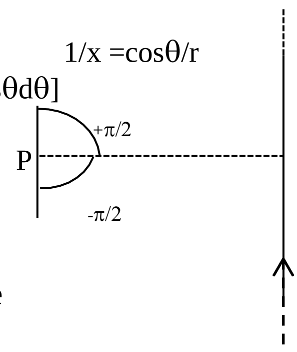
Since AD=xdθ xdθ=dlsinα

$dB = \mu_o/4\pi[d\theta/x]$

In △OPA $\cos\theta = r/x$ $1/x = \cos\theta/r$

$dB = \mu_o/4\pi[I/r\cos\theta d\theta]$

If the wireislong



$B = \mu_o/4\pi.[I/r \int_{-\pi/2}^{+\pi/2}\cos\theta d\theta]$

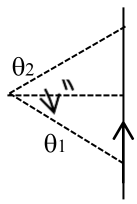
$B = \mu_o/4\pi[2I/r]$

If the wire is long but the point P is near one end.

$B = \mu_o/4\pi.[I/r \int_0^{\pi/2}\cos\theta d\theta]$

$B = \mu_o/4\pi.[I/r]$

For the wire of definite length.

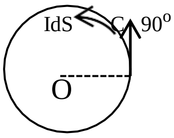


$B = \mu_o/4\pi.[I/r \int_{\theta_1}^{\theta_2}\cos\theta d\theta]$ $B = \mu_o/4\pi.[I/r(\sin\theta_2+\sin\theta_1)]$

Or

ABCD is a circular coil conducting current I of radius r with center at O.

Ids is a current element making an angle 90°with the radius vector.



According to Biot – Savart law.

$dB = \mu_o/4\pi[I\ ds\ \sin 90^o/r^2] = \mu_o/4\pi[(I/r^2)ds]$

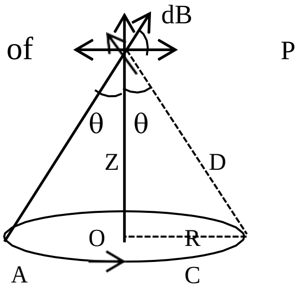
Integrating for circular coil.

$B = \mu_o/4\pi[(I/r^2)\int_0^{2\pi r} ds] = \mu_o/4\pi[2\pi I/r] = \mu_o I/2r$

If the coil has 'n' no. of turns $B = \mu_o nI/2r$

2. ***Derive expression for magnetic field at the axial point of a circular coil carryingcurrent.***

Ans: ABCD is a circularcoil of radius R conducting current I. P is axial point atdistanceZ. Magnetic filed at Pdueto current element Ids.



$dB = \mu_o/4\pi[I\ ds\ \sin 90^o/R^2+ Z^2]$

The resultant field at P due to two diametrically opposite current element.

$dB = 2.\mu_o/4\pi[(I\ ds/R^2+ Z^2)\sin 90^o]$

$= \mu_o/2\pi[(I\ ds/R^2+ Z^2).(R/\sqrt{R^2+ Z^2})]$

$= [\mu_o IR/2\pi(R^2+ Z^2)^{3/2}].ds$

Integratingbothside.

$B = [\mu_o IR/2\pi(R^2+ Z^2)^{3/2}]\int_0^{\pi R} ds$

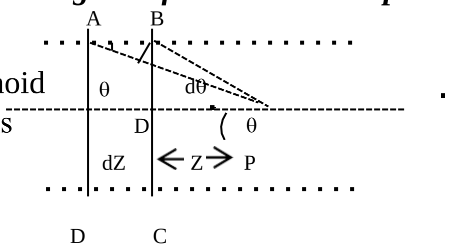
$B = [\mu_o I\pi R^2/2\pi(R^2+Z^2)^{3/2}]$

For 'n' turns.

$B = [\mu_o nIR^2/2(R^2+ Z^2)^{3/2}]$

3. ***Derive expression for magnetic field at the axial point of asolenoid.***

Ans:
X_1X_2 is along solenoid having 'n' no.ofturns per unitlengthand radius R.



$OB = O_1A = \sqrt{R^2+Z^2}$

$OO_1 = dZ$

ABCDis a section of solenoid of thickness dZ having ndZ no. of turns. P is the axial point at distance Z from center of the coil.

Magnetic field at the point P due to the elementarycircularcoil. $dB = [\mu_o ndZIR^2/2(R^2+Z^2)^{3/2}]$

In △ABD

In △ ABD_o ←

$\sin\theta = BD/AB$ $BD = AB\sin\theta = dZ\sin\theta$ And $BD = rd\theta$ Where $BP = \sqrt{R^2+Z^2}$

$rd\theta = dZ\sin\theta$

$dB = [(\mu_o nIR^2/2(R^2+ Z^2)^{3/2}].rd\theta/\sin\theta$

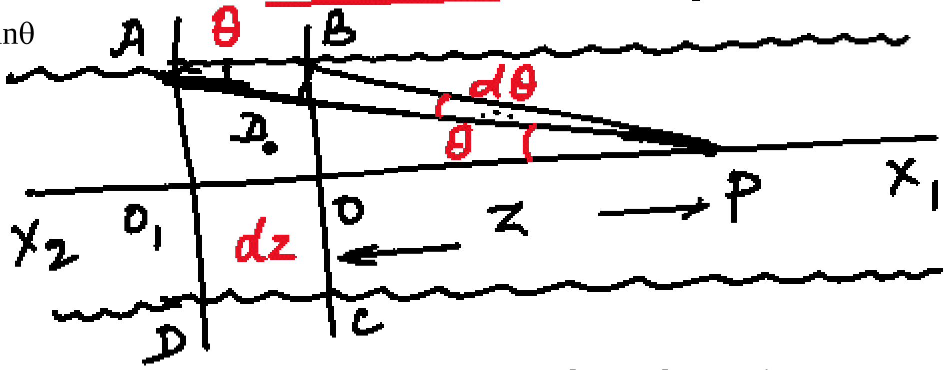
$dB = [\mu_o nI/2.(R/r)^2.d\theta/\sin\theta]$

In △ OBP $\sin\theta = h/r$

$\sin\theta = \frac{BD_o}{AB}$

$BD_o = AB\sin\theta$

Corrected Diagram.



$dB = [(\mu_o nI/2)\sin\theta.d\theta]$

If the solenoid is long and point P lie inside.

$B = (\mu_o nI/2)\int_0^{\pi}\sin\theta.d\theta=\mu_o nI$

Magnetic Force :

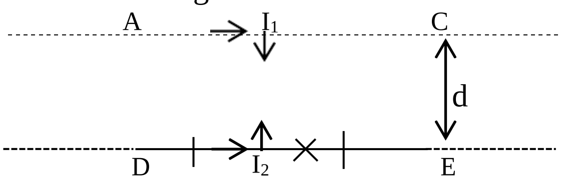
4.Derive expression for magnetic force experienced by two parallel current carrying wire. Define ampere as unit ofcurrent.

Ans: The magnetic force experienced by a current carrying conductor is defined as

$d\vec{F} = I d\vec{l} \times \vec{B}$

Where Idl = current element.

B = magnetic field.



AC and DE are two straight long parallel current carrying wire conducting currents I_1 and I_2 separated by a distance ‘d’.

Magnetic filed at DE due to current I_1

$B_2 = \mu_o/4\pi[2I_1/d]$

The magnetic force experienced by a current element I_2dl.

$dF_2 = I_2 d\vec{l} \times \vec{B_2} = I_2dlB_2\sin90^o$

$= \mu_o/4\pi(2I_1I_2/d)dl$

The magnetic field at AC due to current I_2.

$B_2=\mu_o/4\pi[2I_1/d]$ $\quad$ $dF_1 = I_1 d\vec{l} \times B_1$

$=\mu_o/4\pi(2I_1I_2/d)dl$ Thus the parallel current experience attractiveforce

The magnetic force per unit length.

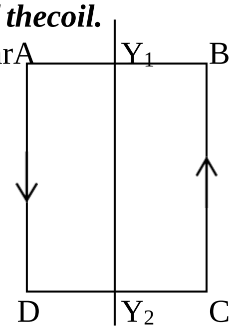
$F = \mu_o/4\pi(2I_1I_2/d)$ N/m

When d= 1m $\quad I_1 = I_2 =1 \quad F = 2\times10^{-7}$

The amount of current flowing through two parallel long wires kept at separation of 1m which generates a magnetic force of 2×10^{-7} Newton per unit meter is called one ampere.

5.Derive expression for torque experienced by a current conducting loop in uniform magnetic field. Derive magnetic moment of thecoil.

Ans: ABCD is arectangular currentconducting loop of length ‘l’ and width ‘b’ and no. of turns ‘N’. when a rectangular coil is pivoted about at axle inthemagnetic filed B which is perpendicular to theaxle.



Area vector of the coil is making an angle θ. Force acting on side AD and BC is BIl.

Torque acting on the sides.

$\tau = -2\times(b/2)BIl\sin\theta$

$= -B.I.l.b.\sin\theta$

If there are N turns.

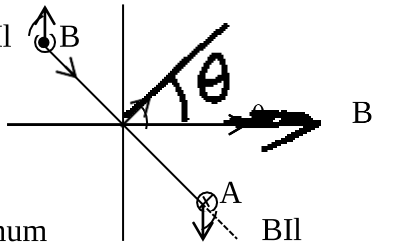
$\tau = -NIA\ B.\sin\theta$

$= -\mu B.\sin\theta$

Where μ= NIAis called magnetic moment.

$\vec{\tau} = -\vec{\mu} \times \vec{B}$

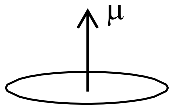
The magnetic moment of coil is defined as maximum value of torque experienced by the coil in the field ofunit strength.



θ=90°

τ_{max}=NIA Where B = 1

Its direction is normalto the coil along the magnetic field due to the current in the coil.

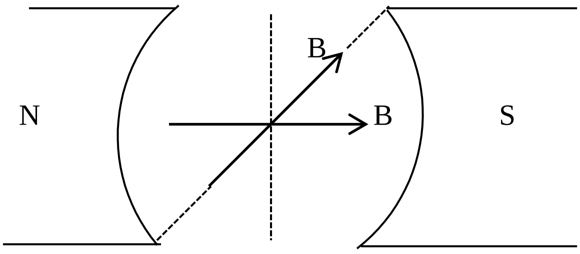


Magnetic field is along x-axis
. Angle Between $\vec{Idl}$ and $\vec{B}$.

6.Describe principle and construction of moving coilGalvanometer.

Ans: Moving coil galvanometer is an instrument used for detection of current flow. It is based on principle of magnetic effect ofcurrent.

It consists of a rectangular coil fitted with axle between two cylindrical magnetic poles faces. Such that magnetic field is perpendicular to the axis of the coil. The coil is fitted with a spiral spring. The cylindrical poles faces makes the field radial. Due to radial magnetic field the angle between field vector and magnetic moment vector of the coil remains 90°. And torque remains maximum.



The deflecting magnetic torque.

$\tau_{def} = \mu_o B \sin 90^o$

$= NIAB$

Where N = no. of turns.

I = current.

A = area.

B = magnetic field.

Due to torque to this coil suffers deflection ϕ. Causing torsion in the spring. The spring generates restoringtorque.

$\tau_{Res} = k\phi$

Where k is called elastic constant.

Under equilibrium condition

NIAB = kϕ

I = (K/NAB).ϕ

The current is measured in turns of angle of deflection ϕ.

<u>Magnetism</u> :

Long Answer Question

7.What do mean by intensity of magnetization magnetic susceptibility & magnetic permeability.Describe modern theory ofmagnetism.

Ans: When a magnetizing field is applied on a magnetic material the randomly oriented magnetic dipoles experience torque and try to align themselves in the direction of the magneticmoment.

The magnetic moment developed in the material per unit volume is called intensity of magnetization.

I = M/V = 2.l.m/2l.A

Where M = magnetic moment.

V = Volume.

m = Pole strength.

A = Cross sectional area.

Magnetic Susceptibility :

The amount of intensity of magnetization dev eloped per unit application of magnetizing field is called Magnetic Susceptibility.

$$k = I/H$$

If k = -ve the material is calleddiamagnetic.

k = +ve the material is called paramagnetic.

Magnetic Permeability :

The ratio of magnetic induction inside t5he magnetic material to the magnetizing field is called Permeability.

$$\mu = B/H$$

If $\mu>1$ the material is paramagnetic or ferromagnetic.

If $\mu<1$ the material is diamagnetic.

According to modern theory of magnetism, the electric orbits are micromagnets. Depending upon the no of electronic orbit, direction of revolution of electrons in the orbit the molecules and atoms have magnetic moment. These magnetic dipoles remains in random orientation in the absence of applied magnetizing field. When external field is applied in the direction of field to generates a strong resultant magnetic moment. Then the material gets magnetized.

ElectromagneticInduction

Long AnswerQuestion

8.State Faraday's Law of Electromagnetic Induction. Prove that law of conservation of energy is valid in the ElectromagneticInduction.

Ans: When ever there is change in magnetic flux intercepted by an electric circuit there is an e.m.f. in the circuit. This phenomenon is called electromagneticinduction.

According to the Faraday's law of Electromagnetic induction.

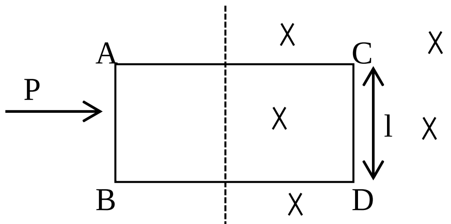
(i) Whenever there is change in magnetic flux intercepted by a circuit there is an e.m.f. The e.m.f. lasts as long the changelasts.

(ii) The induced e.m.f is equal to the rate of change of flux intercepted by the circuit.

$$e = -d\phi/dt$$

Lenz law : The polarity of e.m.f. is always such that it opposes the cause who has generated it.

Law of conservation of energy in E.M.I :-



ABCD is a rectangular conductor wire frame of resistance R partially occupying uniform magnetic field. The wire frame is being pushed with constant external force P at constant speed V.

Theinduced e.m.f. $e = -d\phi/dt$ = -

BlVCurrent in the circuit $I = BlV/R$

Electricalpower $P_E = B^2l^2V^2/R$

Themagneticforce $F_m = BIl = B^2l^2V/R$ Since

its speedis constant $P = F_m = B^2l^2V/R$

The mechanical power delivered to thewireframe $P_{mech} = B^2l^2V^2/R$

The mechanical power delivered by external force is equal to electrical power developed due to electromagnetic induction.

9.What is self - induction. Derive expression for self – inductance of a circularcoil.

Ans: The development of induced e.m.f. in any circuit due to variation of current in the circuit is called self – induction. The property of electric circuit which determines amount of induced e.m.f. per unit change in current in the circuit is called selfinductance.

$\phi \propto I$

$\phi = LI$

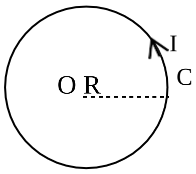
Where L is called self – inductance.

According to Faraday's law ofelectromagneticinduction. $e = -d\phi/dt = -L(dI/dt)$

The unit of inductance is Henry.

If the current variation of 1A/sec causes an induced e.m.f. of 1volt. The inductance is called 1Henry.

ABCD is a circular coil of radius Rnumber of turns 'n' carryingcurrent I. The magnetic field due to current in the circuit.



$B = \mu_o nI/2R$

The magnetic flux intercepted by the circuit.

$\phi = nBA = \mu_o n^2 I\pi R/2$

According to Faraday's law of induction

$e = -d\phi/dt = -\frac{1}{2}\mu_o n^2 \pi R(dI/dt)$ The self inductance of the circular coil

$L = \frac{1}{2}\mu_o n^2 \pi R$

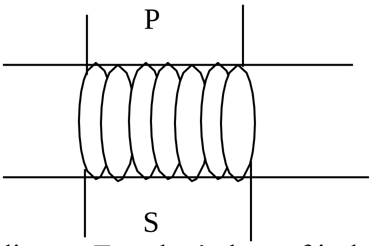
10.Define mutual inductance. Derive expression for mutual inductance of two circular coils woundon samecore.

Ans: The development of induced e.m.f. in any circuit due to variation of current in neighboring circuit is called mutual induction. The circuit in which current varies is called primary circuit and the circuit in which e.m.f. appears is called secondarycircuit.

$\phi_S \propto I_P$

Where I_P is current in primary coil and ϕ_S is flux intercepted by secondary coil.

$\phi_S = MI_P$



According to Faraday's law of induction

$e_S = -d\phi_S/dt = -MdI_P/dt$

Where M is called mutual induction.

P is primary coil having n_P no. of turns and S is the secondary coil having n_s no. of turns.

Field at the center of coil due to current in primary coil.

$B = \mu_o n_P I_P/2r$

Magnetic flux intercepeted by secondary coil.

$\phi_S = n_S B\pi r^2 = (\mu_o n_P n_S \pi r/2).I_P$

According to Faraday's law of electromagnetic induction.

$e = -d\phi_S/dt = (\frac{1}{2}\mu_o n_P n_S \pi r).dI_P/dt$

Thus mutual inductance.

$M = \frac{1}{2}\mu_o n_P n_S$