Chapter = 14

ELECTROMAGNETISM

Magnetic field: "The space or region around a magnet where the effect of its magnetism can be detected is called magnetic field". Its SI unit is tesla.
Hans Oersted was discovered magnetic field around moving charge in 1820

The magnetic field due to current in a long wire

To find the existence of magnetic field due to moving charge consider a thick copper wire that passed vertically through a hole inside a cardboard and Compass needle is placed around the conductor. When current I is passed through wire the needles are deflected along the tangent to the circle. Which show the existence of field. We can conclude from this

i. Magnetic field is setup only in the region around the current carrying wire
ii. Magnetic lines of force are circular and direction depends on current
iii. Magnetic field exists as long as the current is passing through wire
iv. Strength of field is larger near the wire.

Right hand rule for find direction of magnetic field: "If wire is grasped in right hand with the thumb pointing in the direction of current and the curled finger indicate the direction of magnetic field".

Explain and calculate Force On A Current Carrying Conductor In A Uniform Magnetic Field

Let us consider a current carrying wire that is moving on a pair of conducting copper rails lying b/w the poles of horse shoe magnet inside a field pointing vertically upward. When the current is passed through the copper rod, it starts moving under the action of magnetic force which is perpendicular to plane containing rod and field. Following results can be made from it.

Copper rod experience a force when it is placed at right angle to magnetic field
so Force is directly proportional to $\sin\alpha$

$F \propto \sin\alpha$ - - - - - (1)

Force is directly proportional to current flowing

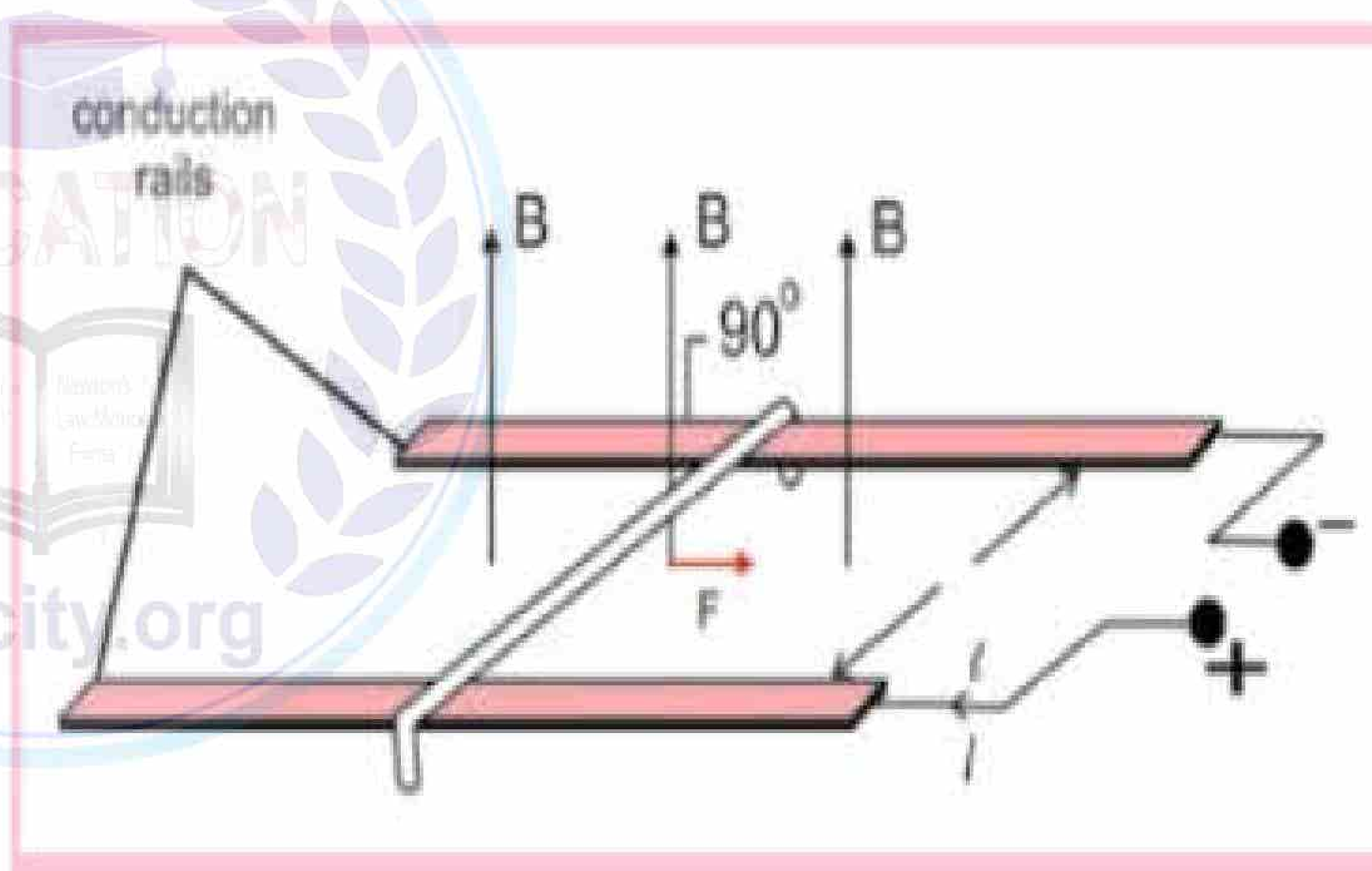
$F \propto I$ - - - - - - - -(2)

Force is directly proportional to lenght of conductor

$F \propto L$ - - - - - - - -(3)

Also Force is proportional to field

$F \propto B$ - - - - - - - -(4)



by combining all the equations we can write

$F \propto ILB\sin\alpha$, which is also written as

$F = ILB\sin\alpha$ and in vector form it can be written as

$\vec{F} = ILB\sin\alpha\,\hat{n} = I(\vec{L} \times \vec{B})$. - - - - - - - - - - - - - -(A)

Case 01: If α=0° or 180° i.e. rod is parallel or anti parallel to field then force acting on it zero, F=0

Case 02: If α=90° i.e. when rod is perpendicular to field then force will maximum. F=ILB

Equation (A) also provide the definition of strength of magnetic induction

Magnetic Induction: The magnetic force on one meter length of a conductor carrying one meter length of a conductor, carrying one ampere current placed at right angle to the magnetic field is called magnetic induction. Its SI unit is tesla.
If I=1A, L=1m and α=90°, then F=B
Tesla: A magnetic field is said to be one tesla if it exert one newton force on conductor of length one meter placed at right angle to the field, when one ampere current passes through it. B=F/IL= 1 tesla= 1 $NA^{-1}m^{-1}$, 1 tesla=10^4 gauss.
Right hand rule for finding the direction of magnetic force: Curl the fingers of right hand **L** to **B** through smaller possible angle. Then erect thumb will be point in the direction of force.
Convention: It is convention to represent current flowing towards the reader by small dot (**.**) and flowing away from him by (x).

What is Magnetic Flux and Flux Density?

Magnetic flux: "**Total number of magnetic field lines passing through certain area is called magnetic flux**". **OR** scalar product of magnetic field and vector area is called magnetic flux
Formula: $_m$=BAcos , Unit of magnetic flux is weber, 1 weber= Nm/A= NmA^{-1}
At =0° =BAcos0°=EA= maximum angle is b/w vector area and field
At =90°, =BAcos90°=0= minimum
Magnetic flux density: The magnetic flux per unit area of a surface perpendicular to magnetic field is called magnetic flux density. B= m/A its SI unit is $NA^{-1}m^{-1}$=$webm^{-2}$= tesla.

State Ampere Law And Determination Of Flux Density.

Statement of Ampere law: The sum of quantities $\bar{B}.\Delta\bar{L}$ for all path elements into which the complete loop has been divided equal to μo times the total current enclosed by the loop. $\sum_{i=1}^{n}(\vec{B}.\Delta\vec{L}) = \mu_o I$ This is called Ampere law.

Permeability of free space: μ_o is called permeability of free space, whose value is $4\pi x10^{-7}$ $WbA^{-1}m^{-1}$.

Calculate the Magnetic field inside a current carrying solenoid.

Solenoid: "**A long tightly cylindrical coil of wire is called solenoid, field due to solenoid**". B=μ_onI
Field due to solenoid: When the current passes through solenoid, then it behave as bar magnet. The field inside the solenoid is strong and uniform as compared to the field outside the solenoid is weak so neglected.
Let us consider a rectangular loop abcd as shown in fig. divide it into four elements of length
$ab = l_1$, $bc = l_2$, $cd = l_3$ and $da = l_4$

Using Ampere Law, we get $\sum_i^4(B.\ \ L)$=μ_o(current enclosed)

Using Ampere law we can find magnetic field $\sum_{i}^{4}(\vec{B}.\Delta\vec{L}) = \mu_o$ x (Current enclosed)

$(\vec{B}.\Delta\vec{L})_1 + (\vec{B}.\Delta\vec{L})_2 + (\vec{B}.\Delta\vec{L})_3 + (\vec{B}.\Delta\vec{L})_4 = \mu_o$ x (Current enclosed) also written as

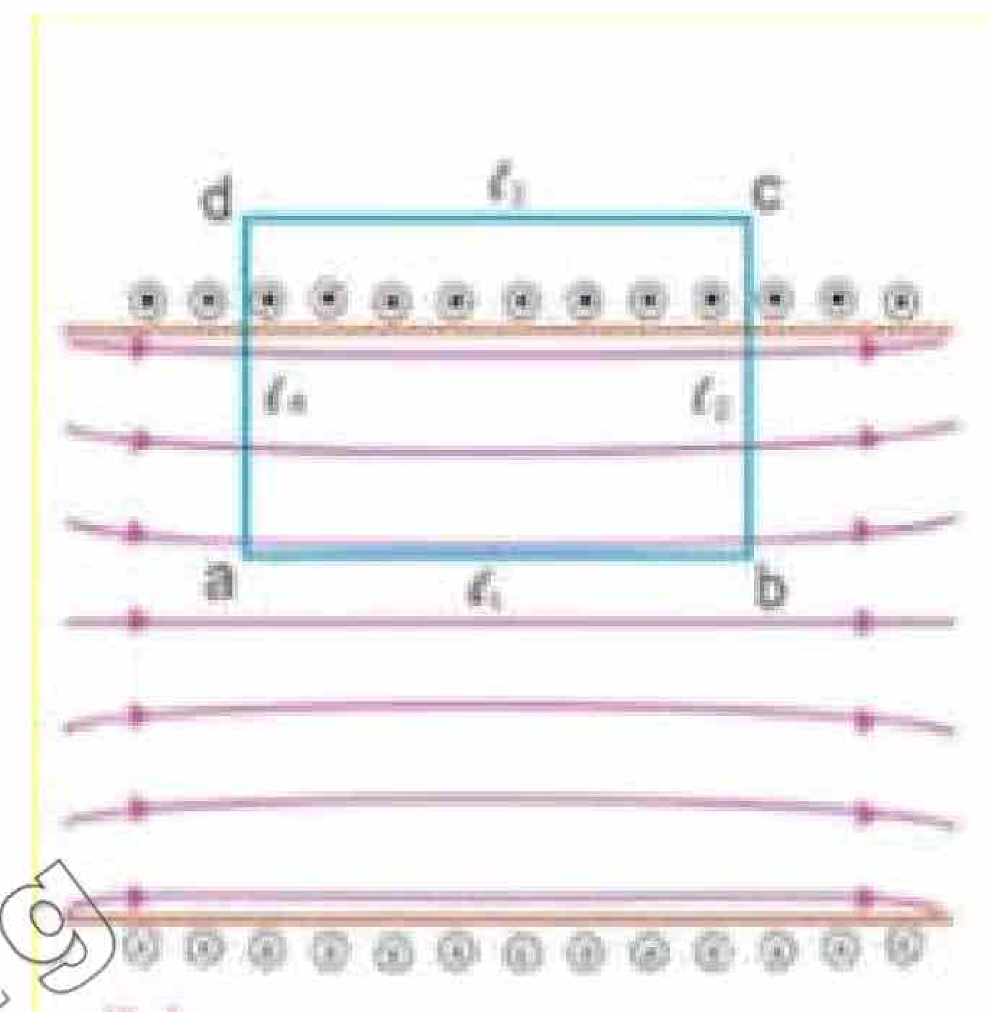
$(\vec{B}.\Delta\vec{L})_{ab} + (\vec{B}.\Delta\vec{L})_{bc} + (\vec{B}.\Delta\vec{L})_{cd} + (\vec{B}.\Delta\vec{L})_{da} = \mu_o$ x (Current enclosed) - - - (1)

$(\vec{B}.\Delta\vec{L})_{ab} = Bl_1\cos\theta = Bl_1\cos 0^o = Bl_1$

$(\vec{B}.\Delta\vec{L})_{bc} = Bl_2\cos\theta = Bl_2\cos 90^o = 0$

$(\vec{B}.\Delta\vec{L})_{cd} = Bl_3\cos\theta = (0)l_3\cos 0^o = 0$ As this lenght lies outside the solenoid

$(\vec{B}.\Delta\vec{L})_{da} = Bl_4\cos\theta = Bl_4\cos 90^o = 0$



Putting these values in equation (1)

$Bl_1 + 0 + 0 + 0 = \mu_o$ x (Current enclosed)

$Bl_1 = \mu_o$ x (Current enclosed) - - - - - - - - - - - - - (2)

$Bl_1 = \mu_o$ x (Current enclosed) - - - - - - - - - - - - - (2)

as Number of turns per unit length of solenoid = n

Number of turns in length l_1 of solenoid = n l_1

current enclosed by the loop = I

current enclosed by n l_1 loops = n $l_1 I$ putting in eq(2)

$Bl_1 = \mu_o$ x (n l_1I) = also written as as n = N/L

$B = \mu_o$ n I OR $B = \mu_o$ (N/L) I This is the value of field due to solenoid

Right hand rule: "Hold the solenoid in right hand with fingers curling in the direction of current, the thumb will point in the direction of field".

Multiple choice questions

1	Unit of magnetic flux is	**Weber**	Gauss	Tesla	Amper/m^2
2	Magnetic flux through an area A is	Ø=E.A	Ø=ExA	**Ø=B.A**	Ø=BxA
3	1 tesla is equal to	**1 $NA^{-1}m^{-1}$**	$1NA^{-1}m$	$1NAm^{-1}$	1Nam
4	Right hand palm rule is used to find the direction of	Current	Emf	**Force**	Temperature
5	Magnetic induction in a solenoid is	**$B=\mu_o nI$**	$B=\mu_o NI$	B=μon	None
6	The mathematical	Lenz law	**Ampere law**	Gauss's law	Faraday law

	expression $\Sigma(B.dl)= \mu_o I$ is known as				
7	A magnetic field acts on a charged particle so as to change its	Speed	Energy	**Direction of motion**	All of these
8	Magnetic field B=4i^+18k^ $webm^{-2}$ passes through $5k\text{^}m^2$ area net flux is	20 web	$90x10^{-4}$ web	**90 web**	Zero
9	For a current carrying conductor the term "n" has unti as	No unit	**m^{-1}**	m^{-2}	m^{-3}
10	Magnetic field inside the turns of toroid of radius r and N turns carrying current I is given by	μo 2πr/NI	**μoNI/2πr**	μonI/2πr	None
11	Two parallel wires current in opposite direction	No effect	**Repel each other**	Attract each other	Neither attract no repel
12	A 5m wire carrying current 2A at right angle to field 0.5T, the force	**5N**	10N	20N	25N
13	Best magnetic material is made up of	**Alnico V**	Iron	Nickel	Cobalt

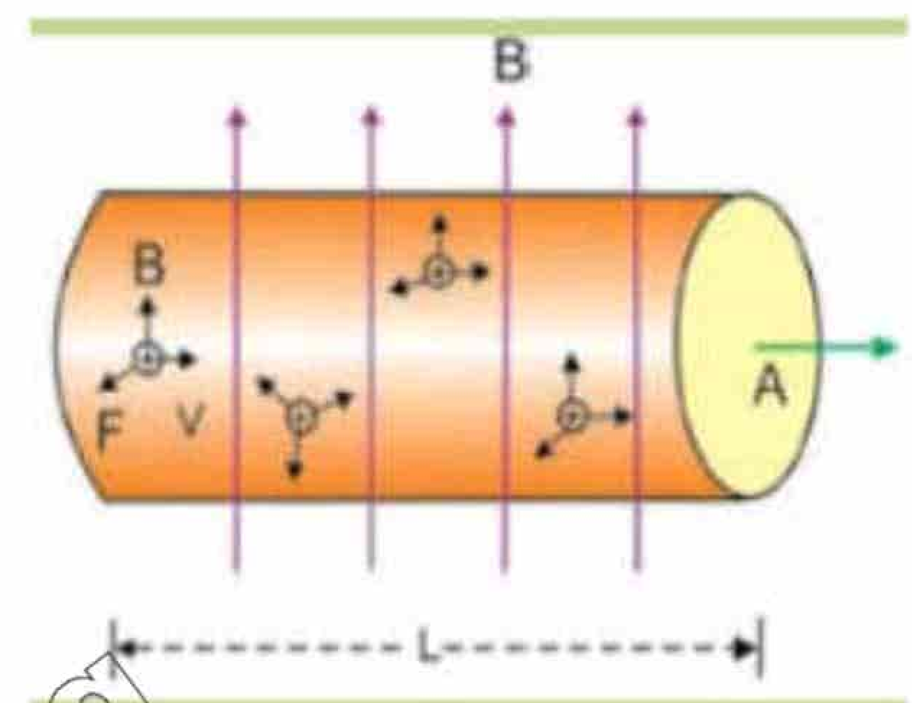
14	The direction of vector LxB is same as	**Force**	Mag. Field	Electric field	Length
15	Electric current produces magnetic field was suggested by	Faraday	**Oersted**	Henry	Lenz
16	One weber is equal to	N/A	Nm-1A	**Nm/A**	N/Am
17	The magnetic force acting on a unit positive charge moving at right angle to the magnetic field with unit velocity is called	Magnetic flux	Induced emf	Motional emf	**Magnetic induction**
18	SI unit of magnetic induction is	Weber	**Tesla**	Gauss	Farad
19	Which one is correct relation?	$Webm^2$=N/Am	1 tesla=10^4gauss	1 $webm^2$=1 tesla	**All of these**
20	The unit of magnetic field in SI is	Weber	**Tesla**	Gauss	Newton
21	If 0.5T field over an area of 2m2 which lies at an angle of 60 with field, then resulting flux	0.50 T	**0.50 Web**	0.25Web	0.25T
22	If the number of turns become doubled but length remains same, then magnetic field in	Half	**Double**	Remains same	Zero

	the solenoid become				
23	In current carrying solenoid the magnetic field does not depends upon	**Radius of solenoid**	Number of turns per unit length	Current	All of these
24	Magnetic lines of force are	**Imaginary**	Real	Perpendicular	Plane to field
25	Ampere law is magnetic equivalent of	Newton law	**Gauss law**	Faraday law	Ohm law
26	If current flowing through solenoid becomes double then magnetic field inside	Becomes half	**Becomes two times**	No effect	Becomes zero
27	Ampere circuital law is given by	μo 2πr/NI	**μoI/2πr**	μonI/2πr	None
28	SI unit of magnetic flux density is	Web m-1	**Web m^{-2}**	web	Joule/sec
29	A power line 10m high carries a current of 200A. the magnetic field of wire at ground	40*10^{-8}T	**40*10^{-6}T**	4*10^{-4}T	4*10^{-3}T
30	Magnetic flux density at a point is calculated using	Gauss law	**Ampere law**	Faraday law	Ohm law
31	Magnetic field inside a long solenoid carrying current I	Weak	**Uniform and Strong**	Zero	Both A&B

Calculate the formula for Force on moving charge placed in a magnetic field

A force is experienced by current carrying conductor placed in uniform magnetic field. As this is the force which is acted upon by magnetic field on charged particles moving in conductor.

To calculate this force consider a wire of length L and area of cross section A



Then no charge carriers in unit volume=n

Length of wire=L, area of wire=A

volume of wire of length L and Area A=AL

Total no of charge carriers in the wire of volume AL=

Charge on a single charge carrier=q

total charge moving due to nAL charge carriers=nALq

Let v is the velocity of single charge q and Δt is the time by charge b/w two ends of wire then

S=vΔt or L=v/Δt because in this case s=L

Current flowinig through wire is $I = \frac{\Delta Q}{\Delta t} = \frac{nALq}{L/v} = nAqv$

using the formula for force on current carrying conductor $\vec{F} = I(\vec{L}x\vec{B}) = nAqv(\vec{L}x\vec{B})$ - - - -(1)

Since the direction of segment L of wire is along the direction of velocity of charge carriers therefore

$\hat{L} = \hat{v}$ so we can write $v\vec{L} = vL\hat{L} = vL\hat{v} = L\vec{v}$ as we know that $(\vec{v} = v\hat{v})$

putting in eq (1) eq (1) $\Rightarrow$ $\vec{F} = nAqv(\vec{L}x\vec{B}) = nAq(v\vec{L}x\vec{B}) = nAq(L\vec{v}x\vec{B}) = nALq(\vec{v}x\vec{B})$

This is the magnetic force acting on conductor due to nAL charge carriers. The force on single is $\vec{F}' = \vec{F}/nAL$.

so $F' = nALq(\vec{v}x\vec{B})/nAL = q(\vec{v}x\vec{B}) = qvB\sin\theta$

This is the force on a moving charge placed in magnetic field

Case 01 : If charge is electron then q = -e then $F = -e(\vec{v} \times \vec{B})$

and electron is deflected vertically downward into $\vec{B}$

Case 02 : If charge is proton then q = +e then $F = +e(\vec{v} \times \vec{B})$

and proton is deflected in verticall upward into $\vec{B}$

Minimum Force : When charge is moving parallel to field then $\theta = 0^\circ$ $F = qvB\sin 0^o = 0$ Minimum force

Maximum Force : When charge is moving perpendicular to field then $\theta = 90^\circ$ then $F = qvB\sin 90^\circ = qvB$ Max force

Direction of Force: Direction of force is found by right hand rule "Rotate the fingers of your right hand through v towards $\bar{B}$ through smallest possible angle then erect thumb will show the direction of force".

Explain Motion of charge particle in electric and magnetic field. What is Lorentz force & formula.

Acceleration of charge particle: When a charge q is placed in electric field b/w two oppositely charged plates then the force acting on it will F=q$\bar{E}$

then by using Newton 2nd law a=F/m =q$\bar{E}/m$, this is uniform acceleration.

Lorentz force: "**Sum of electric force q$\bar{E}$ and magnetic force q($\bar{v}x\bar{B}$) is called Lorentz force**". When a charge particle q is moving with velocity v in region having electric field E and field B, formula for Lorentz force is $\vec{F} = q(\vec{v} * \vec{B}) + q\vec{E}$

Only electric force work, magnetic force is simply deflecting force. Magnetic force does not work.

Explain the Determination of e/m of an electron

JJ Thomson was first person who determined the charge to mass ratio of an electron in 1897.

Principle: When a beam of electron is deflected when it passed through magnetic field.

Explanation: let us consider a beam of electrons moving through uniform magnetic field $\bar{B}$ with velocity$v$.

The force acting on the electron is F=-e(vx$\bar{B}$) and in magnitude form it is F=evBsinϴ

As v and B are perpendicular to each other so ϴ=90°, so F=evBsin90°=evB ------- (1)

This force provides necessary centripetal force Fc=mv^2/r ------------------- (2)

Comparing both equations Fe=Fc evB= mv^2/r

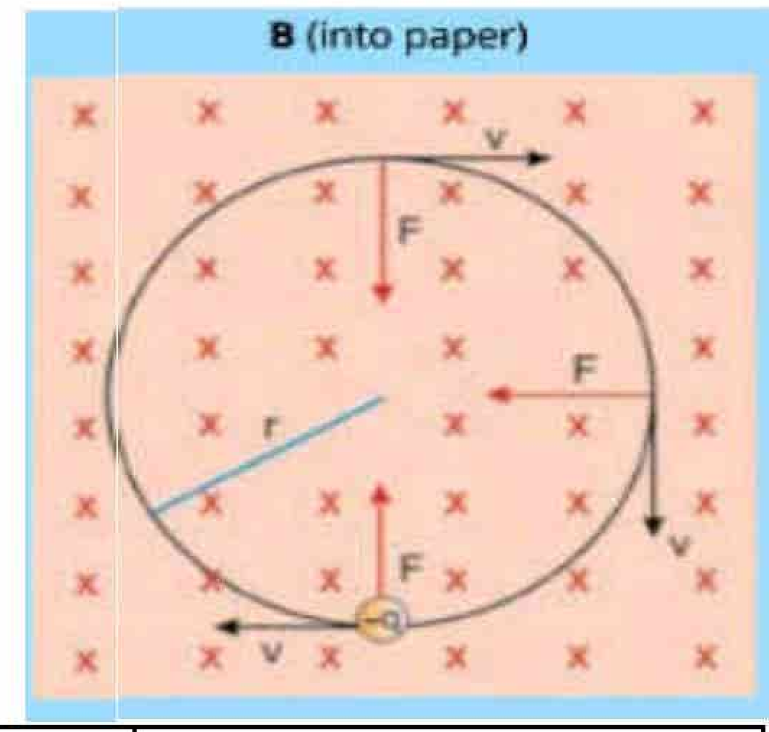
$\frac{e}{m} = \frac{v}{Br}$ --------- (3)

Determination of radius: We can measured the radius of circular path followed by electron by making its path visible by filling the glass tube with hydrogen gas at low pressure placed in known uniform magnetic field. When electrons are projected inside the tube and they began to move along a circle and collide with gas thus the atom become excited, on de excitation of the atoms emit light to make the path of electron visible and it looks like a glowing circle. The diameter of ring can be measured easily.

Determination of velocity by potential difference method: In this method, the electron is accelerated through a potential difference V_o. The energy gained during this acceleration is eV_o which appear as K.E of electrons.

K.E=eVo ……>$\frac{1}{2}mv^2=eVo$ ……….> $v=\sqrt{\frac{2eVo}{m}}$ putting in eq (3)

$\frac{e}{m}=\frac{1}{Br}\left(\sqrt{\frac{2eVo}{m}}\right)$ squaring both sides we get $\frac{e^2}{m^2}=\frac{1}{B^2r^2}\left(\frac{2eVo}{m}\right)$



$\frac{e}{m}=\frac{2V_o}{B^2r^2}$ Value of e/m for electron=$1.7588*10^{11}$ C/kg

Multiple choice questions

1	Magnetic force is simply a	**Deflecting force**	Reflecting force	Restoring force	Gravitational force
2	The value of e/m of electron is C/kg	**$1.75x10^{11}$**	$1.75x10^{-11}$	$1.6x10^{-19}$	Zero
3	e/m of an electron	$B^2r^2/2V$	$Br^2/2V$	**$2V/B^2r^2$**	$2V^2/B^2r^2$
4	Magnetic force on a moving charged particle is perpendicular to the	Magnetic field	Electric field	Velocity of particle	**Both A&C**
5	For an electron e/m is given by	B/Vr	**V/Br**	Br/V	VBr
6	The unit of E is N/C and B is N/Am the unit of E/B is	ms^{-2}	Ms	**ms^{-1}**	$m^{-1}s^{-1}$
7	Two long parallel wires carrying current to same direction will --- each other	Repel	**Attract**	Remains at rest	Start rotating
8	A charged particle moving in a magnetic field experience a	Field	Motion	Opposite to its motion	**Perpendicular to field and its motion**

	resulting force in the direction of				
9	Beam of electron is also called	Positive rays	X-rays	**Cathode rays**	Cosmic rays
10	An electron of mass m and charge e is moving in circle of radius r with speed v in uniform magnetic field B then	**r proportional to m**	r proportional to B	r proportional to 1/v	r proportional to 1/m
11	Force on a moving charge in a uniform magnetic field will be maximum when angle between v and B is	0°	**90°**	60°	30°
12	The sum of electric and magnetic force is	Maxwell force	**Lorentz force**	Newton force	Centripetal force
13	Work done on charge particle moving in uniform magnetic field	Maximum	**Zero**	Negative	Infinity
14	e/m of neutron	Less than electron	Greater then electron	**Zero**	The same as electron
15	The magnetic force on electron travelling at 10^6 m/s perpendicular to the field of strength 1T is	$16*10^{12}$ N	**$1.6*10^{-13}$ N**	0 N	Infinity
16	In expression e/m=v/Br, the radius is	Elliptical	**Visible**	Dark	Hyperbolic

	measured by making electronic trajectory				
17	F=Fe+Fm is called	Electric force	**Lorentz force**	Magnetic force	Weak force
18	When a charge particle perpendicular to uniform magnetic, then path follow will	Straight line	**Cicle**	ellipse	Helix
19	Lorentz force is given by	$\vec{F} = I(\vec{L}x\vec{B})$	$\vec{F} = I(\vec{L}x\vec{B}) + q\vec{E}$	$\vec{F} = q(\vec{v}x\vec{B}) + q\vec{E}$	$\vec{F} = q(\vec{v}) + q\vec{E}$
20	Electronic path in e/m experiment visible if gas is filled at	**Lower pressure**	High pressure	Infinite pressure	Zero pressure
21	e/m is smallest for	**Proton**	Electron	Beta particle	Positron

Write a note on Cathode ray oscilloscope

Definition:" An electronic device which is used for plotting the graphs at a very high speed is called CRO".

Principle of working of CRO: A beam of electrons is deflected while passing through uniform electric field present b/w two sets of plates. This beam falls on screen and makes a spot.

Construction: A CRO consist of following parts and their functions is as follows

Electron gun: Electron gun consists of an indirectly heated cathode, a grid and three anodes and it provides beam of electrons.

Cathode provide electronic beam when heated and anodes cause the electronic beam to accelerate.

Grid: It is at negative potential relative to cathode. It controls number of electrons and brightness of spot on screen.

Sweep or time base generator: The voltage that is applied across X-plates provided by a circuit that is built in CRO is called time base generator. It display saw tooth wave.

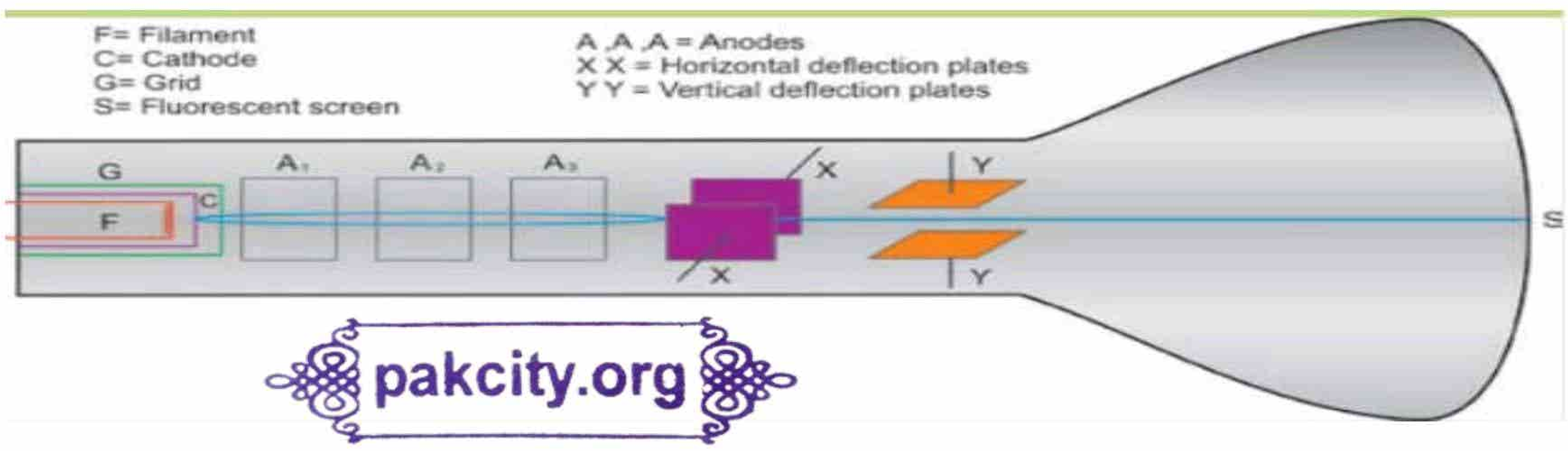
Trace on CRO if voltage is applied across y plates: Sinusoidal trace will appear when voltage is applied across y plates.

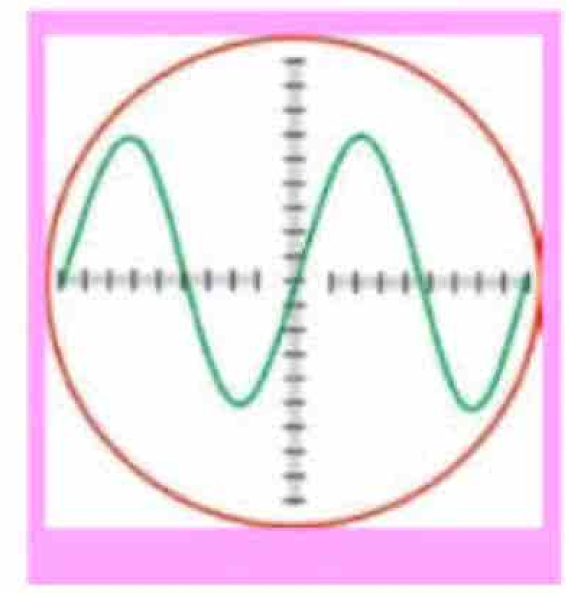
Screen: This is fluorescent screen where it makes a visible spot of deflected beam.

Synchronization control: The frequency of voltage at y plates is adjusted by synchronization control provided on the front panel of the CRO

Uses of CRO: There are following uses of CRO

i. It display the waveform of given voltage
ii. It measure the voltage, frequency and phase of input signal
iii. It measure time period of AC signal and phase difference b/w two phase



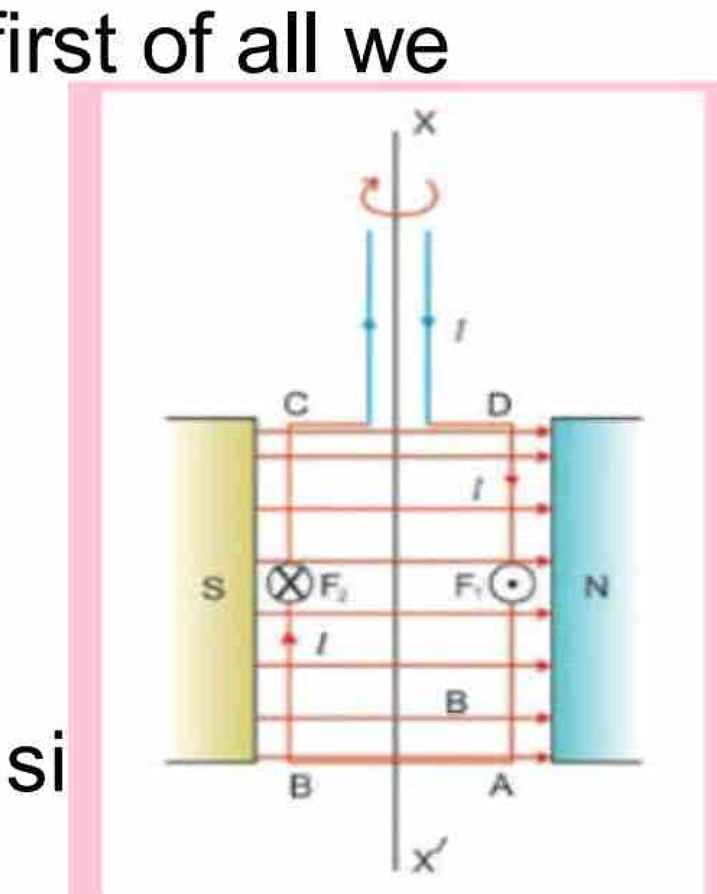


Calculate the Torque on current carrying coil in uniform magnetic field

Consider a rectangular coil of length L and width a carrying current I is placed inside a magnetic field B. Coil is capable of rotating about an axis due to which torque is produced which is calculated here.

Force acting on conductor of length L is F=I($\bar{L}$x$\bar{B}$) =ILB sinϴ, where ϴ is angle b/w $\bar{L}$and$\bar{B}$.

As there are four sides of rectangular coil AB, BC, CD, DA and first of all we calculate the force on each side



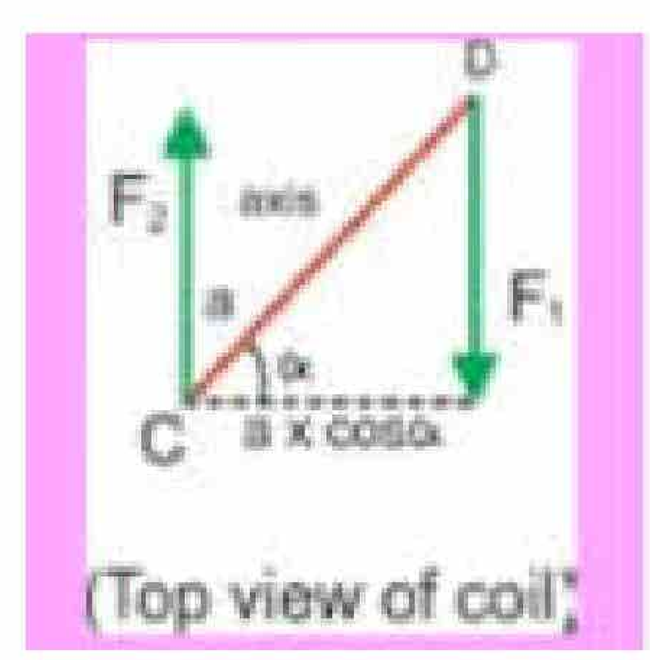
In case of side AB and CD of the coil angle ϴ=0° or 180°

so the force acting these sides

F=ILB sin0° or sin180°=0

In case of sides DA and BC the angle is 90° and force on these si

F_1=F_2=ILB sin90°=ILB



Both forces F_1 and F_2 are equal and opposite form a couple

Which rotate the coil due to which torque is produced

Torque=Force x moment arm= ILB x a=IB (Lxa)

As L x a=area of coil=A

Ʈ= IBA, if the field makes angle α with plane of the coil as shown in fig cosα

Ʈ= IBAcosα, this is the formula for torque on current carrying coil in uniform magnetic field.

What is Galvanometer? Explain its principle, construction and working.

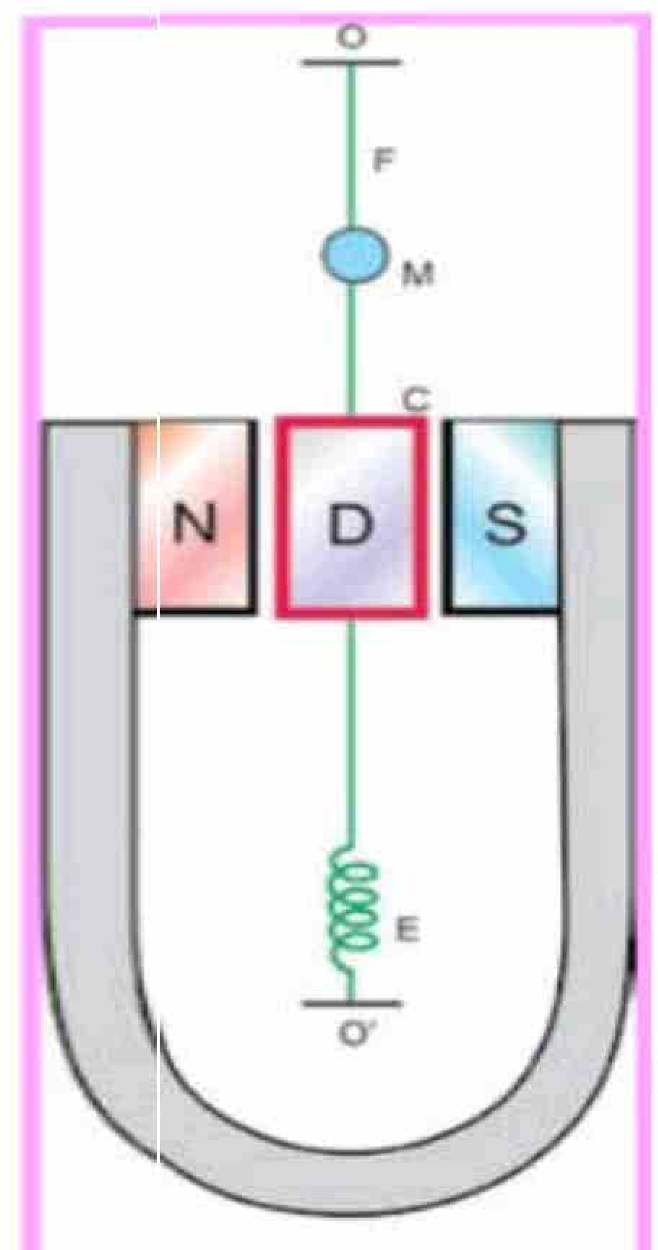
<u>Galvanometer</u>: "Such an electrical instrument which is used to detect the passage of current through circuit is called galvanometer".

<u>Working Principle of galvanometer</u>: It works on principle "**torque acts on a current coil when placed in uniform magnetic field** $\tau = NIBA\cos\alpha$ **".**

<u>Construction</u>: A galvanometer consists of a rectangular coil C suspended b/w the concave pole piece magnet of U shaped by suspension wire made enameled copper wire. The suspension wire F acts as one current lead while the other terminal of coil is connected to loosely spiral spring E which act as 2^{nd} current lead. The mirror M attached to suspension wire used to find angle of deflection.

<u>Working</u>: When the current is passed through the coil, two equal and opposite forces acting on different points of coil which form couple due to magnetic force. Such couple is known as deflecting couple and its produce torque due to number of turns N and A is the area of coil

Deflecting torque=Ʈ= NIBAcosα=NIBAcos0°=NIAB ---(1)



(a)

As the coil turns und the action of deflecting torque then couple produced is restoring couple which is proportional to angle of deflection ϴ so by using Hook's law

Restoring torque ∝ ϴ so Restoring torque=Cϴ------(2)

C is called torsional or twisting constant defined as Restoring Couple per unit twist produced in coil of galvanometer

Comparing equation (1) and (2)

$$NIAB = C\theta$$

$$I = \frac{C\theta}{NBA} \quad \text{or}$$

$$I \propto \theta$$

$$\text{As } \frac{C}{NBA} = \text{constant}$$

This shows that current passing through the coil of galvanometer is proportional to angle of deflection.

How can we Measure of angle of deflection?

: There are two methods for measuring angle of deflection

i. **<u>Lamp and scale arrangement</u>**: In this method a beam of light from the lamp is directed towards the mirror M attached to the coil of galvanometer. After reflecting from the mirror, it produce a sport on transparent scale placed at 1m distance from galvanometer. When the coil rotates the attached to the coil also rotates and spot of light on scale is proportional to angle of deflection.

ii. **<u>Pivoted type galvanometer</u>**: In this type of galvanometer coil is rotated b/w two jeweled bearings. The restoring torque is provided by two hair springs which also act as current lead. An aluminum pointer is attached to the coil which moves over a scale such galvanometer is called Weston type galvanometer.

What is Current sensitivity of galvanometer and the factors upon which it depends

A galvanometer is said to be sensitive if it give one millimeter deflection on scale when microampere current is passed through it. For galvanometer $I = \frac{C\theta}{NAB}$,

Galvanometer can made more sensitive if $\frac{C}{NAB}$ is made small

Sensitivity of galvanometer can be increased by:

i. Increasing number of turns and area of coil
ii. Increasing flux density B
iii. Decreasing C by using wire of large length and small radius

Types of galvanometer/ What is dead beat galvanometer and unstable galvanometer?

Stable or dead beat galvanometer: "A galvanometer in which the coil comes to rest quickly after passage of current through it is called stable or deadbeat galvanometer".

unstable galvanometer: "Such a galvanometer in which the coil of galvanometer is not come to rest and keep on oscillating about its mean position or shoot beyond its fixed position if current is suddenly passed through it is called unstable galvanometer".

What is ammeter? How galvanometer is converted into ammeter?

Ammeter:"An electrical device which is used to measure the current in amperes is called ammeter". It is low resistance galvanometer".

Meter movement: The portion of galvanometer whose motion cause the needle to move across the scale is called meter movement.

Conversion: A galvanometer is converted into ammeter by connecting a low resistance Rs shunt in parallel with galvanometer.

Shunt/bypass resistor:

Small value of resistance connected in parallel with galvanometer to convert into ammeter is called shunt.

Calculation of shunt resistance: shunt resistance is adjusted so that current which give full scale deflection pass through galvanometer and remaining current passes through shunt

Potential difference across galvanometer Rg=Vg=IgRg ---- (1)

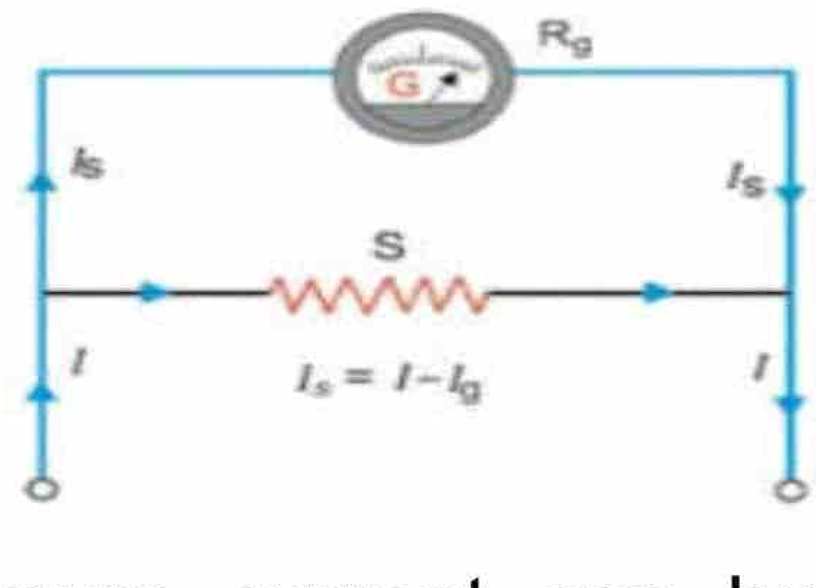
Potential difference across shunt Rs=Vs= (I-Ig)Rs --------(2)

Since the both resistances are parallel so have same P.D so,

Putting the values

(I-Ig)Rs=IgRg

Rs=$\frac{\text{IgRg}}{(\text{I}-\text{Ig})}$, this is the formula for shunt resistance which of few



Ammeter is connected in series with circuit so that maximum current can be measured by it.

What is voltmeter? How galvanometer is converted into voltmeter?

Voltmeter: "An electrical device which is used to measure the potential difference b/w two points is called voltmeter".

It is high resistance galvanometer. An ideal voltmeter has infinite resistance.

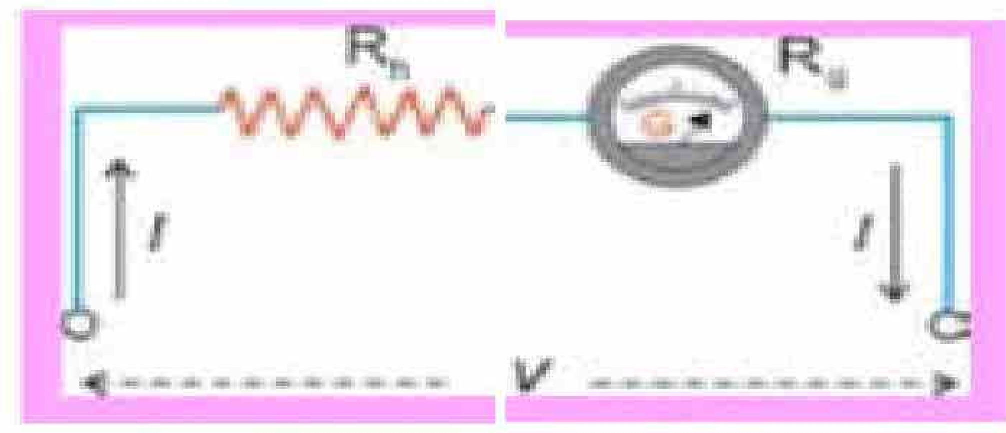
Conversion of Galvanometer: Galvanometer is converted into voltmeter by connecting high resistance R_h in series with coil of galvanometer which give a full scale deflection when connected across P.D V.

As same current Ig is flowing through Rg and R_h so by applying Ohm's law

$V=I_g(R_g+R_h)$

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

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



By connecting the proper value of R_h in series with meter movement, Voltage can be measured. Voltmeter is connected in parallel with circuit.

What is Ohmmeter? How galvanometer is converted into ohmmeter?

Ohmmeter: "**An electrical device which is used for rapid measurement of resistance is called ohmmeter**".

It consists of a galvanometer, an adjustable resistance rs and cell in series.

Conversion: A galvanometer is converted into ohmmeter by connecting An adjustable resistance r and a cell in series with galvanometer.

To measure the unknown resistance, it is connected b/w two terminals c and d And deflection of scale gives R.

What is AVO METER/MULTIMETER?

Definition: "An electrical device which can measure current in ampere, potential difference in volt and resistance in ohm is called AVO meter or multi meter".

Function switch: It is Function selector switch which connects the galvanometer with relevant measuring circuit.

Voltage measuring part of AVO meter: It is actually multi range voltmeter which consists of Number of resistances each connected in series with moving coil galvanometer with function switch. The value of each resistance depends upon the range of Voltmeter which it controls. Alternating voltages are also measured by AVO meter. AC voltage is first converted into DC voltage by using diode as rectifier and then measured.

Current measuring part of AVO meter: It is actually called multi range ammeter consists of a number of low resistances connected in parallel with galvanometer.

Resistance measuring part of AVO meter: It is multi range ohmmeter for each range of this. Meter consists of a battery of emf V_O and variable resistance rs connected in series with Galvanometer of resistance Rg

Digital multimeter(DMM):"An electronic instrument which is used to measure the current, resistance and voltage in circuit. It is digital version of an AVO meter".

Advantages of DMM: There are following advantages of DMM

i. It is digital version of AVO meter
ii. It is very accurate device
iii. It is easy to operate
iv. It removes the reading error

Fig. 14.26

Multiple choice questions

1	In CRO the output waveform of time base generator is	Circular	Square	Sinusoidal	**Saw tooth**
2	The maximum torque on a current carrying coil of N turns is t=?	**NIBA**	IBA	IBAsinΘ	NIBAcosΘ
3	Brightness of the spot of the CRO on the screen is controlled by	Cathode	Anode	**Grid**	Plate
4	A current carrying coil placed in a magnetic field experience torque maximum when angle is	**0 ˚**	90 ˚	180 ˚	45˚
5	An AVO meter is also called	An ammeter	A voltmeter	**A multimeter**	An ohmmeter
6	The anode in CRO	Control the no. of waves	Control the brightness of spot formed	**Accelerate and focus beam**	At negative potential w.r.t cathode
7	Torque on current carrying coil is t=?	**NIABcosΘ**	BILsinΘ	NIABsinΘ	BIL
8	CRO works by deflecting beam of	Neutrons	Protons	**Electrons**	Positrons

Type your text

9	In CRO the number of electrons is controlled by operating	anodes	Cathode	**Grid**	Filament
10)	Grid in CRO	Control the number of waves	**Control the brightnes s**	Has positive potential w.r.t cathode	Accelerate electrons
11)	AVO meter measure	Current	voltage	Resistanc e	**All of these**
12)	An advantage of AVO meter	Digital version	Easy to operate	Remove error of reading	**All of these**
13)	At what angle the value of torque acting current carrying coil becomes half	0	45	90	**60**
14)	Output waveform of built in voltage of CRO is	Sinusoidal	Square	Rectangul ar	**Saw tooth**
15)	An electric circuit in CRO that provides voltage to x plates is called	Tweet	Sleep	Cheap	**Sweep**
16)	Beam of electrons is also called	Canal rays	Gamma rays	X rays	**Cathode rays**
17)	CRO is used to display the waveform of	Current	frequency	amplitude	**Voltage**
18)	Work done on a charged particle moving in uniform magnetic field	Minimum	Maximum	Infinite	**Zero**
19)	Filament in CRO is	***Conducto r***	Insulator	Perfect conductor	Perfect insulator
20)	High resistance Rh that connected in series with galvanometer of resistance Rg to convert into voltmeter of range V volts is given	$\frac{V}{Ig}$+Rg	**$\frac{V}{Ig}$- Rg**	$\frac{V}{Ig}$+IRg	None of these
21)	Galvonometer can be made	Made	**Made**	Remains	None of

22)	more sensitive if the value of factor C/NAB is	large	**small**	constant	these
23)	In order to increase the range of voltmeter the series resistance is	Kept constant	Decreased	**Increased**	Made zero
24)	Which of the following is likely to have least resistance	**Ammeter**	Galvanometer	VTVM	Voltmeter
25)	Voltmeter is always connected in circuit	**Parallel**	Series	Both A&B	None
26)	To measure the current ammeter is always connected	Parallel	**Series**	Both A&B	None
27)	To convert galvanometer into ammeter the parallel shunt resistance Rs equal	**IgRg/I-Ig**	I-Ig/IgRg	IR	None
28)	Shunt resistance is also called	**By pass resistor**	Specific resistance	Reactance	Impedance
29)	Shunted galvanometer is called	**Ammeter**	Voltmeter	Ohmmeter	Potentiometer
30)	In case of conversion of galvanometer into ammeter the shunt resistance is connected	**In parallel**	In series	Neither series nor parallel	Both A&B
31)	The pointer of dead beat galvanometer gives a --- deflection because of eddy current	Variable	**Steady**	Continuous	Slow

EXERCISE SHORT QUESTIONS

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?**

Case 1 When vector area of the conducting loop is in the direction of magnetic field strength =0° then the magnetic flux will maximum:

At =0° =BAcos0°=EA= maximum

Case 2 When vector area of the conducting loop is perpendicular to magnetic field strength then the magnetic flux will minimum:

At =90°, =BAcos90°=0= minimum

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?

a. Magnetic field due to stationary charges is zero: because in this case the value of current is zero so field will be zero. $B = \frac{\mu o I}{2\pi r} = \frac{\mu o(0)}{2\pi r} = 0$

b. Moving charge produce magnetic field: because moving charge produce current which produces magnetic field

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.

a.. In this case magnetic field is reduced to half

As magnetic field due to solenoid $B = \frac{\mu o NI}{L}$ as in this case $L' = 2L$ so $B' = \frac{\mu o NI}{2L}, B' = \frac{1}{2}B$

b. In this case magnetic field increased to double:

$B = \frac{\mu o NI}{L}$ as in this case $N' = 2N$ so $B' = \frac{\mu o 2NI}{L}, B' = 2B$

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**

a. Magnetic force is directed along positive y-axis: Because magnetic force on proton is $\vec{F} = q(\vec{v} * \vec{B})$, according to right hand rule F is perpendicular to v and B along y axis

b. 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

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?**

The two particles are oppositely charged: Because the magnetic force acting on charged particle is $\vec{F} = +e(\vec{v} * \vec{B})$ for positive charge and $\vec{F} = -e(\vec{v} * \vec{B})$ for negative charge and force is deflecting so if q is positive it is deflected in one direction and q is negative then it will be deflected in other direction.

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 q?** pakcity.org

As we know that magnetic force acting on charge particle $\vec{F} = q(\vec{v} * \vec{B})$ is always perpendicular to velocity so angle b/w F and d is 90°,W=Fdcos90°=0 so no work is done by magnetic force.

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?**

No, it may or may not be zero: Because the magnetic force acting on a charge particle $\vec{F} = q(\vec{v} * \vec{B})$ =qvBsin , Force will be zero in the following cases

i. If field is zero
ii. Charge particle move parallel to field =0°
iii. Charge particle movie anti parallel/opposite to field =90°

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

As the picture on TV screen is formed due to the beam of electrons. When a magnet is brought near the screen the path of electrons is disturbed due to magnetic force so the picture on TV screen is distorted

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

Yes it is possible: we know that torque acting on current loop in uniform magnetic field is $\tau = NIBA\cos\theta$ It is clear from expression that when plane of the coil makes an angle of 90° with magnetic field, the torque on the coil will be zero. In this condition, the coil will not tend to rotate.

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

We know that torque acting on current carrying loop is $\tau = NIBA\cos\theta$ so, if current loop is deflected in given region of space then it shows the presence of magnetic field otherwise not.

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

For this purpose the ions of elements are passed through a uniform and perpendicular field, magnetic force act on them so under the action of this force the ions move along circular path of different radii due to their different masses and $qvB = \frac{mv^2}{r}$, and $r \propto m$

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?**

As we know that $\tau = NIBA\cos\theta$

When plane of the coil is parallel to magnetic field, the torque acting on the coil will be maximum given by:

$\tau = NIBA\cos 0$ =NIBA= maximum

When plane of the coil is perpendicular to magnetic field, and the torque acting on the coil will be minimum,

$\tau = NIBA\cos 90$ =0= minimum

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?**

As the plane of the coil is parallel to the pole faces, therefore, it is perpendicular to the magnetic field,
i.e. α = 90°. Torque acting on coil $\tau = NIBA\cos 90$ =0. Therefore, for both A.C. and D.C., the coil will not rotate.

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

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 decrease the current of the circuit that's why resistance of ammeter should be very low so maximum and accurate current measured by it.

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

A voltmeter is connected in parallel with circuit 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 circuit accurately.

Numerical problems

14.1: Find the value of the magnetic field that will cause a maximum force of $7.0\times10^{-3}N$ on a 20.0cm straight wire carrying a current of 10.0A.

$\text{Given}: F = 7*10^{-3}\,N, L = 20cm = 20/100 = 0.20\,m, I = 10A, B = ?$

$$F = ILB \Rightarrow B = \frac{F}{IL} = \frac{7*10^{-3}}{10*0.20} = 3.5*10^{-3}\ T$$

14.2: How fast must a proton move in a magnetic field of $2.50\times10^{-3}T$ such that the magnetic force is equal to its weight?

$\text{Given Data}: \text{Magnetic field} = B = 2.5*10^{-3}\,T, m_p = 1.673*10^{-27}\,Kg, q = 1.6*10^{-19}\,C\ v = ?$

as Magnetic force is equal to weight so $F = W \Rightarrow qvB = mg$

$$v = \frac{mg}{qB} = \frac{1.673*10^{-27}*9.8}{1.6*10^{-19}*2.5*10^{-3}} = 4*10^{-5}\,m/s$$

14.3: A velocity selector has a magnetic field of 0.30T. 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?

$\text{Given Data}: \text{Magnetic field} = B = 0.30\,T, E = 10{,}000\,V/m, \text{speed} = v = ?$

As Magnetic force = electric force, $qvB = qE \Rightarrow vB = E$

$$v = \frac{E}{B} = \frac{10000}{0.30} = 3.3*10^{4}\,m/s$$

14.4: A coil of $0.1m\times0.01m$ and of 200 turns carrying a current of 1.0mA is placed in a uniform magnetic field of 0.1T. Calculate the maximum torque that acts on the coil.

$\text{Given Data}: \text{Area} = A = 0.1*0.1 = 0.01\,m, N = 200, I = 1mA = 1*10^{-3}\,A, B = 0.1\,T, \tau = ?$

$$\tau = NIAB = 200*1*10^{-3}*0.01*0. = 2*10^{-4}\,Nm$$

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

$\text{Given Data}: \text{Height of power line} = h = r = 10m, I = 200A, B = ?$

$$\text{Using Ampere law } B = \frac{\mu_o I}{2\pi r} = \frac{4\pi*10^{-7}*200}{2*3.14*10} = 4*10^{-6}\,T$$

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

Given Data : $B = 0.1T, I = 10A, n = ?$

Using $B = \mu_o nI \Rightarrow n = \dfrac{B}{\mu_o I} = \dfrac{0.1}{4\pi * 10^{-7} * 10} = 7.96 * 10^3$ turn/length

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

Given Data : Length $= L = 0.5$ m, $B = 0.4$ T, $N = 10000$, $n = N/L = 10000/0.5 = 20000$, current $= I = ?$

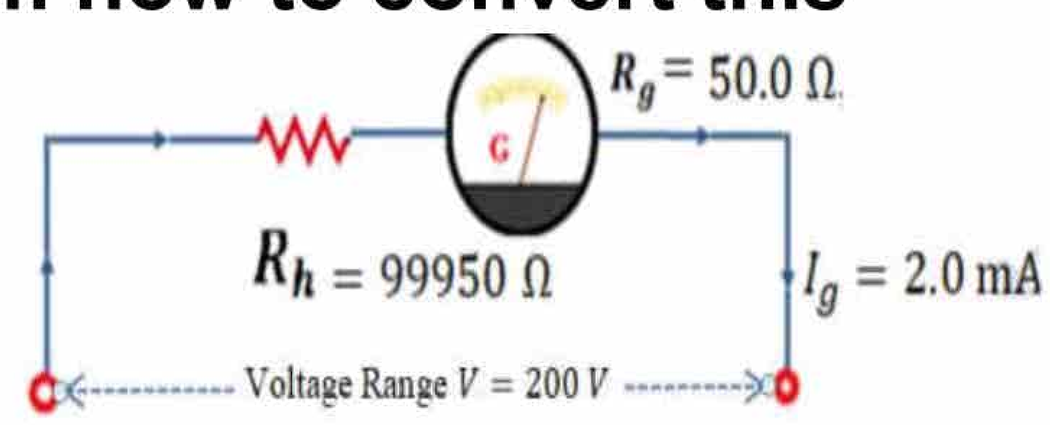
Using $B = \mu_o nI \Rightarrow I = \dfrac{B}{\mu_o n} = \dfrac{0.4}{4\pi * 10^{-7} * 20000} = 15.9$ ampere

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

Given Data : $Rg = 15\Omega \quad Ig = 20\text{ mA} = 20 * 10^{-3}\text{ A}, \quad I = 10\text{ A}, \quad Rs = ?$

$$Rs = \frac{IgRg}{I - Ig} = \frac{20 * 10^{-3} * 15}{10 - 20 * 10^{-3}} = 0.03\text{ ohm}$$

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



Given Data : $Rg = 50\Omega \quad Ig = 2mA = 2 * 10^{-3}\text{ A}, V = 200V, R_h = ?$

$$R_h = \frac{V}{Ig} - Rg = \frac{200}{2 * 10^{-3}} - 50 = 99950\text{ ohm}$$

14.10: The resistance of a galvanometer coil is 10.0Ω and reads full scale with a current of 1.0 mA. What should be the values of resistances R_1, R_2 and R_3 to convert this galvanometer into a multi range ammeter of 100, 10.0 and 1.0A?

Given Data : $Rg = 10\Omega \quad Ig = mA = 1 * 10^{-3}\text{ A}$, Ranges of current $= I_1 = 100A, I_2 = 10A, I_3 = 1A$

$$R_1 = \frac{IgRg}{I_1 - Ig} = \frac{1 * 10^{-3} * 10}{100 - 10 * 10^{-3}} = 0.0001\text{ ohm}$$

$$R_2 = \frac{IgRg}{I_2 - Ig} = \frac{1 * 10^{-3} * 10}{10 - 10 * 10^{-3}} = 0.001\text{ ohm}$$

$$R_3 = \frac{IgRg}{I_3 - Ig} = \frac{1 * 10^{-3} * 10}{1 - 10 * 10^{-3}} = 0.01\text{ ohm}$$

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