ELECTRICITY, MAGNETISM AND ELECTROMAGNETISM (16SCCPH4)

(Brief notes for reference)

BY

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Note: Students are instructed to refer book for study and reference respectively for further elaborate points as prescribed by the University.

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Unit - I → Electrostatics:

coulomb's law - Gauss law and its applications, electric potential - potential at a point due to a uniformly conducting sphere. principles of a capacitor - spherical and cylindrical capacitors - Energy stored in a charged capacitor, loss of energy on sharing charges

Unit - II → current Electricity:

Ampere's circutal law and its applications, Field along the axis (circular coil & solenoid), B.G figure of merit, Damping correction, Kirchoff's law, wheatstone's bridge, carey foster bridge, potentiometer, Ammeter, voltmeter (law scotish &

high), Resistance calibration.

unit - III → Electromagnetic Induction :

laws of EMI, self Induction - solenoid, Mutual Induction - pair of solenoids, co-efficient of coupling, Rayleigh's method, Experiment - Mutual Inductance, Growth of decay of L, Growth of decay of CRR, Measurement of HR, by leakage.

unit - IV → Ac circuits :

Alternating Emf applied to Series (LC, CR and LR), LCR circuit, series and parallel (LCR), sharther of resonance circuit, power in Ac circuit (R, L-R, L-C-R), power factor, choke, transformer and skin effect.

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unit - V → Magnetism :

Intensity, susceptidity, permeability, Types of magnetic material and properties, law geviti's theory of dia and para, weiss theory of ferro, B-H, B-H by BG, magnetic properties of Iron, & steel.

Date 09.01.2020

1. Electric field:

The space surrounding a charged conductor within which its influence can be felt.

2. Define coloumb:

It is defined as the amount of charge that flows through a conductor in one second when a current of 1 ampere flows through it.

3. Electric intensity at a point:

Electric intensity at a point in an electric field is defined as the force experienced by a unit positive charge place at that point.

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4. permitivity:

permitivity of a mater is the product of permitivity of free space and relative permitivity. $\varepsilon = \varepsilon_0 \varepsilon_r$

$\varepsilon_0 = 8.85 \times 10^{-12} \ C^2/Nm^2$

5. coloumb's law:

coloumb's law state that, the force of attraction or repulsion between two charges q_1 and q_2 is directly proportional to the product of the charges q_1 and q_2 and inversely proportional to the square of the distance between them.

$$F \propto q_1 q_2$$

$$F \propto \frac{1}{r^2}$$

$$F \propto \frac{q_1 q_2}{r^2}$$

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$$F = k \frac{q_1 q_2}{r^2}$$

where $k = \frac{1}{4\pi\varepsilon_0}$

$$\therefore F = k \frac{q_1 q_2}{r^2}$$

6. Electric potential:

Electric potential is defined as the amount of work done in moving a unit positive charge from infinity to that point. unit of electrical potential is volts.

7. Equipotential surface:

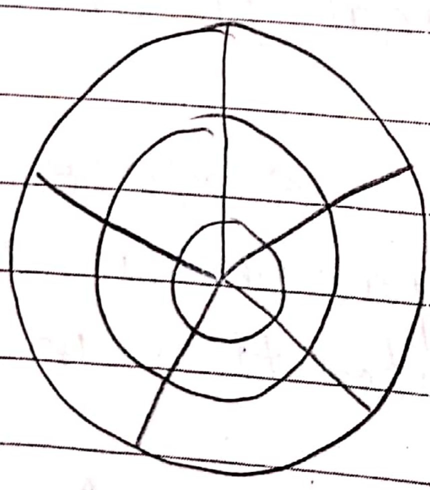
A graphical representation of electric potential in an electric field.

It is a surface at all points the electric potential is same.

Electric field at a point on an equipotential surface is perpendicular to that point.

A line of force is the path taken by a unit positive charge and the direction of the electric intensity at any point is tangential to that point.

The equipotentials are more crowded in a region of strong electric field than the weaker region.



(relation between electric field and electric potential)

$$E = -\frac{dv}{dx}$$

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8. lines of force :

An electrostatic lines of force is defined as the path taken by a unit positive charge in an electrostatic field.

9. Gauss theorem :

(varies from gauss law)

Gauss theorm states that the total normal electrical induction over a closed surface is equal to Σq to the total charge present inside the surface.

10. Electrical image :

Electrical image is defined as an electric point (or) electrical system of points on one side of an electrified surface produces the same electrical action on the other side.

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11. Electric flux:

Number of electrica lines of force per unit area is called electric flux.

12. capacity of a conductor: (capacitance)

If the charge on a conductor is gradually increased its potential also increases.

charge is directly proportional to the electric potential.

$q \propto V$

$q = CV$ [$\because$ C => capacitance]

13. Farad:

A conductor has a capacity of one Farad. If a charge of one coloumb raises its potential by one volt.

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14. condensor:

A condenser consist of two conductors, one charged and the other earthed.

The principle of condenser is to increase the capacity of a conductor.

Derive an expression for electric potential at a point.

Consider a point at a distance 'r' from the conductor having a charge '+q',
the electrostatic intensity,

$$E = \frac{q}{4\pi\varepsilon_0 r^2}$$

The electrostatic potential is the amount of work done in taking positive charge from infinity to that point p.

$$V = \int_{\infty}^{r} -E\,dr$$

$$= \int_{\infty}^{r} -\left[\frac{q}{4\pi\epsilon_0 r^2}\right] dr$$

$$= q\left[\frac{-1}{4\pi\epsilon_0 r}\right]_{\infty}^{r}$$

$$V = \frac{q}{4\pi\epsilon_0 r}$$

2. properties of lines of force,

They are continous curves in an electric field starting from positive and ending by negative.

The tangent to the curve at any point gives the direction of electric intensity.

It never intersect the lines of force have lateral pressure

The lines of force have

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no continuvity.

Gauss law and its applications

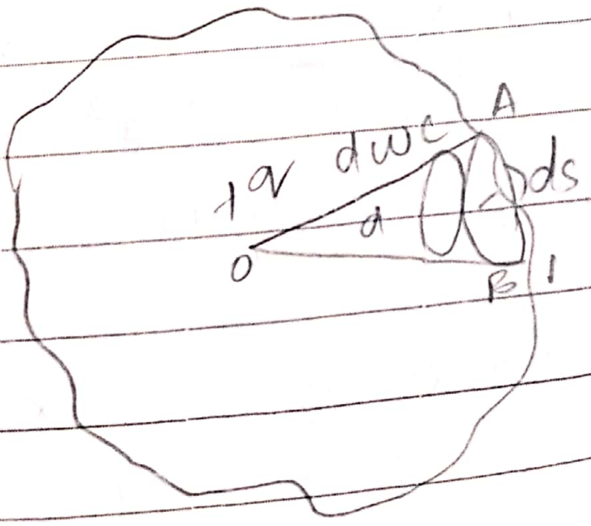
10m
3. state and prove Gauss law:

statement:

Gauss law states that total number of electrical induction over a closed surface is equal to Σq the total charge inside the surface.

proof:

consider a closed surface with charge q at the point 'o' and a small element of the surface "AB" of area "ds".



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∴ The electric intensity at a point on the surface AB

$$\Rightarrow \frac{+q}{4\pi \varepsilon_0 \varepsilon_r r^2}$$

∴ the component of the intensity perpendicular to the surface

$$= E\cos\theta$$

$$= \frac{q}{4\pi \varepsilon_0 \varepsilon_r r^2} \cdot \cos\theta$$

∴ Total number of electric intensity over this elementary surface is equal to the

⇒ permitivity × Electric intensity × surface area

$$= \varepsilon_0 \varepsilon_r \times \frac{q}{4\pi \varepsilon_0 \varepsilon_r r^2} \times AB$$

Here, on perpendicular

$$= \varepsilon_0 \varepsilon_r \times \frac{q}{4\pi \varepsilon_0 \varepsilon_r r^2} \times AB\cos\theta$$

$$= \frac{q}{4\pi r^2} AB\cos\theta$$

$$= \frac{q}{4\pi}\left[\frac{AB\cos\theta}{r^2}\right]$$

$\frac{AB\cos\theta}{r^2} = d\omega$ (solid angle suspended by AB)

$\therefore \; q/4\pi = \omega$

The solid suspended angle in a closed surface $= 4\pi$.

$\therefore$ Total Electric intensity $= \frac{q}{4\pi} d\omega$

case(i)

If there are so many charges ($q_1, q_2, q_3 \ldots$ so on) then, total number of electric intensity $= \Sigma q$

case(ii)

If the charges are outside the surface of the total output (total no. of electric intensity $= 0$).

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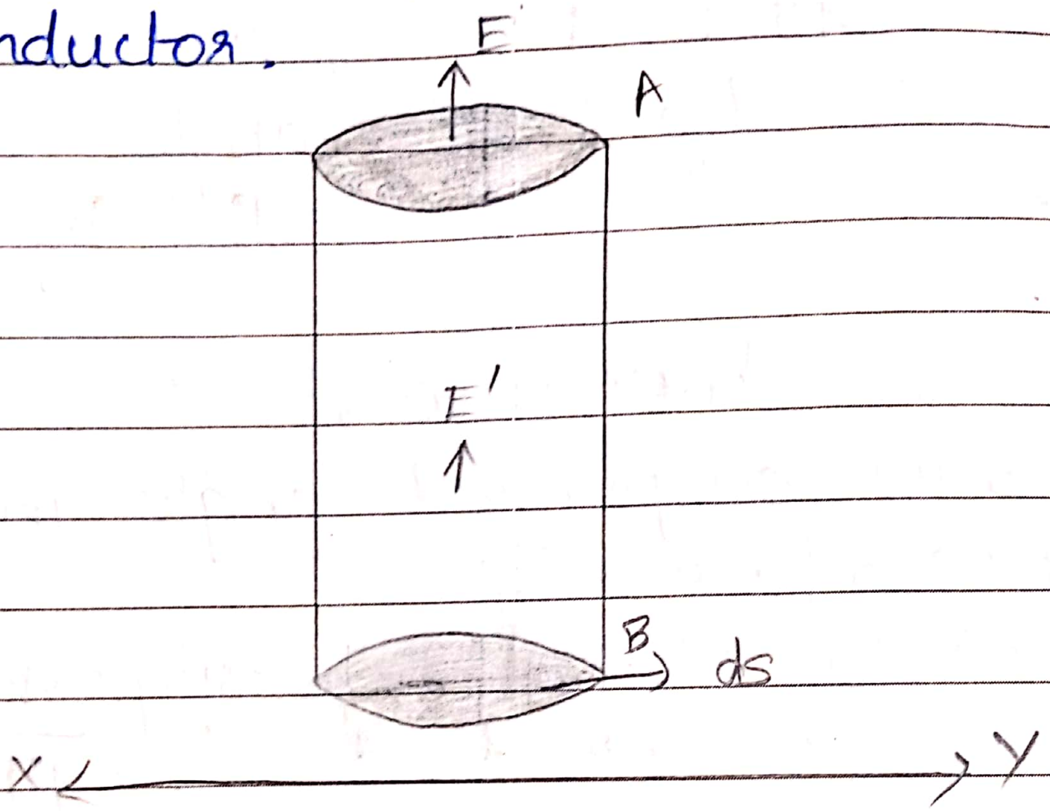
Applications of Gauss law:

Electric intensity at a point due to a infinite plane charged conductor.



Let XY be a plane charge conductor having surface density σ.
Let AB are the two points near the conductor.
Let EE' the electric intensities at A and B respectively.

Total no. of electric intensities at A $\Big\} = \varepsilon_0 \Sigma \, \pi \times E \times ds$

Total number of electric intensities at B $= \varepsilon_0 \cdot \varepsilon_r \times E' \times ds$

Total number of electric intensities $\Rightarrow \varepsilon_0 \varepsilon_r E ds - \varepsilon_0 \varepsilon_r E' ds$

According to Gauss law,

Total number of electric intensity inside the cylinder $= 0$

$\therefore \varepsilon_0 \varepsilon_r E ds - \varepsilon_0 \varepsilon_r E' ds = 0$

(i.e) $E = E'$

Now, By Gauss theorem,

Total number of electric intensity inside the cylinder $= \sigma ds$

$\therefore$ For the whole cylinder, total number of electric intensity $= 2 \varepsilon_0 \varepsilon_r E ds$

$$E = \frac{\sigma}{2 \varepsilon_0 \varepsilon_r}$$

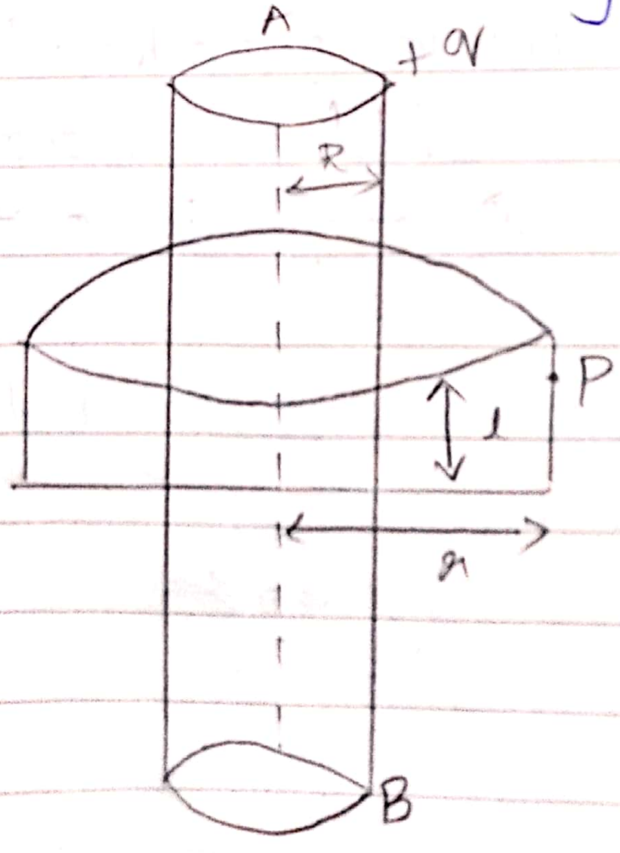
$[\because \sigma ds = 2 \varepsilon_0 \varepsilon_r E ds]$

$$\therefore E = \frac{\sigma}{2 \varepsilon_0 \varepsilon_r}$$

Electric intensity due to a point uniformly charged cylinder.

Let AB the charged cylinder having q units per meter. p is the point among the distance r from the axis of the cylinder. And R is the radius of the cylinder.

construct an imaginary cylinder of radius 'r' and the length 'l' round the cylinde.



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∴ Total number of electric intensity over a curved surface of the cylinder of radius "r"

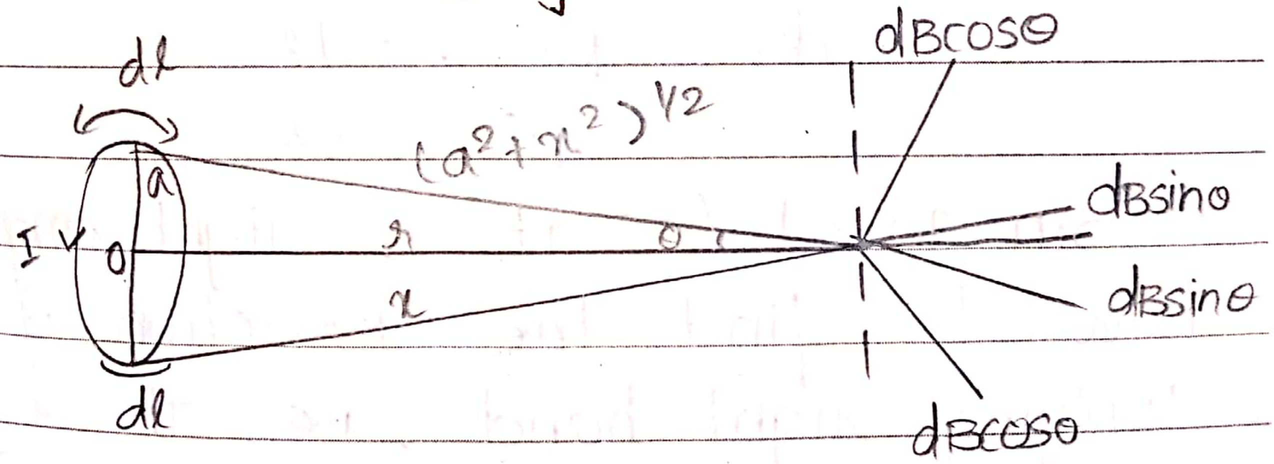
$$\Rightarrow \varepsilon_0 \varepsilon_r E\, 2\pi r l$$

∴ Total number of electric intensity over a surface cylinder using the Gauss theorem

$$\Rightarrow q l \quad \therefore q l = \varepsilon_0 \varepsilon_r . E . 2\pi r l$$

$$\therefore E = q / \varepsilon_0 . \varepsilon_r . 2\pi r$$

10m Magnetic field along the axis through circular coil carrying current.



Let us consider a circular coil carrying a current I with radius 'a' at distance x at a point p from the centre o. [$(a^2+x^2)^{1/2}$ circumference of the coil at any point from distance p.]

By Bio-savart law, It says the magnetic field for small element. Now, we consider a small element in the circular coil:

The small element is of length dl with distance r and the sin θ is the angle between dl and r.

$$\therefore dB = \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{r^2} \sin\theta$$

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{r^2}$$

$\sin 90^\circ = 1$ ($\because$ It is right angle)

Now to find the direction of dB Applying right hand rule, The right angle is produced at the point p.

The resultant is

$$\Sigma\, dB \sin\theta$$

[∵ All $dB\cos\theta$ are cancelled]
Because they are opposite.
Total magnetic field is

$$B = \Sigma dB \sin\theta$$

$$B = \oint \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{r^2} \sin\theta$$

$$\Rightarrow \oint \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{(a^2+x^2)} \times \frac{a}{(a^2+x^2)^{1/2}}$$

$$= \frac{\mu_0}{4\pi} \frac{I \cdot a}{(a^2+x^2)^{3/2}} \oint dl$$

$\left[\sin\theta = \frac{a}{r} \right.$

$\left. r = (a^2+x^2)^{1/2} \right]$

$$= \frac{\mu_0 \, Ia \, 2\pi a}{4\pi (a^2+x^2)^{3/2}}$$

$\oint dl = 2\pi a$

circumference of the circle.

$$= \frac{\mu_0 I}{4\pi} \frac{2A}{(a^2+x^2)^{3/2}}$$

$\pi a^2 = $ Area.

$$= \frac{\mu_0 I a \, 2\pi a}{4\pi (a^2+x^2)^{3/2}}$$

$$B = \frac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}}$$

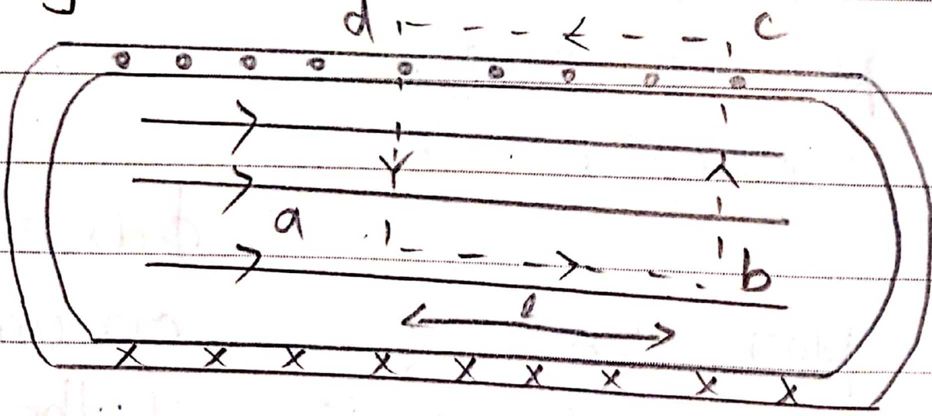
For n number of turns,

$$B = \frac{\mu_0 n I a^2}{2(a^2+x^2)^{3/2}}$$

At the centre of the coil, $x = 0$

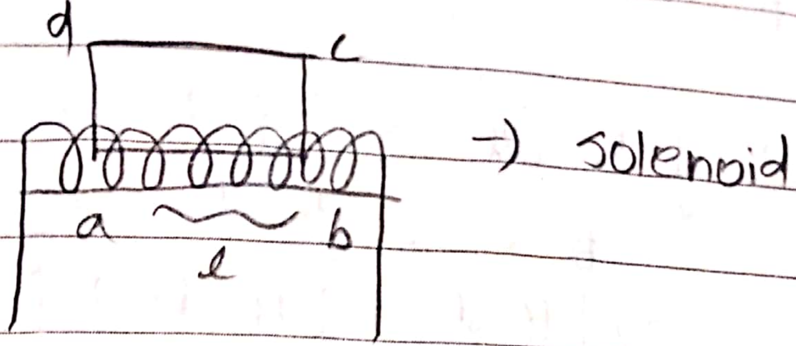
$$B = \frac{\mu_0 n I}{2a}$$

10m Magnetic field along the axis through solenoid:



Let us consider an infinitely long solenoid having n turns per unit length carrying current of I.

The magnetic field outside the solenoid is zero.



n - no. of turns

N - Total no. of turns $\quad \frac{N}{l} = n$

l - length $\quad N = nl$

A long solenoid appears like a long cylindrical metal sheet. The upper view of dots is like a uniform current sheet coming out of the plane paper. The lower row of crosses is like a uniform current sheet going into a plane of the paper.

To find the magnetic field at a point inside the solenoid.

A solenoid is symmetry. So, we consider a rectangular Amperean loop abcd.

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$\oint \vec{B}.\vec{dl}$ for loop abcd is the sum of four integrals.

$$\therefore \oint \vec{B}\,\vec{dl} = \oint_{abcd} B.dl$$

$$= \int_a^b B.dl + \int_b^c B.dl + \int_c^d B.dl + \int_d^a B.dl$$

$$= B\int_a^b dl + 0 + 0 + 0$$

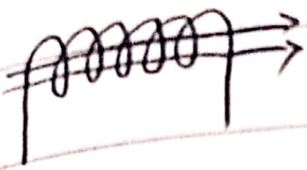
$$\oint \vec{B}.\vec{dl} = Bl$$

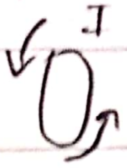
Since for a loop there is no angle at ab due to the symmetry. so ab = no angle. At bc the angle is 90° and da is also has the angle 90°.

$\therefore$ Angle at 90° for both bc and da is zero. The angle at cd is 180° and the magnetic field is out side the solenoid. so, cd also zero.

To find the current passing

through the loop,





I goes out +I

I goes in -I

$$I_0 = I.nl$$

(∵ All the loop has +I due to the Amperean loop)

W.K.T $N = nl$

By Ampere's circuital law for closed loop is

Ampere's circuital law

↑

$$\oint \vec{B}.\vec{dl} = \mu_0 . I_0$$

$$Bl = \mu_0 . Inl \qquad \left[\oint \vec{B}\vec{dl} = Bl \quad I_0 = Inl \right]$$

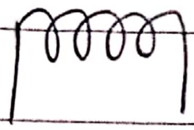
$$B = \mu_0 I n$$

If it is inserting a soft iron core inside the solenoid, a large number of magnetic field is produced.

$$B = \mu n I$$

$$B = \mu_0 \mu_r n I$$

Solenoid → A long closely wound helical coil is called solenoid



→ It consists the number of turns.

5m Ampere's circuital law:

Biot - savart law expressed in alternative way is called Ampere's circuital law

$$B = \frac{\mu_0 I}{2\pi a} \Rightarrow B(2\pi a) = \mu_0 I$$

where, $B(2\pi a)$ product of magnetic field and circumference.

If L is perimeter of closed curve and I_0 net current enclosed by closed curve,

$$BL = \mu_0 I_0$$

It can be written as,

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_0$$

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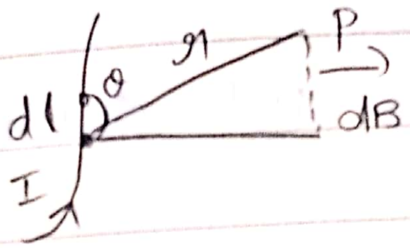
Biot - savart law:

Electric current source of magnetic field and current mo creates moving charges.



I - current

dl - small length without length charge cannot flow to the medium.

P - magnetic field create at that point, $d\vec{B}$ magnetic field

$dB \propto I\,dl$

[∵ length and current large strength magnetic field is large]

$$dB \propto \frac{1}{r^2}$$

Where, $\vec{r}$ is inversely proportional. It is as columb's law strength of magnetic field decrease as square of distance - inverse square law.

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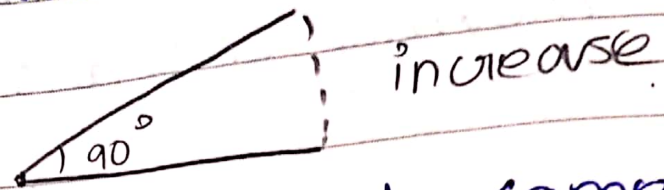
$$dB \propto \sin\theta$$

[∵ At right angle, the magnetic field increase.



Magnetic field is not same at all distance.

Now the equation is

$$dB \propto \frac{idl \sin\theta}{r^2}$$

Where, idl is current element.

The dB depends on the property of space,

[By coulomb's law, W.K.T

$$\text{Electric field} \propto \frac{q}{r^2}$$

Source →

It is parallel to the equation.

permiability:

It allows the magnetic field. It is denoted by μ (for medium) μ_0 (for free space)

$$\therefore dB = \frac{1}{4\pi} \mu_0 . \frac{idl \sin\theta}{r^2}$$

[$\frac{1}{4\pi}$ is constant for the direction at the point]

$$dB = \frac{\mu_0}{4\pi} . \frac{idl \sin\theta}{r^2}$$

$$\left[\frac{\mu_0}{4\pi} = 10^{-7} , \quad \mu_0 = 4\pi \times 10^{-7} \right]$$

Mechanical force experienced by unit area of a charged surface:

When the surface density of charge is σ, 'AB' is surface unit area on the charged surface.

consider, PQ one outside and other inside the charged surface.

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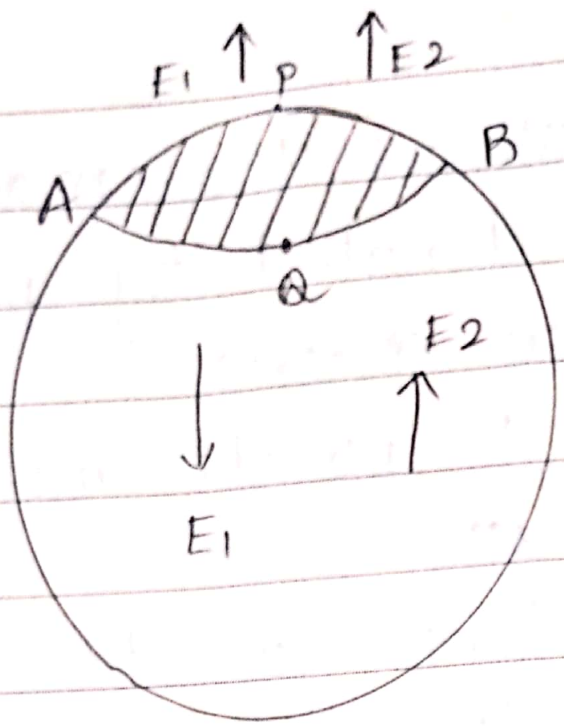

Electric intensity at P

$$E_P = E_1 + E_2$$

$$= \frac{\sigma}{\varepsilon_0 \varepsilon_r}$$

E_1 is the force experienced by positive charge on AB. E_2 is the force experienced due to the rest surface. The two forces are same, Electric intensity at Q

$$E_Q = E_1 - E_2 = 0$$

$$E_1 = E_2$$

$$E_Q = 2E_1 \text{ (or) } 2E_2$$

$$F_2 = \frac{\sigma}{2\varepsilon_0\varepsilon_r}$$

(i.e) A unit positive charge on AB experiences an upward force $\frac{\sigma}{2\varepsilon_0\varepsilon_r}$ due to the charge present on the rest surface.

∴ the force experience by unit area of the charged surface.

$$F = \frac{\varepsilon_0\varepsilon_r E^2}{2}$$

principle of capacitor :

capacity of a spherical conductor :

A sphere of radius 'r' is given a charge q.

the potential $V = \frac{q}{4\pi\varepsilon_0 r}$

$$\therefore C = \frac{q}{V}$$

$$C = \frac{q}{V} = 4\pi\varepsilon_0 r$$

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Principle :

Let x, a charged conductor, and y the earth connected conductor.

If y is absent the charge of x + q and the potential v represents the capacitance.

$$C = \frac{q}{v}$$

If Y is ~~kept~~ the absent the charge of ~~x+q~~ and the potential v represents the capacitance.

If Y is kept near x Electrostatic induction takes place.

Free electrons flows to the earth and y will have bound negative charge.

Then the potential of x decreases and capacity increased.

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REASON :

Because of the presence of y initiates the amount of work done in bringing a unit positive charge from infinity to x decreases as there will be a force of repulsion due to x and force of attraction due to y.

The Resultant force of repulsion on unit positive charge is reduced. The amount of work done is less and the potential of x decreases.

∴ The capacity of x increases.

In actual practice, two spaced conductors of different shapes are used with different shay dielectric.

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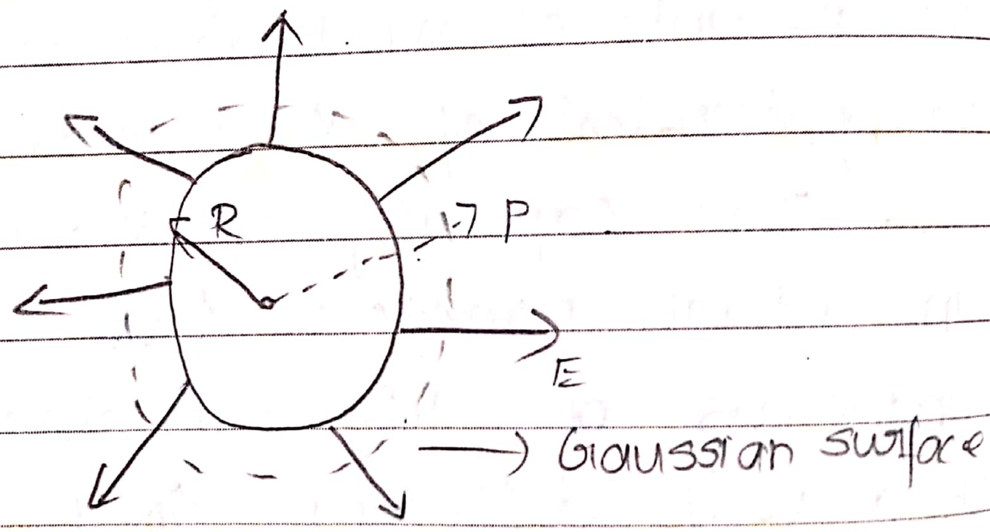
Gauss law applica.

Electric field due to uniformly charged spherical shell:

consider a charged shell of Radius R. Let p be a point outside the shell at a distance r from the centre O.

Let us construct a Gaussian surface with r as radius. The electric field E is normal to the surface.



The flux crossing the Gaussian sphere normally in an outward direction is

$$\phi = \int_S \vec{E}\cdot\vec{ds} = \int_S E\,ds = E(4\pi r^2)$$

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($\because$ angle between E and ds is zero)

By Gauss's law, $E.(4\pi r^2) = \frac{q}{\varepsilon_0}$

(or) $E = \frac{1}{4\pi\varepsilon_0} . \frac{q}{r^2}$

From the equation that the electric field at a point outside the shell will be the same as if the total charge on the shell is concentrated at its centre

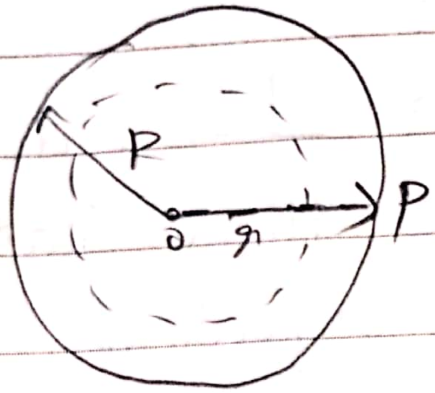
ii) At a point on the surface:

the electric field E for the points on the surface charged spherical' shell is

$$E = \frac{1}{4\pi\varepsilon_0} \frac{q}{R^2} \quad (\because r = R)$$

iii) At a point inside the shell:

consider a point p' inside the shell at a distance r' from the centre of the shell. Let us construct a Gaussian surface with radius r'



The total flux ~~conta~~ crossing the Gaussian sphere normally in an outward direction is

$$\phi = \oint_S \vec{E} \cdot \vec{ds} = \oint_S E\,ds = E \times (4\pi r^2)$$

Since there is no charge enclosed by the gaussian surface. according to Gauss law,

$$E \times 4\pi r^2 = \frac{q}{\varepsilon_0} = 0 \qquad \therefore E = 0$$

(i.e) the field due to uniformly charged thin shell is zero at all points inside the shell.

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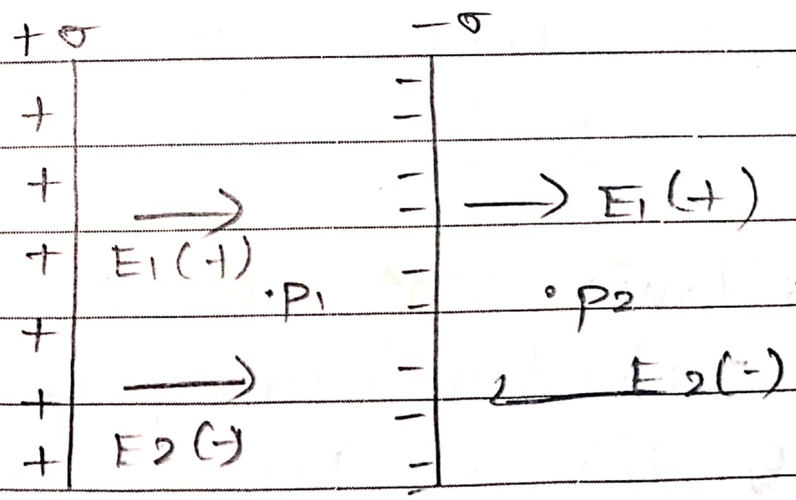
Electric field due to two parallel charged sheets:

consider two plane parallel infinite sheets with equal and opposite charge densities $+\sigma$ and $-\sigma$. the magnitude of electric field on either side of a plane sheet of charge is

$$E = \frac{\sigma}{2\varepsilon_0}$$

It act perpendicular to the sheet, direct outward (+) or inward (−)



i) when the point p_1 is in between the sheets, the field due to two sheets will be equal in magnitude and in same direction. the resultant

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field at P_1 is

$$E = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$E = \frac{\sigma}{\varepsilon_0} \text{ (towards right)}$$

ii) At a point P_2 outside the sheets, the electric field will be equal in magnitude and opposite in direction. The resultant field at P_2 is

$$E = E_1 - E_2 = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

2m Gauss law:

The law states that the total flux of the electric field E over any closed surface is equal to $1/\varepsilon_0$ times the net charge enclosed by the surface. $\phi = \frac{q}{\varepsilon_0}$

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Moving coil Ballistic Galvanometer

principle:

When a current is passed through a coil, suspended freely in a magnetic field, it experiences a force in a direction given by Fleming's left hand rule.

construction:

It consists of a rectangular coil of thin copper wire wound on a non-metallic frame of ivory. It is suspended by means of a phosphor bronze wire between the poles of a powerful horse-shoe magnet. A small circular mirror is attached to the suspension wire. Lower end of the coil is connected to a hair-spring. The upper end of a suspension wire and the lower end of the spring are connected to terminals T_1 and T_2.

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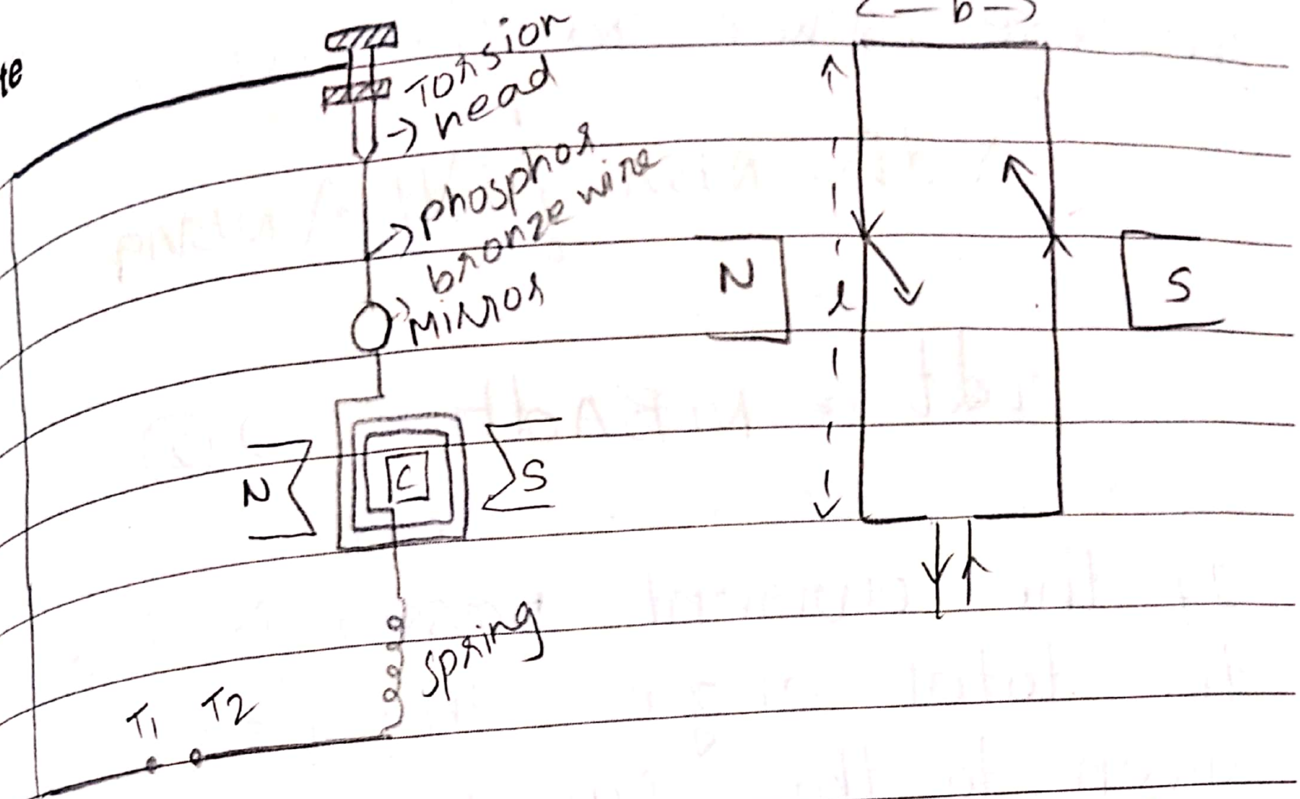
A cylindrical soft iron core (c) is placed symmetrically inside the coil between the magnetic poles which are also made ~~b~~ cylindrical in shape. this iron core concentrates the magnetic field and helps in producing radial field.

The B.G is used to measure electric charge. the charge has to pass through the coil as quickly as possible and before the coil starts moving. The coil thus gets an impulse and a throw is registrated

To achieve this result, a coil of high moment of inertia is used so that the period of oscillation of the coil is fairly large. the oscillations of the coil are practically undamped.



Theory:

(i) consider a rectangular coil of N turns placed in a uniform magnetic field of magnetic induction B. Let l be the length of the coil and b its breadth.

Area of the coil $= A = lb$

When a current i passes through the coil,

torque on the coil $= \tau = NiBA$ —①

If the current passes for a short interval dt, the angular

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produced in
impulse given to the coil is

$$\int_0^t I\,dt = NBA\int_0^t i\,dt = NBAq$$

$$I\,dt = NiBA\,dt \rightarrow (2)$$

If the current passes for t sec, the total angular impulse given to the coil is

$$\int_0^t I\,dt = NBA\int_0^t i\,dt = NBAq \rightarrow (3)$$

Here $\int_0^t i\,dt = q$ is a total charge passing through the galvanometer coil.

Let I be the moment of inertia of the coil about the axis of suspension and ω its angular velocity. Then, change in angular momentum of the coil $= I\omega \rightarrow (4)$

$$I\omega = NBAq \rightarrow (5)$$

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ii) The kinetic energy of the moving system $\frac{1}{2} I\omega^2$ is used in twisting the suspension wire through an angle θ. Let c be the restoring couple per unit twist of the suspension wire. Then, work done in twisting the suspension wire by an angle

$$\theta = \frac{1}{2} c\theta^2$$

$$\frac{1}{2} I\omega^2 = \frac{1}{2} c\theta^2$$

$$I\omega^2 = c\theta^2 \quad \rightarrow (6)$$

iii) The period of oscillation of coil is

$$T = 2\pi\sqrt{\left(\frac{I}{c}\right)} \quad \text{or} \quad T^2 = \frac{4\pi^2 I}{c}$$

$$I = \frac{T^2 c}{4\pi^2} \quad \rightarrow (7)$$

Multiplying eqn. (6) and (7)

$$I^2\omega^2 = \frac{c^2 T^2 \theta^2}{4\pi^2} \quad \rightarrow (8)$$

$$I\omega = \frac{cT\theta}{2\pi}$$

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Equating ⑤ and ⑥,

$$NBAq = \frac{CT\theta}{2\pi}$$

$$q = \left(\frac{T}{2\pi}\right)\left(\frac{C}{NBA}\right)\theta \rightarrow ⑨$$

This gives the relation b/w the charge flowing and the ballistic throw θ of the galvanometer.

$$q \propto \theta$$

$\left(\frac{T}{2\pi}\right)\left(\frac{C}{NBA}\right)$ is called the ballistic reduction factor(k).

$$q = k\theta$$

2m Skin effect :

The tendency of an alternating electric current (AC) to become distributed within a conductor such that the current density is largest near the surface of the conductor, and decreases with greater depths in the conductor.

Date 24.02.2020

10m

1. spherical capacitor
2. cylindrical capacitor
3. loss of energy on sharing charges.
4. Gauss law & its applications (" cylinder
5. field along the axis of circular coil.
6. field along the axis of solenoid
7. Measurement of leakage (High resistance,
8. self induction - Rayleigh experiment.
9. LCR circuit.
10. Langesins theory of dia, para
11. weiss theory of ferro, dia, para

5m

1. potential at a point due to a field
2. principle of capacitors
3. wheat stone's bridge
4. carey Fosters bridge
5. Kirchoff's law (proof)
6. Ampere's circuital law (proof)
7. Growth and decay of L & R
8. Growth and decay of C & R

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9. Transformer
10. power in RL circuit
11. Dia, para, ferro (properties)
12. B-H & Hysteresis

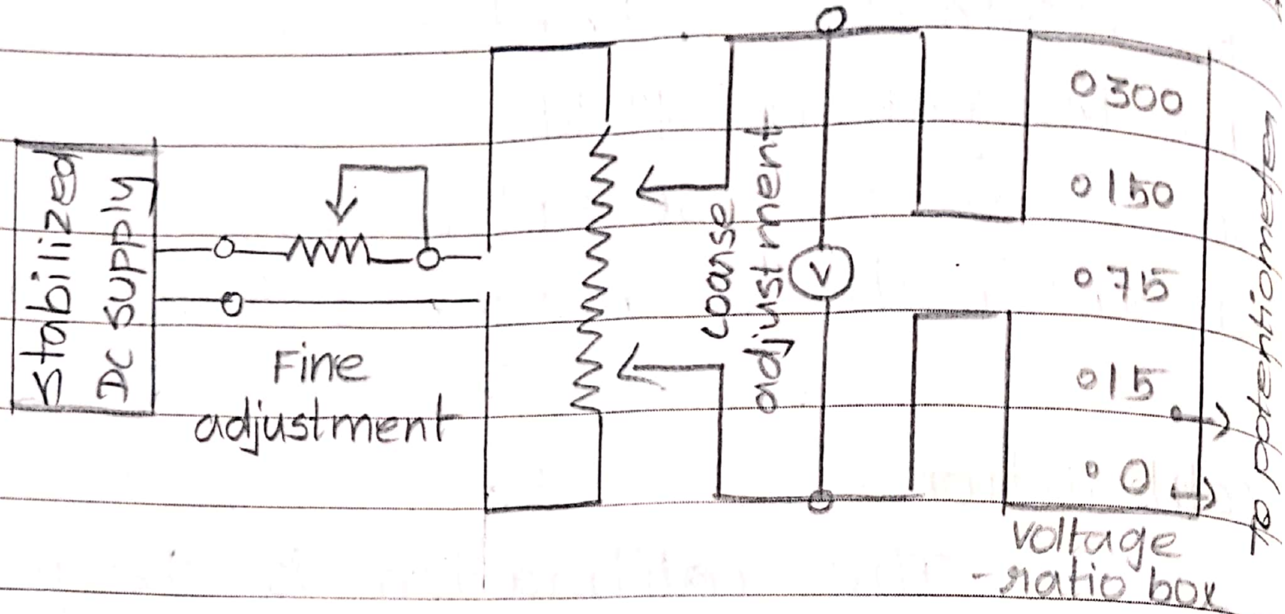
2m
1. couloumb's law
2. Electrical potential
3. Gauss law
4. capacitance of a capacitor
5. couloumb
6. uses of capacitor
7. current and voltage law
8. potentiometer
9. Figure of merit
10. Damping correction
11. Mutual inductance
12. Self inductance
13. Define Henry
14. laws of EMI
15. q factor
16. power factor

17. Skin effect
18. Magnetic potential
19. Magnetic field
20. Magnetic suceptibility.
21. Intensity of magnetisation.

calibration :

The calibration is the process of checking the accuracy of the result by comparing it with the standard value. In other words, calibration checks the correctness of the instrument by comparing it with the reference standard. It helps us in determining the error occur in the reading and adjusts the voltage for getting the ideal reading.

Calibration of voltmeter with potentiometer



The circuit requires two rheostats, one for controlling the voltage and another for adjustment. The voltage ratio box is used for to step-down the voltage to a suitable value. The accurate value of voltmeter is determined by measuring the value of the voltage to the maximum possible range of the potentiometer.

The potentiometer measures the maximum possible value of voltages. The negative and positive error occurs

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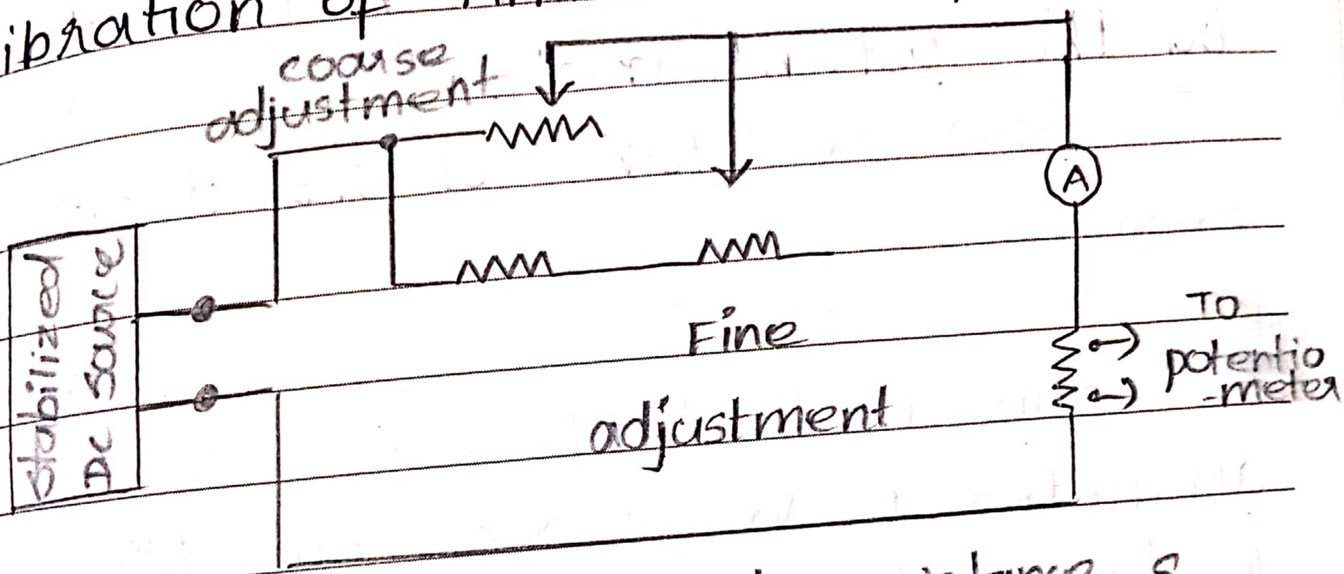
in the readings of the voltmeter if the readings of potentiometer and the voltmeter are not equal.

calibration of Ammeter with potentiometer:



standard resistance, S

The standard resistance is connected in series with ammeter which is to be calibrated. The potentiometer is used for measuring the voltage across the standard resistor. The below mentioned formula determines the current through the standard resistance.

$$I = \frac{V_s}{S}$$

Where,

$V_s \rightarrow$ voltage across the standard resistor as indicated by the potentiometer.

$S \rightarrow$ resistance of standard resistor.

this method of calibration of ammeter is very accurate because in this method the value of standard resistance and the voltage across the potentiometer is exactly known by the instrument.

2m potentiometer:

A potentiometer is defined as a 3 terminal variable resistor in which the resistance is manually varied to control the flow of current.

Date 10.03.2020

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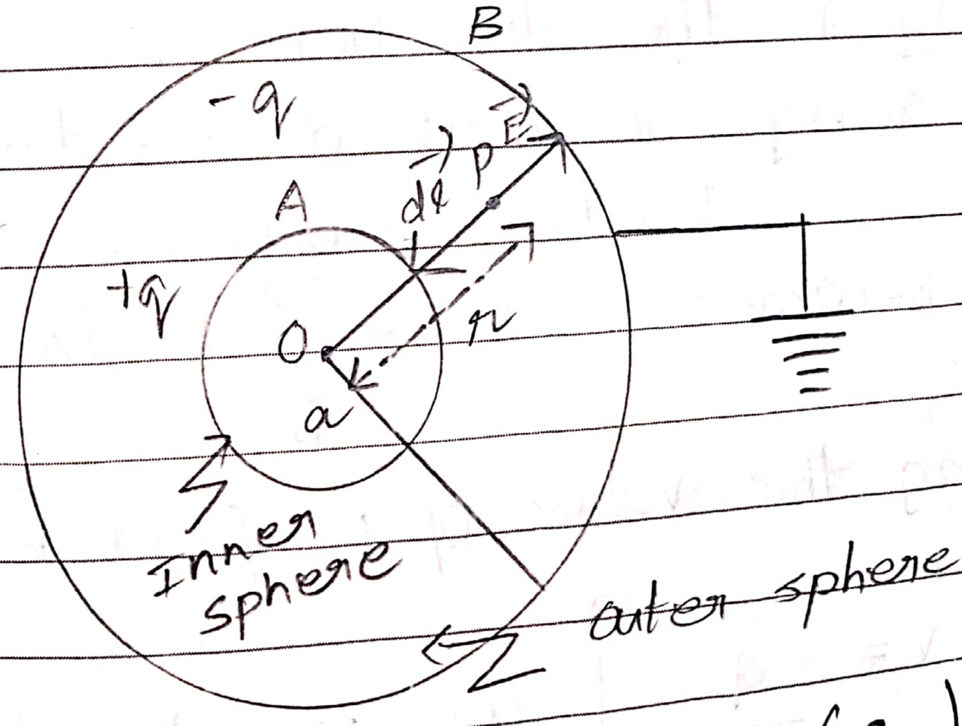
Capacitance of a spherical capacitor : (outer sphere earthed)

Let A and B be two concentric metal spheres of radii a and b respectively with air as the intervening medium. The outer sphere B is earthed. A charge +q is given to the inner sphere. the induced charge on the inner surface of the outer sphere is -q. p is a point at a distance r from the common centre o.



Electric field at p, $E = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r^2}\right)\hat{r}$ —(1)

Date 10.03.2020

Capacitance of a spherical capacitor: (outer sphere earthed)

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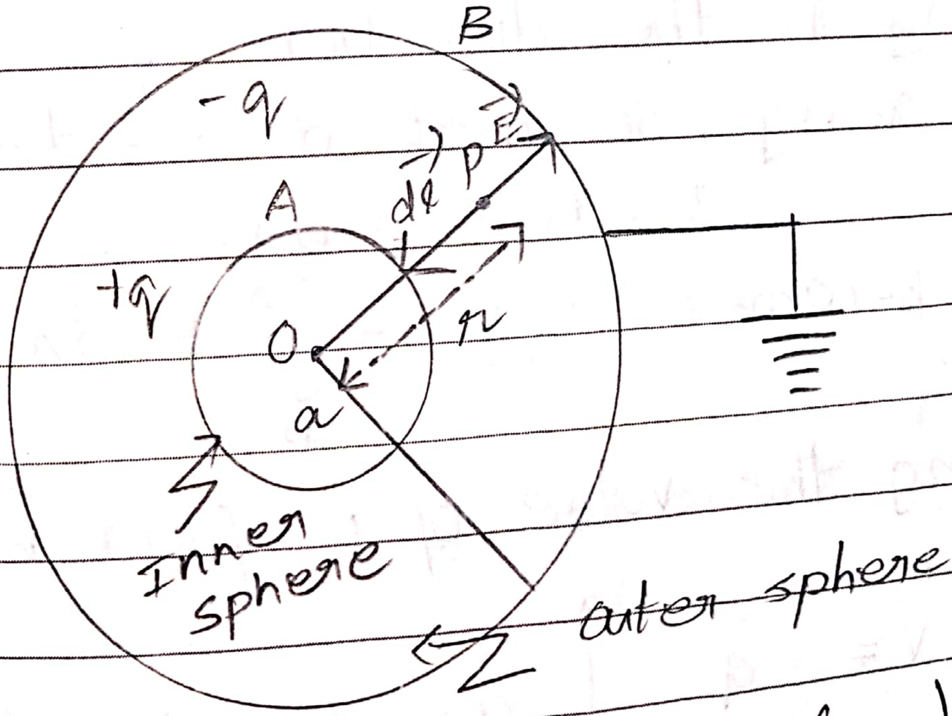

Electric field at p, $E = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r^2}\right)\hat{r}$ —①

where $\hat{r}$ is the unit vector along $\vec{OP}$

The potential difference between the spheres A and B is given by

$$V = \int_b^a E \cdot dl \longrightarrow (2)$$

Here dl is the differential vector displacement along a path from B to A.

But $E \cdot dl = E\,dl \cos 180^\circ = -E\,dl$

Further, in moving a distance dl in the direction of motion, we are moving in the direction of r decreasing, so that $dl = -dr$. Hence,

$$E \cdot dl = E\,dr.$$

Eq. (2) becomes, $V = -\int_b^a E \cdot dr.$

putting the value of E from Eq. (1), we get

$$\frac{1}{r^2} \rightarrow r^{-2}$$

$$V = \frac{-q}{4\pi\varepsilon_0}\int_b^a \frac{dr}{r^2} = -\frac{q}{4\pi\varepsilon_0}\left\{-\frac{1}{r}\right\}_b^a$$

$$\frac{r^{-2+1}}{-2+1} = -\frac{1}{r}$$

$$\frac{r^{1}}{1}$$

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$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{b}\right] = \frac{q}{4\pi\varepsilon_0}\,\frac{b-a}{ab}$$

$\therefore$ capacitance of the spherical capacitor

$$c = \frac{q}{V}$$

$$= \frac{q}{(q/4\pi\varepsilon_0)(b-a/ab)}$$

$$= 4\pi\varepsilon_0\,\frac{ab}{(b-a)} \quad \rightarrow (3)$$

Now Eqn. (3) can be written in the form

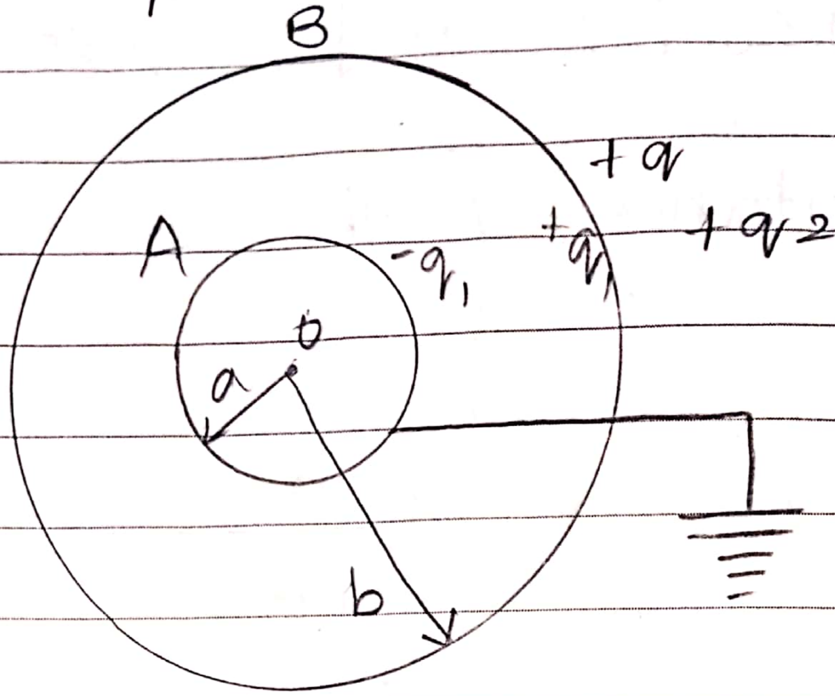
$$c = 4\pi\varepsilon_0\,\frac{ab}{b-a}$$

$$= \frac{4\pi\varepsilon_0}{\left(\frac{1}{a} - \frac{1}{b}\right)}$$

When $b \rightarrow \infty$, $c = 4\pi\varepsilon_0 a$

this is the capacitance of an isolated conducting sphere of radius a.

ii) (inner sphere earthed:



A and B are two spheres of radii a and b. Suppose a charge $+q$ is given to the outer ~~surface~~ sphere B. $+q$ is distributed on its inner and outer surfaces by amounts $+q_1$ and $+q_2$ respectively so that $q = q_1 + q_2$. The charge $+q_1$ on the inner surface of B induces a charge $-q_1$ (bound charge) on the outer surface of A and charge $+q_1$ on the inner surface of A. The charge $+q_1$ on the inner surface of

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A_1 being free, leaks to the earth.

The two spheres now behave as two capacitors connected in parallel.

(i) the inner sphere of radius a and the inner surface of outer sphere from a capacitor of capacitance.

$$C_1 = \frac{4\pi\varepsilon_0 ab}{b-a}$$

(if the dielectric is air)

(ii) the outer surface of B and the earth from a capacitor of capacitance.

$$C_2 = 4\pi\varepsilon_0 b$$

Total capacitance,

$$C = C_1 + C_2$$

$$= \frac{4\pi\varepsilon_0 ab}{b-a} + 4\pi\varepsilon_0 b$$

$$C = \frac{4\pi\varepsilon_0 b^2}{b-a} = 4\pi\varepsilon_0\left(\frac{ab}{b-a} + b\right)$$

$$= 4\pi\varepsilon_0 \cdot \frac{ab + b(b-a)}{b-a}$$

$$= 4\pi\varepsilon_0 \frac{(\cancel{ab} + b^2 - \cancel{ab})}{b-a}.$$

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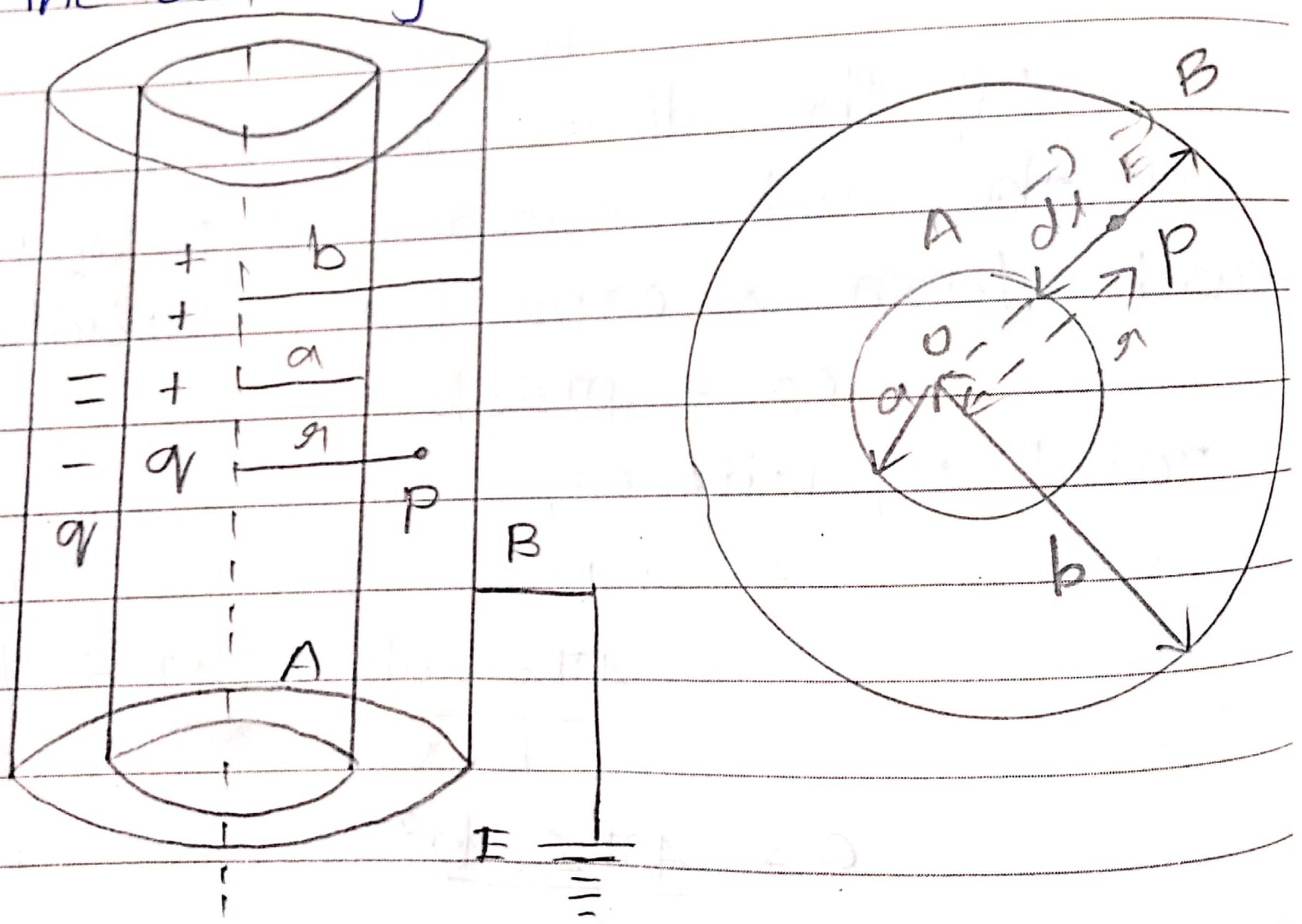
10m capacitance of a cylindrical capacitor

consider a cylindrical capacitor formed by two coaxial cylinders A and B of radii a and b respectively and each of length l. Air is the medium between A and B. The outer cylinder B is earthed.



If a charge +q is given to the inner cylinder, then an equal charge -q is induced on the inner surface of the outer cylinder and a charge +q on the outer surface of the outer cylinder. The charge +q induced on the outer cylinder flows to the earth.

The electric field at a point p in the space between the two cylinders at a distance r from the axis is

$$E = \frac{1}{2\pi\epsilon_0 l} \cdot \frac{q}{r} \rightarrow (1)$$

The potential difference V between the cylinders A and B is

$$V = -\int_b^a E.dl \rightarrow (2)$$

Here dl is the vector displacement along a path from B to A.

Now E is radially outward and dl is inward.

Therefore,

$$E.dl = Edl\cos 180^\circ = -Edl$$

As we move a distance dl from B to A. we move in the direction of

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decreasing r. so $dl = -dr$

$$E.dl = E\,dr$$

Eq. (2) becomes,

$$V = -\int_b^a E\,dr$$

$$= -\frac{q}{2\pi\varepsilon_0 l}\int_b^a \frac{dr}{r} \quad (\text{from } (1))$$

$$= \frac{-q}{2\pi\varepsilon_0 l}\left\{\log_e r\right\}_b^a$$

$$= \frac{-q}{2\pi\varepsilon_0 l}\left\{\log_e a - \log_e b\right\}$$

$$= \frac{q}{2\pi\varepsilon_0 l}\log_e \frac{b}{a}.$$

Hence the capacitance of the cylindrical capacitor is

$$C = \frac{q}{V}$$

$$= \frac{2\pi\varepsilon_0 l}{\log_e (b/a)}$$

Loss of energy on sharing of charges between two capacitors :

consider two capacitors of capacitances C_1 and C_2 charged to potentials V_1 and V_2 when they are joined by a wire, they attain a common potential V.

$$V = \frac{\text{Total charge}}{\text{Total capacitance}}$$

$$= \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

Total energy of the two capacitors before contact.

$$U_1 = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2 \quad -(1)$$

Total energy of the two capacitors after contact

$$U_2 = \frac{1}{2}(C_1 + C_2)V^2$$

$$= \frac{1}{2}(C_1 + C_2)\left[\frac{C_1V_1 + C_2V_2}{C_1 + C_2}\right]^2$$

$$= \frac{1}{2}\frac{(C_1V_1 + C_2V_2)^2}{C_1 + C_2} \quad -(2)$$

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loss of energy due to contact,

$$\Rightarrow U_1 - U_2$$

$$= \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2 - \frac{1}{2}\frac{(C_1V_1 + C_2V_2)^2}{(C_1 + C_2)}$$

$$\Rightarrow \frac{1}{2(C_1+C_2)}\left[(C_1 + C_2)(C_1V_1^2 + C_2V_2^2) - (C_1V_1 + C_2V_2)^2\right]$$

$$= \frac{1}{2(C_1+C_2)}\left[C_1^2V_1^2 + C_1C_2V_2^2 + C_1C_2V_1^2 + C_2^2V_2^2 - C_1^2V_1^2 - C_2^2V_2^2 - 2C_1C_2V_1V_2\right]$$

$$= \frac{C_1C_2}{2(C_1+C_2)}\left[V_1^2 + V_2^2 - 2V_1V_2\right]$$

$$= \frac{C_1C_2}{2(C_1+C_2)}(V_1 - V_2)^2$$

Since $(V_1 - V_2)^2$ is always positive, V_2 must be less than V_1. Hence there is a loss of energy on sharing the charges. The loss of energy appears partly as heat in the connecting wire and partly as light and sound if sparking occurs.

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Date 18.03.2020

1. Magnetic field:

The space around the magnet in which its magnetic influence a force in the region is magnetic field.

2. Magnetic permeability:

The ratio of normal lines of force per unit area in the medium to the lines of force per unit area in the air or vaccum (i.e) Ratio between magnetic induction and field.

$$\mu = B/H \quad (\text{or}) \quad \mu = \mu_0 \mu_r$$

3. Relative permeability:

The ratio of the force between the magnetic poles at a fixed distance in vacuum to the force between them in the medium at the same distance.

For air $\mu_r = 1$

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4. Magnetic susceptibility:

The magnetic susceptibility is defined as the intensity of magnetisation (I) which is proportional to the field (H).

$$\lambda = I/H$$

5. Magnetic flux density:

Due to the field, the total number of lines of force per unit area induces a force in the region called magnetic flux density. Its unit is $wb\,m^{-2}$.

6. Magnetic intensity:

Magnetic intensity is defined as the magnetic moment per unit volume. $I = M/V$ $wb\,m^{-2}$

7. Magnetic Moment:

The product of pole strength

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and the length of the magnet gives the magnetic moment, $M = 2l \times m = 2ml$

8. Magnetic potential:

The amount of work done in moving a unit north pole from infinity to point gives the magnetic potential. It is denoted by V.

$$V = \frac{m}{4\pi \mu_0 r}$$

9. Magnetic shell:

Magnetic shell is a thin sheet having magnetic property.

Magnetic moment dissipates with respect to the area of the shell.

10. Hysteresis:

The lagging of magnetising field behind the effect is called Hysteresis.

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11. Retentivity / Remanence / Residual magnetism

Even after the removal of the magnetic effect, the material has magnetic flux density in it represents retentivity.

part - B.

1. Relation b/w Magnetic field & potential

we know that,

$$B = \frac{m}{4\pi \mu_0 r^2} \rightarrow (1)$$

work done in moving the magnetic pole effect from ∞ to the point is

$$W = -B\,dx \rightarrow (2)$$

$$= \frac{-m}{4\pi \mu_0 r^2}\,dx$$

$$\because W = V_1 - V_2 = dv$$

$$\frac{-m}{4\pi \mu_0 r^2}\,.dx = dv$$

$$B = -dv/dx \rightarrow (3)$$

2. Short note on Magnetic shell :

* Magnetic shell is a thin sheet having magnetic property.

* The point perpendicular to the shell be affected by the effect.

* Number of magnetic dipoles are arranged adjacently to form the shell.

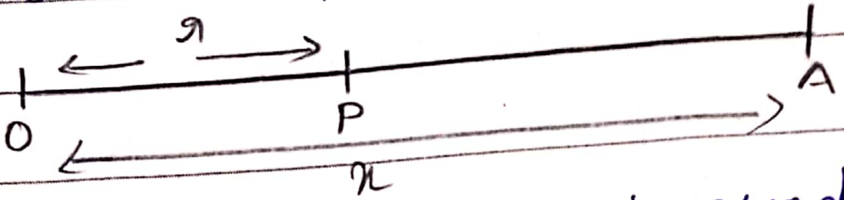
* The strength of the shell depends on the magnetic moment with respect to the surface area.

(ie) $\phi = \frac{M}{A}$ (or) $\phi = I \times t$ I -) intensity
t -) thickness of shell.

* It has number of divisions having magnetic strength.

3. Derive an expression for the magnetic potential at a point.

consider an isolated north pole strength m, at a point r distance from the centre O. Let the point P get effect from the infinity by work done. The amount of work done by giving magnetic force from ∞ to that point. The distance between the point A and O is r, as shown in figure.



The force experienced by north pole placed at A,

$$F = \frac{m}{4\pi\mu_0 x^2} \rightarrow (1)$$

work done $W = -F\,dx \rightarrow (2)$

$$dv = \frac{-m}{4\pi\mu_0 x^2}\,dx$$

$$V = \int_{\infty}^{r} \frac{-m}{4\pi\mu_0 x^2}\,dx$$

$$= \frac{-m}{4\pi\mu_0}\left[\frac{1}{x}\right]_{\infty}^{r}$$

$$V = \frac{m}{4\pi\mu_0 r} \rightarrow (3)$$

4. properties of para, Dia and ferro

para:

*substances that are attracted towards the stronger magnetic field.

* If temperature decreases, magnetic effect increases.

* when this type of materials placed in uniform magnetic field, the assigned parallel to the field.

* paramagnetic substances having lines of force tend to concentrate through the body.

* suceptibility is a small positive value.

* Suceptibility is inversely proportional to the absolute temperature.

* Eg. Al, pt, o, cr etc

Dia:

* substances that are attracted towards the weaker field.

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*substances are independent of the temperature.

*In this dia type, the material placed in field is perpendicular to the field.

*Diamagnetic substances having lines of force do not tend to concentrate through the body.

*Magnetic suceptibility is negative

*suceptibility being a negative, it cannot be attracted by the magnet

* Eg. Bi, H_2O, H etc

Ferro:

*substances which have strong field when compared to para and dia substances are ferro.

* Ferro magnetic substance decreases in its magnetic effect when temperature increases.

* Ferro magnetic substances

are parallel to the field.

* These substances have positive suceptibility.

* suceptibility is inversely proportional to the absolute temperature.

[* As the temperature increases, susceptibility decreases. Above a particular temperature, ferro becomes para and that temperature is called curie-temperature. Eg. Fe, Ni etc] 2mark

part-c

1. Derive an expression for magnetic potential due to dipole.

consider a barmagnet of length 2l. A point p at a distance r from o is the mid point of the magnet o is selected. Magnetic potential at the point p have to be determined. let op makes an angle θ with dipole axis as shown in the figure.

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potential at p due to north pole

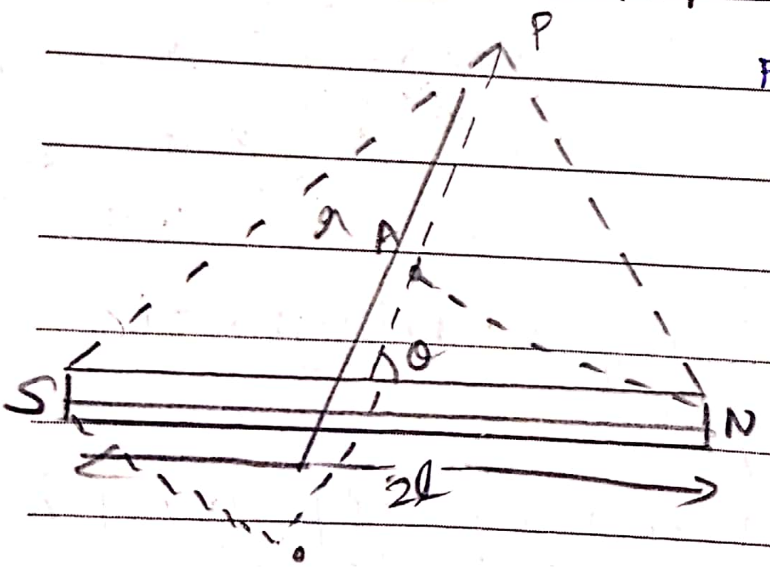
$$\Rightarrow \frac{m}{4\pi\mu_0 (NP)} \rightarrow (1)$$

potential at p due to south pole

$$\Rightarrow \frac{-m}{4\pi\mu_0 (SP)} \rightarrow (2)$$

Resultant potential,

$$V = \frac{m}{4\pi\mu_0}\left[\frac{1}{NP} - \frac{1}{SP}\right] \rightarrow (3)$$



From fig,

NP = $(r - l\cos\theta)$

SP = $(r + l\cos\theta)$

∴ on substituting in (3),

$$V = \frac{m}{4\pi\mu_0}\left[\frac{1}{(r-l\cos\theta)} - \frac{1}{(r+l\cos\theta)}\right]$$

$$= \frac{m}{4\pi\mu_0}\left[\frac{(r+l\cos\theta)-(r-l\cos\theta)}{(r^2-l^2\cos^2\theta)}\right]$$

$a^2 - b^2$ form

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$$= \frac{m}{4\pi\mu_0}\left[\frac{r + l\cos\theta - r + l\cos\theta}{(r^2 - l^2\cos^2\theta}\right]$$

$$V = \frac{m\,2l\cos\theta}{4\pi\mu_0(r^2 - l^2\cos^2\theta)} \longrightarrow (4)$$

As $r >> l\cos\theta$, l^2 can be neglected.

$$\therefore V = \frac{m\,2l\cos\theta}{4\pi\mu_0 r^2} \longrightarrow (5)$$

put $\mu = 2ml$.

then eqn. (5) becomes

$$V = \frac{\mu\cos\theta}{4\pi\mu_0 r^2} \longrightarrow (6)$$

cases:

(i) If $\theta = 90°$ (axial)

$$V = \frac{\mu}{4\pi\mu_0 r^2} \longrightarrow (7)$$

(ii) If $\theta = 0°$ (equatorial)

$$V = 0 \longrightarrow (8)$$

2. Derive an expression for potential due to a magnetic shell.

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consider a uniform magnetic shell of strength ϕ. The distance between the centre o and the point p perpendicular to the shell is r. Let op makes an angle θ with an angle θ with normal of the shell, dA be the small element.

$\therefore$ potential at p due to dA

$$= \frac{M \cos\theta}{4\pi\mu_0 r^2} \rightarrow (1)$$

W.K.T

$$M = \phi . dA \rightarrow (2)$$

$$dv = \frac{\phi . dA \cos\theta}{4\pi\mu_0 r^2} \rightarrow (3)$$

put $\frac{dA \cos\theta}{r^2} = d\omega \rightarrow (4)$

$$\therefore dv = \frac{\phi}{4\pi\mu_0} d\omega \rightarrow (5)$$

$\therefore$ Total potential, $v = \frac{1}{4\pi\mu_0} \int \phi \, d\omega \rightarrow$

From a uniform shell, ϕ is same at all points.

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$$\therefore\ V = \frac{\phi}{4\pi\mu_0} \int d\omega$$

$$V = \frac{\phi}{4\pi\mu_0} \cdot \omega \rightarrow (7)$$

cases:

i. potential inside a shell:

Angle = 4π

potential = ϕ / μ_0

(V) potential difference = 0

Magnetic field = 0

ii. potential at a point on a shell at infinite

Angle = 2π

potential = $\phi / 2\mu_0$

potential difference (V) = ϕ / μ_0

iii. potential outside a shell:

Angle = small

potential = 0

potential difference = 0

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5m

3. Hysteresis.

when a magnetic substance is taken through a complete cycle of magnetisation, the flux density always lag behind the magnetising field. The lagging of magnetisation behind the field is called Hysteresis.

(i) By placing a magnetic substance in a solenoid, it is magnetised by passing a current through the solenoid. As the magnetic field increases, the flux density also increases and reaches a saturation point.

(ii) when field decreases to zero, flux density reaches a constant value and not zero. This property is called retentivity.

(iii) Now, when the field is reversed field increases and flux density decreases and then to zero. This property is called coercivity.

(iv) Now if the field increases further, it reaches a saturation point.

(v) As shown in figure, ABCDEFA gives the Hysteresis loop.

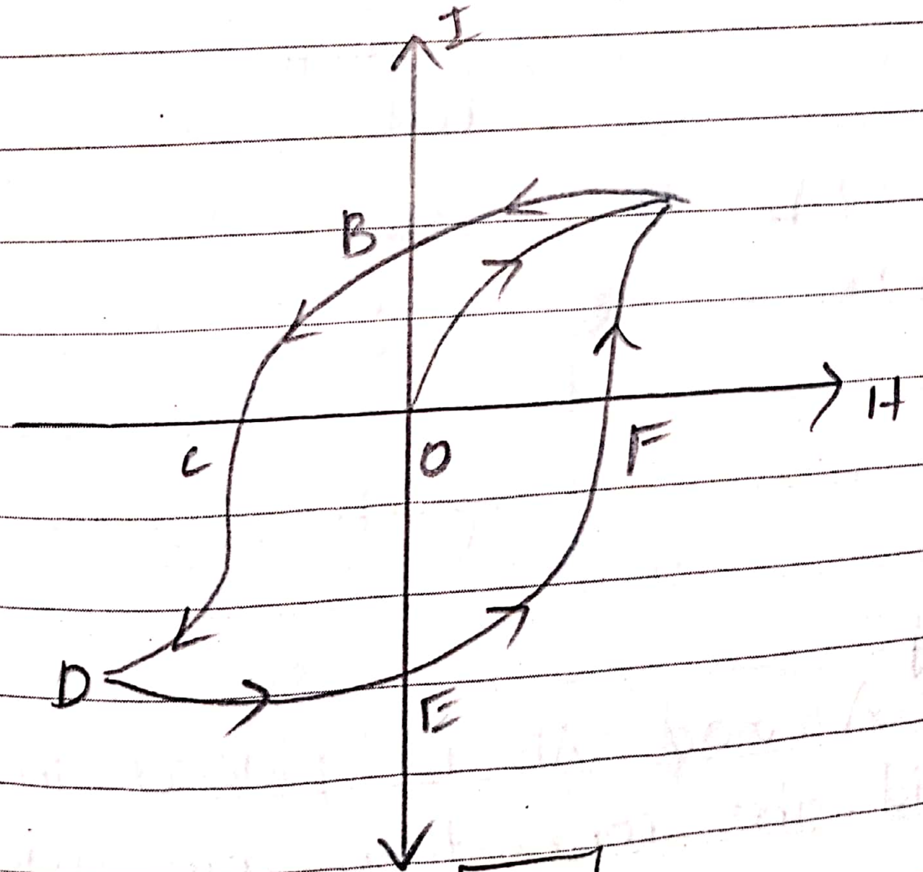
(vi) There is always a loss of energy for hysteresis loop.

(vii) The magnetic moment M can be resolved into two components.

(i) $M\cos\theta$ (ii) $M\sin\theta$

$M\cos\theta \rightarrow$ parallel to field.

$M\sin\theta \rightarrow$ perpendicular to field.



$\boxed{\text{Loop}}$

Intensity $I = \Sigma m \cos\theta$

$dI = -\Sigma m \sin\theta \, d\theta$

The couple on M

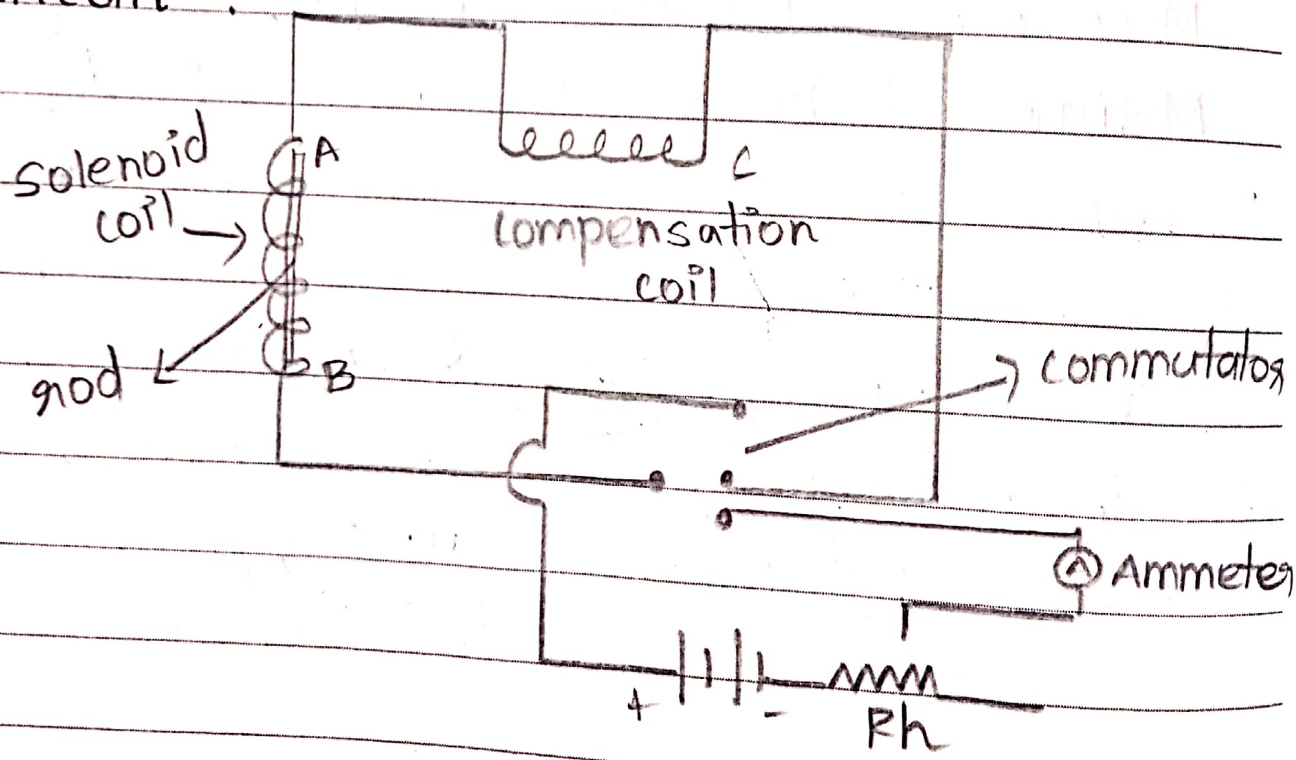
$C = MH \sin\theta$

work done $w = \Sigma dw$

[∴ w.d complete cycle] $w = -\Sigma MH \sin\theta \, d\theta$

$W = \oint H \, dI$

4. Experimental set up of Hysteresis circuit :



working :

A rod AB is placed inside a solenoid. the connections are made as

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shown in figure. when a current is passed through the solenoid, the magnetising field is produced. The rod is magnetised. Magnetometer measure the field. To compensate this, a compensating coil is used. The rod magnetometer M and coil c are arranged. After removing the rod, current is passed. compensating coil is adjusted for null deflection. Different current is applied ~~to~~ through the solenoid and the deflections are noted.

Magnetic field intensity $H = ni$

Field due to rod at A, $A = \frac{m}{4\pi\mu_0 d^2}$

Field due to rod at B, $\Rightarrow \frac{m}{4\pi\mu_0 r^2}$

Resultant field (AB)

$$= \frac{m}{4\pi\mu_0 d^2} - \frac{m}{4\pi\mu_0 (d^2+l^2)} . \cos\theta$$

put $\cos\theta = \dfrac{d}{(d^2+l^2)^{1/2}}$

$\therefore$ Field $F = \dfrac{m}{4\pi\mu_0}\left[\dfrac{1}{d^2} - \dfrac{d}{(d^2+l^2)^{3/2}}\right] \rightarrow (1)$

We know that

$$F = H \tan\theta \rightarrow (2)$$

$\therefore (1) = (2)$

$$\frac{m}{4\pi\mu_0}\left[\frac{1}{d^2} - \frac{d}{(d^2+l^2)^{3/2}}\right] = H\tan\theta \rightarrow (3)$$

$\therefore$ Intensity,

$$I = \frac{4\pi\mu_0 H_0 \tan\theta}{a\left[\frac{1}{d^2} - \frac{d}{(d^2+l^2)^{3/2}}\right]} \rightarrow (4)$$

The experiment is repeated for different values of current and the deflection and their parameters are calculated.

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part - A

1. Induced current:

when a conductor which is influenced by a current flow, gets magnetic effect near it, produces induced current. This current which is produced by emf is called induced emf.

2. Electromagnetic induction laws:

i. whenever the magnetic flux associated with a closed circuit changes an induced current flows through the circuit which lasts only so long as the change lasts.

ii. the magnitude of the induced emf produced in a coil is proportional to rate of change of the magnetic flux through the coil.

$$e \propto \frac{d\phi}{dt}$$

3. State lenz's law:
Lenz's law states that the direction of the induced emf is such as to oppose the change in flux which induces it.

4. Fleming's Right hand rule:
Stretch the thumb, the fore finger and the central finger mutually perpendicular to each other. If the thumb represents the direction of the motion of the conductor and the fore finger the direction of the magnetic field, then the central finger points the direction in which current is induced in the circuit.

5. Self inductance:
If a current flows through a coil, magnetic flux produced in a coil induces emf. This phenomenon is known

as self induction. Its unit is henry.

$$e = -L\, di/dt$$

6. coefficient of self inductance:

The self inductance of a coil is defined as the magnetic flux linked with the coil when unit current flows through it.

7. Henry:

The self inductance of a coil is one Henry. if an emf of 1V is induced in it due to the current flowing through itself changes at the rate of 1 ampere per second.

8. Mutual Inductance:

The production of an emf in one coil when the current changes in another coil is called mutual inductances. Its unit is Henry.

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9. coefficient of coupling :

TWO coils which are close together that the effective flux in one coil is completely linked with the other

$$M = \sqrt{L_1 L_2}$$

10. Eddy current :

The induced current flows throughout the conductor form eddies. These current are otherwise called as Faucault current.

11. Transformer :

* The transformer is an electrical device.

* It is based on the principle of electromagnetic induction.

12. copper loss :

Due to Joule heating effect, heat produced in the coils when the

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current passes through them results a loss called copper loss.

power loss = $i^2 R$

part - B

1. Eddy current and its uses:

consider a conductor which is suspended in the gap between the pole pieces of an electromagnet. If the conductor is rotated, it oscillates. If the electromagnet is switched on, the conductor slows down in its rotation. If the conductor is in rotation again if the electromagnet is switched on

the induced current flows throughout the conductor from eddies.

uses:

i. Due to eddy current, the cylinder in inductor motor rotates along the field Two single phase current produces magnetic field on rotation, is the

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principle behind this concept.

ii. In energy meters, the armature coil carries a maetallic disc which rotates between poles, produces eddy current for armature rotation change. This effect gives energy consumption.

iii. In trains, the drum which is influenced by eddy current and magnetic field tend to stop the wheel axe.

iv. In dead beat galvanometer, the coil rotates, eddy current produced and opposes the coil motion results dead beat in galvanometer.

v. In inductance furnance, eddy current produced due to magnetic field variation produces heat.

vi. In speedometer, a cylindrical drum rotates with the wheel of automobile have magnetic effect & produces eddy current. The dragging angle gives the speed of the automobile.

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Transformer:

Transformer is a device which works under electromagnetic induction principle. Types:

* step down
* step up

(i) step down: converts high voltage to low voltage (a.c)

(ii) step up: converts high current (low voltage) to low current (high voltage).

construction:

It consists of two coils

* primary * secondary in a laminated soft iron core. The core is made up of sheets of stalley which are insulated from each to avoid losses.

*. primary & secondary coils:

The a.c conversion between the coils the output is taken across the secondary.

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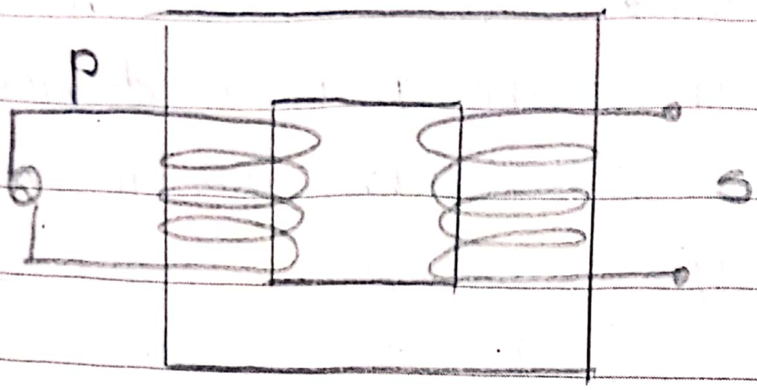

Working:

An a.c is applied to primary coil, as a result induction forms in secondary. a.c in primary changes magnetic flux linked with it. This induces emf in secondary. Everytime the current in the primary reverses the field associated with it also reverses. The secondary coil is close to the primary continously reversing field with it will produce same effect in secondary.

Theory:

Let ϕ be the flux linked with each other.

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$N_p \rightarrow$ Number of turns in primary
$N_s \rightarrow$ Number of turns in secondary.
emf induced in primary =)

$$e_p = -N_p \frac{d\phi}{dt}$$

emf induced in secondary =)

$$e_s = -N_s \frac{d\phi}{dt}$$

$$\eta = \frac{e_s}{e_p} = \frac{N_s}{N_p} \text{ (transformer ratio)}$$

step down : $E_p > E_s$, $\eta < 1$
step up : $E_p < E_s$, $\eta > 1$

Energy losses :
i. copper loss : Due to an Joule heating effect, heat produced in the coils when the current passes through them results a loss called copper loss.
ii. Eddy loss : when the flux linked with the core of the transformer changes, eddy currents are produced. Due to this,

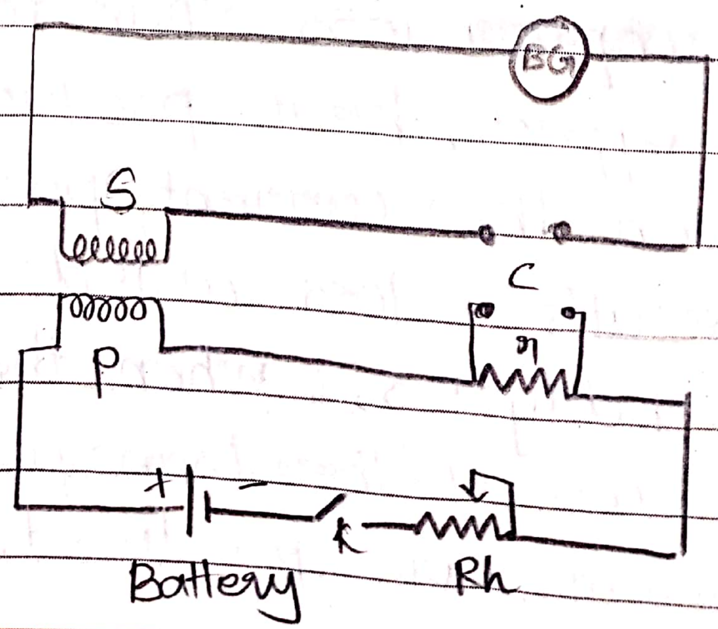
heat loss appears this loss is eddy loss

iii. Hysteresis loss : The loss of power in magnetising an iron core and taking it through a complete cycle of magnetisation soft iron reduces the loss.

iv. Magnetic flux leakage : This leakage results lack of flux in primary with respect to secondary happens. This gives an energy loss supplied to the primary. The loss can be minimised by shell type core.

3. Determination of Mutual inductance.

Circuit :



Construction :

It consists of primary and secondary coils mutually arranged as shown in figure. compensating coils can be arranged by Quadrant key c. BG is connected in secondary circuit. Rheostat Rh is connected in series with battery and key.

Working :

These circuits are connected to each other. so that B.G and secondary coil may form closed circuit when the key is pressed, the current in primary p reaches a maximum value, the flux linked with the s coil changes, Hence an induced emf is produced in s coil and a momentary current flows in this coil, BG throw appears. emf induced in s circuit,

$$e = -M \, di/dt$$

Instantaneous current,

$$i' = \frac{M}{R}\frac{di}{dt}$$

During this time interval t, the total charge,

$$q = \int_0^t i'\,dt = \frac{M}{R}\int_0^{i_0} di$$

$$= \frac{M i_0}{R}$$

Throw θ in BG,

$$q = \frac{T}{2\pi} \cdot \frac{c}{nBA}\,\theta_1 \left(1 + \frac{\lambda}{2}\right)$$

If resistance r is induced in p coil, steady current is observed. The potential difference across r is $i_0 r$.

$$M = \frac{Tr}{2\pi}\,\frac{\theta_1}{\theta_0}\left(1 + \lambda/2\right)$$

$\theta_0 \rightarrow$ steady deflection of BG.

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4. coefficient of coupling:

consider two coils close together. the effective flux in one coil linked with other.

Mutual inductance $M = \frac{\phi_{12}}{I_2} = \frac{\phi_{21}}{I_1}$

self inductance $L_1 = \frac{\phi_1}{I_1}$

$L_2 = \frac{\phi_2}{I_2}$

$\therefore \quad M = \frac{\phi_2}{I_1} = \frac{\phi_1}{I_2}$

$M^2 = \frac{\phi_1}{I_1} \cdot \frac{\phi_2}{I_2} = L_1 L_2$

$M = \sqrt{L_1 L_2}$

$K = \frac{M}{\sqrt{L_1 L_2}}$

$K \rightarrow$ coefficient of coupling

5. Determination of self inductance (Anderson's method):

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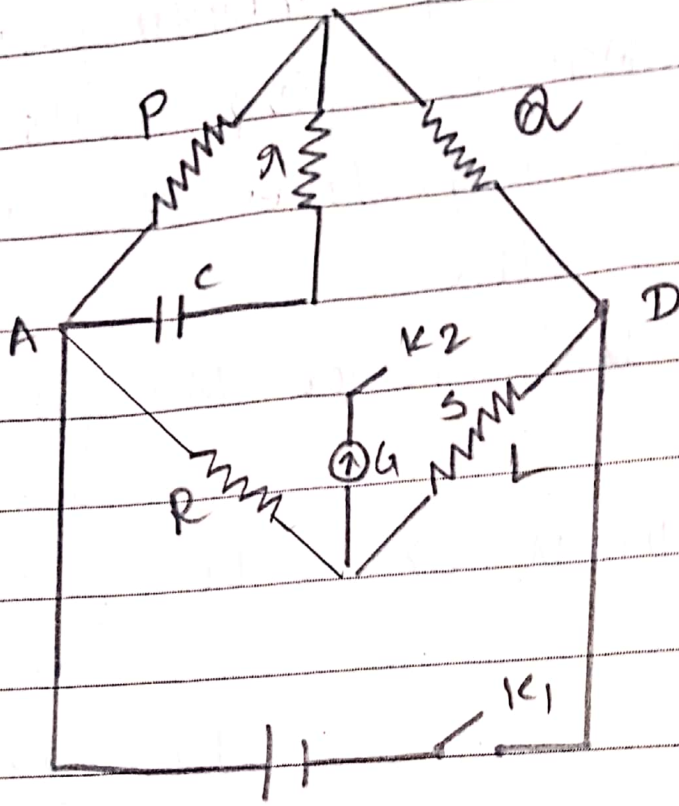
circuit :



operation :

Initially K_1 is pressed, P, Q and R boxes are adjusted until the galvanometer shows null deflection when K_2 is pressed. Now the bridge is balanced for steady current. Now K_1 is opened and K_2 is closed. r box is adjusted so that there is no kick when K_1 is pressed.

Keeping variation in current values, the experiment is repeated.

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Theory :

At ABFA,

$$P\frac{dx}{dt} = \frac{z}{c} + x \cdot \frac{dz}{dt}$$

$$\frac{dx}{dt} = \frac{z}{cP} + \frac{x}{P}\frac{dz}{dt}$$

At AEFA,

$$R \cdot \frac{dy}{dt} = \frac{z}{c}$$

$$\frac{dy}{dt} = \frac{z}{CR}$$

At DEBD,

$$L \cdot \frac{d}{dt}\left(\frac{dy}{dt}\right) + S \cdot \frac{dy}{dt} = x \cdot \frac{dz}{dt} + Q\left[\frac{dx}{dt} + \frac{dz}{dt}\right]$$

$$L\frac{d^2y}{dt^2} + S\frac{dy}{dt} = x\frac{dz}{dt} + Q\frac{dx}{dt} + Q\frac{dz}{dt}$$

$$\frac{1}{CR}\frac{dz}{dt} \qquad \frac{z}{CR}$$

$$\therefore \frac{L}{CR} \cdot \frac{dz}{dt} + \frac{Sz}{CR} = x \cdot \frac{dz}{dt} + \frac{Qz}{cP} + \frac{Qx}{P} \cdot \frac{dz}{dt} + Q \cdot \frac{dz}{dt}$$

$$\frac{dz}{dt}\left[\frac{L}{CR} - r - \frac{Qr}{P} - Q\right] = \frac{Z}{C}\left[\frac{Q}{P} - \frac{S}{R}\right]$$

$\neq 0$ $\qquad$ $= 0$

$$\therefore \frac{Q}{P} = \frac{S}{R}$$

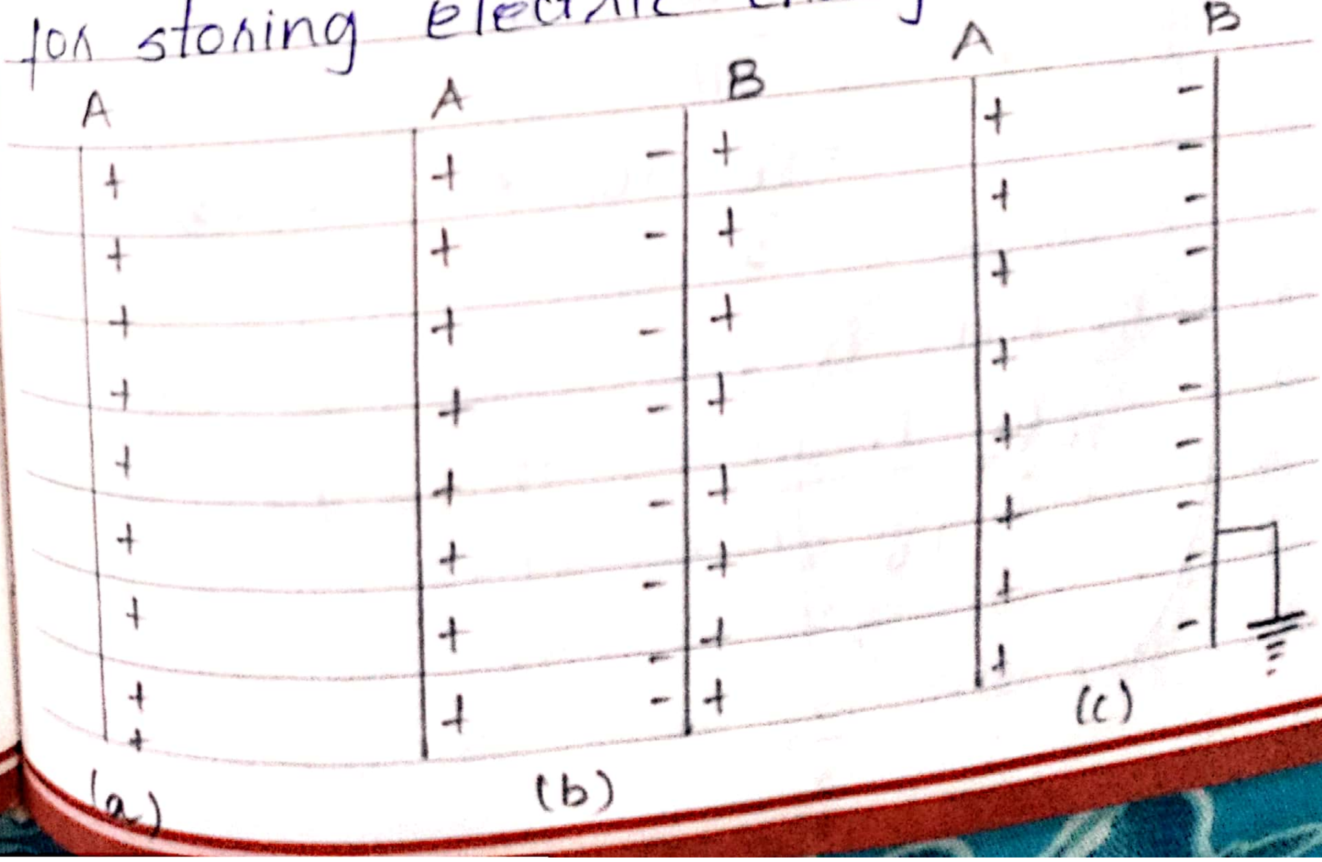
$$L = C\left[Rr + \frac{QRr}{P} + QR\right]$$

5m principle of capacitors:

consider an insulated conductor (plate A) with a positive charge 'q' having potential v. The capacitance of A is $C = q/v$. when another insulated metal plate B is brought near A, negative charges are induced on the side of B near A. An equal amount of positive charge is induced on the other side of B. The negative charge in B decreases the potential of A. The positive charge in B increases the potential of A. But the negative charge on B is nearer to A than the positive charge on B. so the net effect is that, the potential of A decreases. thus the capacitance of A is increased.

If the plate B is earthed, positive charges get neutralized then the potential of A decreases further. thus the capacitance of A is considerably increased.

The capacitance depends on the geometry of the conductors and nature of the medium. A capacitor is a device for storing electric charges.



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10m langevity theory of dia, para.

i. Langevin's theory of Dia magnetism:

consider an electron (mass = m, charge = e) rotating about the nucleus (charge = ze) in a circular orbit of radius r. Let ω_0 be the angular velocity of the electron. Then,

$$F_0 = m\omega_0^2 r = ze^2/(4\pi\varepsilon_0 r^2)$$

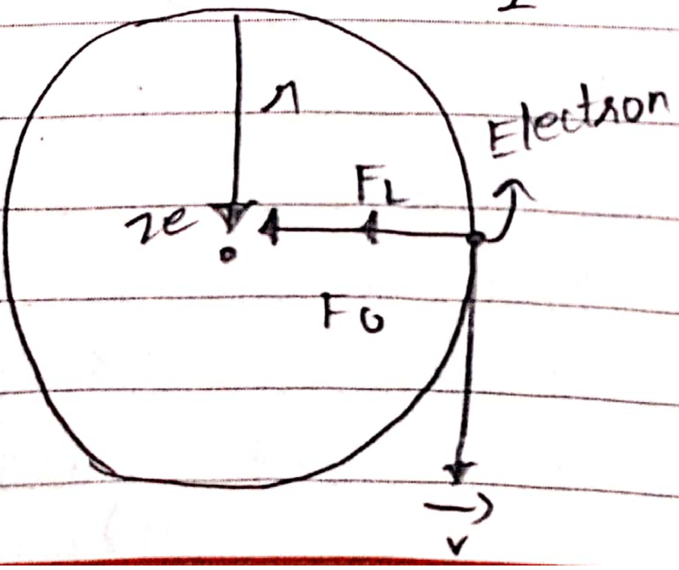
$$\omega_0 = \sqrt{\frac{ze^2}{4\pi\varepsilon_0 m r^2}} \rightarrow (1)$$

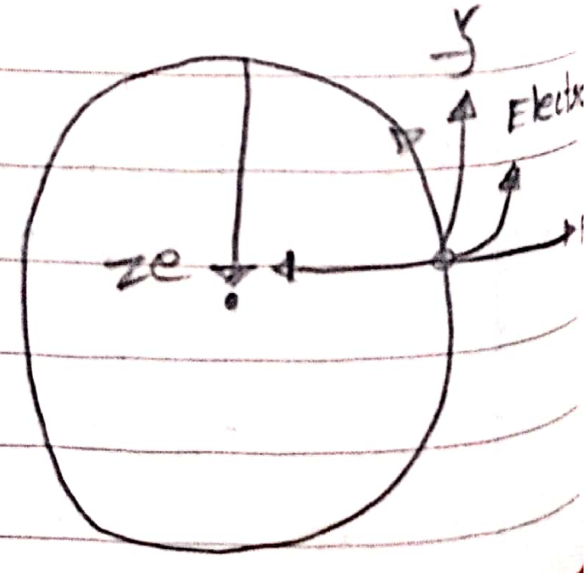
The magnetic moment of the electron is

$$\vec{m} = \text{current} \times \text{area}$$

$$= \frac{e\omega_0}{2\pi} \times \pi r^2$$

$$= \frac{e}{2}\omega_0 r^2 \rightarrow (2)$$





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An additional force F_l called Lorentz force acts on the electron.

$$F_L = -e(V \times B) = -eBr\omega$$

The condition of stable motion is now given by,

$$mr\omega^2 = \frac{Ze^2}{4\pi\varepsilon_0 r^2} - eBr\omega \rightarrow (3)$$

Solving the quadratic eqn. in ω:

$$\omega = \frac{-\frac{eB}{m} \pm \sqrt{\left(\frac{eB}{m}\right)^2 + 4\left(\frac{Ze}{4\pi\varepsilon_0 mr^3}\right)}}{2}$$

$$\omega = \pm\sqrt{\omega_0^2 + \left(\frac{eB}{2m}\right)^2} - \frac{eB}{2m}$$

(or)

$$\omega = \pm\omega_0 - \frac{eB}{2m} \rightarrow (4) \quad \left(\because \frac{eB}{2m} \ll \omega_0\right)$$

Thus the angular frequency is now different from ω_0. The result of establishing a field of flux density B is to set up a precessional motion of electronic orbits with angular velocity $-(e/2m)B$. This is called Larmor theorem.

then, change in frequency of revolution of the electron $= \delta n = \frac{-eB}{4\pi m}$

The corresponding change in the magnetic moment of the electron is

$$\Delta m = \text{current} \times \text{area}$$

$$= \left\{ e \times \left(\frac{-eB}{4\pi m} \right) \right\} \times \pi r^2$$

$$= -\frac{Be^2 r^2}{4m} \rightarrow ⑤$$

$$M = -\frac{NBe^2 \Sigma r^2}{4m} \rightarrow ⑤$$

volume susceptibility of the material

$$\chi_m = \frac{M}{H} = \frac{NBe^2 \Sigma r^2}{6mH} = -\frac{\mu_0 Ne^2 \Sigma r^2}{6m}$$

ii. Langevin's theory of paramagnetism:

He assumes that each atom has a permanent magnetic moment m. The only force acting on the atom is that due to the external field B.

Let θ be the angle of inclination of the axis of the atomic dipole with the direction of the applied field B. Then magnetic potential energy of the atomic dipole is

$$U = -mB\cos\theta$$

Now, on classical statistics, the number of atoms making an angle between θ and $\theta + d\theta$ is

$$dn = ce^{mB\cos\theta/KT} \sin\theta \, d\theta$$

$$dn = ce^{mB\cos\theta/KT} \sin\theta \, d\theta$$

$$dn = ce^{\alpha\cos\theta} \sin d\theta \rightarrow (1)$$

Hence the total number of atomic magnets in unit volume of paramagnetic material, $n = \int_0^{\pi} dn = \int_0^{\pi} ce^{\alpha\cos\theta} \sin\theta \, d\theta \rightarrow (2)$

$$\therefore c = \frac{n\alpha}{e^{\alpha} - e^{-\alpha}}$$

The component of each dipole moment parallel to B is $m\cos\theta$. The total magnetic moment of all the n atoms contained in unit volume of the gas is the magnetisation.

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It is given by $M = \int_0^{\pi} m\cos\theta$

$$dn = \int_0^{\pi} m \cos\theta \, c e^{\alpha\cos\theta} \sin\theta d\theta \rightarrow (4)$$

case (i)

At low temperature or large applied field $L(\alpha) \rightarrow 1$. Hence magnetisation M in this case will be

$$M = mm$$

case (ii)

under normal conditions, α is very small, then,

$$\chi m = \frac{M}{H} = \frac{\mu_0 n m^2}{3KT} = \frac{C}{T}$$

Failure of Langevin theory:

* It was unable to explain a more complicated dependence of susceptibility upon temperature exhibited by several paramagnetics such as highly compressed and cooled gases, very concentrated solution of salts etc.

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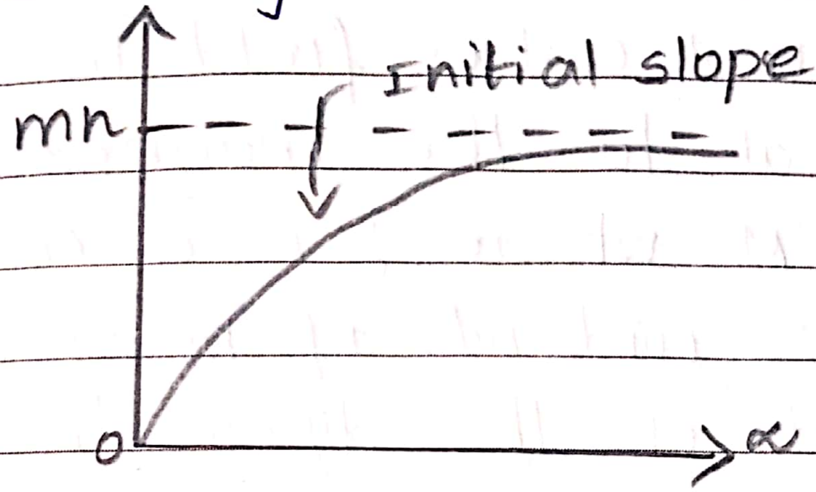
* Langevin's theory could not account for the intimate relation b/w para and ferro magnetism.



10m

Weiss theory of Ferromagnetism

Assumption:

* Weiss assumed that a ferromag-netic specimen contains a number of small regions (domains) which are spontaneously magnetised. The total spontaneous magnetisation is the vector sum of the magnetic moments of the individual domains.

* The spontaneous magnetisation of each domain is due to the existence of an internal molecular field. This tends

to produce a parallel alignment of the atomic dipoles.

Weiss also assumed that the internal molecular field H_i is proportional to the magnetisation M, (i.e) $H_i = \gamma M$ where γ is a contant called weiss contant. If now an external field H acts on the dipole, then the effective field H_{eff} is given by

$$H_{eff} = H + H_i = H + \gamma M$$

According to Langevin's theory of paramagnetism at high temperature

$$M = \frac{nm^2 \mu_0 H}{3KT}$$

$$M = \frac{nm^2 \mu_0}{3KT} [H + \gamma M] \quad (or) \quad M = \frac{nm^2 \mu_0 H}{3K\left(T - \frac{nm^2 \gamma \mu_0}{3K}\right)}$$

the susceptibility $\chi_{ferro} = \frac{M}{H} = \frac{nm^2 \mu_0}{3K\left(T - \frac{nm^2 \gamma \mu_0}{3K}\right)} = \frac{C}{(T - \theta)}$

Here $\frac{nm^2 \mu_0}{3K}$ is called the curie and

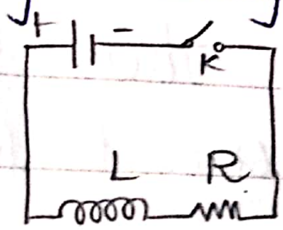
$\theta = \frac{nm^2 \gamma \mu_0}{3K}$ is called curie temperature.

Growth and decay of L & R.

* Growth of current in L & R

consider a circuit containing a battery, a key, an inductance L and a Resistance R Joined in series. Emf of the battery = E. when the Key is suddenly pressed, there is growth of current in circuit and back emf is induced.

suppose the current flowing at any instant during growth = I



$$E = RI + L\frac{dI}{dt} \rightarrow (1)$$

when the current reaches maximum value I_0, $L\frac{dI}{dt} = 0$ $\quad E = RI_0 \rightarrow (2)$

From (1) & (2) $\quad RI_0 = RI + L\, dI/dt$

$$R(I_0 - I) = L\, dI/dt$$

we take $(I_0 - I) = x \rightarrow (3)$

Diff. w.r.t time, $-dI/dt = dx/dt$

$$\therefore Rx = -L\, dx/dt$$

$$dx/x = -R/L\, dt$$

Integrating, $\log_e x = -R/L\, t + K$, θ is constant

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$$\log_e (I_0 - I) = -R/L\, t + K$$

when, $t = 0$, $I = 0$ $\therefore \log_e I_0 = K$

$$\therefore \log_e (I_0 - I) = -R/L\, t + \log_e I_0$$

(or) $\quad I - I/I_0 = e^{-R/L\, t}$

$$I = I_0 (1 - e^{-R/L\, t})$$

L/R is called the time constant of circuit

If $L/R = t$, $\quad I = I_0 (1 - e^{-1}) = I_0 (1 - 1/e)$

But, $1/e = 1/2.718 = 0.368$

$$I = I_0 (1 - 0.368) = 0.632\, I_0$$

Thus the time constant (L/R) of a circuit is time taken by the circuit to grow from zero to 0.632 times the steady maximum value in circuit.

* Decay of current in L & R

When the current is the circuit containing a resistance and inductance is suddenly switched off, an induced emf is again produced. In this case $E = 0$ and at any instant during decay,

$$0 = RI + L \frac{dI}{dt}$$

Date $dI/I = -R/L \, dt$

integrating, $\log_e I = -R/L \, t + K$ where K is constant.

when $t = 0$, $I = I_0$ $\therefore \log_e I_0 = K$

$\therefore \log_e I = -R/L \, t + \log_e I_0$

$\log_e I/I_0 = -R/L \, t$

$I/I_0 = e^{-R/L \, t}$

$\therefore I = I_0 e^{-R/L \, t}$ $\rightarrow$ (5)

5m Growth and decay of C & R (charging of a condenser)

A condensor C and a resistance R are joined to a battery through a morse key as shown. When the key is pressed the condensor is charged and when the key is released the condenser gets discharged. Emf of battery = E

$E = Q/C + RI$

Where Q is the charge on condensor at any instant where its potential $V = Q/C$ current at instant $= I$, Maximum current $= I_0$

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potential difference $E = \frac{Q_0}{C}$

$\therefore \; Q_0/C = Q/C + RI$ but, $I = dQ/dt$

$\therefore \; Q_0/C = Q/C + R\, dQ/dt$

$(Q_0 - Q) = CR\, dQ/dt$

$\left(\frac{dQ}{Q_0 - Q} \right) = dt/CR$

Integrating, $\int \frac{dQ}{Q_0 - Q} = \frac{1}{CR} \int dt$

$-\log_e (Q_0 - Q) = t/CR + K$

where K is a constant

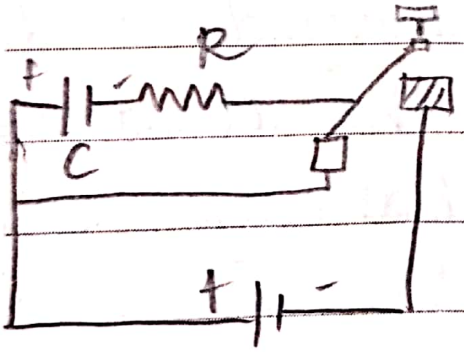
when $t = 0$, $Q = 0$ $\therefore -\log_e Q_0 = K$

Substituting K,

$-\log_e (Q_0 - Q) = t/CR - \log_e Q_0$

$\log_e (Q_0 - Q) = -t/CR + \log_e Q_0$

$\log_e (Q_0 - Q) - \log_e Q_0 = -t/CR$



$\log_e \left(\frac{Q_0 - Q}{Q_0} \right) = -\frac{t}{CR}$

$\frac{Q_0 - Q}{Q_0} = e^{-t/CR}$ $\quad 1 - \frac{Q}{Q_0} = e^{-t/CR}$

$\therefore \; Q = Q_0 (1 - e^{-t/CR})$

Dividing by C, $\frac{Q}{C} = \frac{Q_0}{C} (1 - e^{-t/CR})$

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$$V = E_0 (1 - e^{-t/CR})$$

Here CR is a constant, taking $CR = t$,

$t/CR = 1 \quad \therefore Q = Q_0(1 - e^{-1})$

$= 0.632\, Q_0$

Here, C is measured in farad, z in ohm, t in sec

5m power in RL circuit

In this case, the current lags behind the emf by θ

where, $\theta = \tan^{-1} \frac{L\omega}{R}$

At any instant, $E = E_0 \sin\omega t$

$I = I_0 \sin(\omega t - \theta)$

power at any instant $= E \times I$

$= E_0 I_0 \sin\omega t . \sin(\omega t - \theta)$

$= E_0 I_0 \sin\omega t [\sin\omega t \cos\theta - \cos\omega t \sin\theta]$

$= E_0 I_0 [\sin^2\omega t \cos\theta - \sin\omega t \cos\omega t \sin\theta]$

$= E_0 I_0 \sin^2\omega t \cos\theta - \frac{E_0 I_0}{2} \sin 2\omega t \sin\theta$

Average power for a complete cycle,

$$P = \frac{E_0 I_0 \cos\theta \int_0^T \sin^2\omega t \, dt}{\int_0^T dt} - \frac{\frac{E_0 I_0}{2} \int_0^T \sin 2\omega t \sin\theta \, dt}{\int_0^T dt}$$

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$$P = \frac{E_0 I_0 \cos\theta}{2} = \frac{E_0}{\sqrt{2}} \cdot \frac{I_0}{\sqrt{2}} \cos\theta$$

$$\therefore P = E_v \times I_v \cos\theta \quad \rightarrow (1)$$

power factor,

$$\cos\theta = \frac{R}{\sqrt{R^2 + (L\omega)^2}} \quad \rightarrow (2)$$

True power = $E_v \times I_v \times \cos\theta$

$E_v \times I_v$ is known as apparent power.

True power = Apparent power × power factor.

$$\text{power factor} = \frac{\text{True power}}{\text{Apparent power}} = \frac{\text{True watts}}{\text{Apparent watts}}$$

5m potential at a point due to a field

consider a point at a distance r from the conductor having a charge $+q$ the electrostatic intensity

$$E = \frac{q}{4\pi\varepsilon_0 r^2}$$

The electrostatic potential is the amount of work done in taking

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positive charge from infinity to that point 'p'

$$v = \int_{\infty}^{r} -E\,dr$$

$$= \int_{\infty}^{r} -\left[\frac{q}{4\pi\varepsilon_0 r^2}\right] dr$$

$$= q\left[\frac{1}{4\pi\varepsilon_0 r}\right]_{\infty}^{r}$$

$$v = \frac{q}{4\pi\varepsilon_0 r}$$

10m Measurement of High resistance (Leakage)

To measure a high resistance of the odour of megohm (10^6 ohms), a condenser is initially charged and the charge is allowed to leak through the given resistance for a known interval of time (a few second) and the residual charge on the condensor is measured with a ballistic galvanometer. Let c be the capacity of the condenser and R high resistance, q_0 r_0 the initial charge and

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potential of the condenser and q, v the corresponding values after time t taken in seconds.

At any instant during leakage.

$$q/c + QI = 0$$

where, I is the leakage current through the resistance

$$I = dq/dt$$

$$q/c + Q\,dq/dt = 0$$

$$dq/q = -dt/Qc$$

$$\log_e q = -t/Qc + K \quad \text{—)} \; ①$$

where $t=0$, $q = q_0$

$$\log_e q_0 = K$$

substituting this value of K in ①

$$\log_e q = -t/Qc + \log_e q_0$$

$$\log_e (q_0/q) = t/cQ$$

$$Q = \frac{t}{c \log_e \left(\frac{q_0}{q}\right)}$$

$$\therefore \; c = \frac{q_0}{v_0} = \frac{q}{v}$$

$$q_0/q = v_0/v$$

But, $$Q = \frac{t}{c \log_e \frac{v_0}{v}}$$

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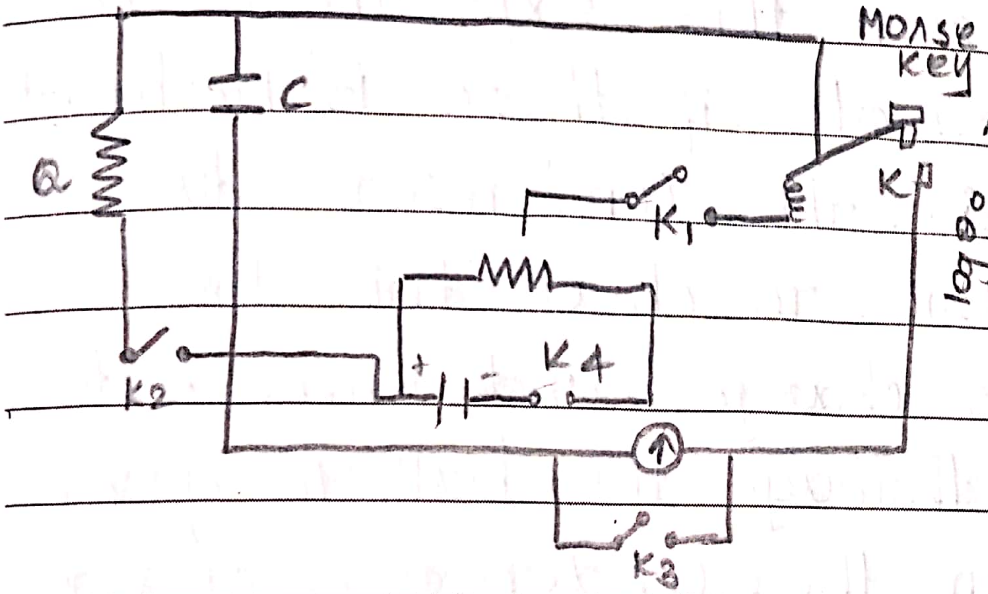
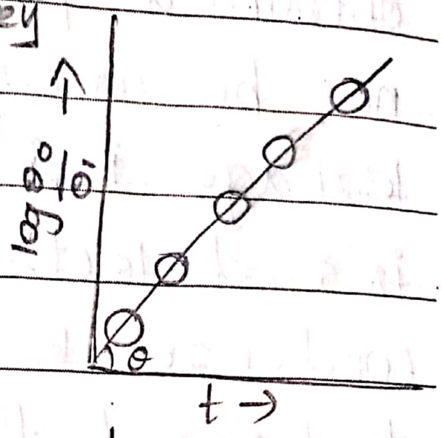
$$= \frac{t}{2.3026\, c \log_{10}\left(\frac{V_0}{V}\right)} \rightarrow (2)$$

The resistance and the condenser are connected in the circuit as shown





b

Substituting, $\frac{V_0}{V} = \frac{\theta_0}{\theta_1}$ in (1)

$$Q = \frac{t}{2.3026\, c \log_{10}\left(\frac{\theta_0}{\theta_1}\right)} \rightarrow (3)$$

or equation (iii) if c is towards and t is in seconds that Q is in ohms. Knowing the value of c, Q can be calculated.

The values of θ_1 are noted for different value and a graph is drawn between t and $\log_{10}\left(\frac{\theta_0}{\theta_1}\right)$. The graph is

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a straight line and, the slope measures $\frac{1}{2.3026\, CQ}$

The value of the high resistance obtained from this experiment may nor be accurate if there is natural leakage in ir. The condenser due to ir's dielectric. To check this the condenser is charged and immediately discharged through the ballistic galvanometer. Again the condenser is charged and discharged through the galvanometer after 5 to 10 mins.

Then as Q_1 and Q are in parallel $1/Q' = 1/Q_1 + 1/Q$ from which Q can be calculated:

$$Q_1 = \frac{t}{2.3026\, c \log_{10}\left(\frac{\theta_0}{\theta_1}\right)}$$

$$Q_2 = \frac{t}{2.3026\, c \log_{10}\left(\frac{\theta_0}{\theta_2}\right)}$$

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$$\frac{Q_1}{Q_2} = \frac{\log_{10}\left(\frac{\theta_0}{\theta_1}\right)}{\log_{10}\left(\frac{\theta_0}{\theta_2}\right)}$$

It can be calculated from graph b/w $[\log_{10}(\frac{\theta_0}{\theta_1})]$ and (t) for Q_1 and $[\log_{10}(\frac{\theta_0}{\theta_2})]$ and (t) for Q_2

10m

Self Induction - Rayleigh method

The inductance L to be measured is placed in one of the arms of a wheatstone's bridge. In this case, post office Box is preferred. The galvanometer used in a ballistic galvanometer and not dead beat. The resistance r in the arm AB is a standard resistance 0.1, 0.01 or 0.001 ohm. The key K is closed so that the inductance L and its the resistance are in circuit. The battery key K_1 is closed first and galvanometer key K_2 is closed after some time and the resistance The arms are adjusted so that there is no deflection in the galvanometer, now both the keys K_1 and K_2 are opened when the K_2 is closed first and K_1 is closed afterwards, a throw θ_1 is obtained in BG. The balance is disturbed bcoz of an extra emf $L\, dI/dt$ is produced in the arm DB while the current is flowing.

Any change in emf in the arm AB produces a proportionate emf in galvanometer circuit and thus a proportionate current flows in galvano-meter. suppose an emf E in the arm AB produces a current xE in the galvanometer circuit

Total charge $q = \int_0^{I_0} xL \frac{dI}{dt}$

$$= xL \int_0^{I_0} dI = xL I_0$$

$$q = \frac{CT}{2\pi r AB} \theta_1 \left(1 + \frac{\lambda}{2}\right) \longrightarrow (1)$$

The key K is opened and the r is included the arm AB. close K_1

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first and K_2 afterwards and note steady deflection for θ_2. The resistance produces at additional p.D $= I_0 r$ in the arm AB.

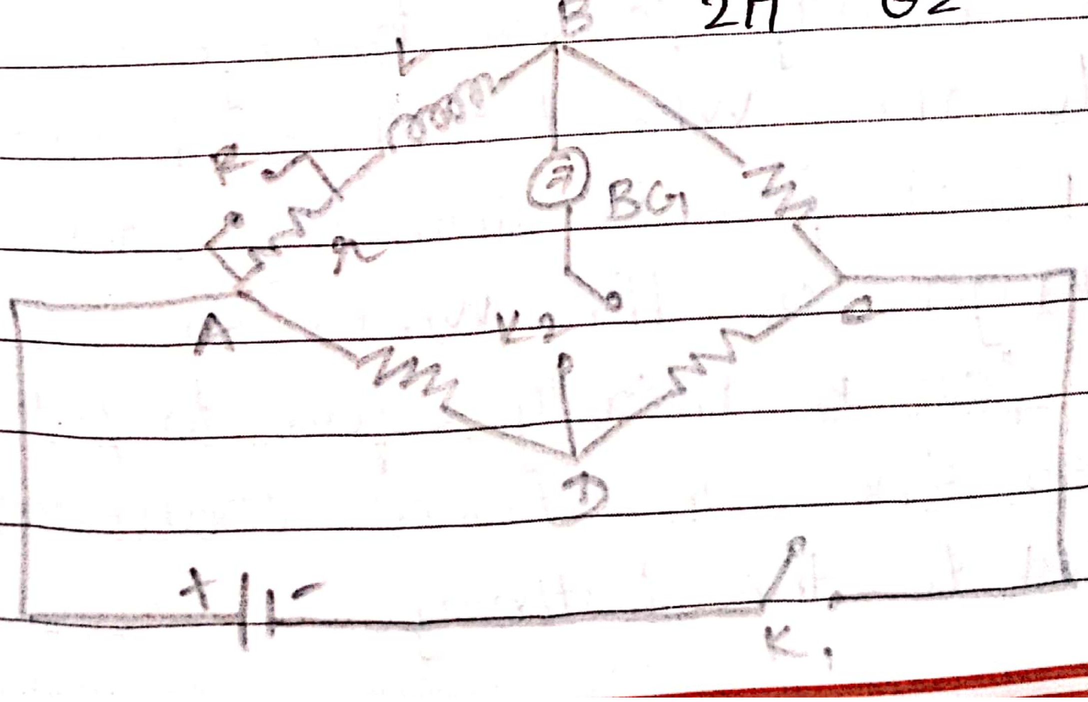
$\therefore$ The current through the galvanometer due to the extra p.D across the arm AB $= n I_0 r$

For steady deflection $n I_0 r = \frac{C}{nAB}\theta_2$ → (2)

Here, $\frac{C}{nAB}$ is the current reduction factor of galvanometer.

Dividing, $\frac{L}{r} = \frac{T}{2\pi}\frac{\theta_1}{\theta_2}\left(1+\frac{\lambda}{2}\right)$

$L = \frac{rT}{2\pi}\frac{\theta_1}{\theta_2}\left(1+\frac{\lambda}{2}\right)$ → (3)



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This method is used at present for practical purposes. But this was the first method available for the determination of self inductance. It is usually determined by A.c bridge viz (i) owen's bridge and (ii) Anderson's bridge.

5m

carey Foster's bridge:

Aim:

To find the resistance of the given coil using carey foster bridge and calculated. the specific resistance of the material also determined.

construction:

The carey foster bridge is similar to the wheatstones bridge. The potential fall is directly proportional to the length of the wire. The potential fall is nearly equal to potential fall across the resistance connected in parallel to the battery.

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Theory :

TWO resistance to be compared x and Y are connected in series with the bridge wire, thus considered as a wheatstone's bridge, the two resistance are x plus a length of bridge wire, Y plus remaining arms are the nearly equal resistance P and Q connected in the inner gaps of the bridge.

$$\frac{P}{Q} = \frac{R + \alpha + l_1 p}{S + \beta + (100 - l_1) p} \rightarrow (1)$$

In second case,

$$\frac{P}{Q} = \frac{S + \alpha + l_2 p}{R + \beta + (100 - l_2) p} \rightarrow (2)$$

Equating (1) & (2)

$$\frac{R + \alpha + l_1 p}{S + \beta + (100 - l_1) p} = \frac{S + \alpha + l_2 p}{R + \beta + (100 - l_2) p}$$

$$\frac{R + \alpha + l_1 p + S + \beta + 100p - l_1 p}{S + \beta + (100 - l_1) p}$$

$$= \frac{S + \alpha + l_2 p + R + \beta + 100p - l_2 p}{R + \beta + (100 - l_2) p}$$

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$$\frac{R+S+\alpha+\beta+100p}{S+\beta+(100-l_1)p} = \frac{R+S+\alpha-\beta-100p}{R+\beta+(100-l_2)p} \rightarrow (3)$$

$\therefore$ $S+\beta+100p-l_1p = R+\beta+100p-l_2p$

(or)

$$S-l_1p = R-l_2p$$

$$R-S = p(l_2-l_1) \rightarrow (4)$$

$$R = S+p(l_2-l_1) \rightarrow (5)$$

This knowing the values of l_1 and l_2 the difference R-S can be callculated

To determine the resistance per unit length of bridge wire. R=0 the balancing length l_1'. S is left gap.

copper strip in the right gap balancing length l_2 is determined with the same values P and Q.

Eqn. (5)

$$0 = S+\rho(l_2'-l_1')$$

$$\rho = \frac{S}{(l_1'-l_2')}$$

Scanned with CamScanner

10m Correction for damping in BG.

We have assumed that the whole of the kinetic energy imparted to the coil is used in twisting the suspension of the coil. In actual practise the motion of the coil is damped by air resistance and the induced current produced in the coil. The first throw of the galvanometer is therefore, smaller than it would have been in the absence of damping. Let $\theta_1, \theta_2, \theta_3$.. be the successive maximum deflections from zero position to the right and left. Then it is found that

$$\theta_1/\theta_2 = \theta_2/\theta_3 = \theta_3/\theta_4 = \ldots = d \quad -(1)$$

The constant d is called the decrement perhalf vibration.

Let $d = e^{\lambda}$ so that $\lambda = \log_e d$.
Here λ is called logarithmic decrement.
For a complete vibration,

$$\frac{\theta_1}{\theta_3} = \frac{\theta_1}{\theta_2} \times \frac{\theta_2}{\theta_3} = d^2 = e^{2\lambda}$$

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let θ be the true first throw in the absence of damping.

$$\frac{\theta}{\theta_1} = e^{\lambda/2} = \left(1+\frac{\lambda}{2}\right) \Rightarrow \theta = \theta_1\left[1+\frac{\lambda}{2}\right] \rightarrow (2)$$

$$\frac{\theta_1}{\theta_{11}} = \frac{\theta_1}{\theta_2} \cdot \frac{\theta_2}{\theta_3} \cdot \frac{\theta_3}{\theta_4} \frac{\theta_4}{\theta_5} \frac{\theta_5}{\theta_6} \frac{\theta_6}{\theta_7} \frac{\theta_7}{\theta_8} \frac{\theta_8}{\theta_9} \frac{\theta_9}{\theta_{10}} \frac{\theta_{10}}{\theta_{11}}$$

$$= e^{10\lambda}$$

(or) $\lambda = \frac{1}{10} \log_e \frac{\theta_1}{\theta_{11}} = \frac{2.3026}{10} \log_{10} \frac{\theta_1}{\theta_{11}}$

(or) $q = (T/2\pi)(C/NBA)\,\theta_1(1+\lambda/2) \rightarrow (3)$

2m [The figure of merit or current sensitivity (S_c) of a moving coil mirror galvanometer is the current that is required to produce a deflection of 1mm on a scale kept at a distance of 1m from mirror. It is expressed in $\mu A/mm$]

charge on capacitor $q = \frac{EP}{P+Q} \times C\ \mu C$

Undamped throw $\theta = \theta_1\left(1+\frac{1}{2}\lambda\right)$

charge required to produce unit

Date

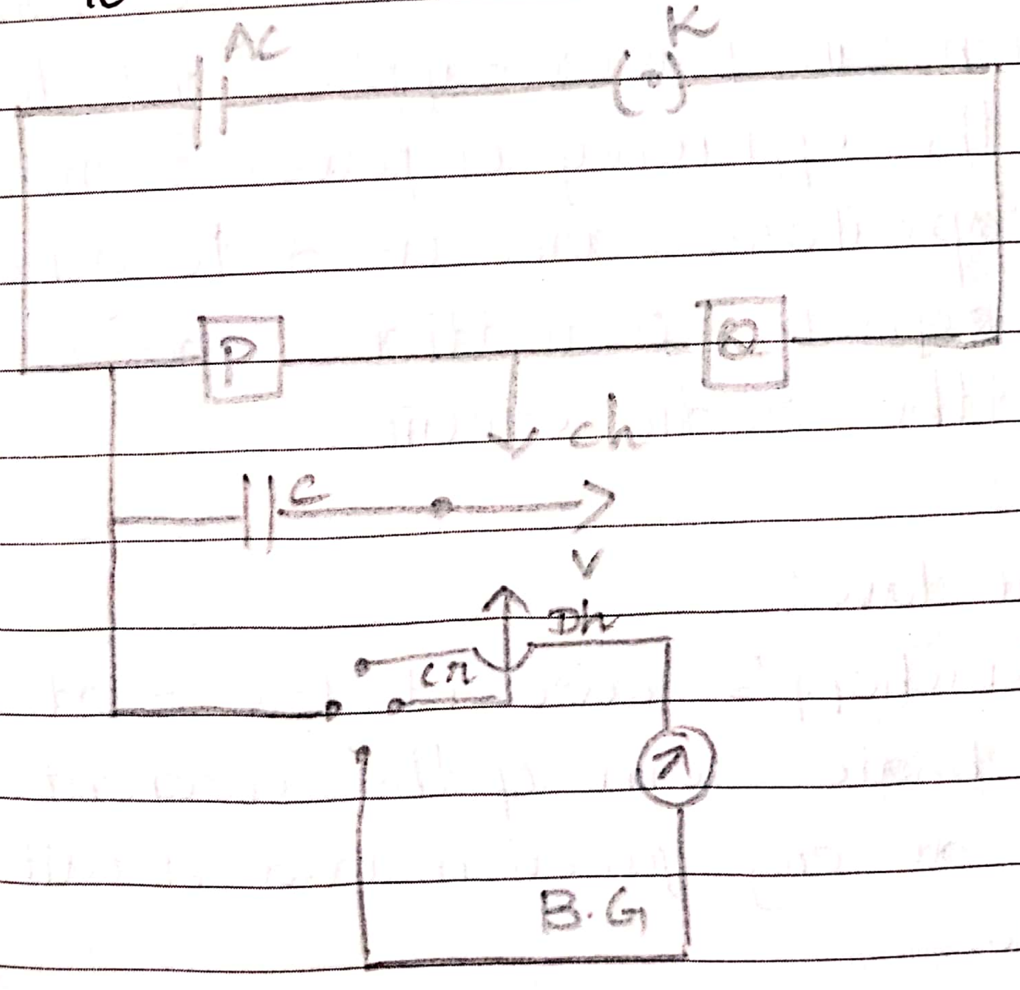
deflection $= K$.

$$K\theta_1\left(1+\frac{1}{2}\lambda\right) = \frac{EP}{(P+Q)} \times C$$

$$K = \frac{EC}{P+Q} \times \frac{P}{\theta_1\left(1+\frac{1}{2}\lambda\right)} \quad \mu C/\text{div}.$$

The value of λ is obtained by observing the first throw θ_1 and then the eleventh throw θ_{11} and using the relation.

$$\lambda = \frac{1}{10}\log_e\frac{\theta_1}{\theta_{11}} = \frac{1}{10} \times 2.3026 \times \log_{10}\frac{\theta_1}{\theta_{11}}$$



2m Capacitance of a capacitor

The capacitance of a capacitor is defined as the charge stored per unit potential difference change Its unit is farad (F) $C = Q/V$

2m Uses of capacitors:

* They are used in the ignition system of automobile engines to eliminate sparking.
* They are used to reduce voltage fluctuations in power supplies and to increase the efficiency of power transmission.
* capacitors are used to generate electromagnetic oscillations and in turning the radio circuits.

2m Current law:

Kirchoff's current law states that the algebraic sum of the current meeting at any junction in a circuit is zero.

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2m

voltage law:

Kirchoff's second law states that the algebraic sum of the products of resistance and current in each part of any closed circuit is equal to the algebraic sum of the emf's in that closed circuit.

2m

power factor:

It is the ratio between the power that can be used in electric circuit and the power from the result of multiplication between the current and voltage circuit. It ranges from zero to one.

2m

q factor:

The quality factor is a measure of the sharpness of the resonance peak; the larger the q value, the sharper the peak.

$$Q = \frac{\omega_0}{BW} \quad (\text{Band width})$$

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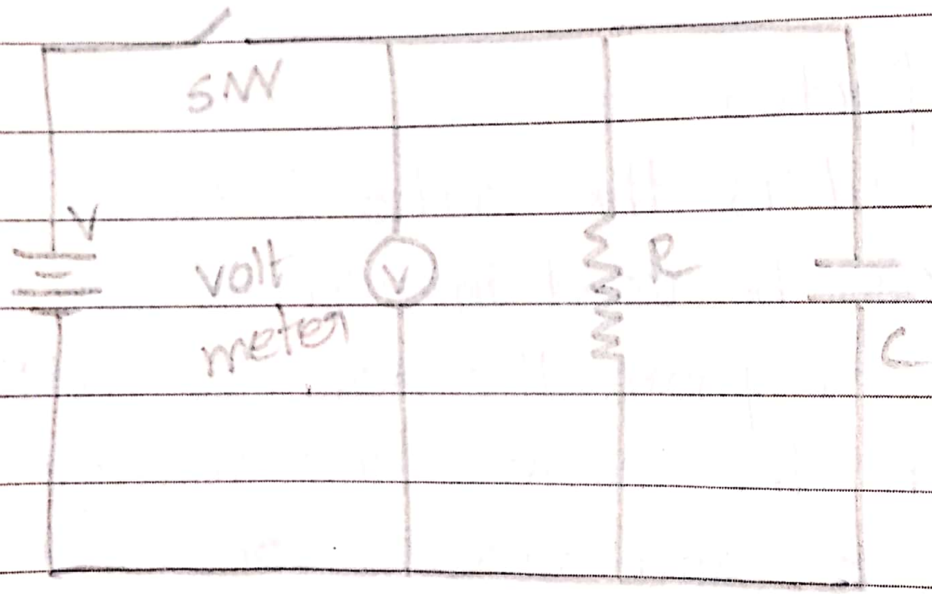
Measurement of High Resistance.

* Direct deflection method
* Loss of charge method
* Mega ohm bridge
* Megger.

Loss of charge method



construction:

R, an unknown resistance is connected in parallel with a capacitor c and electrostatic voltmeter. A battery with emf v in parallel with R and c.

operation:

capacitor is charged to suitable voltage by battery. Then allowed to discharge through resistance. Terminal voltage is observed over a considerable period of time during discharge. After application of voltage, voltage across the capacitor at any instant 't'

$$v = Ve^{(-t/CR)}$$

$$V/v = e^{t/CR}$$

$$\log_e V/v = t/CR$$

$$R = t / [C \log_e V/v]$$

$$= \frac{0.4343\, t}{[C \log_{10} V/v]}$$

If R is very large, time for appreciable fall in voltage is very large. Care is to be taken while measuring V and v. (i.e) voltage at beginning and end of time 't' Error in V/v. Better results by change in voltage (V-v) directly and calculating R as $R = \frac{0.4343\, t}{[C \log V/(V-e)]}$ where, $V-v = e$

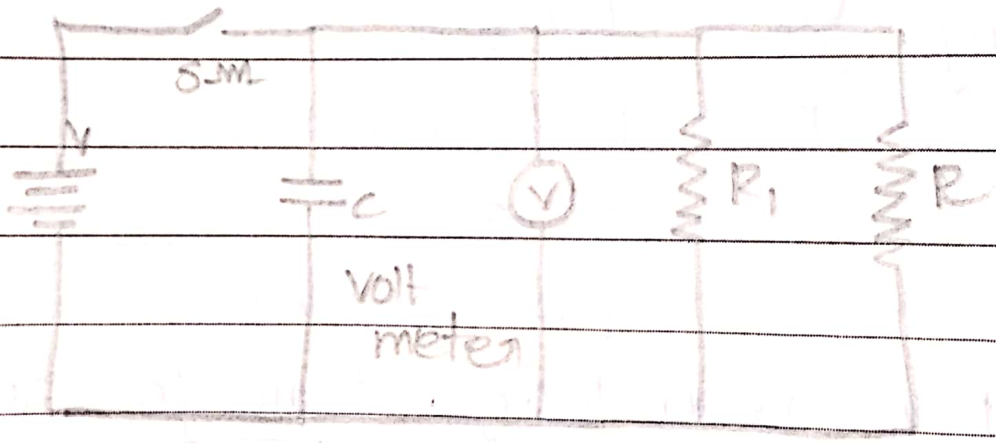
This method is applicable to high resistance. It requires capacitor of high leakage resistance.

Short comings:

True value of R is not measured as Rv, voltmeter resistance and leakage resistance of capacitor considered to infinite.

Correction:

Two resistances are taken into account.



First if R' is equivalent Resistance of R1 and R. Then discharge eqn. gives

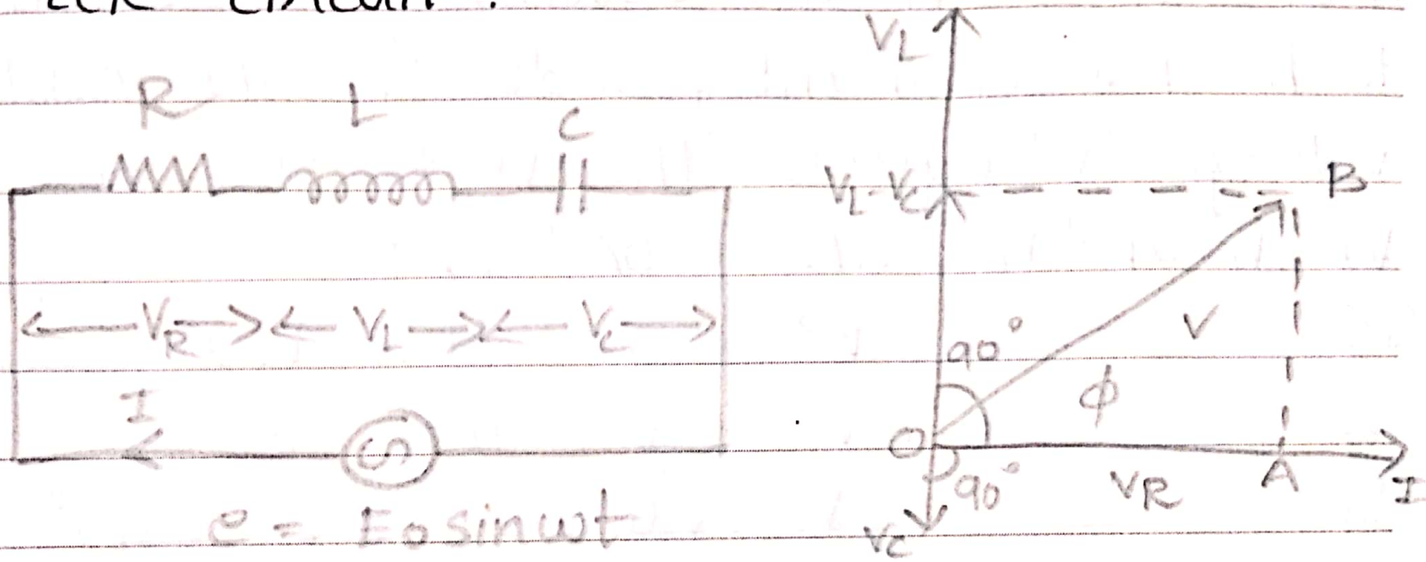
$$R' = \frac{0.4343t}{[C \log_{10} V/v]} \rightarrow (1)$$

Second test is repeated with R disconnected, capacitor discharge through R1., R1 is obtained from here is substituted in eqn. ① which gives

$$\frac{R R_1}{R+R_1} = \frac{0.4343\,t}{[c \log V/v]}$$

10m

LCR circuit :



Let an alternating source of emf e be connected to a series combination of a resistor of resistance R, inductor of inductance L and a capacitor of capacitance C.

Let the current flowing through circuit be I.

The voltage drop across resistor $V_R = IR$

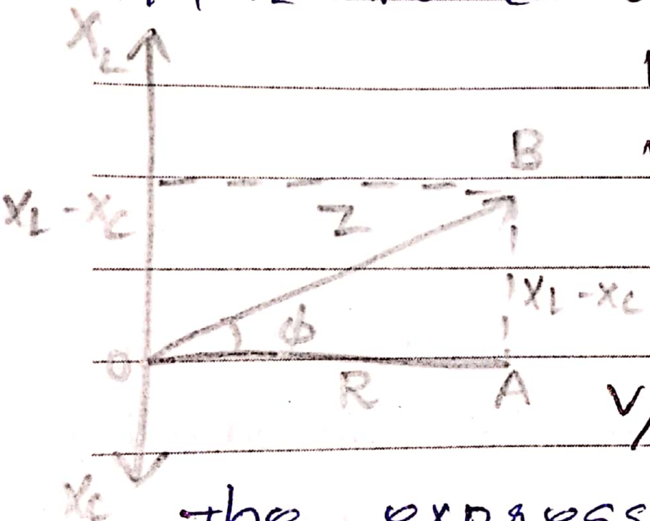
The voltage across inductor coil $V_L = I X_L$

The voltage across capacitor is $V_C = I X_C$

The voltage across the different

component are represented in the voltage phasor diagram.

V_L and V_C are 18° out of phase with each other and the resultant of V_L and V_C is $(V_L - V_C)$ assuming the circuit to be predominantly inductive. The applied voltage 'v' equals the vector sum of V_R, V_L and V_C



$$OB^2 = OA^2 + AB^2$$

$$V^2 = V_R^2 + (V_L - V_C)^2$$

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

$$= I\sqrt{R^2 + (X_L - X_C)^2}$$

$$V/I = Z = \sqrt{R^2 + (X_L - X_C)^2}$$

The expression $\sqrt{R^2 + (X_L - X_C)^2}$ is the net effective opposition offered by the combination of resistor, inductor and capacitor known as the impedance of the circuit and it is represented by z. Its unit is ohm. The values are represented in the impedance diagram.

phase angle ϕ between the

voltage and current is given by

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{IX_L - IX_C}{IR}$$

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\text{net reactance}}{\text{resistance}}$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$\therefore I_0 \sin(\omega t \pm \phi)$ is the instaneous current flowing in the circuit.

Faraday's law of induction:

* whenever the flux of magnetic field through the area bounded by a closed conducting loop changes, an emf is produced in the loop.
* the magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

$$\varepsilon = -\frac{d\phi}{dt}$$

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The negative sign indicates the direction of current according to the lenz's law.

* For closely wound coil of N turns, the expression changes as

$$\varepsilon = -N \frac{d\phi}{dt}$$

5M// Wheat stone bridge

5M// Kirchoff's law

Self induction of a long solenoid

Mutual induction of two long solenoids

2.7.1 *Wheatstone's bridge*

An important application of Kirchoff's law is the Wheatstone's bridge (Fig 2.12). Wheatstone's network consists of resistances P, Q, R and S connected to form a closed path. A cell of emf E is connected between points A and C. The current I from the cell is divided into I_1, I_2, I_3 and I_4 across the four branches. The current through the galvanometer is I_g. The resistance of galvanometer is G.

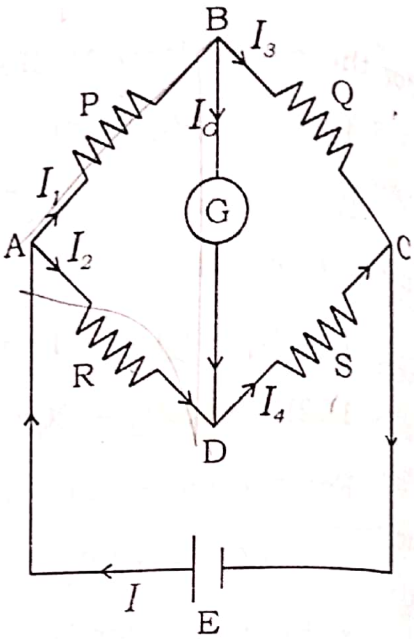


Fig 2.12 Wheatstone's bridge

Applying Kirchoff's current law to junction B,

$$I_1 - I_g - I_3 = 0 \quad \text{...(1)}$$

Applying Kirchoff's current law to junction D

$$I_2 + I_g - I_4 = 0 \quad \text{...(2)}$$

Applying Kirchoff's voltage law to closed path ABDA

$$I_1 P + I_g G - I_2 R = 0 \quad \text{...(3)}$$

Applying Kirchoff's voltage law to closed path ABCDA

$$I_1 P + I_3 Q - I_4 S - I_2 R = 0 \quad \text{...(4)}$$

When the galvanometer shows zero deflection, the points B and D are at same potential and $I_g = 0$. Substituting $I_g = 0$ in equation (1), (2) and (3)

$$I_1 = I_3 \quad \text{...(5)}$$

$$I_2 = I_4 \quad \text{...(6)}$$

$$I_1 P = I_2 R \quad \text{...(7)}$$

Substituting the values of (5) and (6) in equation (4)

$$I_1 P + I_1 Q - I_2 S - I_2 R = 0$$

$$I_1 (P + Q) = I_2 (R+S) \quad \text{...(8)}$$

Dividing (8) by (7)

$$\frac{I_1(P+Q)}{I_1 P} = \frac{I_2(R+S)}{I_2 R}$$

$$\therefore \frac{P+Q}{P} = \frac{R+S}{R}$$

$$1 + \frac{Q}{P} = 1 + \frac{S}{R}$$

$$\therefore \frac{Q}{P} = \frac{S}{R} \quad \text{or} \quad \frac{P}{Q} = \frac{R}{S}$$

This is the condition for bridge balance. If P, Q and R are known, the resistance S can be calculated. SM

2.7 Kirchoff's law

Ohm's law is applicable only for simple circuits. For complicated circuits, Kirchoff's laws can be used to find current or voltage. There are two generalised laws : (i) Kirchoff's current law (ii) Kirchoff's voltage law

Kirchoff's first law (current law)

Kirchoff's current law states that the algebraic sum of the currents meeting at any junction in a circuit is zero.

The convention is that, the current flowing towards a junction is positive and the current flowing away from the junction is negative. Let 1,2,3,4 and 5 be the conductors meeting at a junction O in an electrical circuit (Fig 2.10). Let I_1, I_2, I_3, I_4 and I_5 be the currents passing through the conductors respectively. According to Kirchoff's first law.

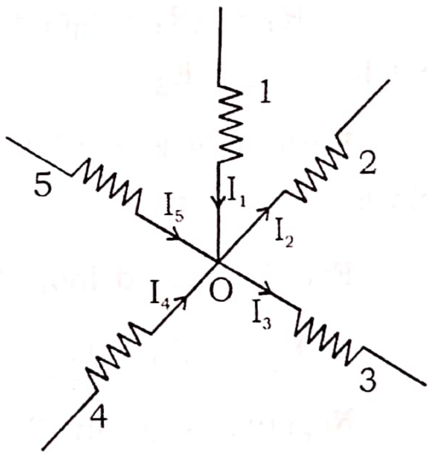


Fig 2.10 Kirchoff's current law

$$I_1 + (-I_2) + (-I_3) + I_4 + I_5 = 0 \quad \text{or} \quad I_1 + I_4 + I_5 = I_2 + I_3.$$

The sum of the currents entering the junction is equal to the sum of the currents leaving the junction. This law is a consequence of conservation of charges.

5m

Kirchoff's second law (voltage law)

3m [Kirchoff's voltage law states that the algebraic sum of the products of resistance and current in each part of any closed circuit is equal to the algebraic sum of the emf's in that closed circuit. This law is a consequence of conservation of energy.] 3m

In applying Kirchoff's laws to electrical networks, the direction of current flow may be assumed either clockwise or anticlockwise. If the assumed direction of current is not the actual direction, then on solving the problems, the current will be found to have negative sign. If the result is positive, then the assumed direction is the same as actual direction.

It should be noted that, once the particular direction has been assumed, the same should be used throughout the problem. However, in the application of Kirchoff's second law, we follow that the current in clockwise direction is taken as positive and the current in anticlockwise direction is taken as negative.

Let us consider the electric circuit given in Fig 2.11a.

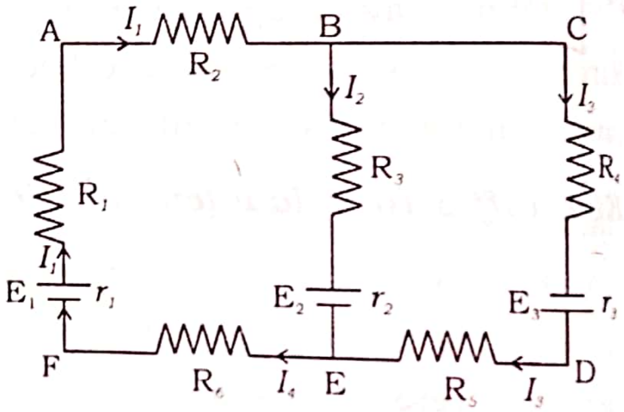


Fig 2.11a Kirchoff's laws

Considering the closed loop ABCDEFA,

$$I_1R_2 + I_3R_4 + I_3r_3 + I_3R_5 + I_4R_6 + I_1r_1 + I_1R_1 = E_1 + E_3$$

Both cells E_1 and E_3 send currents in clockwise direction.

For the closed loop ABEFA

$$I_1R_2 + I_2R_3 + I_2r_2 + I_4R_6 + I_1r_1 + I_1R_1 = E_1 - E_2$$

Negative sIgn in E_2 indicates that it sends current in the anticlockwise direction.

As an illustration of application of Kirchoff's second law, let us calculate the current in the following networks.] 5m

4.2.2 *Self inductance of a long solenoid*

Let us consider a solenoid of N turns with length l and area of cross section A. It carries a current I. If B is the magnetic field at any point inside the solenoid, then

Magnetic flux per turn = B × area of each turn

But, $B = \frac{\mu_o NI}{l}$

Magnetic flux per turn = $\frac{\mu_o NIA}{l}$

Hence, the total magnetic flux (ϕ) linked with the solenoid is given by the product of flux through each turn and the total number of turns.

$$\phi = \frac{\mu_o NIA}{l} \times N$$

i.e $$\phi = \frac{\mu_o N^2IA}{l} \quad ...(1)$$

If L is the coefficient of self induction of the solenoid, then

$$\phi = LI \quad ...(2)$$

From equations (1) and (2)

$$LI = \frac{\mu_o N^2IA}{l}$$

$$\therefore \quad L = \frac{\mu_o N^2 A}{l}$$

If the core is filled with a magnetic material of permeability μ,

then, $$L = \frac{\mu N^2 A}{l}$$

4.2.6 Mutual induction of two long solenoids.

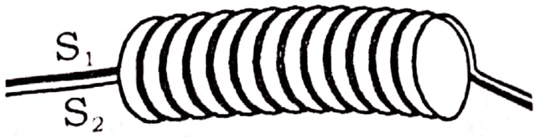


Fig 4.8 Mutual induction between two long solenoids

S_1 and S_2 are two long solenoids each of length l. The solenoid S_2 is wound closely over the solenoid S_1 (Fig 4.8).

N_1 and N_2 are the number of turns in the solenoids S_1 and S_2 respectively. Both the solenoids are considered to have the same area of cross section A as they are closely wound together. I_1 is the current flowing through the solenoid S_1. The magnetic field B_1 produced at any point inside the solenoid S_1 due to the current I_1 is

$$B_1 = \mu_o \frac{N_1}{l} I_1 \qquad ...(1)$$

The magnetic flux linked with each turn of S_2 is equal to B_1A.

Total magnetic flux linked with solenoid S_2 having N_2 turns is

$$\phi_2 = B_1 A N_2$$

Substituting for B_1 from equation (1)

$$\phi_2 = \left(\mu_o \frac{N_1}{l} I_1\right) A\ N_2$$

$$\phi_2 = \frac{\mu_o N_1 N_2 A I_1}{l} \qquad ...(2)$$

But $\phi_2 = MI_1 \qquad ...(3)$

where M is the coefficient of mutual induction between S_1 and S_2.

From equations (2) and (3)

$$MI_1 = \frac{\mu_o N_1 N_2 A I_1}{l}$$

$$M = \frac{\mu_o N_1 N_2 A}{l}$$

If the core is filled with a magnetic material of permeability μ,

$$M = \frac{\mu N_1 N_2 A}{l}$$

...nown lo

Comparison of two low resistances. Two low resistanc of the same order can be compared using a potentiometer. In t experiment discussed above, let R and r be two résistances of the sar order connected in the circuit as shown in Fig. 13·62. Putting t keys 1 and 3 the balancing length l_1 corresponding to the potent difference across R is determined. Then the keys 1 and 3 removed and 2 and 4 are inserted and the balancing length l_2 corr ponding to the potential difference across r is determined.

p1

$$\frac{R}{r} = \frac{PD \text{ across } R}{PD \text{ across } r} = \frac{l_1}{l_2}$$

p2

Different readings can be obtained by changing the current through the potentiometer wire or by changing the current through R and r. If one of the resistances is of a standard known value, the other can be calculated. This method can conveniently be employed to compare high resistances or low resistances. For comparison of low resistances, it is desirable that the rheostat used in the potentiometer circuit should have high resistance while the rheostat in series with R and r must have a low resistance.

$$I_0 = \frac{E_0}{\frac{1}{j\omega C}}$$

or $$I_0 = (j\omega C)\, E_0$$

It means that current vector is rotated by $+90°$ into the pure imaginary axis. Thus the current vector is ahead of the voltage vector by $90°$.

20·21. LCR Circuit (Series Resonance Circuit)

Consider a circuit containing an inductance L, a capacitance C and a resistance R joined in series. This series circuit is connected to an AC supply given by

$$E = E_0\, e^{j\omega t} \quad \text{...(i)}$$

The total impedance of the circuit is given by

$$Z = R + j\left(L\omega - \frac{1}{C\omega}\right) \quad \text{...(ii)}$$

The current I at any instant is

$$I = \frac{E}{Z}$$

$$I = \frac{E_0\, e^{j\omega t}}{R + j\left(L\omega - \frac{1}{C\omega}\right)}$$

$$I = \frac{E_0\, e^{j(\omega t - \delta)}}{\sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}} \quad \text{...(iii)}$$

$$= \frac{E_0\, e^{j\omega t}}{\sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}} \angle \tan^{-1} \frac{L\omega - \frac{1}{C\omega}}{R} = \delta$$

Here $$\tan\delta = \frac{L\omega - \frac{1}{C\omega}}{R} \quad \text{...(iv)}$$

But
$$I_0 = \frac{E_0}{\sqrt{R^2+\left(L\omega-\frac{1}{C\omega}\right)^2}}$$

$\therefore$
$$I = I_0\, e^{j(\omega t-\theta)} \qquad \ldots(v)$$

20·22. Parallel Resonance Circuit (Rejector Circuit)

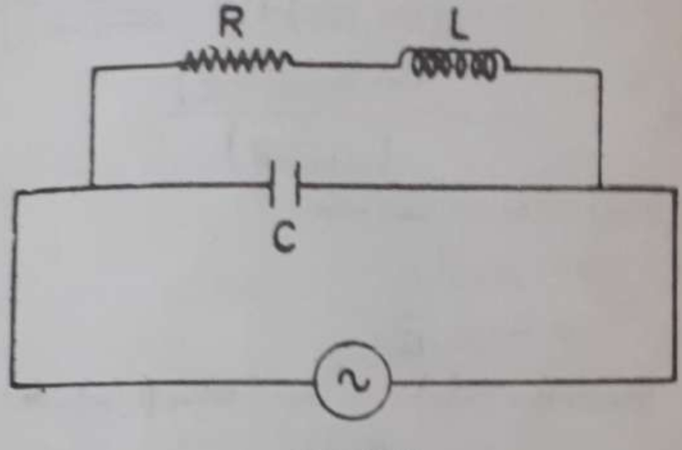


Fig. 20·17

In parallel circuit, capacitor C is connected in parallel to the series combination of resistance R and inductance L. The combination is connected across the AC source (Fig. 20·17). In this case

$$Z_1 = R+jL\omega \qquad \ldots(i)$$

$$Z_2 = \frac{1}{jC\omega} \qquad \ldots(ii)$$

Z_1 and Z_2 are in parallel

$\therefore$
$$\frac{1}{Z} = \frac{1}{Z_1}+\frac{1}{Z_2}$$

$$\frac{1}{Z} = \frac{1}{R+jL\omega}+\frac{1}{\frac{1}{jC\omega}} \qquad \ldots(iii)$$

$\therefore$
$$Y = \frac{1}{R+jL\omega}+jC\omega$$

$$Y = \frac{R-jL\omega}{R^2+(C\omega)^2}+jC\omega$$

$$Y = \frac{R}{R^2+(L\omega)^2}+j\left[+C\omega-\frac{L\omega}{R^2+(L\omega)^2}\right]$$

$\therefore$
$$Z = \frac{1}{Y} = \frac{1}{\frac{R}{R^2+(L\omega)^2}+j\left[C\omega-\frac{L\omega}{R^2+(L\omega)^2}\right]}$$

The current

$$I = \frac{E}{Z} = EY$$

$$\therefore \quad I = E\left[\frac{R}{R^2+(L\omega)^2} + j\left(C\omega - \frac{L\omega}{R^2+(L\omega)^2}\right)\right]$$

$$I = E\left[\left(\frac{R}{R^2+(L\omega)^2}\right)^2 + \left(C\omega - \frac{L\omega}{R^2+(L\omega)^2}\right)^2\right]^{1/2} \angle\theta$$

$$\theta = \tan^{-1}\frac{C\omega - \left(\frac{L\omega}{R^2+(L\omega)^2}\right)}{\left(\frac{R}{R^2+(L\omega)^2}\right)}$$

Here I will be maximum when

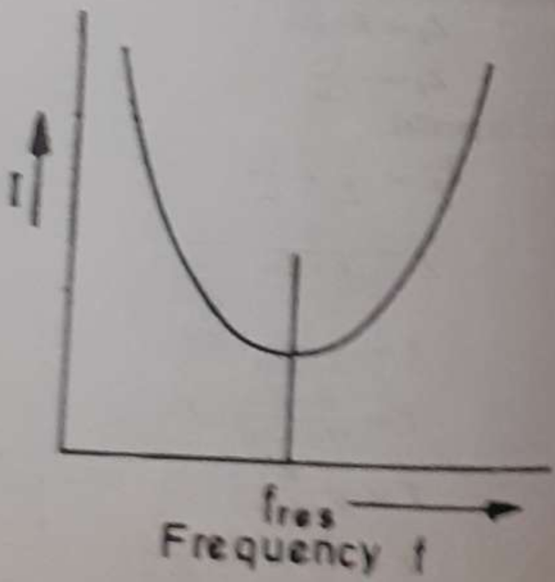
$$C\omega - \frac{L\omega}{R^2+(L\omega)^2} = 0$$

$$C\omega = \frac{L\omega}{R^2+(L\omega)^2}$$

$$R^2+(L\omega)^2 = \left(\frac{L}{C}\right) \quad \text{or} \quad L^2\omega^2 = \left(\frac{L}{C}\right) - R^2$$

$$\omega = \left(\frac{1}{LC} - \frac{R^2}{L^2}\right)^{1/2}$$

$$f_{res} = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$



At a particular frequency f which is called resonant frequency the current is minimum and impedance is maximum. Therefore it is called a *Rejector circuit*. If a graph is plotted between current and frequency, it is as shown in Figure 20·18.

In this case frequency of the AC is varied and r.m.s. value of applied e.m.f. is kept fixed. Only at one particular frequency f_{res}, the impedance is maximum and the current will be minimum. At resonance

$$Z = \frac{R^2+(L\omega)^2}{R}$$

But $\quad R^2+(L\omega)^2 = \frac{L}{C}$ at resonance

$$\therefore \qquad Z = \frac{L}{RC} = R_e$$

R_e is called the *dynamic resistance* of the circuit

i.e., $$R_e = \frac{L}{CR}$$

If R is zero, R_e is infinite

As at resonant frequency the current is minimum it is called *Rejector circuit.*

Example 20·4. *Calculate the effective impedance and effective admittance of the following circuit.*

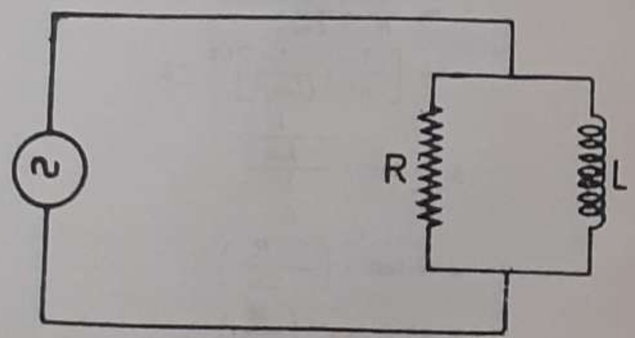


Fig. 20·19

As R and L are in parallel (Fig. 20·19)

$$\frac{1}{Z} = \frac{1}{Z_1}+\frac{1}{Z_2}$$

$$Z_1 = R \qquad \text{and} \quad Z_2 = jL\omega$$