Accuracy :-

closeness with which an instrument reading approaches the true value of the variable being measured.

Precision :-

Precision is a measure of the degree to which successive measurement differ from one another.

Sensitivity :-

The ratio of the magnitude of the output signal to the input signal.

Error :-

variation from the true value of the measured variable.

Resolution :-

The smallest changes in measured variable to which the instrument will response

Tolerance :-

It is the difference of the maximum measurement value to the actual value.

Measuring instruments :-

These are of 2 types :-

(1) Abolute instrument.

(2) Secondary instruments

→ Secondary instrument are of 2 types :-

(i) Digital (ii) Analog

→ Again Analog instruments is of 3 type;

(i) indicating (ii) Recording (iii) Integrating.

→ The classification of Analog instruments are indicating type instruments, Recording type instruments and integrating type instruments.

→ Indicating type instruments :-

These type of instruments indicate th instant value of the quantity to be measu

eg → Ammeter, Voltmeter.

→ Recording type instrument

These type of instrument are indic instruments with a recording arrangement

eg → Recording instruments for frequency Power ~~fraction~~ factor.

Assentials of an inicating type instruments:-

An indicating is a moving instrument.

Deflecting Torque :-

The torque is necessary to move the pointer of the instrument from its zero position. Deflecting torque can be produced by utilising any one effect of the following;

(i). Magnetic effect
(ii) Electro dynamic effect
(iii) Electro magnetic induction effect
(iv) Electro static effect
(v) chemical effect
(vi) Thermal effect.

controlling Torque :-

Controlling is assential to balance or oppose the deflecting torque. Also this torque brings the pointer to '0' position after the measure quantity is withdrawn. This torque can be provided by 2 methods,

(ii) Gravity control :-

which is provided by a small weight called controlled weight attached to the moving system. This torque produced due to the gravitational force acting on it.

Dt → 18/01/13

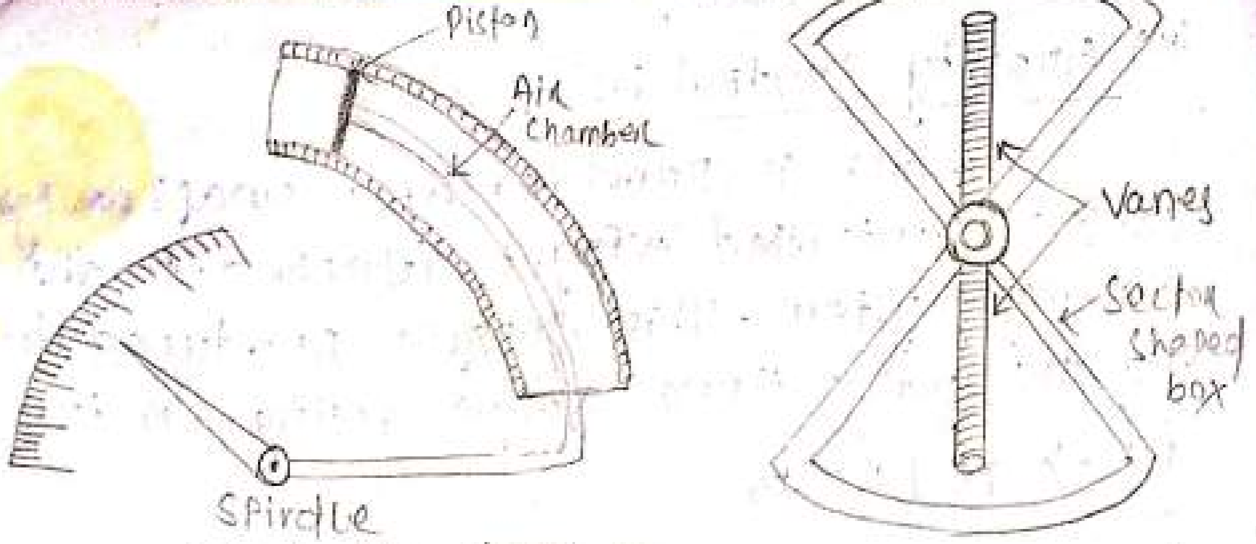
Damping Torque :-

with the current is suddenly increased from zero to certain value and if there is no damping the pointer will ossillate about its final position due to inertia of the moving system. when a damping device is used the pointer moves slowlly and reaches it final position without ossillation.

(i) Air friction damping.

(ii) Eddy current damping

has been measured

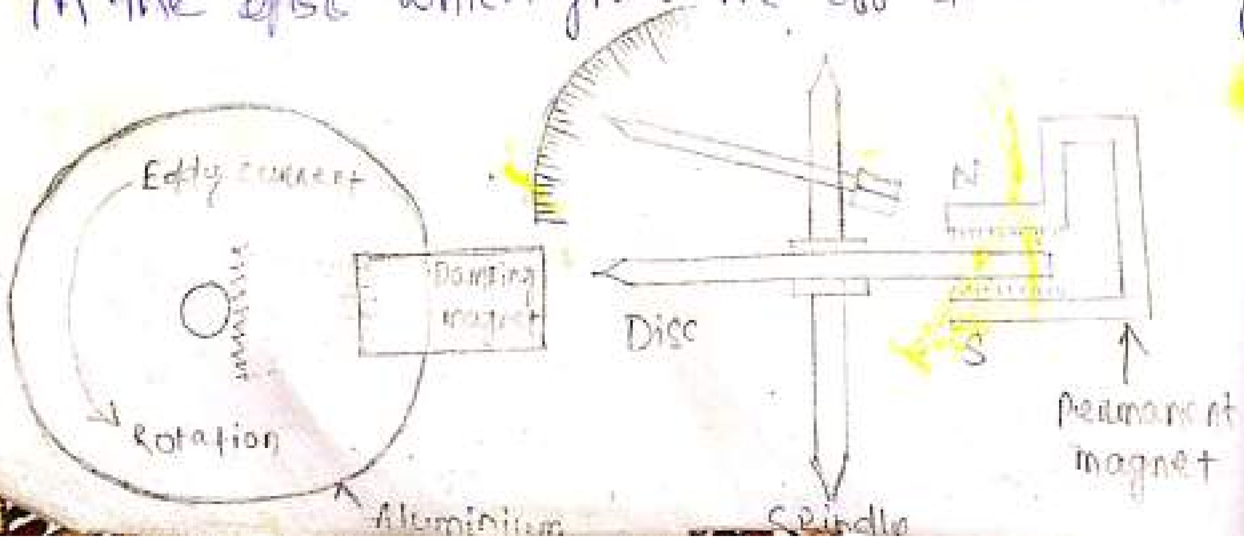


Air friction damping.

The spindle to which the pointer is attached has vanes which moves in a sector or air chamber. As the pointer is deflected the vanes moves in the chamber against the air pressure. So the compressing of the air at the back provides the required damping.

Eddy current damping :-

In such damping a conducting but non magnetic material disc is fixed on the spindle when the pointer moves the disc also moves, so the flux is cut by the disc and the eddy current are induced in the disc which gives the effective damping.



CHAPTER - 2

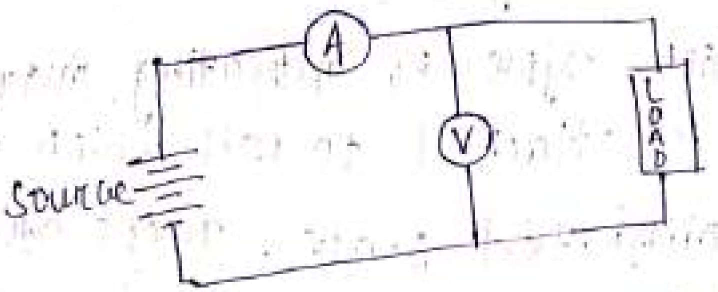
Voltmeter & Ammeter :—

Voltmeter :—

A voltmeter is used to measure the potential difference between the two points of circuit. It is connected in parallel with the circuit. The voltmeter is always design with very high internal resistance.

Ammeter :—

An ammeter is used to measure the flow of current in a circuit. So it is connected in series with the circuit. So, an ammeter is design with very low internal resistance.



The basic principle of voltmeter and ammeter is same. Both are current operated device. That is the deflecting torque is produced when current flows through there operating coils.

In volt voltmeter the torque produced is directly propersonal to the current flowing through the operating coils. which is propersonal to the measured voltage.

* The types of indicating type instruments are:

(1) M.C type use for DC ckt only.
(Moving coil)

(2) MI type used for both AC and DC type ckt.
(Moving iron)

(3) Hot wire type used for both AC and DC ckt.

(4) Thermo couple type used for " "

(5) Electro static type " "

(6) Indicating type used for AC ckt only.

Moving coil (MC type) :-

→ PMMC type

→ Dynamo meter type

In this type of indicating instrument the pointer is attached to coil which moves over the calibrated scale. These are of 2 type (i) → PMMC
(ii) → Dynamo meter

PMMC :-

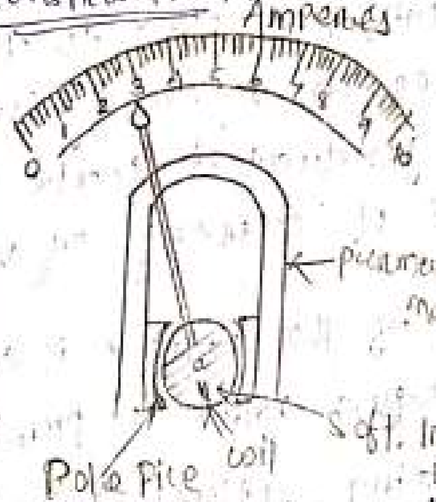
These instruments are either used as ammeters or voltmeters and suitable for dc work only.

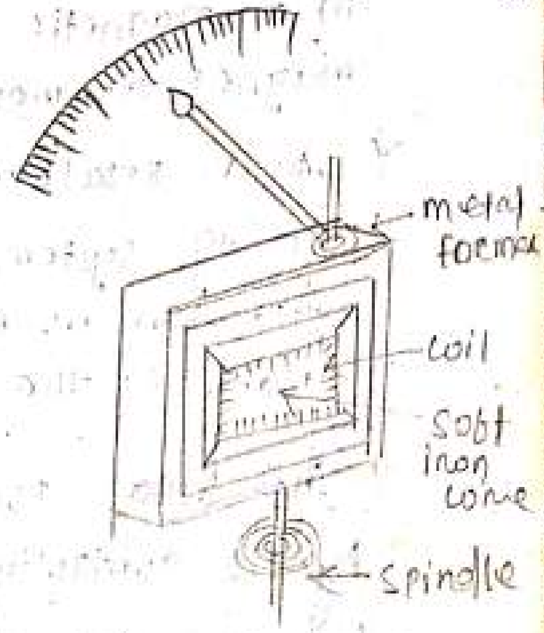
Principle :-

→ This type of instument is based on the Principle that when a current carring conductor is placed in a magnetic field a mechanical force act on the conductor.

→ The coil placed in the magnetic field and carrying the operating current is attached to the moving system, with the movement of the coil the pointer moves over the scale to indicate the electrical quantity being measured.

Construction :-





→ It consist of a light rectangular coil of many turns of thin wire wound on an aluminium former. inside which is an iron core.

→ The coil is pivoted upon jewel bearing and is mounted between the cores of a permanent magnet.

→ The current is lead into an out of the coil by two control here bring one about the other below the coil.

→ The springs also provides the controlling torque. The damping torque is provided by eddy current induced in the aluminium former as the coil moves from 1 coil to another.

Working :—

When the instrument is connected in the circuit to measure the current or voltage the operating current flows through the coil.

→ Since the coil is carrying and is placed in a magnetic field of the permanent magnet as mechanical force is acting it.

→ As a result the pointer attached to the moving system moves in a clock wise direction over the graduated scale to indicate the value of current or voltage.

→ The final position of the pointer is controlled by the controling torque which is produced by the two air spring attached to the spindle.

→ The aluminium former over which the coil is wound provides the necessary damping torque.

Torque equⁿ :—

Let B = flux density Wb/m²
l = length
I = current in Amp

A = cross-sectional area of / Torque equation
N = No. of turns

Deflecting force
= BIL N Newton

Deflecting torque
$T_d = BINA$

Controlling torque
$T_c = K\theta$
K = spring constant
θ = Angle of deflection

At final position
$T_d = T_c$
$BINA = K\theta$
$\Rightarrow \theta = \frac{BINA}{K}$

$T_d = NBAI$
$\therefore T_d = GI$
where $G = NBA$ = constant

The controlling torque is provided by the spring & is proportional to the angular deflection of the pointer. $T_c = K\theta$
where T_c = controlling torque
K = spring constant Nm/rad
θ = angular deflection
For the final steady state position $T_d = T_c$
$\therefore GI = K\theta$ so, $\theta = G/K$
or $I = (K/G)\theta$.
Thus the deflection is directly proportional to the current pass through the coil. The pointer deflection can therefore be used to measure current.

Advantages:—
→ They have uniform scale
→ High torque / wt. ratio
→ It is very accurate

Disadvantage:—
→ They can not be used in AC
→ It is very costly

Uses:—
It is used in voltmeter, ammeter and galvanometer.

Dynamometer type instrument :-

These instruments are the modified form of PMMC type instrument. Here the magnetic field is not produced by the parmanent magnet but by two air part fixed coil plagesed on either sides of the moving coil.

Such instrument can be used as ammeters or voltmeter but generally they are used as watt meter.

They are suitable for both ac and dc.

Principle :-

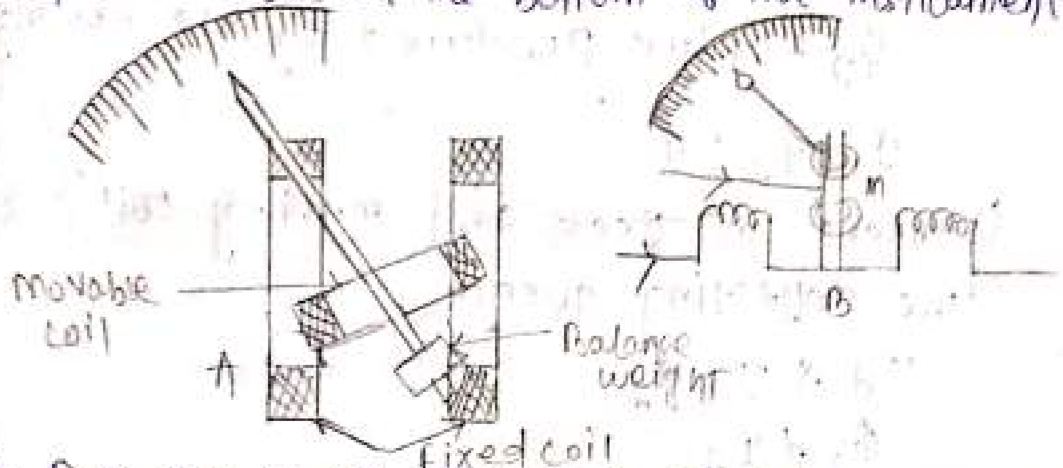
This instruments are based on the principle that mechanical force exist between the current carrying conductors.

Construction :-

It is essentially consist of a fixed coil and a moving coil. The fixed coil is devided into two equal part which are plagced closed together and help to each other. The M.C is pivotated in between the 2 fixed coils and carries a pointer.

The current is lead into an out of the moving coil by means of 2 spiral hair spring which provides the controlling torque.

Air friction damping is provided by means of the aluminium vanes that move in the sector shape chamber at the bottom of the instrument.



→ For use as an ammeter or voltmeter the fixed coil and moving coil are so connected that the same current flows through the 2 coils.

→ Due to these current the mechanical force exist between the coil.

→ The result is that the moving coil M moves the pointer over the scale.

→ The pointer comes to reset at a position where the deflecting torque is equal to the controling torque. Since the polarity of the fields produce by both fixed and moving coil is reversed by the reversal of current

→ the deflection of the moving system is always in the same direction.

→ So for this reason dynamo meter type instrument can be used for both ac and dc measurement.

Torque equn :-

Let ϕ_1 = Flux density of fixed coil

ϕ_2 = Flux produced by the moving coil

$I_1 = I_2 = I$

(current in fixed and moving coil)

The deflecting torque

$T_d \propto I_1 \phi_2$

$\phi_2 \propto I_2$

$T_d \propto I_1 I_2$

$T_d = K_1 I_1 I_2$

$T_c = K\theta$

$T_d = T_c \Rightarrow K_1 I_1 I_2 = K\theta$

$\boxed{\theta \propto I^2}$ Ammeter

$\boxed{\theta \propto V^2}$ voltmeter

Advantage :-

→ These instruments can be used for both ac and dc.

→ A PMMC instrument cannot be used as a wattmeter but dynamo-type instruments can be used as a watt meter.

Disadvantage :-

→ It is less desity

→ It is costly

Uses :- Ammeter, voltmeter, wattmeter

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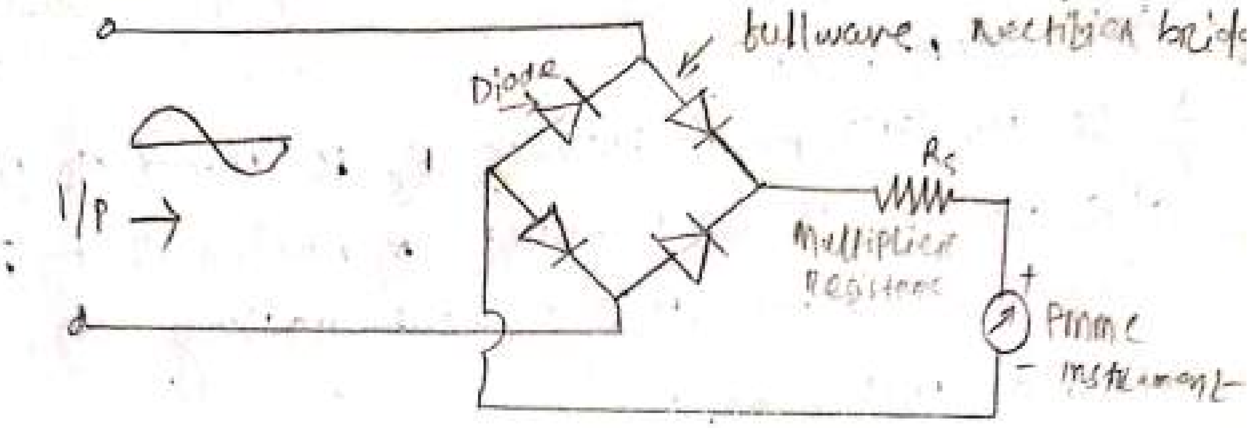
Rectifier type instrument :-



→ Rectifier type instrument are used for measurement of AC voltage and current by using a rectifier aliment. which convert AC to a unidirectional dc.

→ And then using amiter to dc to indicate the value of the rectifier AC.

→ the indicating instrument is PMMC instrument type.

→ The arrangement which amploes a fullwave rectifier circuit using a diode.

→ Recitier instrument are perticularly suited to measurment on comunication circuit, and for all ciret light current work. where the voltages are low and resistance is high.

→ It is asential that for this application that the current run by the voltmeter does not exied 1mA so that there are no loading affect and the rectifier

CHAPTER- 03

Watt-meters :—

(I) Dynamometer type or moving coil type

(II) Induction type

(I) ~~Dynamometer type~~ :—

→ A wattmeter as its name implise measures electrical power given to or developed by an electric apparatus or circuit a wattmeter may be of two type.

(I) Dynamometer type

(II) Induction type

fixed coil (current coil)

movable coil (Potential coil)

(I) Dynamometer type :—

→ It consist of two fixed coil c_1 and c_2 connected in series with load. they are known as current coils.

→ The pressure coil 'p' is of fine wire wound on a light frame mounted on a spindle and pivoted to turn to the magnetic field produced by the current coils.

→ The control torque for such instruments is provided by two spyral spring of Phuspher bronze. these springs are also Provides a path to load the current in an out of the pressure coil.

→ The pointer is attached to the spindle which moves over a graduated scale. To control the pressure coil currents each at hig

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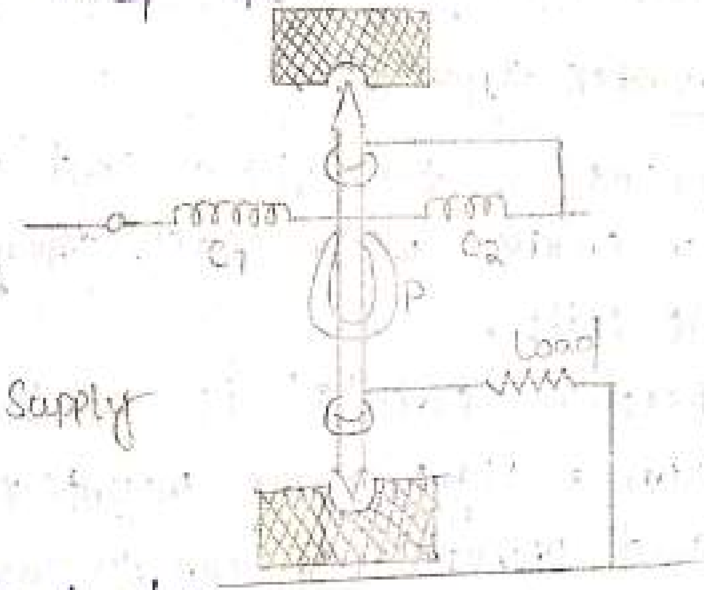
resistance is connected in series with the Pressure coil.

→ Under the action of the two fields due to the fix end moving coil, the moving coil moves round against the action of Spyral spring.

→ The torque depending on the product of current in two coils that is the torque is proportional to the power.

→ The power as indicated by the scale is the mean power.

→ These meters can be used on both ac and dc.



Dynamometer type watt meter

Dt → 30/01/13

Moving iron type instruments :-

These are of two types :-

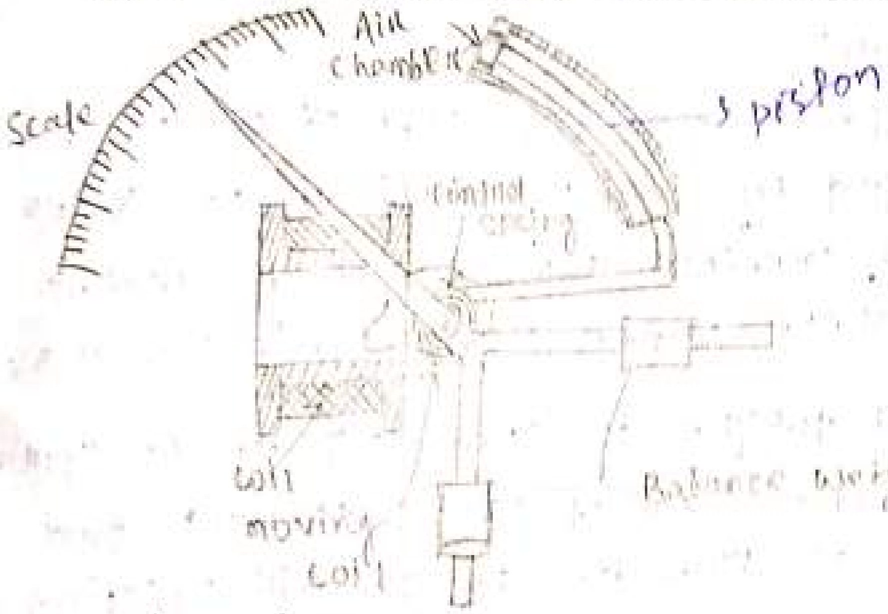
(I) Attraction types (II) Repulsion types

This type of instruments are used for measurement of AC and DC voltage.

Attraction types :-

Construction :-

- It consists of a cylindrical coil which is kept fixed on an oval shaped soft iron is attached to the spindle in such a way that it can move in an out of the coil.
- A pointer is attached to the spindle so that it is deflected with the motion of the soft iron.
- The controlling torque is provided by one spiral spring arranged at the top of the moving element.
- The damping torque is provided by the alluminium vane attached to the spindle which moves in a closed air chamber.



Working :-

- When the instrument is connected in the circuit to measure the voltage or current the operating current flowing through the coil and set up a magnetic field, or the coil behaves like a magnet.

has been

- So it attracts the soft iron pice towards it.
- The result is that the pointer attached the moving system moves from 'O' position
- The pointer will comes to rest at a position where deflecting torque is equal to the controlling coil.
- If the current in the coil is reversed the direction of the deflecting torque remains unchanged : so it is used for both ac and dc.

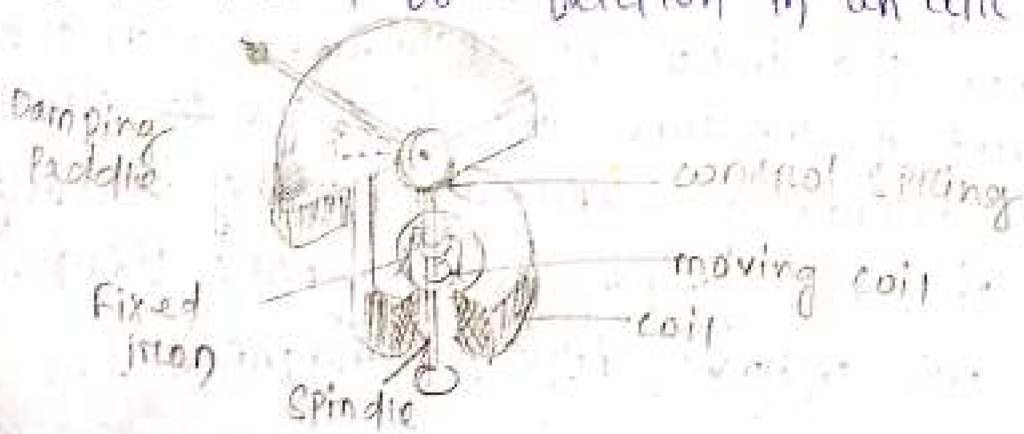
Dt → 05/02/13

Repulsion type :–

Construction :–

It consists of two soft iron pieces or vanes surrounded by a fixed cylinderical hollow coil which carriese the operating current. One of these vaneis fixed other one is movable

Controll torque is provided by one spiral spring at the top of the instrument. And damping is provided by the air friction due to the motion of a friction in an air chamber



Working :-

- When current to be measured flows through the coil a magnetic field is setup by the coil.
- This magnetic field magnetises the two vane in the same direction i.e same polarities are developed at the same end of the vanes.
- Since the adjecent sides vanes are of same polarity and the two vanes repeal each other.
- As the fixed vane can not move the movable vane deflects and causes the pointer to move from '0' position,
- The pointer will come to rest at a position where deflecting torque is equal to controlling torque. This is used for both ac and dc.

Torque equ^n :-

$T_d \propto I^2$

$T_c = K\theta$

$T_d = T_c$

$I^2 = K\theta$

$\theta \propto I^2$

where θ = angle of deflection,

Application :-

The MI instruments are primarily used for ac measurement. They are be used for dc measurement but usually not done so as it's less accurate.

Advantages :—

- It is cheap
- It is used for both ac and dc

Disadvantages :—

- It is less accurate
- Less sensitive
- The scale is not linear.

Dt → 06/02/13

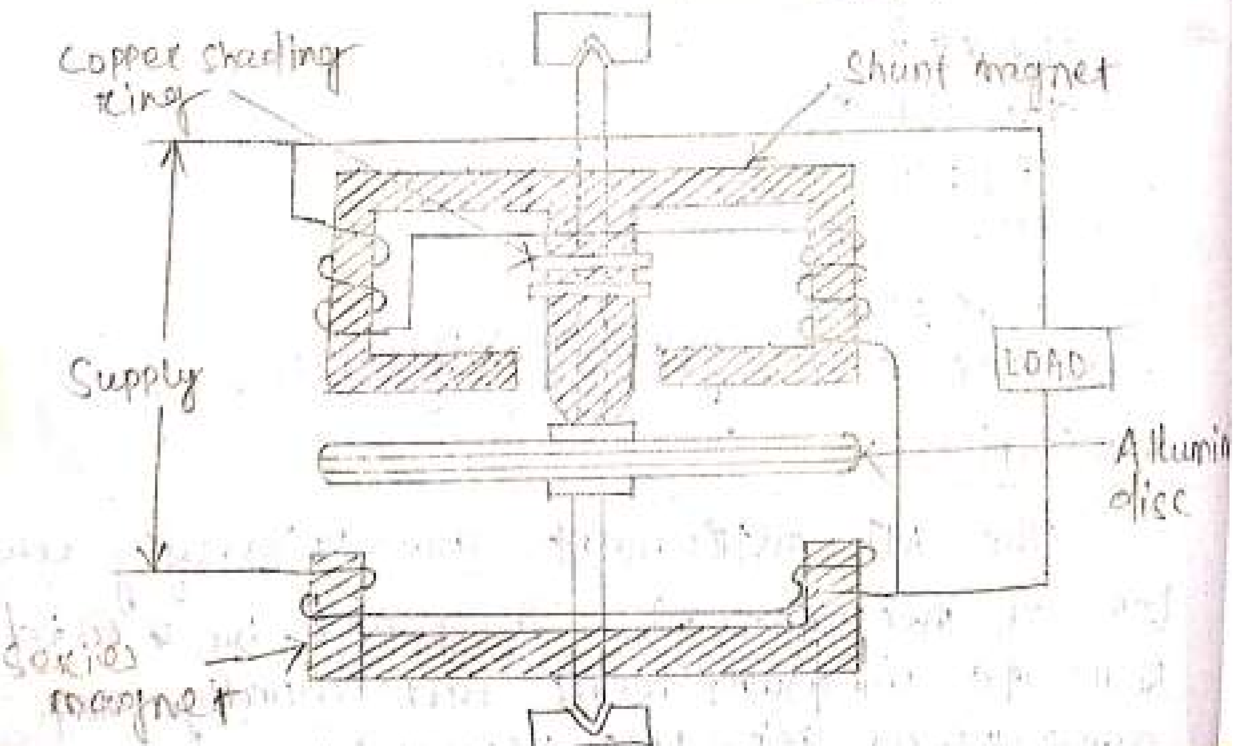
Induction type watt meter :—

Construction :—

This type of watt meter is used on ac only. induction type wattmeter consist of 2 electro magnets.

(a) series magnet → It is connected in series with the load.

(b) shunt magnet → it is connected in parallel with the load.



A thin alluminium disc is mounted between the two magnets. when the current flows in the magnet the alluminium disc cutts the flux of both magnet so eddy current are induced in the disc. The eddy currents and inducing fluxes interect and produce a deflecting torque.

→ A few cu-rings are fixed on the central part of the shunt magnet to make the resultant flux in the shunt magnet leg behind the applied voltage by 90°.

→ current phase displacement between the shunt and series magnet fluxes can be obtain by adjusting the cu-shading rings.

→ The instrument is provided with the spring and produces a controlling torque.

→ Eddy current damping used for this instrument

Advantages :-

→ These instruments have larger deflecting torque.

→ They have a very long scale up to 300°.

Disadvantages :-

→ They have a ~~mea~~ heavy moving system and are less accurate.

→ ~~Their power~~ They are power consuption is high.

→ They are used only on AC.

Error in dynamometer type Wattmeter :

The error in dynamometer type Wattmeter are :-

1) Pressure coil inductance
2) Pressure coil capacitance.
3) Error due to mutual inductance effects
4) Error caused due to wrong connections
5) Eddy current errors.
6) Stray magnetic field errors.
7) Error caused by vibration of moving system.
8) Temperature errors.

The method of connections are for error (i) a capacitor must be connected in parallel with a portion of multiplier as shown in fig.

The error (ii) can be corrected making inductive reactance equal to capacitive reactance i.e ($X_L = X_C$) & the error = 0

Error (III) → can be corrected by ~~modifying~~ reducing the coupling betn the coils.

Error (iv) → can be corrected by connecting the Pressure coil across the supply & current coil in series with the load.

v) → can be corrected by using standard conductors to minimize ~~curr~~ the eddy current flowing in the current coil itself.

vi) can be corrected by Proper shielding i.e the watt meter must be Properly Shielded to reduce the magnetic effect.

vii) The vibration, frictions can be reduced by using light weight moving system.

viii) The temperature rise can be corrected by using copper of resistance alloy which has temp. coefficient of 1:10.

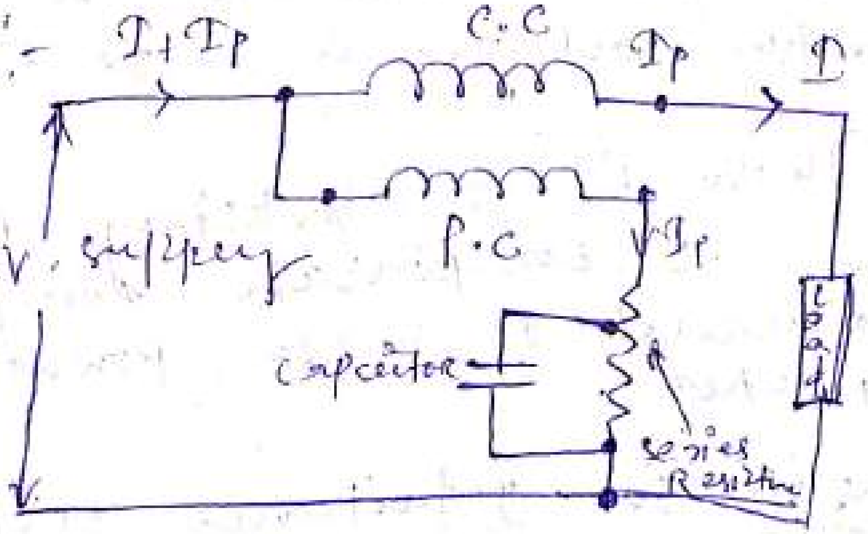
Low power factor wattmeter (Electro dynamo meter type)

Measurement of power in circuit having low powerfactor by ordinary electro-dynamometer wattmeter is difficult and inaccurate because :-

i) The deflecting torque on the moving system is small even when the current of pressure coil are fully excited

(ii) error introduced because of inductance of pressure coil tend to be large at low power factor.

Special features of incorporate in electro dynamo meter wattmeter is :-



Low power factor wattmeter

1) Pressure coil current! -

Pressure coil ~~current~~ circuit is design to have low value resistance, so, that the current, flowing through it is increased to give an increased operating torque. The pressure coil current in a low power factor wattmeter may be as much as 10 times the value employed for high power factor

Compensate for Pressure coil! -

The power being measured in a low power factor circuit small & current is high on account of low power factor cannot be used because large load current there would be large power loss in the current coil & therefore the wattmeter will give a large error.

→ There it is absolutely necessary to compensate for pressure coil current in a low power factor wattmeter.

Compensate for inductance coil

→ In a low power factor wattmeter we must compensate for the error caused by inductance of the pressure coil. This is done by connecting a capacitor across (power factor), a part of series resistance in the pressure coil circuit.

Small control torque :- Low power factor wattmeter are design with to have a small control torque so that they give full scale deflection even for power factor.

CHAPTER - 04

Dt → 20/03/13 1-φ Energy meter, Induction ty.

→ The power delivered over a period of time, called energy.

Energy = $\int VI\cos\phi \, dt$

→ There are 4 main parts of single φ energy meter.

(I) Driving system
(II) Moving system
(III) Breaking system
(IV) Registering system or Recording.

(I) Driving system :-

The driving system consist of 2 electro magnet
(I) shunt magnet (II) series magnet

→ The core of these electromagnet is made up of silicon steel lamination.

→ The coil of one of the electromagnet is exited by load current.

→ Hence the coil is called as current coil.

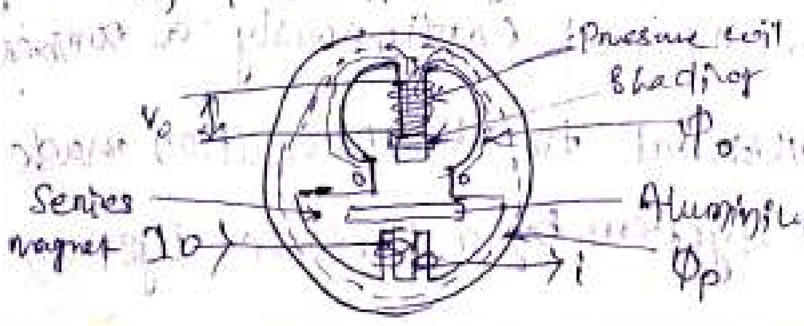
→ The coil of second electromagnet is connected across the supply and the coil carry a current proportional to supply voltage.

→ The coil is known as pressure coil.

Copper shading bands are provided on the central limb.

→ The position of these band is adjustable.

→ This band is used to bring the flux produced by the shunt magnet exactly in quadrature with the applied voltage.



Moving system:-

→ It consist of aluminium disc. The disc is caped in bet'n series and shunt magnet.

→ The uper part of moving system is a steel pin located in a hole in the bearing cap fix to the shaft.

→ Heave the rotating shaft has a small magnet at each end where the copper magnet of the shaft is attracted to a magnet in the uper bearing.

→ The moving system thus floats without touching either bearing surface.

Bearing system:-

→ A permanent magnet position near the edge of the aluminium disc moves in the field of disc magnet and thus provides a breaking torque. can be adjusted by shifting the permanent magnet to different radial positions.

Registering mechanism:-

The function of a registering or counting mechanism is to record continuously a number which is proportional to the revolution made by the moving system by a suitable system a train of reduction gear the pinion of the motor shaft drives a series of five or six pointer. These rotate on round dials which have mark with ten equal division.

'Testing of Energy meters

The term of 'testing' includes the checking of the actual registration of the meter as well as the adjustment done to bring the error of the meters within the prescribed limits.

A.C Energy meters :-

Meter should be tested for following conditions.

1) At 5 percent of marked current with unity power factor.

2) At 100 or 125 percent of marked current with unity power factor

3) At the one intermidiate load with the unity power factor.

4) At marked current and 0.5 lagging power factor.

Adjustment in single-ϕ energy meter

Some adjustment are carried on energy meters so that they correctly & their error are within allowable limits.

The sequence of the adjustment are :-

(1) **Preliminary light load adjustment :-**

The Rated voltage is applied to the potential coil with no current through the current coil.

The light load device is adjusted until the disc just fails to start.

full load unity factor adjustment

The pressure coil is connected across the rated supply voltage and rated full load current at unity power factor is passed through the coil. The position of the brake magnet is adjusted to vary the braking torque so that the meter revolves at the correct speed within required limits of error.

3) Lag adjustment :- (LPF adjustment)

The pressure coil is connected across rated supply voltage and rated full load current is passed through the current coil at 0.5 p.f lagging. The lag device is adjusted till the meter runs at correct speed.

(vi) Creep adjustment

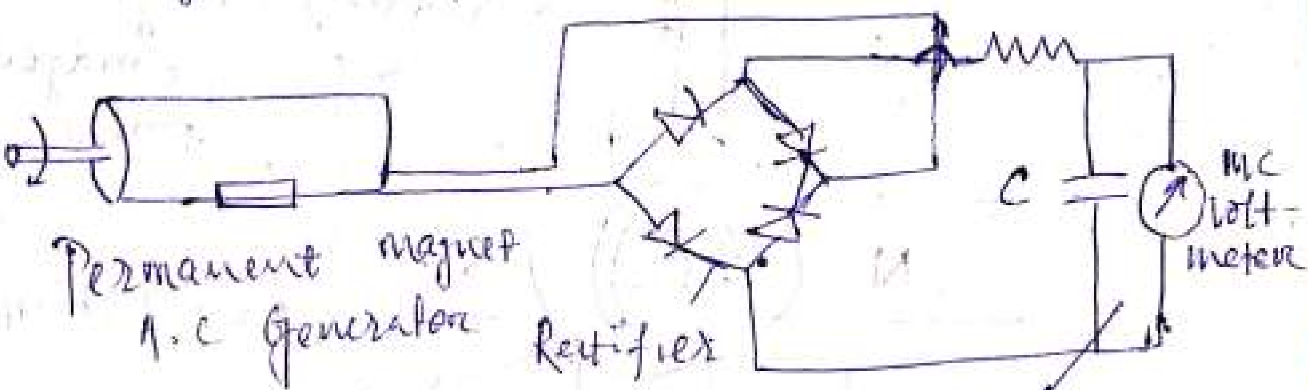
As a bimas check on light load adjustment the Pressure coil is excited by 110 percent of rated voltage with zero load current. If the light load adjustment is correct the meter should not creep under these conditions.

etc.

CHAPTER - 05

Measurement of Speed frequency Power-factor Meter

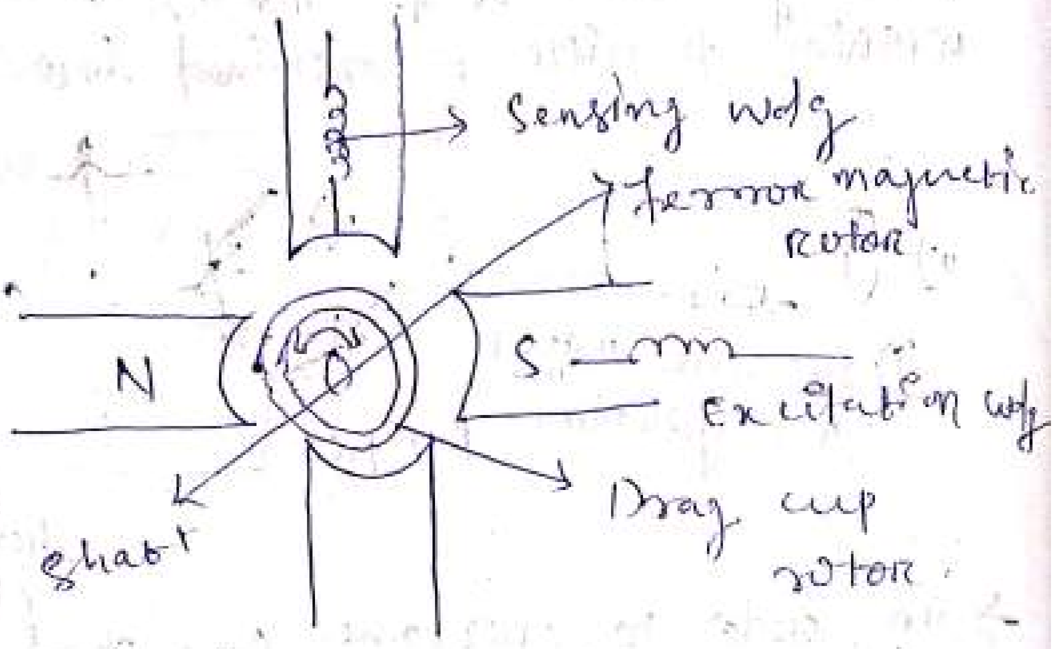
Tachometer is an instrument to measure the rotating speed of d.c m/c or ac m/c. the working principle is explained below.



→ In order to overcome some of the difficults mentioned above i.e. due to maintenance problem, brush contact, commutator etc dc tachogenerator have rotating magnet which may be either a Permanent magnet, or an electro magnet. The coil is wound on the stator.

→ The rotation of Magnet causes an emf to be induced in the stator coil. The amplitude & frequency of this emf are both proportional to the speed of rotation. Thus either amplitude or frequency of induced voltage is used as a measure, the o/p voltage of a.c tachogenerator is rectified and is measured with a permanent magnet moving coil

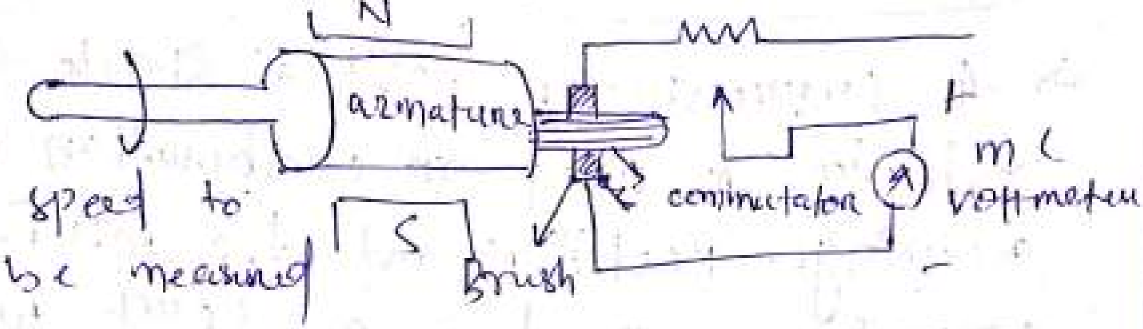
→ In case of drag cup type Rotor Ac Tacho generator there are two winding i.e Excitation wdg and sensing wdg



→ The rotor is very light & highly conducting and acts as S.C wdg. A low reluctance plate is provided. The rotation of rotor causes an induced voltage. In the sensing wdg & this voltage is proportional to the inst. value of speed. If the excitation frequency is very large as compared with speed.

→ DC Tachogenerator is transducer which is used to measure the angular speed of the rotating M/C.

→ The angle (θ) of the angular shaft is connected to elect O/P.



Working Principle :-

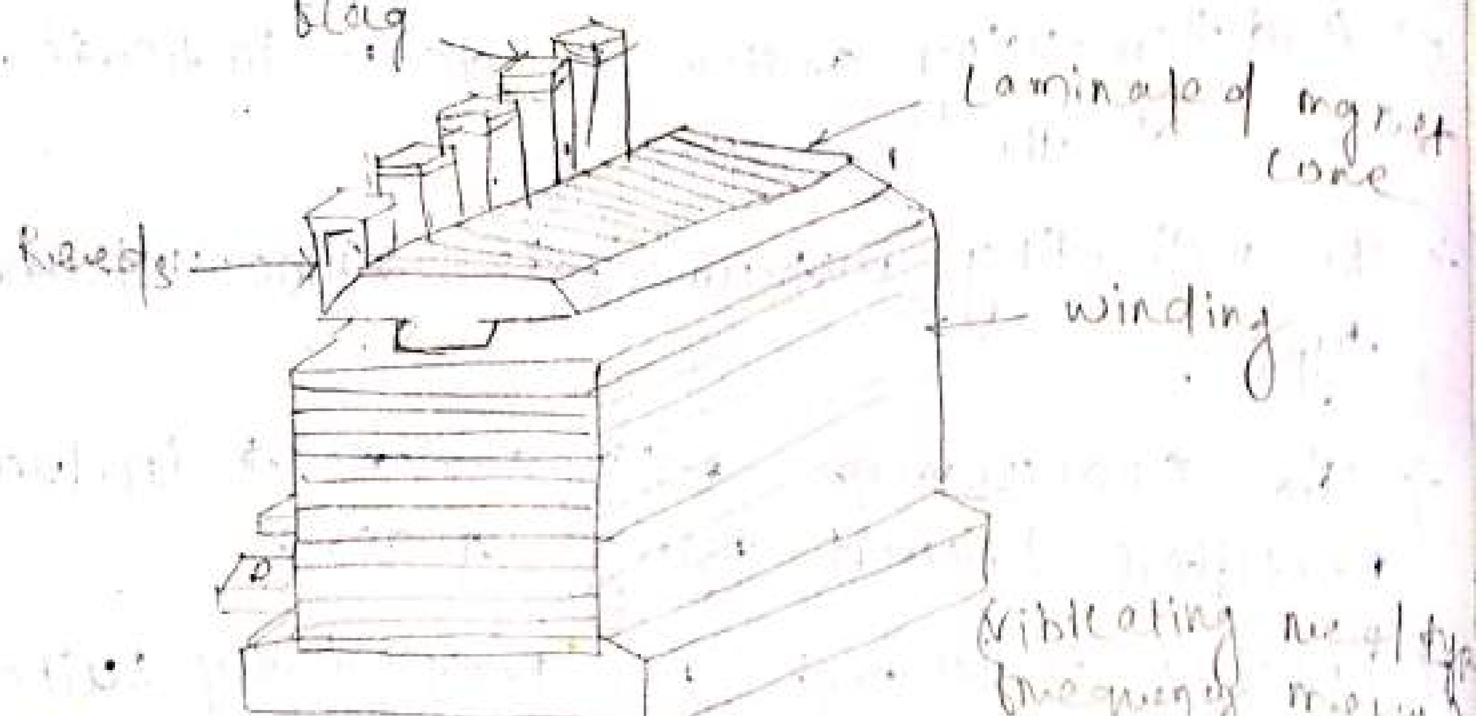
Consider two permanent ~~mag~~ magnetic poles N and S inside which an armature is placed. A commutator is ~~connected~~ connected to the armature whose speed is to be measured.

The angular speed of the shaft can be measured by comparing the elect. O/P of then m/c

$\therefore N \propto E_0$.

The advantages of this transducer is 10mV/Rpm sensitivity & can be measured with the M.C voltmeter.

Mechanical Resonance type frequency meter



Construction

- This meter consist of number of thin steel strips called reeds.
- The reeds are placed in a row and closed to an electromagnet.
- The electromagnet has a laminated iron core and its coil is connected in series with a resistance across a supply whose frequency is to measured.

→ These reeds are aproximatly about 4 mili-metre wide and 0.5 mm thick.
→ All reeds are not exactly similar to each other.
→ The natural frequency of vibraration of the reeds depends upon there weight and dimention.
Since the reeds have different weight and sizes their natural frequency of vibration are different.
→ The reeds are arranged in ascending order of natural frequency.
→ The different in frequency is in usually 0.5 Hz.
→ So the natural frequency of 1st reeds may be 47Hz
→ The flags are painted white to afford max. contrast against their black background.
→ When the frequency meter is connected across the supply whose frequency is to be measured. The coil of electro magnet carry a current "i". which alternate at the supply frequency the force of attraction betn the reeds and the electromagnet is proportional to i^2 so these force varys at twice the supply frequency.

→ So the force is exerted on the reeds varies every half cycle, all the reeds will tend to vibrate. But the reed whose natural frequency is equal to twice the frequency of suppy will be in resonance. and will vibrat most.

Advantages :-

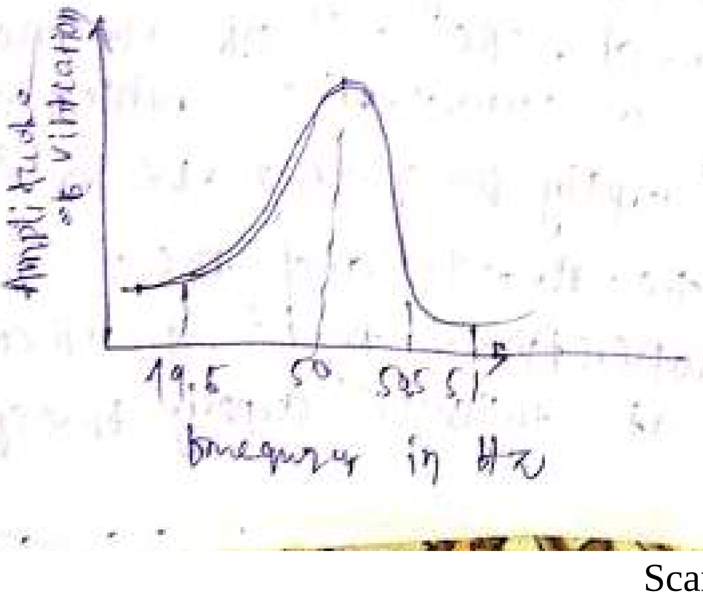
→ The indication is virtualy independent of the wave form of supply voltage.

→ The indication is independent of magnitude of applied voltage also provided the voltage is not too low.

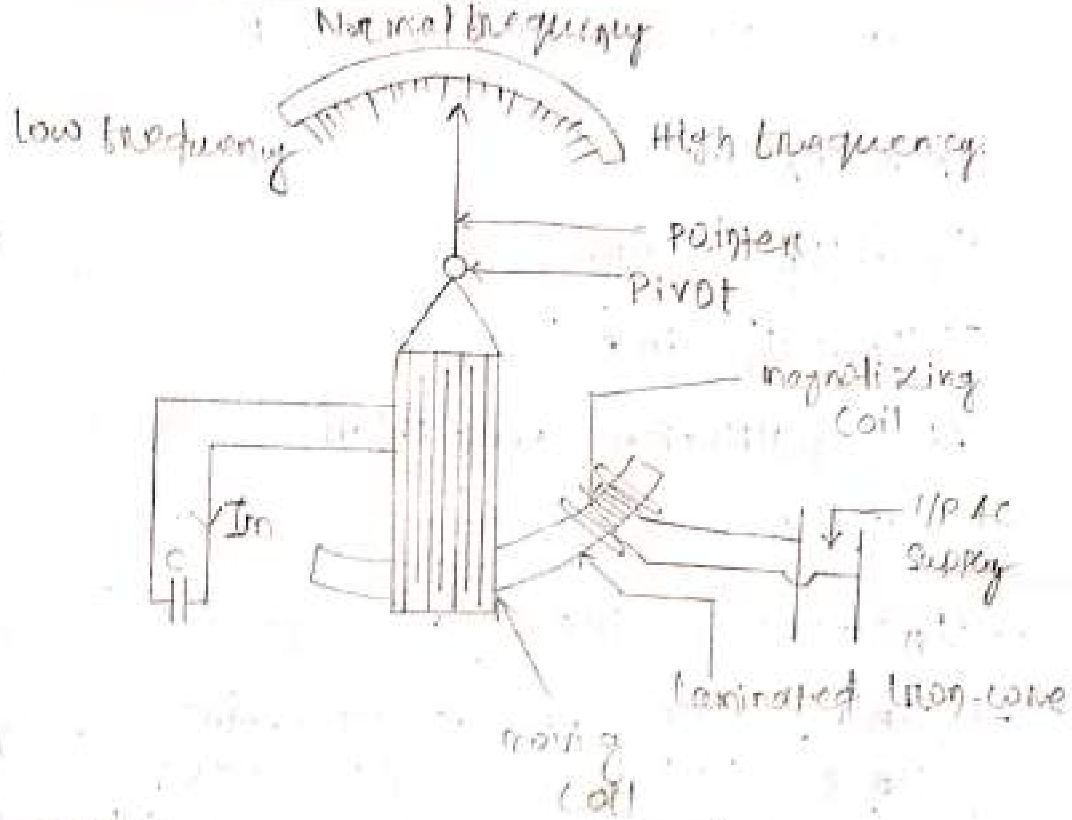
Disadvantages :-

→ Such instrument can not be read much closer then half the frequency difference betn adjecent reeds.

→ The reliability of reading also depends upon the accuracy with which the meter reading have been tuned.



Electrical Resonance type :-



Principle :-

The working principle of this instrument is based on the working principle of resonance in a R L C circuit.

Construction :-

It consist of a fixed coil which is connected across the supply whose frequency should be measure.

→ This coil is also called as magnetising coil.

→ The magnetising coil is mounted on a laminated iron core.

→ The moving coil is attached with a spindle which is pivoted on the bearing which is allow to move freely.

→ A pointer fixed with spindle which moves over a calibrated scale and a capacitor of suitable value is connected across the moving coil.

Working :—

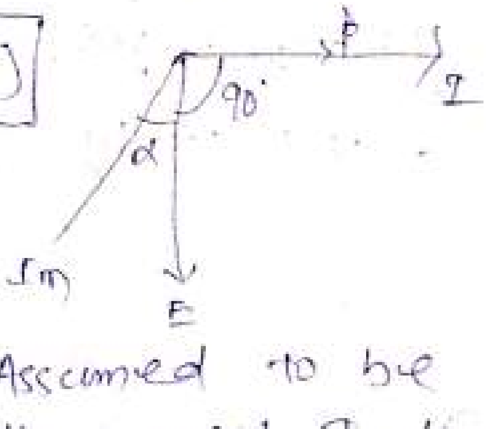
→ The fixed coil draws a current I and this current produces a flux ϕ. If we neglect the resistivity of the coil and iron loss in the core flux (ϕ) in phase with current I, this flux ϕ being alternating in nature, produces an emf E and this emf lag behind the flux by 90°. The Emf induces a current I_m in the moving coil.

1st case

The circuit of the moving coil is assumed to be inductive. Then the current I_m lags behind the emf 'E' by an angle α.

The torque acting on the moving coil is

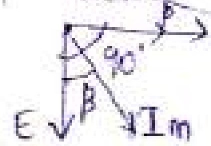
$$T_d \propto I_m \cos(90^\circ + \alpha)$$



Case 2

The moving coil is assumed to be purely capacitive. Then the current I_m leads the emf by an angle β and therefore the deflecting torque is

$$T_d \propto I_m \cos(90^\circ - \beta)$$

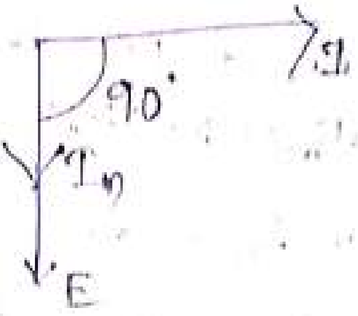


Case III

The inductive reactance is support to be equal to the capacitive reactance, there fore the ckt is under resonance condition. ($X_L = X_C$) So the moving coil ckt is purely resistive and I_m is inphase with E.

$T_d \propto I_m \cos 90° = 0$

$T_d \propto I_m$



The pointer does not move or the pointer is act as equilibrium when $X_L = X_C$.

For high frequency $X_L > X_C$

For low frequency $X_L < X_C$

Advantage :-

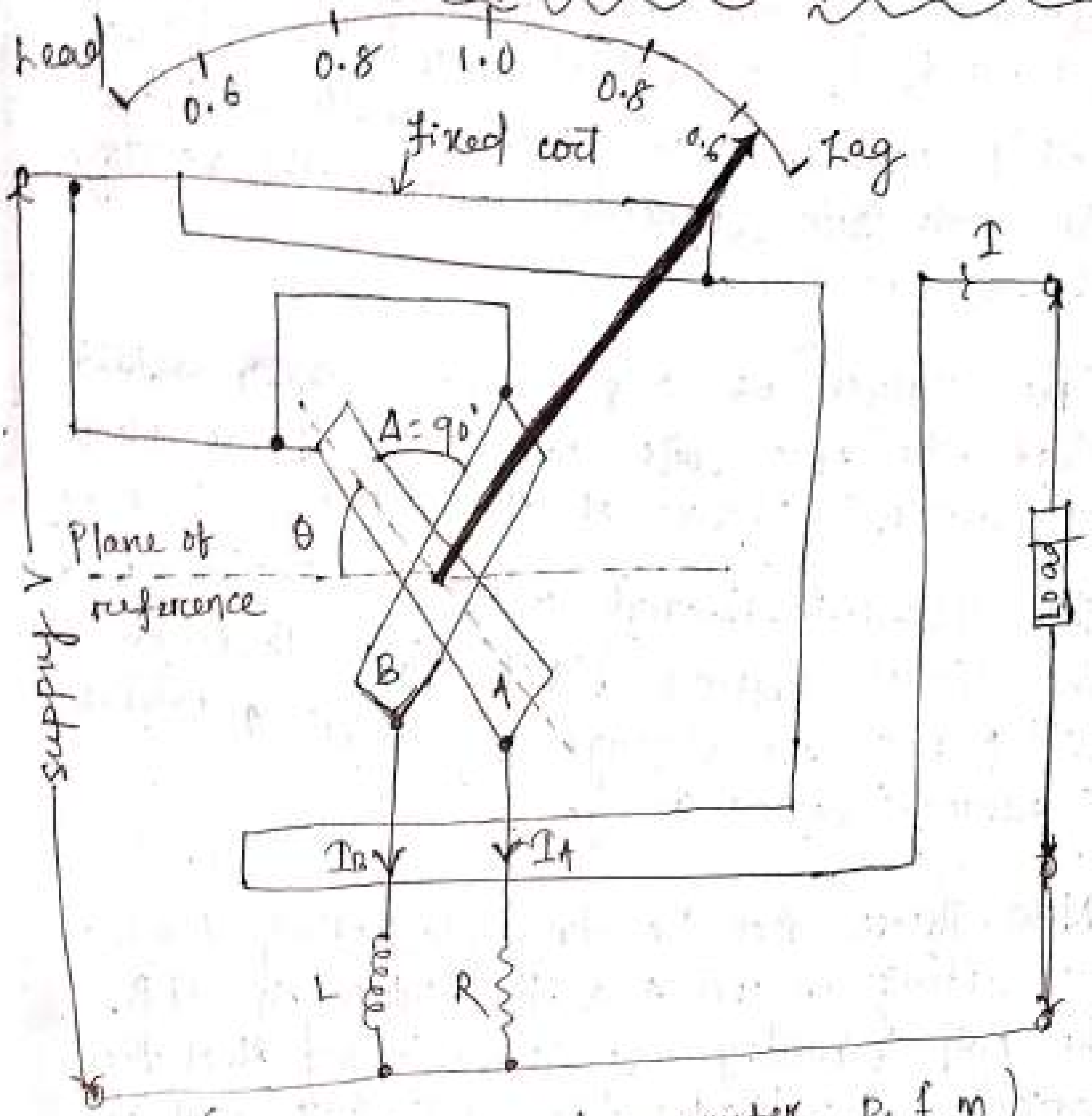
→ It is highly sensitive

→ It can be used for measurement of wide range of frequency.

Disadvantages :-

→ It is costly.

Single-ϕ Electrodynamometer power factor meter



(single-ϕ electrodynamometer p.f.m)

→ It consists of fixed coil which acts as the current coil. This coil is split up into two parts and carries the current of the circuit under test.

→ Therefore, the magnetic field produced by this coil is proptional to the main current.

→ Two identical Pressure coil A & B pivoted on a spindle constitute the moving system.

→

→ Pressure coil A has a non inductive resistance R connected in series with it, and coil B has a highly inductive choke coil 'L' connected in series with it. The two coils are connected across the voltage of the circuit.

→ The values of R & L are so adjusted that the two coils carry the same value of current at normal frequency i.e R = ωL

→ The current through coil A is in phase with the circuit voltage while that through coil B lags the voltage by angle A which is nearly equal to 90°.

→ Now, there will be two deflecting torque one acting on coil A & the other on coil B. The coil winding are so arranged that the torque due to the two coils are opposite direction. Therefore the pointer will take up a position where these two torques are equal.

→ Let us consider in the case of lagging power factor of $\cos\phi$.

Deflecting torque acting on coil A is -

$T_A = KVI\,M_{max}\cos\phi\,\sin\theta$

θ = angular deflection from the plane of reference,

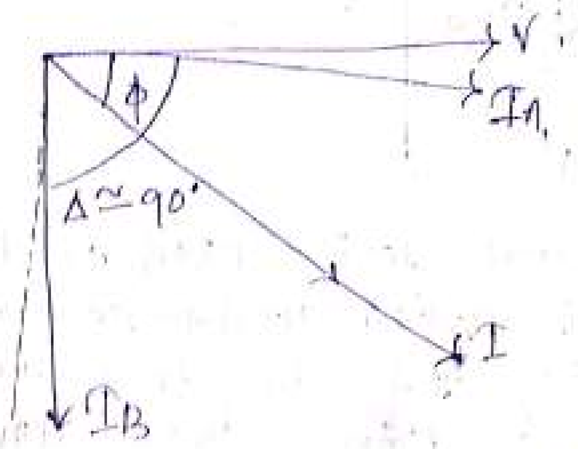
and M_{max} = maximum value of mutual inductance between the two coils.

This torque says acts in the clockwise direction.

→ Deflecting torque acting on coil B is:-

$T_B = KVI M_{max} \cos(90° - \phi) \sin(90° + \theta)$

$= KVIM_{max} \sin\phi \cos\theta$



The coils will take up such a position that the two torque are equal.

Hence at equilibrium $T_A = T_B$

or, $KVIM_{max} \cos\phi \sin\theta = KVIM_{max} \sin\phi \cos\theta$

or, $\theta = \phi$

Therefore the deflection of the instrument is measure of phase angle of the circuit. The scale of the instrument can be calibrated directly in term of power factor.

$\cos\phi \cdot \sin\theta = \sin\phi \cdot \cos\theta$

$\frac{\sin\theta}{\cos\theta} = \frac{\sin\phi}{\cos\phi} \Rightarrow \tan\theta = \tan\phi$

$= \boxed{\theta = \phi}$

CHAPTER - 06

Measurement of Resistance Chapter - 7

Classification of Resistor :-

- Low resistance $R \leq 1$
- midium resistance $1 < R < 100K$
- High resistance . $R > 100\,\Omega$

Low Resistance :-

All resistancess of the oder $1\,\Omega$ or less then $1\,\Omega$ are classified as low resistance.

Eg → Series field resistance, Armeture

Medium Resistance :-

This class include resistance from $1\,\Omega$ to $100K\,\Omega$.

Eg - shunt field resistance, incandescent lamp.

High resistance :-

Resistance of the order $100K\,\Omega$ and upward as classified as high resistance.

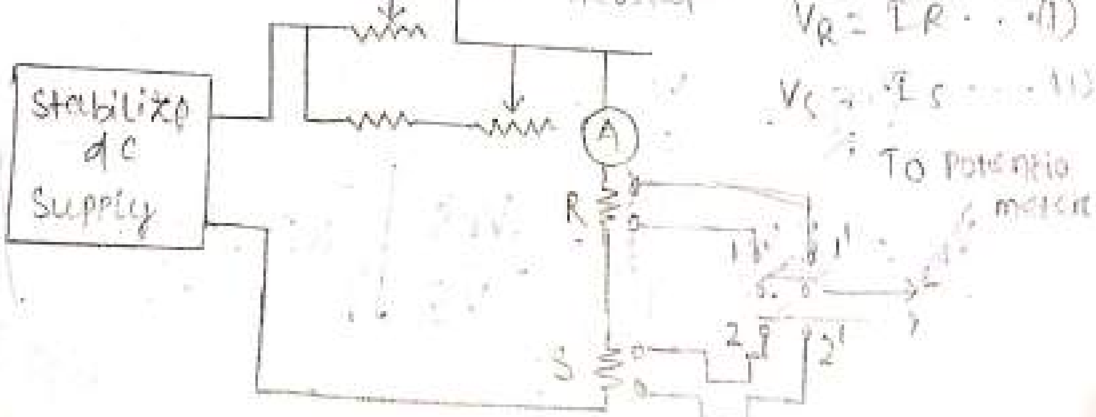
Eg - Insulation resistance.

Measurment of low Resistences :-

Potentio meter method :-

$V_R = IR$ . . (1)

$V_S = IS$ . . (2)



R is a unknow resistor which is connected in series with the standard resistor S. The current through the circuit is controlled by the rheostat.

→ A 2 Pole double through switch is use in the circuit. when this switch is Put in position 1 and 1' it connect to the unknown resistance to the potention meter. so 8.

Suppose the reading of the Potentio meter is $V_R = IR$ ... (1)

$$I = \frac{V_R}{R} \quad \text{....(2)}$$

Now again the switch put in the Position of 2 & 2' and it connect standard resistance to the potentio meter.

So the reading of the Potentio meter is V_S

$$V_S = IS \quad \text{....(3)}$$

$$I' = \frac{V_S}{S} \quad \text{....(4)}$$

Comparing equation (2) & (4)

$$\frac{V_R}{R} = \frac{V_S}{S}$$

$$V_R = \frac{RV_S}{S}$$

$$\boxed{R = \frac{V_R S}{V_S}}$$

$$\boxed{R = \frac{V_R}{V_S} \cdot S}$$

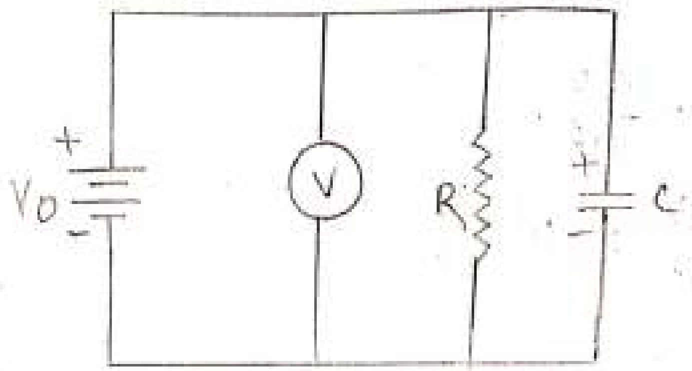
Scince the value of standard resistance as is know. the value of R can also be known.

This method is suitable for Low resistance.

Dt → 26/02/13

Measurement of High Resistance :-

Loss of charge Method :-



In this method the insulation resistance R is measured. which is connected in parallel with a capacitor c and an electro-static voltmeter.

The capacitor is charge by means of a battery, having voltage V_0. Then the capacitor is allow to discharg through the resistance.

The current through the capacitor at time T second

$$i = \frac{-dq}{dt} \quad \text{----(I)}$$

$$i = \frac{V}{R} \quad \text{----(II)}$$

Now $q = CV \qquad dq = Cdv$

Putting the value of dq in eqn (1)

$$i = -c\frac{dv}{dt} \quad \text{------ (ii)}$$

Again

$$i = \frac{v}{R} \quad \text{------ (iii)}$$

from eqn 2 & 3

$$\frac{v}{R} = -c\frac{dv}{dt}$$

$$\Rightarrow \frac{v}{Rc} = -\frac{dv}{dt}$$

$$\Rightarrow \frac{v}{Rc} + \frac{dv}{dt} = 0$$

Let $\frac{d}{dt} = D$

$$\frac{v}{Rc} + Dv = 0$$

$$\Rightarrow v\left(\frac{1}{Rc} + D\right) = 0$$

$$\Rightarrow \left(\frac{1}{Rc} + D\right) = 0$$

$$= \boxed{D = -\frac{1}{Rc}}$$

GS =

$$v = CF + PI$$

$$C.F = ke^{Dt} = ke^{\frac{-1}{Rc}t}$$

$$= Ke^{-\frac{t}{RC}}$$

$$P.I = 0$$

$$V = CF + PI = Ke^{-t/RC} \quad \ldots (4)$$

~~know that~~

Now let $t = 0$ $V = V_0$ $\quad [e^0 = 1]$

$$V_0 = Ke^{-0/RC} \Rightarrow \boxed{V_0 = K}$$

By puting the value of K in eq^n 4

we get

$$V = V_0 e^{-t/RC}$$

$$\Rightarrow \frac{V}{V_0} = e^{-t/RC}$$

Taking log on both side

$$\log \frac{V}{V_0} = \log e^{-t/RC} \quad [\log \frac{a}{b} = \log a - \log b]$$

$$= \ln V - \ln V_0 = -\frac{t}{RC} \log e \quad [\log_{10} x = \ln x]$$

$$[\log e^n = n \log e]$$

$$= -\frac{t}{RC} \quad [\log e = 1]$$

~~$\log(\ln V_0 - \ln V) = +t/RC$~~

$$\Rightarrow \ln V_0 - \ln V = \frac{t}{RC}$$

$$\boxed{R = \frac{1}{C} \cdot \frac{t}{\ln \frac{V_0}{V}}}$$

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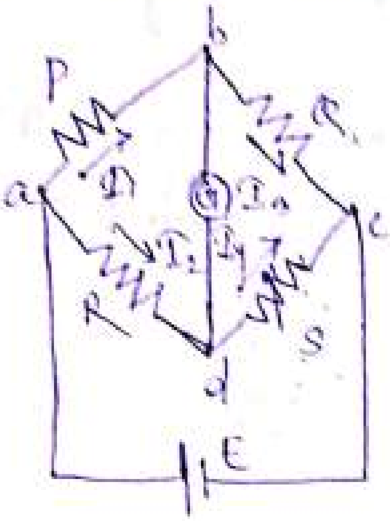
Measurement of Medium Resistance by Wheatstone bridge method :-



→ A very important device used in the measurement of medium resistances is the Wheatstone Bridge. A Wheatstone bridge has been in use longer than almost any electrical measuring instrument.

→ It has four resistive arms, consisting of resistances P, Q, R and S together with a source of emf, usually a Galvanometer 'G' or other sensitive current meter.

→ For bridge balance, we can write

$I_1 P = I_2 R$ ——(i)

For the galvanometer current to be zero, the following conditions also exist:-

$I_1 = I_3 = \frac{E}{P+Q}$ ——(ii)

& $I_2 = I_4 = \frac{E}{R+S}$ ——(iii)

Where E = emf of the battery.

combining eq^n 1, 2, & 3 and simplifying we obtain –

$$\frac{P}{P+Q} = \frac{R}{R+S} \text{ ——— (4)}, \quad PR + PS = PR + QR$$

from which $QR = PS$ ——— (5)

equation (5) is the well known expression for the balance of Wheatstone bridge. If three of the resistances are known, the fourth may be determined from eq –(5) we obtained :–

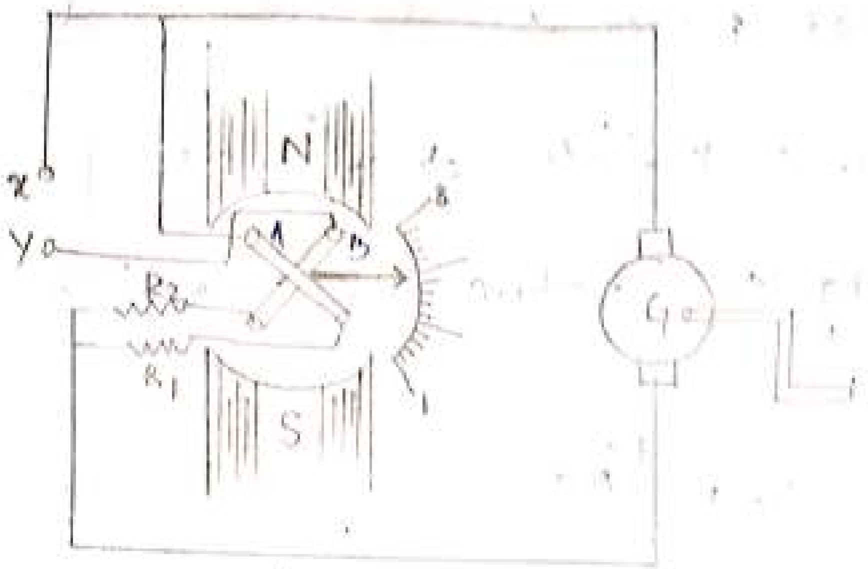
$$R = S \cdot P / Q$$

where 'R' is the unknown resistances, S is called the 'standard arm' of the bridge and P & Q are called the 'ratio arms'.

– o –

Meggers—

Meggers are the instrument which measure the electric insulation resistance of the electric circuit.



(megger)

Construction :—

It consists of a hand driven dc generator and an ohm meter. The ohm meter consists of 2 coils A and B.

→ The pointer is attached to the spindle which moves over a calibrated scale.

→ The two coils are kept inside a permanent magnetic field.

→ Let R_1 & R_2 be the 2 resistance of the coil A and B.

→ The terminal x & y are used to connect the resistance whose value measured.

Let I_A = current in the coil A
I_B = current in the coil B

$T_A \propto I_A \cos\theta$

$T_B \propto I_B \cos(90-\theta)$

$\Rightarrow T_B \propto I_B \sin\theta$

At equilibrium condition

$T_A = T_B$

$\Rightarrow I_A \cos\theta = I_B \sin\theta$

$\Rightarrow \frac{I_A}{I_B} = \frac{\sin\theta}{\cos\theta} = \tan\theta$

$\theta = \tan^{-1}\left(\frac{I_B}{I_A}\right)$

$= \tan^{-1}\left(\frac{V/R_1}{V/R_2}\right)$

$\theta = \tan^{-1}\left(\frac{R_2}{R_1}\right)$

$\frac{I_A}{I_B} = \frac{\sin\theta}{\cos\theta} = \tan\theta$.

$\theta = \tan^{-1}\left(\frac{I_A}{I_B}\right)$

$= \tan^{-1}\left(\frac{V/R_1}{V/R_2}\right) = \theta = \tan^{-1}\left(\frac{R_2}{R_1}\right)$

By knowing the value of angle θ, R_1 and R_2 will be found out.

Dt → 06/03/13

Frequency meters :-

It is of two type.

(1) mechanical

(2) Electrical Resonance type

Maxwell's variable inductance Bridge :-

The value of
$R_1 = R_1$
$L_1 = jwL_1$
$C_1 = \frac{1}{jwC_1}$

Let L_1 is the unknown inductance
R_1 is the unknown Resistance
R_2 is the variable resistance
L_2 is the variable inductance with internal resistance r_2
R_3 & R_4 is the known resistances

At balance condition :-

$$Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow (R_1 + jwL_1)R_4 = (R_2 + r_2 + jwL_2)R_3$$

$$\Rightarrow R_1R_4 + jwL_1R_4 = R_2R_3 + R_3r_2 + jwL_2R_3$$

$$\Rightarrow R_1R_4 - R_2R_3 - R_3r_2 = jwL_2R_3 - jwL_1R_4$$

$R_1R_4 - R_2R_3 - R_3r_2 = 0$

$\Rightarrow R_1R_4 = R_3(R_2 + r_2)$

$$R_1 = \frac{R_3(R_2 + r_2)}{R_4}$$

$j\omega L_2R_3 - j\omega L_1R_4 = 0$

$j\omega L_2R_3 = j\omega L_1R_4$

$j\omega(L_2R_3 - L_1R_4) = 0$

$(L_2R_3 - L_1R_4) = 0$

$$L_1 = \frac{L_2R_3}{R_4}$$

$T_d \propto I_A \cos\theta$

$T_D \propto I_B \sin\theta$

$\cos(90 - \theta)$

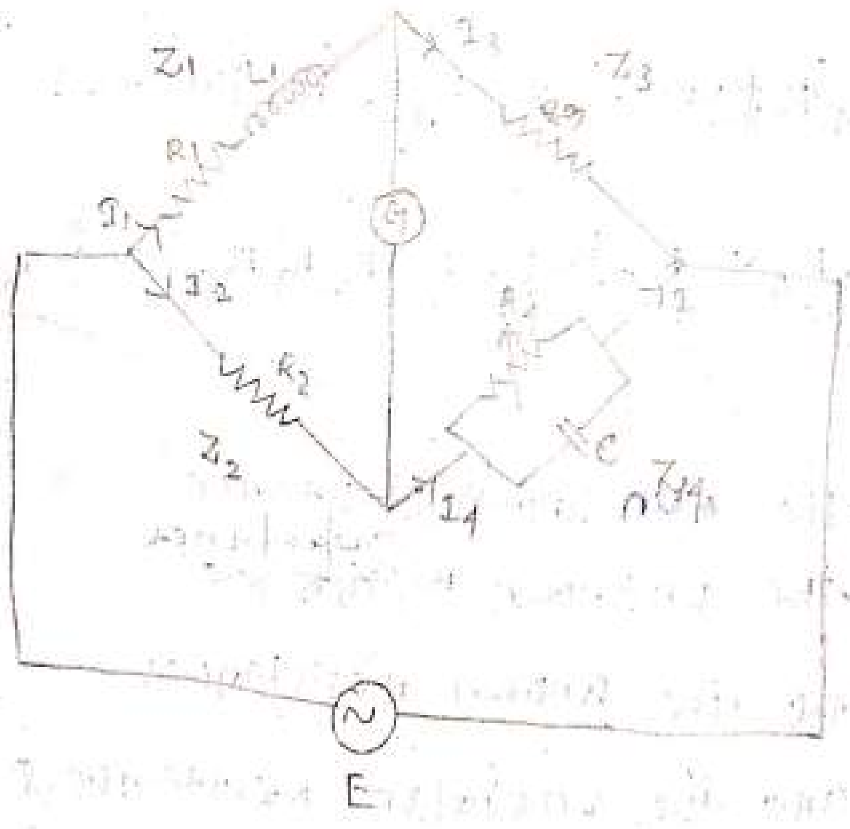
$\sin\theta$ ...

$\frac{\cos\theta}{\sin\theta} =$

$\theta = \left(\frac{R_L}{R}\right) \frac{1}{R_1} \frac{1}{R_2}$

Dt→12/02/13

Maxwell's inductance & capacitance Bridge :-



At balance condition:-

$$Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow (R_1 + j\omega L_1)\left(\frac{R_4 X_C}{R_4 + X_C}\right) = R_2 R_3$$

$$= (R_1 + j\omega L_1)\left(\frac{R_4 \frac{1}{j\omega C}}{R_4 + \frac{1}{j\omega C}}\right) = R_2 R_3$$

$$= (R_1 + j\omega L_1)\left(\frac{\frac{R_4}{j\omega C}}{\frac{R_4 j\omega C + 1}{j\omega C}}\right) = R_2 R_3$$

$$= (R_1 + j\omega L_1)\left(\frac{R_4}{R_4 j\omega C + 1}\right) = R_2 R_3$$

$$= R_4(R_1 + j\omega L_1) = R_2 R_3 (R_4 j\omega C + 1)$$

$$= R_1 R_4 + R_4 j\omega L_1 = R_2 R_3 R_4 j\omega C + R_2 R_3$$

Here

R_1 is the unknown resistance

L_1 is the unknown inductance

$R_2 R_3$ are the known resistances

$R_4 C$ are the variable Resistance & capac

$\Rightarrow R_1R_4 - R_2R_3 = R_2R_3R_4 jwC - R_4 jwL_1$

$R_1R_4 - R_2R_3 = 0$

$R_1R_4 = R_2R_3$

$$R_1 = \frac{R_2R_3}{R_4}$$

$R_2R_3R_4 jwC - R_4 jwL_1 = 0$

~~$R_2R_3R_4jwC =$~~

$R_4 jw(R_2R_3C - L_1) = 0$

$\Rightarrow R_2R_3C - L_1 = 0$

$$\Rightarrow L_1 = R_2R_3C$$

Quality factor :-

Quality factor is the ratio of the inductance to resistance.

$$Q = \frac{wL_1}{R_1} = \frac{w(R_2R_3C)}{\frac{R_2R_3}{R_4}} = \frac{wR_3C}{R_4} = wCR_4$$

$$Q = wCR_4$$

Advantages:-

→ The 2 balance equation are independent if we chose R_1 & C as variable element.

→ The frequency does not appear in any one of 2 eqn.

Disadvantage:-

→ This bridge required a variable standard capacitor which may be very expensive.

→ The bridge is limited to measurement of low quality factor.

CHAPTER - 07

Sensor and transducer

(***) **Transducer** -: Transducer is a device which converts the energy from one form to another. (Convert mechanical force into electrical signal) Ex-: used in industrial instrumentation etc.

* An electronic instrumentation system consists of a no. of components to perform a measurement and record its results.
* In general measurement system consists of three major component
a> An input device.
b> A signal conditioning or processing device.
c> An output device.
* The input device receives the measurand or the quality under measurement and delivers a proportional or analogous electrical signal to the signal conditioning device.
* Here the signal is amplified, attenuated, filtered, modulated or modified in such a format, so that it is acceptable by the output device.
* The input quantity for most instrumentation system is a "non-electrical quantity". In order to use electrical methods & techniques for measurement, manipulation or control, the non-electrical quantity is generally converted into an electrical form by a device called a "transducer". (***)
* Example -: Mobile phone -: (converts the sound into electrical signals and then amplifies it into the preferred range. Then, alters the electrical signals into audio signals at the o/p of the speaker.
* Transducer contains two important parts.
a> Sensing or Detector element.
b> Transduction element.

Sensing or Detector Element -: A detector or a sensing element is that part of a transducer which responds to a physical phenomenon or a change in a physical phenomenon.

* Here the response of the sensing element must be closely related to the physical phenomenon.

Transduction element :-

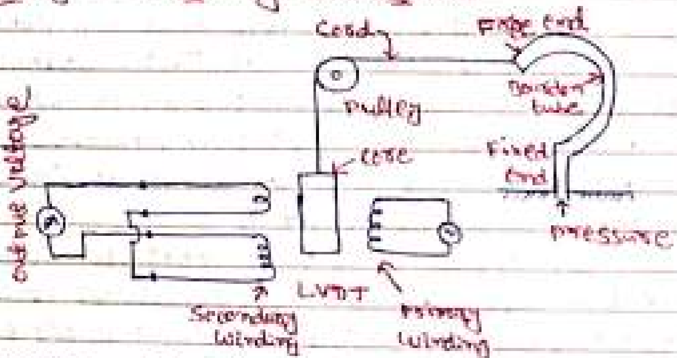
* A transduction element transforms the output of a sensing element to an electrical output.
* Here the transduction element, in a way, acts as a secondary transducer.

classification of transducers :-

* The transducers can be classified

a) on the basis of transduction form used (on the basis of resistance, capacitance, inductance)
b) As primary and secondary transducers.
c) As passive and active transducers.
d) As analog and digital transducers.
e) As transducers and inverse transducers.

Primary & secondary transducers



* Consider a Bourdon's tube, which is set up as shown in figure above.
* This tube acting as a primary detector senses the pressure and converts the pressure into a displacement of its free end side.
* The displacement of the free end moves the core of a linear variable differential transformer (LVDT) which produces an output voltage.

analogous :- comparable in certain respects.

* This voltage is proportional to the movement of a core, which is proportional to the displacement of the free end & is proportional to the pressure.
* Here two stages of transduction occured. Firstly the pressure is converted into a displacement by bourdon tube then the displacement is converted into an analogous voltage (output voltage) by LVDT.
* The bourdon tube is called a "primary transducer" while the L.V.D.T is called a secondary transducer".
* LVDT :- The linear variable differential transformer is a type of electrical transformer used for measuring linear displacement.

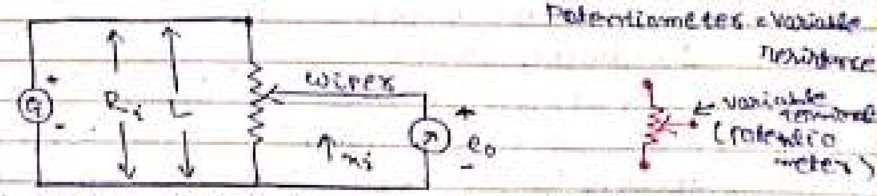
Passive & active transducers -

Passive transducers :-

* Passive transducers required an auxiliary power source for transduction. So it is also called as "externally powered transducers".

Ex- passive transducers are resistive, inductive and capacitive transducers.

* Let us take a passive transducer called "POT" (Linear potentiometer)
* The "POT" is a resistive transducer powered by a source voltage (e_i) and used for measurement of linear displacement (x_i).

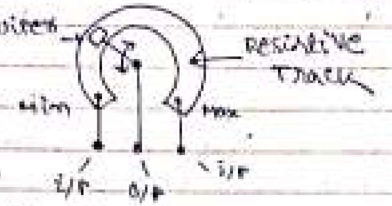


* If 'L' is the total length of potentiometer.

R_i = total resistance.
x_i = input displacement.

output voltage $e_o = \frac{x_i}{L} e_i$ or $x_i = \left(\frac{e_o}{e_i}\right) L$

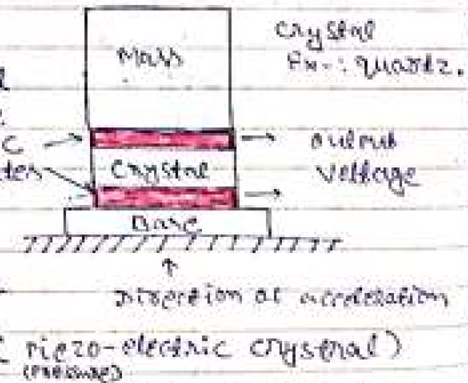
* Potentiometer =



* used in Radio, fan regulator etc.

Active Transducers :-

* Active Transducers are that type of transducers in which an auxiliary power source is not required to produce their output.
* This type of transducers develop their own output voltage or current, hence they are called as self generating type transducers.
* velocity, temperature, light intensity and force can be transduced with the help of active transducers.
* let us take an example of a piezoelectric crystal, which is used for measurement of acceleration.
* Here the crystal is sandwiched between two metallic electrodes and the base is supported the entire structure.



* Now, a fixed mass is placed on the top of the sandwich crystal.
* The property of the piezo-electric crystals is that when a force is applied to them, they produce an output voltage.
* when the acceleration is applied to the base, due to which the mass produces a force and output voltage will be generated.

* If we fixed the mass, then the force is proportional to acceleration and also to the output voltage.
* This transducer is called as "accelerometer" which converts acceleration into electrical voltage & does not need any auxilliary power.

Analog transducers :-

* These transducers convert the input quantity into an analog output which is a continuous function of time.

Ex-: LVDT, strain gauge, thermistor etc.

* Thermistor -: An electrical resistor whose resistance is reduced by heating, used for measurement & control.
* Continuous function -: small change in input = small change in o/p.

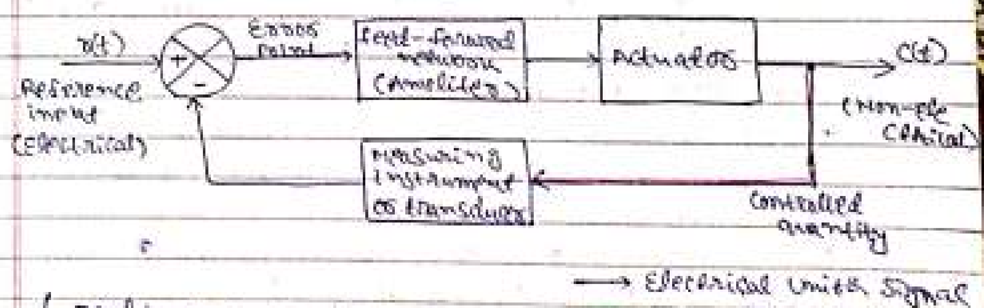
Digital Transducers :-

* These transducers convert the input quantity into an electrical output which is in the form of pulses.
* Discontinuous function -: small change in input = large change in o/p

Ex-: Glass scale, metal scale.

Transducer -: A transducer can be defined as a device which converts a non-electrical quantity into an electrical quantity.

Inverse Transducer -: An inverse transducer is defined as a device which converts an electrical quantity into a non-electrical quantity.



(Feedback control system
for control of non-electrical quantities)

* output - non electrical signal, input - electrical signal
* The controlled quantity is measured & converted into an analogous quantity by transducers which form the feedback loop.
* The loop input quantity (electrical in nature) is compared with the electrical quantity proportional to the output in a comparator.
* In this case, the two signal are not equal, so an error signal is produced.
* This error signal is amplified and applied to an actuator in the forward path, which corrects the output quantity till the output quantity reaches the desired level.
* actuator - a device that causes a machine or other device to operate.

Resistive transducers -

* Resistive transducers are used to measure the change of resistance and it is a very suitable method for both the cases. (alternating current & voltage, direct current & voltage).

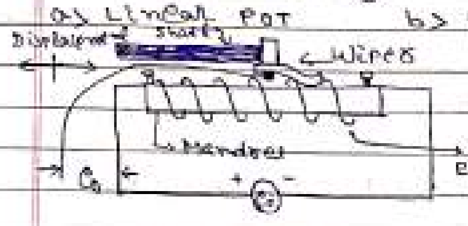
* $R = \rho l/A$

R = resistance (Ω)
l = length of the conductor (m)
A = cross-sectional area of conductor (m²)
ρ = resistivity of conductor (Ω-m)

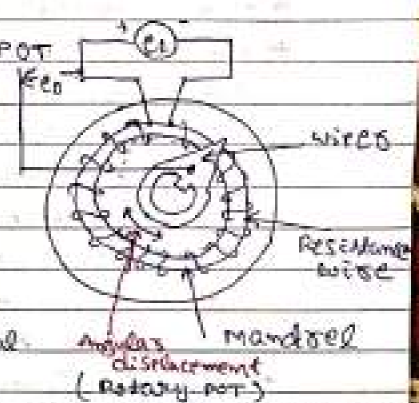
Ex - POT (potentiometer)

* POT consists of a resistive element provided with a sliding contact. This sliding contact is called a wiper.
* The motion of the sliding contact may be translatory or rotational.
  - translatory → the motion in which all the particle of a body move through the same distance in the same time.

* POT are of several type.
  a) Linear POT b) Rotary POT



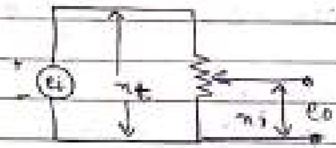
(Linear pot)



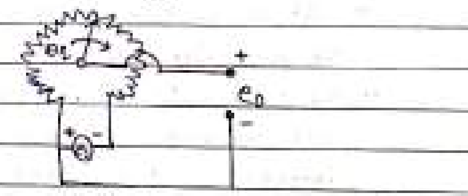
(Rotary pot)

Mandrel - a cylindrical rod of metal.

Angular displacement -
* Angular displacement of a body is the angle in radians through which a point revolves around a centre or line has been rotated in a specified sense about a specified axis. θ (radian)
* Some pots use the combination of the two motion i.e. (translational & rotational).
* These POTS have their resistive element in the form of a helix and therefore, they are called helipots.



(Linear pot)



(Rotational) (Helimet)

* Helix - It is a type of smooth space curve i.e. a curve in three-dimensional space.
* The translational resistive elements are straight device (2 mm to 0.5 m)
* The rotational devices are circular in shape and are used for measurement of angular displacement.
* They may have a full scale angular displacement as small as 10°.

* It may provide accurate measurement upto 357°.
* Multiturn potentiometers may measure upto 3500° of rotation through use of helipots.
* It can be used for measurement of either translational or rotary motion.
* The resistive element of the POT may be excited by either d.c or a.c voltage.

Adv. -:

* They are inexpensive.
* They are simple to operate and are very useful for measurement of displacement & Angular displacement.
* Their electrical efficiency is very high and they provide sufficient output.

Disadvantage -:

* Linear POT is required a large force to move their sliding contacts (wiper)
* The ~~other problems~~ are ~~generate noise~~ ~~its can be contaminated~~
* It will create or generate noise during the operation

Strain Gauges -:

* If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both length & diameter of conductor change.
* Thus resistivity of the conductor will also be change.
* This property of the conductor is called as Piezoresistive effect & the resistance strain Gauges are also known as piezoresistive gauges.
* This device is used for measurement of stress and strain.
* Stress = $\frac{\text{Force}}{\text{Cross Section Area}}$

$$\boxed{\sigma = \frac{F}{A}}$$

Bourdon tubes,
Bell Gauge.

* strain = $\frac{\text{Extension (change in length)}}{\text{original length}}$

$$\varepsilon = \frac{\Delta L}{L}$$

* $$Y = \frac{\sigma}{\varepsilon}$$ Y = Young's Modulus.

* Gauge factor = G_f = $\frac{\text{Change in resistance}}{\text{strain}} = \frac{\Delta R / R}{\Delta L / L}$

Theory of strain Gauges:

* If we apply force to a elastic material, the longitudinal dimension will be increase & lateral dimension will be decrease. (length = increase, area of cross section = decrease)

* Here L = length ΔL = Change in length
  A = Area ΔA = Change in Area
  D = Dimeter ΔD = Change in Dimeter
  R = Resistance. ΔR = Change in resistance.

* we known $R = \rho \frac{L}{A}$ —(i) (find ΔR/R)

To find ΔR, differentiate the above Eqn with respect to stress 's'.

$$\frac{dR}{dS} = \frac{\rho}{A}\frac{\partial L}{\partial S} - \frac{\rho L}{A^2}\cdot\frac{\partial A}{\partial S} + \frac{L}{A}\frac{\partial \rho}{\partial S} \quad \text{— (ii)}$$

$(A' = -A^{-2})$

Dividing $R = \rho L/A$ on both side

$$\frac{1}{R}\frac{dR}{dS} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{1}{A}\frac{\partial A}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S} \quad \text{— (iii)}$$

we known Area (A) $= \pi r^2$ $(D = 2r \Rightarrow r = D/2)$

$$= \pi\left(\frac{D}{2}\right)^2 = \frac{\pi}{4}D^2$$

$$\frac{\partial A}{\partial S} = 2\cdot\frac{\pi}{4}\cdot D\cdot\frac{\partial D}{\partial S} \quad \text{— (iv)}$$

$\updownarrow D \; \ell \leftarrow D$

∂L

Divide area $(A) = \frac{\pi}{4} D^2$ in eqn (iv)

$$\Rightarrow \frac{1}{A}\frac{\partial A}{\partial S} = \frac{(2\pi/4) D \cdot \frac{\partial D}{\partial S}}{(\pi/4) D^2} = \frac{2}{D} \cdot \frac{\partial D}{\partial S} \quad \text{--- (v)}$$

put the value of eqn (v) in eqn (iii)

$$\frac{1}{R}\frac{dR}{dS} = \frac{1}{L} \cdot \frac{\partial L}{\partial S} - \frac{2}{D} \cdot \frac{\partial D}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S} \quad \text{--- (vi)}$$

Now, poisson's ratio (ν) or (μ) = $\frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{-\partial D/D}{\partial L/L}$ ← diameter reduce

$$\Rightarrow \partial D/D = -\nu \times \frac{\partial L}{L} \quad \text{--- (vii)}$$

Put the value of eqn (vii) in eqn (vi)

$$\frac{1}{R}\frac{dR}{dS} = \frac{1}{L} \cdot \frac{\partial L}{\partial S} + \frac{2\nu}{L}\frac{\partial L}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S} \quad \text{--- (viii)}$$

for small variations, $\frac{dR}{dS} = \Delta R$ (↑ Delta), $\frac{\partial L}{\partial S} = \Delta L$, $\frac{\partial \rho}{\partial S} = \Delta \rho$

$$\text{then } \frac{\Delta R}{R} = \frac{\Delta L}{L} + 2\nu\frac{\Delta L}{L} + \frac{\Delta \rho}{\rho} \quad \text{--- (ix)}$$

we know $G_f = \frac{\Delta R/R}{\Delta L/L} = \frac{\frac{\Delta L}{L} + 2\nu\frac{\Delta L}{L} + \frac{\Delta \rho}{\rho}}{\Delta L/L}$

~~then $\frac{\Delta R}{R} = G_f \cdot \frac{\Delta L}{L}$~~

~~$\Rightarrow \frac{\Delta R}{R} = G_f \times \varepsilon$~~

$$= 1 + 2\nu + \frac{\Delta \rho/\rho}{\Delta L/L} \quad (\Delta L/L \to \varepsilon)$$

$$= 1 + 2\nu + \frac{\Delta \rho/\rho}{\varepsilon}$$

- 1: Resistance change due to change of length
- 2ν: Resistance Change due to change of Area
- $\frac{\Delta \rho/\rho}{\varepsilon}$: Resistance Change due to change in piezo resistive effect

* If we neglected the resistivity of the material

then $\boxed{G_f = 1 + 2\nu}$

* A resistance wire strain gauge uses a soft iron wire of small diameter. The gauge factor is 4.2. Neglecting the piezo-resistive effects, calculate the poisson's ratio.

$$G_f = 1 + 2\nu + \frac{\Delta\rho/\rho}{\varepsilon}$$

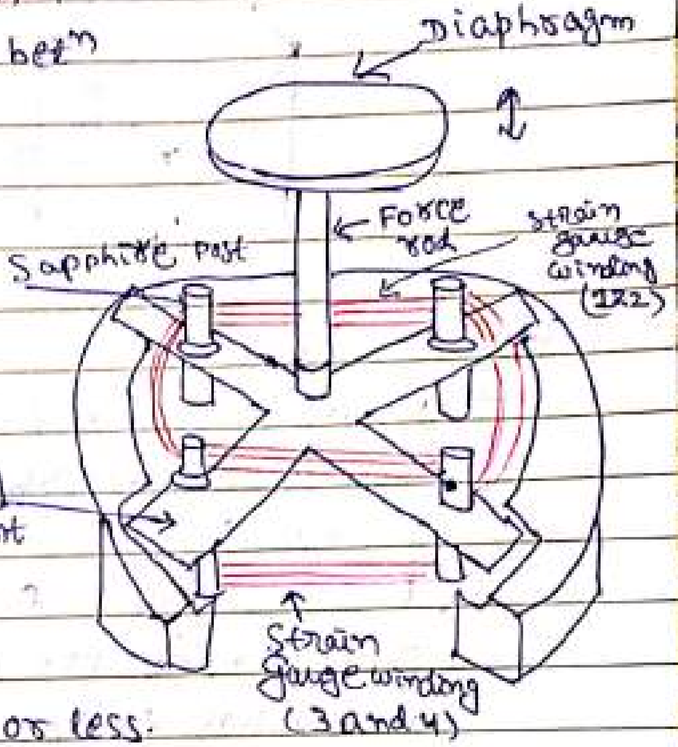
If piezoresistive effect is neglected,

$$G_f = 1 + 2\nu$$

$$\Rightarrow \nu = \frac{G_f - 1}{2} = \frac{4.2 - 1}{2} = 1.6 \text{ (Ans)}$$

Unbonded Metal Strain Gauges-:

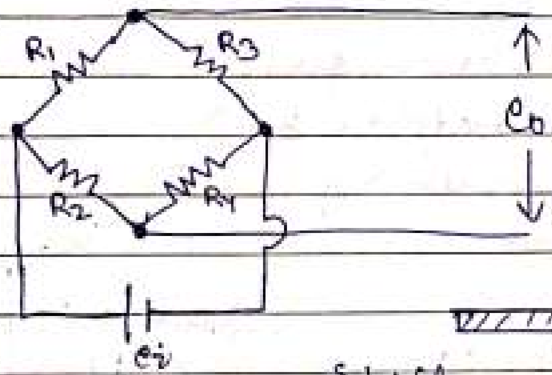
* In this figure a wire stretched betn two points in an insulating medium such as air.
* The wires is made of copper nickel alloys or nickel iron alloys. ~~or Chrome~~
* Diameter of the wire is 0.003 mm.
* Gauge factor (G_f) = 2 to 4
* Force = 2 mN
* length of the wire = 25 mm or less.

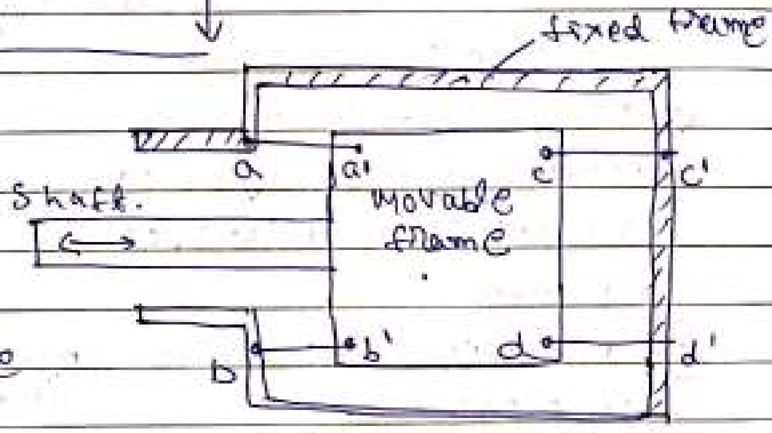


* Here a spring element is connected via a rod to a Diaphragm which is used for sensing of pressure.
* The unbonded metal wire gauges used for transducer applications, employ preload resistance wires connected in a wheatstone bridge.
* At initial preload, the strains and resistance of the four arms are equal and output voltage $e_0 = 0$.
* Application of pressure produces a small displacement which is about 0.004 mm (full scale).
* The displacement increase tension in two wires

and decrease it in the other two, thereby increase the resistance of two wires which are in tension and decreases ~~it in the other two~~ of the remaining two wires.

* Due to This unbalance of resistance, we can get output voltage
* Electric resistance of each arm is 120Ω to 1000Ω, the i/p voltage to the bridge is 5 to 10V. and the output of the bridge is 20mV to 50mV.





Construction :-

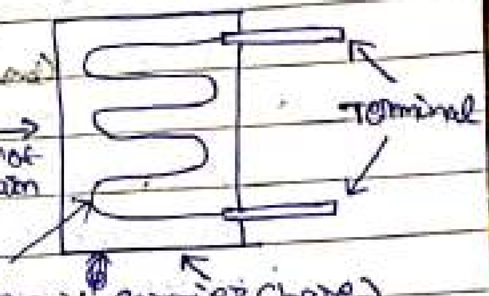
* It consist of fixed frame & a moveable frame.
* The moveable frame connected on a shaft which move under the application of force or strain which has to be measure.
* The 4 strain gauge wire having uniform cross section area and equal length are connected in such a manner that one end is connected to the fixed frame & other end is connected to the movable frame.
* The resistance of the wire are equal in magnitude
* This device is used for measurement of force, stress or displacement.
* Here the 4 strain gauge wire form a wheatstone bridge ckt.

work

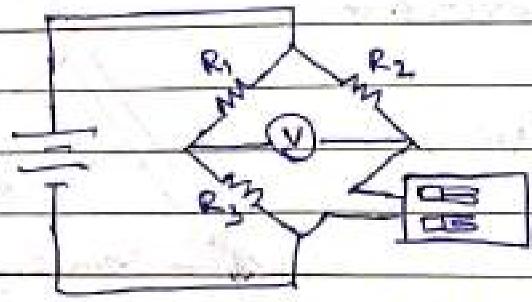
* If F is zero, then resistance of each strain gauge wire is equal in magnitude & we can get the output voltage ($e_0 = 0$).
* When we applied the force on the shaft the moving frame is move & it will change the resistance of the strain gauge wire. Due to change in resistance we can
* find the output.

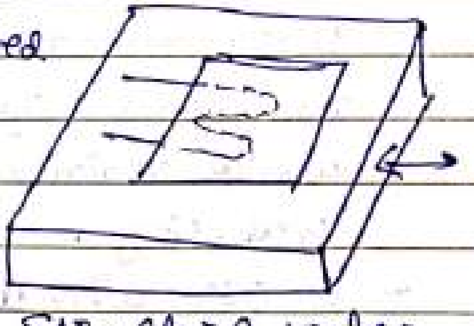
Bonded wire strain Gauges:-

* The bonded metal-wire strain gauges are used for both stress analysis and for construction of transducers.
* It consists of a thin sheet insulating material such as paper, bakelite. (cone type of plastic compound)
* Here, we consider a strain gauge (resistive type) wire of uniform cross sectional area and its diameter is about 0.025mm or less.



* This wire is uniformly semented betn two thin insulating material which prevent it from any mechanical damage.
* The spreading of wire permits a uniform distribution of stress over the grid.
* Here, two terminal are taken out from the wire and consider as terminal lead.
* This strain gauge is bounded with an additional material for study purpose.
* Here, the strain gauge is connected to a wheatstone bridge.





Structure under study.

* If we don't apply stress to the wire, then the

output will be zero. But if we apply stress on the strain gauge, then the value of resistance in the wheatstone bridge will be unequal & we can get the output.

* The resistance wire strain gauges should have the following characteristics.

a> The strain gauge should have a high value of gauge factor(Gf)

b> The resistance of the strain gauge should be as high as possible to minimize the effects of undesirable variations of resistance in the measurement circuit.

c> The strain gauge should not have any hysteresis effects in its response.

d> The strain gauges should have a low resistance temperature co-efficient. This is essential to minimise errors on account of temp. variations which affect the accuracy of measurements.

Resistance Thermometer -:

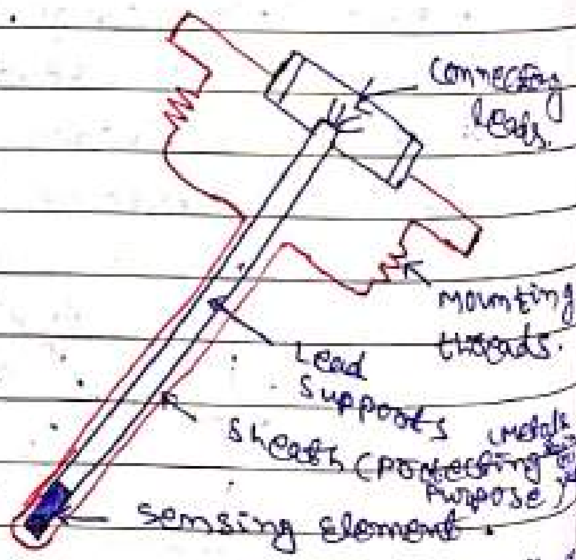
* The resistance of a conductor changes when its temp. is changed. This property is utilized for measurement of temperature.

* The variation of resistance (R) with temp. T(°K) can be represented by $R = R_0(1 + \alpha_1 T + \alpha_2 T^2 + \dots + \alpha_n T^n \dots)$

where R_0 = resistance at temperature T = 0 & $\alpha_1, \alpha_2, \alpha_3 \dots \alpha_n$ are constants.

* platinum is used in this thermometer as it can withstand high temperatures while maintaining excellent stability.

* we can also used Nickel and copper also.



Industrial platinum resistance thermometer

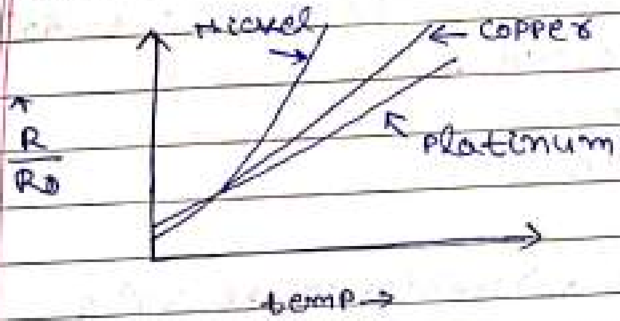
	Min	Max
* platinum -:	-260°C	110
* copper -:	0°C	180
* Nickel -:	-220°C	300

* requirements of a conductor material to be used in RTD are -:

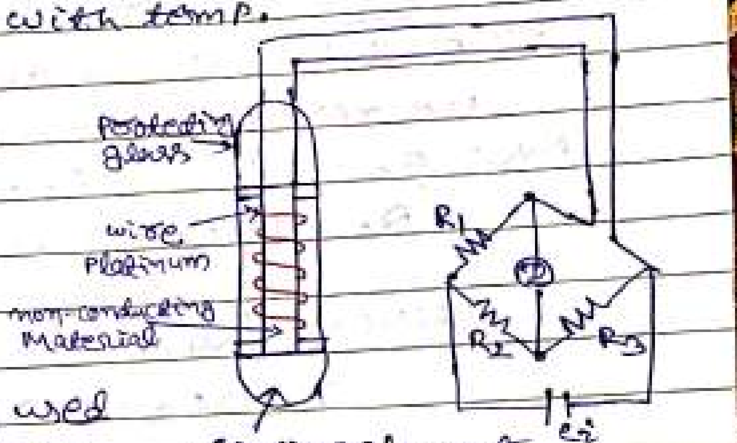
a> The change in resistance of material per unit change in temp. should be as large as possible (error minimize)

b> The material should have a high value of resistivity so that minimum volume of material is used for the construction of RTD.

c> The resistance of materials should have a continuous and stable relationship with temp.



(characteristics of materials used for resistance thermometers)



sensing element
(Lab type RTD)

* Supply electric supply to wheatstone bridge ckt.
* set the ~~resistance~~ Detector value to a null position (zero) by adjusting the resistance value.
* Then set the instrument according where we can measure the temp.
* The sensing element sense the temp.
* when temp rises, the length of the ~~wire~~ wire increases & when temp decrease, the length of the wire decreases, & we can get the resistance value by the help of detector.

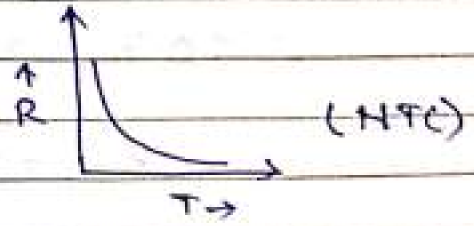
$$R = \frac{\rho L}{A}$$

Thermistors

* It is a semiconductor device whose resistance depends on temperature.
* It is also known as temperature sensitive resistance.
* It is of two type.

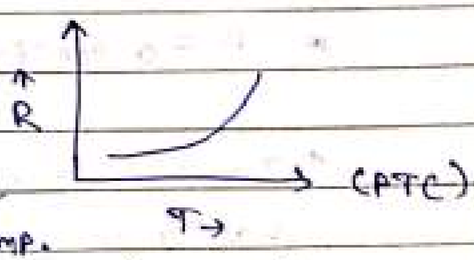
a) NTC (Negative temp. coefficient)

* Here resistance is decrease with increase in temp.



b) PTC (Positive temp. coefficient)

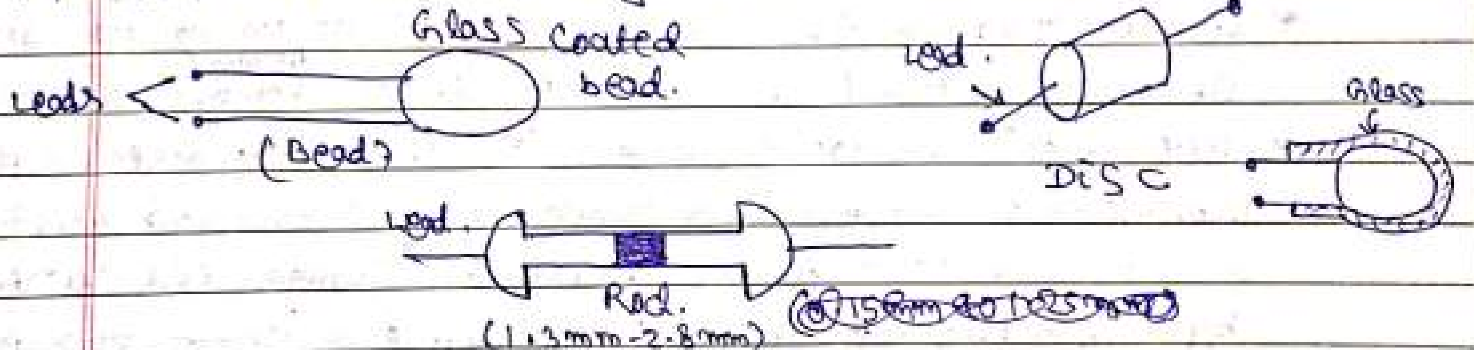
* Here resistance is increase with increase in temp.



* It more efficient then RTD because it measure very small change in temp.
* Measurement range of thermistor = -60°c to 15°C
* Resistance of thermistor = 0.5Ω to 0.75 MΩ

Construction

* Thermistors are composed of a mixture of metallic oxides such as nickel, cobalt, copper, iron etc.
* It is of several types.



* A thermistor in the form of a bead is smaller in size & the bead may have a diameter of 0.015mm to 1.25 mm.
* Beads may be sealed in the tips of solid glass rods to form probes. Glass probes have a diameter of 2.5 mm & length is 6mm to 50mm.
* Discs are made by pressing material under high pressure into cylindrical flat shapes with diameters 2.5mm to 25mm.

°C to K = 273.15

Resistance-Temperature characteristics of Thermistor:-

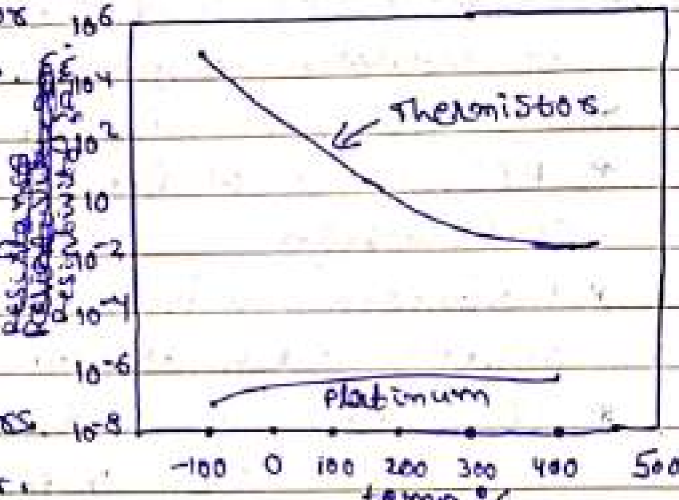
* mathematical expression for the relationship betn the resistance of a thermistor and absolute temp. of thermistor is

$$R_{T_1} = R_{T_2} \exp\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right] \quad \text{---} (1)$$

where R_{T_1} = resistance of the thermistor at absolute temp. T_1 ; °K

R_{T_2} = resistance of the thermistor at absolute temp. T_2 ; °K

* β = a constant depending upon the material of thermistor, typically 3500 to 4500 °K.



Resistance-temp. characteristics of a typical thermistor & platinum.

* In this graph, a thermistor has a very high -ve temp. co-efficient
* Here, we can see the resistance temp. characteristics of platinum which is commonly used material for resistance thermistors.
* Let us compare the char. of two materials.
* Betn -100°C to 400°C, the thermistor changes its resistivity from 10^5 to 10^{-2} Ωm, a factor of 10^7 while platinum changes its resistivity by a factor of about 10 within the same temp. range.
* This explains the high sensitivity of thermistors for measurement of temp.
* For a limited range of temp. (in case of linear approximation) will be

$$R_\theta = R_{\theta_0}[1 + \alpha_{\theta_0}\Delta\theta]$$

* An termistor curve can be represent as steinhart-Hart eqn $\boxed{\frac{1}{T} = A + B \cdot \log_e R + C(\log_e R)^3}$

T = temperature; °K

R = resistance of thermistor; Ω

A, B, C = curve fitting constants (3 data point on the curve)

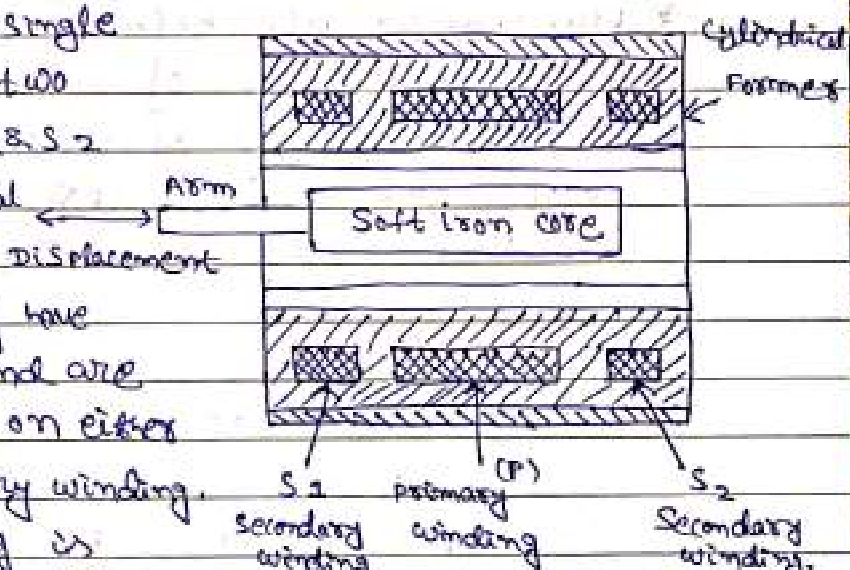
* If the Data point are choosen in betn 100°C then A simpler eqn is $\boxed{T = \frac{B}{\log_e R - A} - C}$

* Another eqn used for resistance - temp. curve of thermistors is $R_T = a R_0 \exp(b/T)$

R_T; R_0 = resistance of thermistor at temp T°K and ice point resepectively.

Linear variable Differential Transformer (LVDT)

* Most widely used inductive transducer is LVDT.
* The T/F consist of a single primary winding (P) & two secondary windings S_1 & S_2 wound on a cylindrical former.
* The secondary winding have equal no. of turns and are identically placed on eiter side of the primary winding.
* The primary winding is connected to an AC source.



(LVDT)

* A movable soft iron core is placed inside the former.
* The displacement to be measured is applied to the arm attached to the soft iron core.
* The core is made of nicuel, iron which is hydrogen annealed & it's permeability is high.

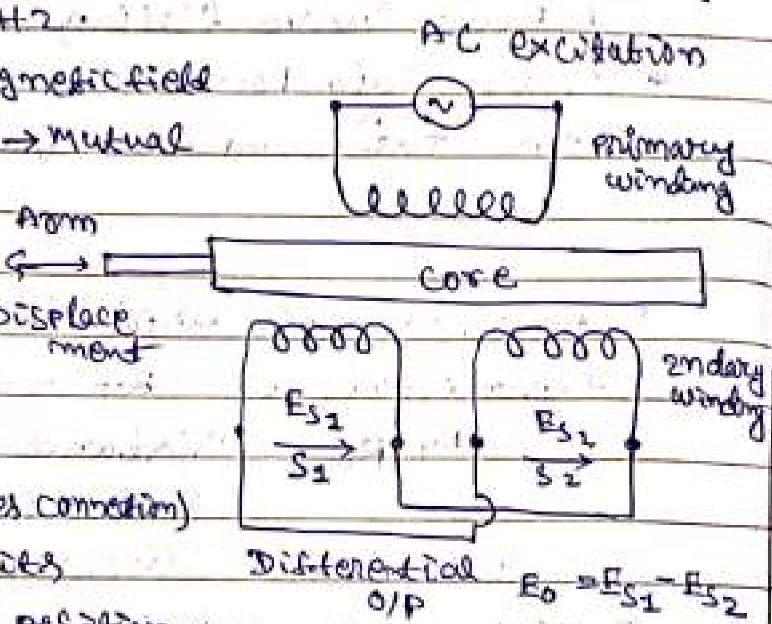
annealed: heat treatment to eliminate hydrogen.

permeability: ability of metal to generate magnetic flux.

* This gives low harmonics, low null voltage and a high sensitivity & reduce eddy current loss.
a current induced in the conductor by a varying magnetic field.

* The freq. of A.C applied to primary windings may be betⁿ 50Hz to 20KHz.

* 1° winding current → Magnetic field (flux) created → emf induced → mutual inducted to 2° winding.



* O/P Vtg. in Secondary winding S_1 is E_{S_1} & S_2 is E_{S_2}

* then Diff. O/P Vtg.
$E_0 = E_{S_1} - E_{S_2}$ (series connection)

* when the core is at its normal position (null) position.

* Flux linking with both 2° windings is equal.
So, $\boxed{E_{S_1} - E_{S_2} = 0}$

* Core left side of null position
More flux in S_1 & less flux in S_2.
So output vtg. $E_{S_1} > E_{S_2}$. So $E_0 = E_{S_1} - E_{S_2}$ (+ve value)
(O/P vtg is inphase with primary vtg)

* Core Right side of Null Position.
More flux in S_2 & less flux in S_1.
So output vtg. $E_{S_2} > E_{S_1}$. So $E_0 = E_{S_1} - E_{S_2}$ (-ve value)
(O/P vtg. is 180° out of Phase with 1° vtg.)

* Voltage change on 2° winding ∝ movement of core.

* By calculate the O/P vtg. increasing or decreasing we can determine the direction of motion.

Capacitive Transducers :-

* The principle of operation of capacitive transducers is based upon the eqn $C = \varepsilon A/d$

$$C = \varepsilon_0 \varepsilon_r A/d$$

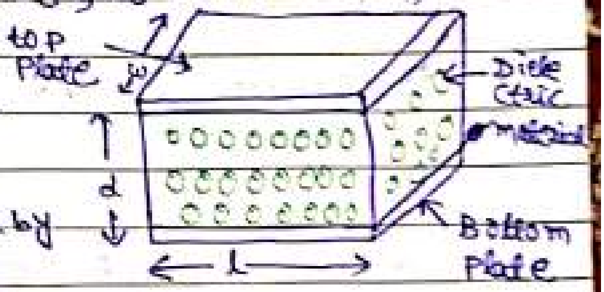
A = overlapping area of plates ; m^2

d = distance betn 2 plates ; m

$\varepsilon = \varepsilon_0 \varepsilon_r$ = permittivity of medium ; F/m

ε_r = relative permittivity

ε_0 = Permittivity of free space ; (8.85×10^{-12} F/m)



* The capacitive transducer works on the principle of change of capacitance which may be caused by

a> Change in overlapping area (A)

b> Change in the distance (d) betn the plates.

c> change in dielectric constant. ($\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$)

* The capacitance may be measured with bridge ckt. The output impedance of a capacitive transducer is

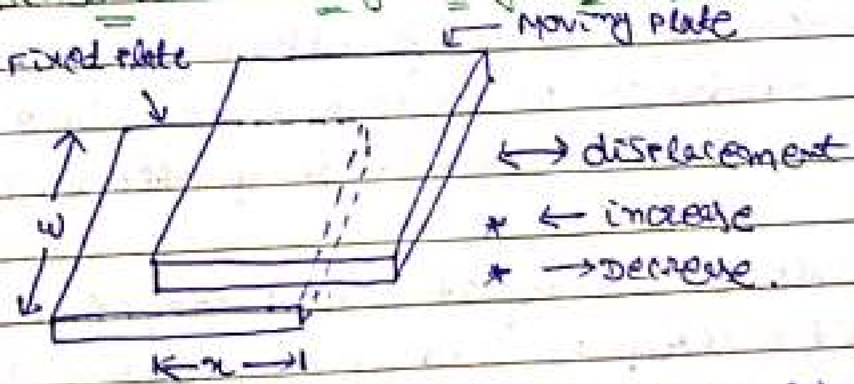
$$X_C = 1/2\pi f C$$

f = freq.

C = capacitance.

* Generally, the o/p impedance of a capacitive transducer is high.

Transducers using change in Area of plates :-



* For a parallel plate capacitor, the capacitance is

$$C = \frac{\varepsilon A}{d} = \frac{\varepsilon x w}{d} \text{ F} \quad -(i)$$

x = length of overlapping part of plates, m.

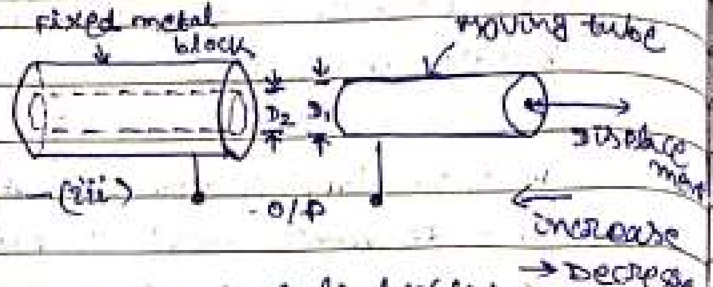
w = width of overlapping part of plates, m.

Date
Page

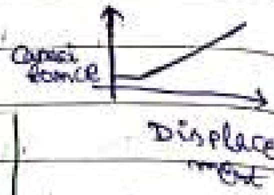
$$\text{Sensitivity } (S) = \frac{\partial C}{\partial x} = \varepsilon \frac{w}{d} \text{ F/m} \quad \text{---(ii)}$$

* For a cylindrical capacitor, the capacitance is

$$C = \frac{2\pi \varepsilon x}{\log_e (D_2/D_1)} \text{ F} \quad \text{---(iii)}$$



x = length of overlapping part of cylinder (m)
D_2 = inner diameter of cylinder. (m)
D_1 = outer diameter of cylinder. (m)



∴ → $$\text{Sensitivity } (S) = \frac{\partial C}{\partial x} = \frac{2\pi \varepsilon}{\log_e (D_2/D_1)} \text{ F/m}$$

Capacitor microphone
Dielectric gauge

Advantages of capacitive transducers :-

a) They required very small forces to operate them & hence are very useful for use in small systems.
b) They are extremely sensitive.
c) They have a good frequency response. (up to 50 KHz)
d) They have a high input impedance. ↳ effective resistance

Disadvantages :-

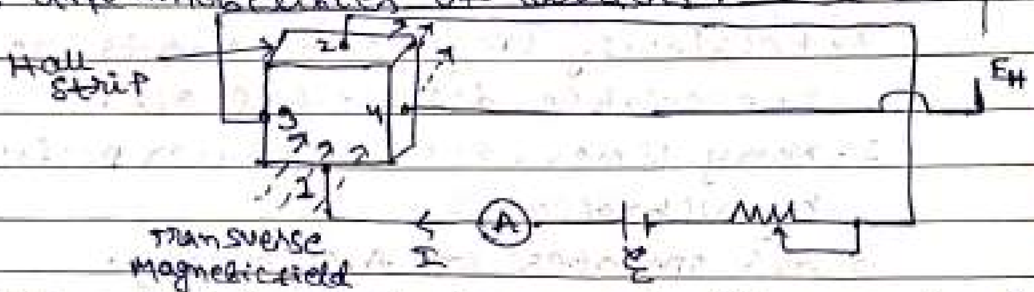
a) The metallic parts of the capacitive transducers must be insulated from each other & frames must be earthed.
b) The capacitive transducers show non-linear behaviour on few times. (due to edge effect)
c) The o/p impedance of capacitive transducers show high impedance. (Due to loading effects)

(5.9) Hall effect Transducers :-

* The principle of working of a Hall effect transducer is that if a strip of conducting material carries a current in the presence of a transverse magnetic field, a potential difference is produced betn the opposite edges of the conductor.

* Transverse Mag. Field :- perpendicular magnetic field measured in a plane perpendicularly.

* Here the magnitude of the voltage depends upon the current, the strength of magnetic field and the property of the conductor called Hall effect.
* The hall effect is present in metals and semiconductors in varying amount, depending upon the densities and mobilities of carriers.



* In this fig., the current is passed through lead 1 and 2 of the strip.
* The O/P leads connected to edges 3 & 4 are at the same potential when there is no transverse magnetic field passing through the strip.
* When a transverse magnetic field passes through the strip, an O/P voltage appers across the O/P leads.
* This voltage is proportional to the current and the magnetic field strength.
* The O/P vtg. is $\boxed{E_H = K_H IB/t}$

K_H = Hall effect coefficient ; $\left(\frac{V-m}{A-Wb\,m^{-2}}\right)$

t = thickness of strip ; (m)

I = current (A) ; B = flux density Wb/m^2

* The Hall effect emf is very small in conductors & is difficult to measure. But in case of semiconductor (germanium), the emf can be measured.

Advantages of LVDT :-

1. High range of measurement of displacement.
2. Low power consumption.
3. Low Hysteresis loss.
4. High input & high sensitive.

Disadvantages of LVDT :-

1. Relatively large displacements are required for appreciable differential O/P.
2. Many times, the transducer performance is affected by vibrations.
3. It's operates in A.C Supply.
4. Temp. affects the performance of the transducer.

CHAPTER - 08

CRO -: (Cathode Ray Oscilloscope) → graphically display signal

* Cathode Ray oscilloscope is an electronic device which displays & measures the signals by its shape, frequency & phase shift.
* It is constructed by its several circuit.

CRT -: (cathode ray tube)

* It is the heart of the CRO. It is a vacuum tube of special geometrical shape and converts an electrical signal into visual one.
* Here an electron gun is there, which generated electron beam.
* First it deflected by two pair of deflection plate, then strike on fluoresent screen & produces visible light.

* It has two main parts
a) Electron gun assembly b) Deflection system (vertical & Horizontal)

Y-input -:
* It is the main i/p of CRO where i/p signal is connected. The wave froms of input signal displayed on the CRT screen.

Vertical Amplifier -:
* It is a set of pre amplifier which receives the external i/p signal.
* This signal is connected to the vertical deflection plate through a Delay line.

Delay line -:
* It delays the striking of electron beam on the screen & syncronize the arrival of time base generator signal starts sweeping horizontally. It is around 0.25 m sec.

Trigger circuit -:
* It takes the sample of i/p signal voltage and feeds to time base generator to start only when i/p 'y' signal is present.

Time base Generator -:
* It produces a saw tooth wave form.
* This wave form is used to sweep the electron beam horizontally on the screen.
* This is controlled by Time/Division knob.
* The saw tooth wave control the horizontal deflection of electron beam along x-axis.

Horizontal Amplifier -:
* It amplifiers the saw tooth wave form which is connected to Horizontal plate of CRT.
* It helps to move the electron beam from left to right on CRT screen.

HV/LV power supply -: It provides the necessary high voltages to CRT & low voltage to other circuit of CRO.