CH-1 MEASURING INSTRUMENTS.

Purpose of measurement system

Any physical quantity is expressed in terms of numerical value followed by its unit.

→ The purpose of measurement is to present measured values to numerical values.

* Measured values :- Any value or any reading calculated from measurement system or measuring instrument is known as measured values.

* True values :- Any values calculated from rated values is known as True values. These values are also known as Actual values.

Accuracy and Precision.

* Accuracy (how accurate) :- The accuracy of a measurement is a measure of how close the measured value is to the true value of the quantity.

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

ERROR

The deviation of the measured values from the true values. It is denoted by δ.

$$\delta = A_m - A_T$$

Types of Errors

① Systematic errors

② Random errors.

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Systematic Error

The systematic errors are those errors that tend to be in one direction either positive or negative.

↑ses, goes increasing.

↓ses, goes decreasing.

(i) **Instrumental errors.**

It arises due to the defects in the instrument.

(ii) **Environmental errors**

When the surroundings cause problems with the lab

(iii) **Observational errors**

When the observer does not read the measurement carefully.

(iv) **Theoritical errors**

When the experiment procedure is flawed creating inaccuracies in the experiment.

Random Errors.

These errors arises due to random and unpredictable fluctuations in experimental conditions, personal errors by the observer taking readings etc.

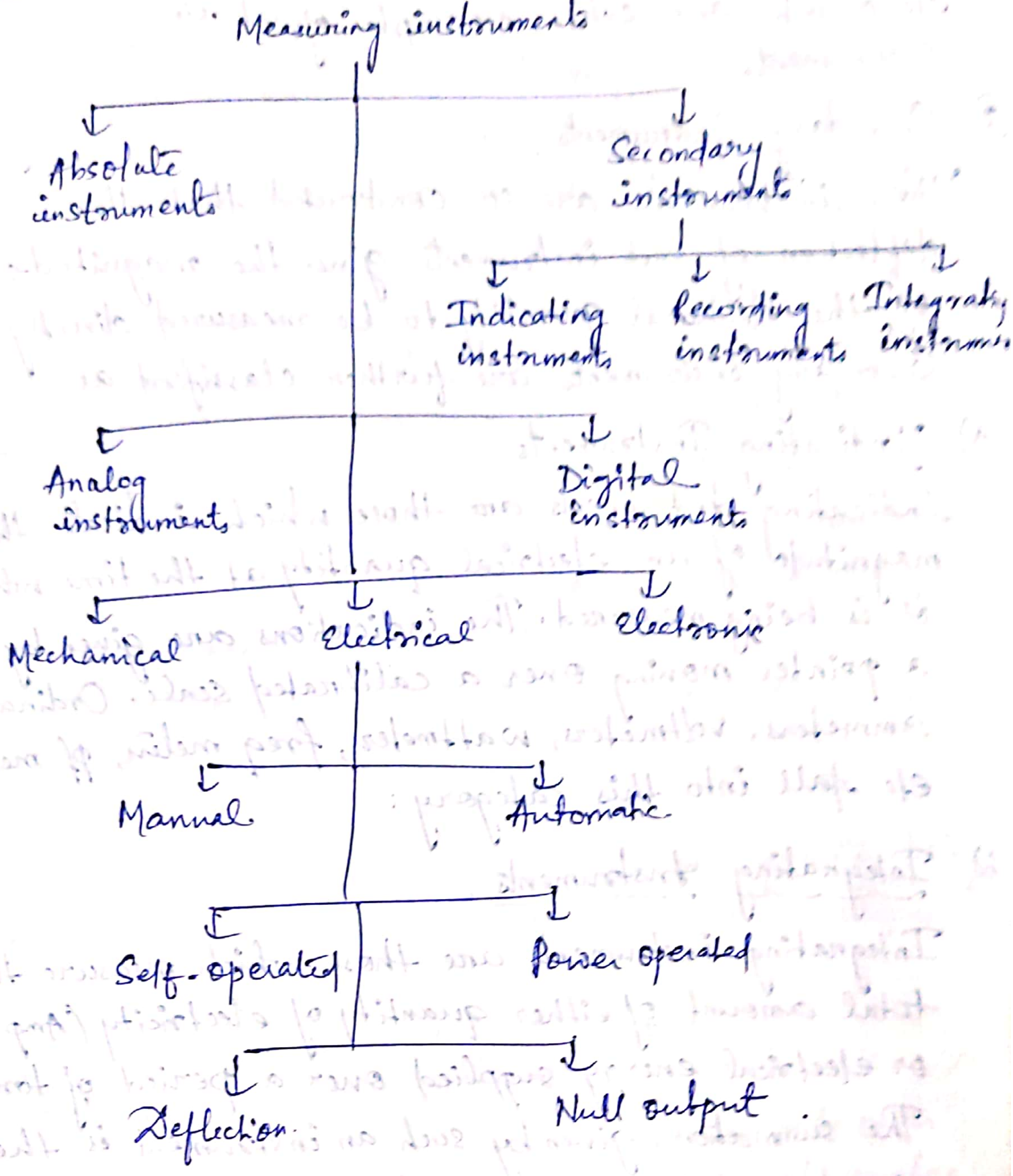
Resolution And Sensitivity.

Resolution :- It is the smallest change in input signal detected by any instrument.

Sensitivity :- It is the ratio of the change in output/response of the instrument to a change of input/quantity under measurement.

→ The sensitivity of an instrument should be high.

CLASSIFICATION OF MEASURING INSTRUMENT



(1) Absolute Instruments

The instruments of this type give the value of the measurand in terms of instrument constant and its deflection. The example of this type of instrument is tangent Galvanometer, which gives the value of the current to be measured in terms of tangent of the angle of deflection produced, the horizontal component of the earth's magnetic field, the radius and the no. of turns of the wire used.

Rayleigh current balance and absolute electrometer are other examples of absolute instruments.

2) <u>Secondary Instruments</u>.

These instruments are so constructed that the deflection of such instruments gives the magnitude of the electrical quantity to be measured directly. Secondary instruments are further classified as

a) <u>Indicating Instruments</u>.

Indicating Instruments are those which indicate the magnitude of an electrical quantity at the time when it is being measured. The indications are given by a pointer moving over a calibrated scale. Ordinary ammeters, voltmeters, wattmeters, freq meters, pf meters etc fall into this category.

b) <u>Integrating Instruments</u>.

Integrating instruments are those which measure the total amount of either quantity of electricity (Amp-hour) or electrical energy supplied over a period of time. The summation, given by such an instrument is the product of time and an electrical quantity under measurement. The ampere-hour meters and energy meters fall in this class

c) <u>Recording instruments</u>

Recording instruments are those which keep a continuous record of the variation of the magnitude of an electrical quantity to be observed over a definite period of time. Ex:- X-Y Plotter.

Analog and Digital Instruments.

① **Analog Instruments**:

The signals of an analog unit vary in a continuous fashion and can take on infinite number of values in a given range. fuel gauge, ammeter, & voltmeters, wrist watch, speedometer fall in this category.

② **Digital Instruments.**

Signals varying in discrete steps and taking on a finite number of different values in a given range are digital signals and the corresponding instruments are of digital type. Digital instruments have some advantages over analog meters in that they have high accuracy and high speed of operation. It eliminates the human operational errors. A digital multimeter is the example of a digital instrument.

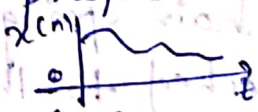
② **Secondary Instruments.**

These instruments are so constructed that the quantity being measured can only be measured by observing the output indicated by the instrument.

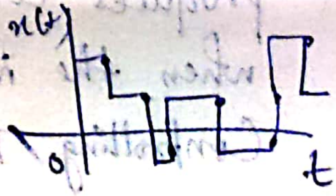
Secondary instruments work in two modes:

(i) Analog mode and (ii) Digital mode.

Signals that vary in a continuous fashion and take on an infinity of values in any given range are called analog signals. The devices which produce these signals are called as analog devices.



Whereas, the signals which vary in discrete steps and thus take up only finite different values in a given range are called Digital signals. The devices that produce such signals are called digital devices.

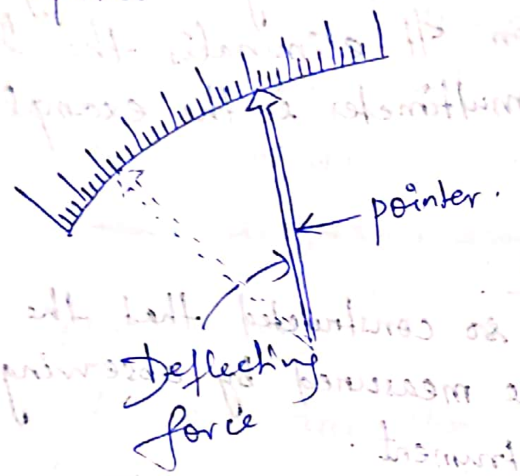


Indicating type instruments

(a) Deflecting force
(b) Controlling force
(c) Damping force.

Deflecting Force.

When there is no input signal to the instrument, the pointer will be at its zero position. To deflect the pointer from its zero position, a force is necessary which is known as deflecting force. A system which produces the deflecting force is known as a deflecting system. Generally deflecting system converts electrical signal into a mechanical force



Controlling Force.

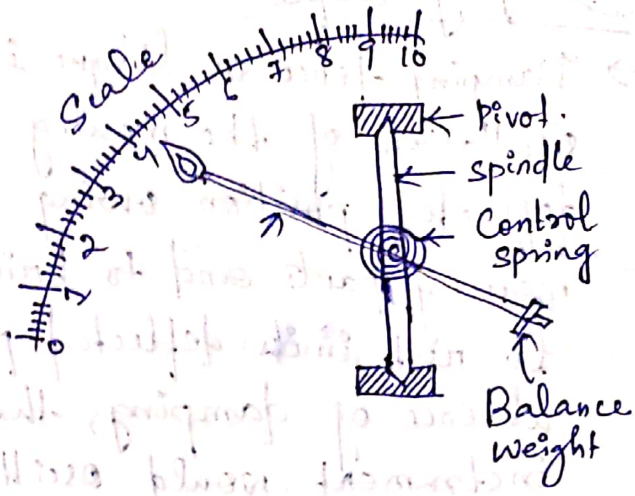
This torque is provided by two methods:-

(i) Spring Control.

It utilises a hair spring of large number of turns which is attached to the moving system or spindle s. When the pointer is deflected by deflecting torque, the spring gets twisted in opposite direction which produces controlling torque. It comes to an equilibrium when the magnitude of deflecting torque is equal to Controlling Torque.

Further, the torque of a spiral spring is proportional to the angle of twist, the controlling torque is directly proportional to the angular deflection (θ)

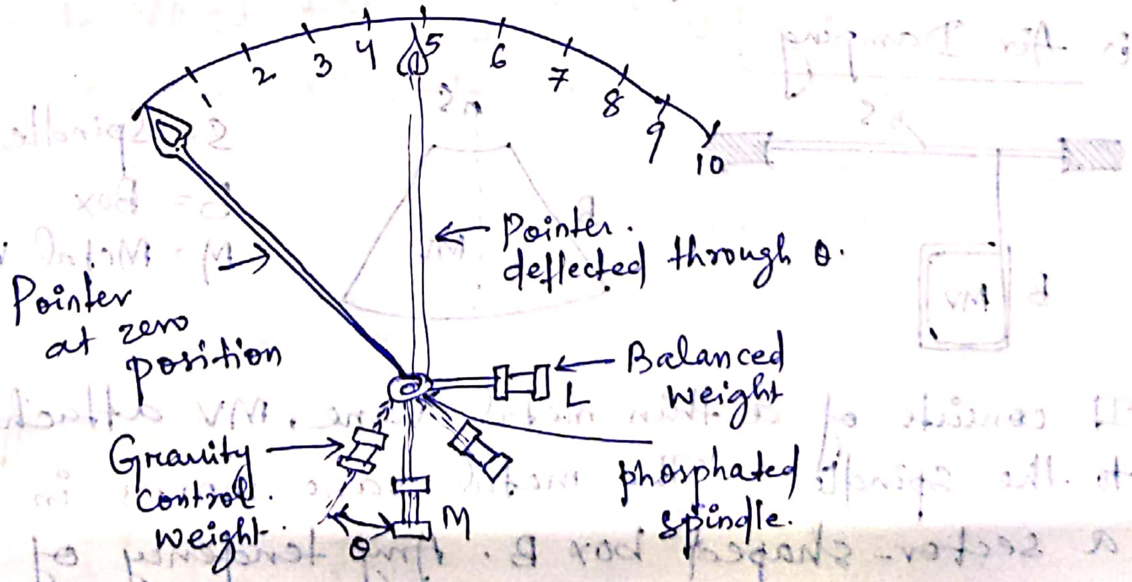
i.e $\boxed{T_c \propto \theta}$



(ii) Gravity Control:

With gravity control, weights L and M are attached to the spindle S. The function of L being to balance the weight of the pointer P. Weight M therefore provides the controlling torque. When the pointer is at zero, M hangs vertically downwards. When P is deflected through angle θ, the controlling torque is equal to (wt of M × dist d) and is therefore proportional to the sine of ~~angle~~ Angular deflection.

$\boxed{T_c \propto \sin\theta}$



Damping Torque

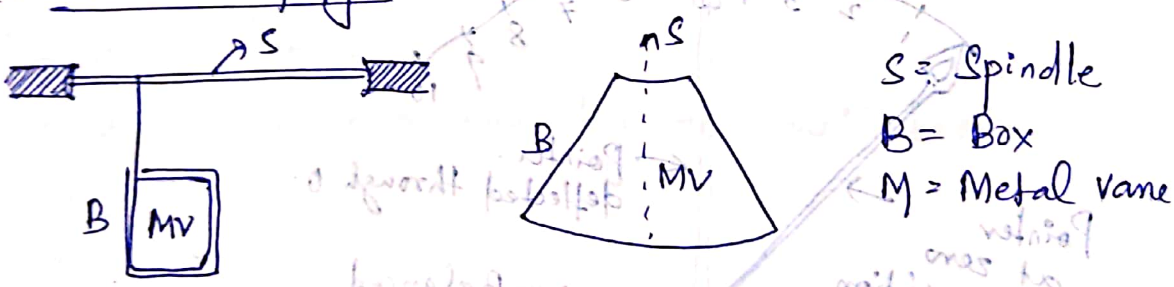
→ Damping force or torque is necessary to avoid oscillations of the moving system about its final deflected position owing to the inertia of the moving parts and to bring the moving system to rest in its deflected position quickly. In the absence of damping, the moving system and instrument would oscillate about the position at which the deflecting and restoring torques are equal. The function of damping is to absorb energy from the oscillating system and to bring it to rest promptly in its equillibrium position so that its indication may be observed. The various methods of obtaining damping are :-

(i) Air friction Damping

(ii) Eddy current Damping

(iii) fluid damping.

(i) Air Damping.



It consists of a thin metal vane, MV attached to the spindle S. The metal vane moves in a sector-shaped box B. Any tendency of the moving system to oscillate is damped by the action of the air on the vane.

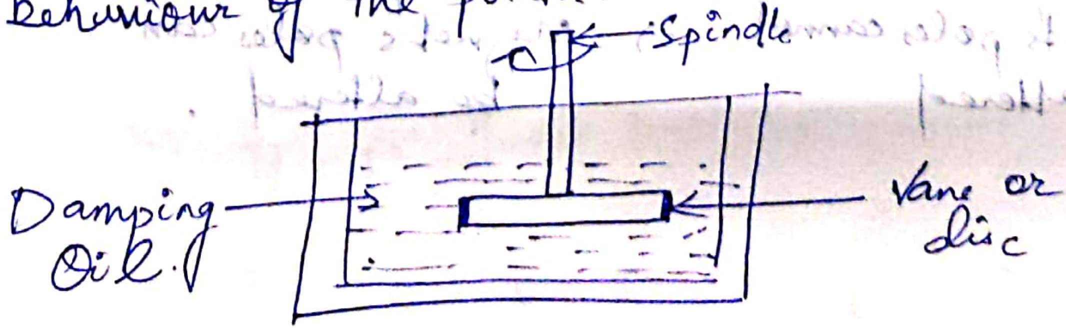
(ii) Eddy current

This method of damping is based on the principle that whenever a sheet of conducting but non-magnetic material like Copper or Aluminium moves in a magnetic ~~material~~ field so as to cut through lines of force, eddy currents, ~~a force~~ are set up in the sheet. Due to these eddy currents, a force opposing the motion of the sheet is experienced between them and the magnetic field. This force is proportional to eddy currents and the strength of the magnetic field. The eddy currents are proportional to the velocity of the moving system. Hence, if the strength of the magnetic field is constant the damping force is proportional to the velocity of the moving system and is zero when the moving system is at rest.

(iii) Fluid Friction Damping

This method is similar to air friction damping, only air is replaced by working fluid. The friction betn the disc and fluid is used for opposing motion. Damping force due to fluid is greater than that of air due to more viscosity. The disc is also called vane.

It consists of a vane attached to the spindle which is completely dipped in the oil. The frictional force between oil and the vane is used to produce the damping torque, which opposes the oscillating behaviour of the pointer.



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Calibration of Measuring Instruments

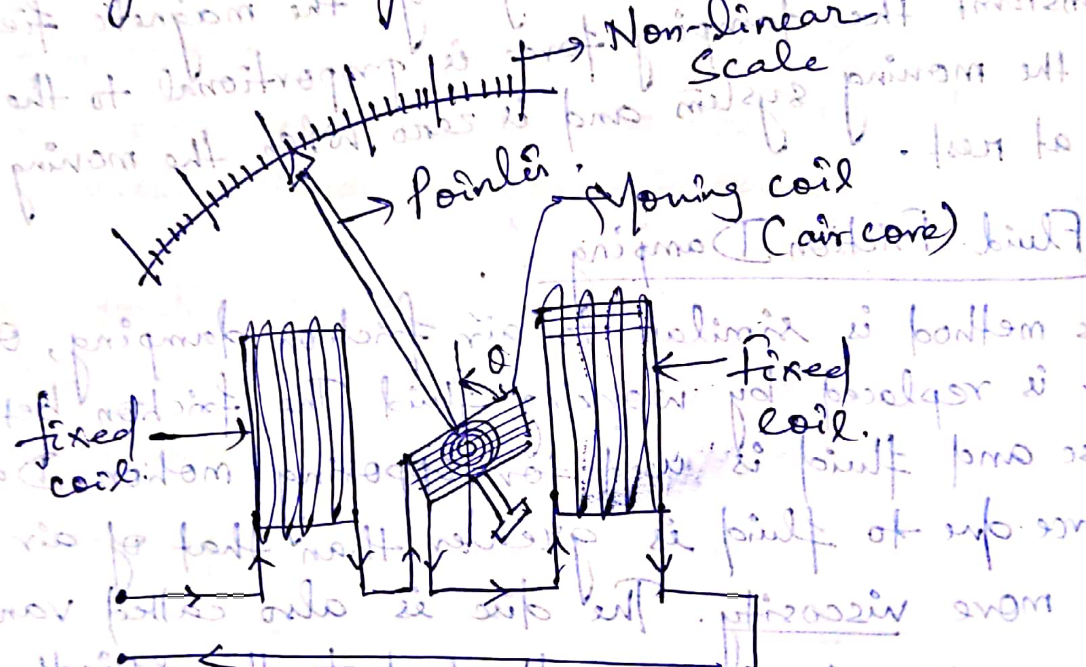
The process involves obtaining a reading from the instrument and measuring its variation from the reading obtained from a standard instrument.

→ Calibration of an instrument is the process of determining its accuracy.

→ The best method of calibration is to measure ??

Electro Dynamometer type Instruments

→ Electromagnetic moving coil (Emmc)



Permanent Magnet	Electromagnet
→ Permanently magnetised	→ Temporarily Magnetised
→ made of Hard magnetic materials	→ soft magnetic materials
→ Magnet's poles cannot be altered	→ Magnet's poles can be altered.

Operation with DC

$T_d = I_1 I_2 \, dM/d\theta$

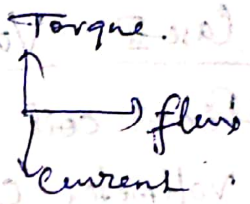
$T_c = K\theta$

At steady state,

$T_d = T_c$

$\Rightarrow I_1 I_2 \frac{dM}{d\theta} = K\theta$

$$\theta = \frac{I_1 I_2}{K} \frac{dM}{d\theta}$$



Operation with A.C.

$$\theta = \frac{I_1 I_2 \cos\phi}{k} \frac{dM}{d\theta}$$

Extension of EMMC instrument

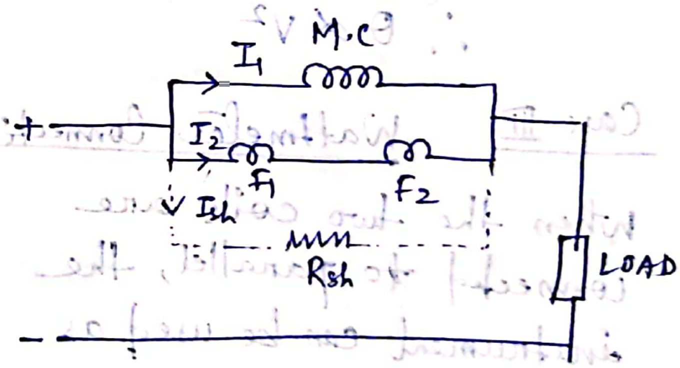
Case-1 Ammeter Connection,

Fixed coil and moving coil are connected in parallel for ammeter connection. The coils are designed such that the resistance of each branch is same.

Therefore,

$I_1 = I_2 = I$

To extend the range of current a shunt may be connected in parallel with the meter. The value R_{sh} is designed such that equal current flows through moving coil and fixed coil.



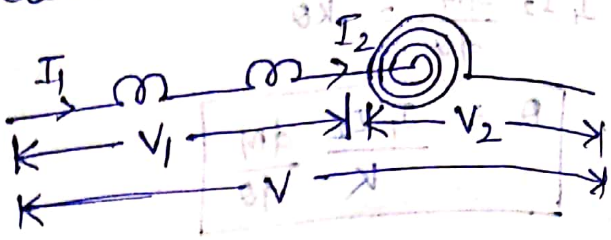
$\therefore T_d = I_1 I_2 \frac{dM}{d\theta}$

$\Rightarrow T_d = I^2 \frac{dM}{d\theta}$

$T_c = K\theta \Rightarrow \theta = \frac{I^2}{K} \frac{dM}{d\theta}$ $\quad \theta \propto I^2$

Case II Voltmeter Connection.

Fixed coil and moving coil are connected in series for voltmeter connection. A multiplier may be connected in series to extend the range of voltmeter.



$$T_d = I_1 I_2 \frac{dM}{d\theta}$$

$$I_1 = I_2 = \frac{V}{Z}$$

$$T_d = \left(\frac{V}{Z}\right)\left(\frac{V}{Z}\right)\frac{dM}{d\theta}$$

$$= \left(\frac{V^2}{Z^2}\right)\frac{dM}{d\theta}$$

{ $\because V_1 = V_2 = V$. Impedance in each coil is same.

$$T_d = T_c.$$

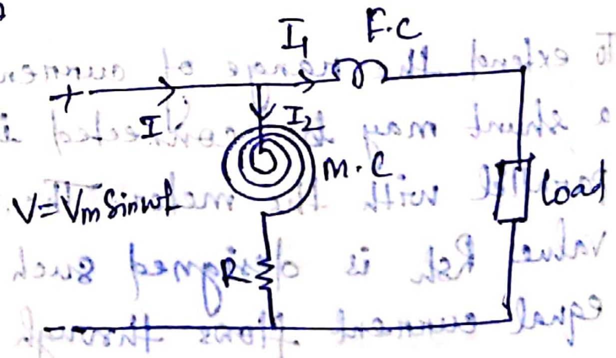
$$\Rightarrow \left(\frac{V^2}{Z^2}\right)\frac{dM}{d\theta} = K\theta$$

$$\Rightarrow \theta = \frac{V^2}{KZ^2}\frac{dM}{d\theta}$$

$$\therefore \theta \propto V^2$$

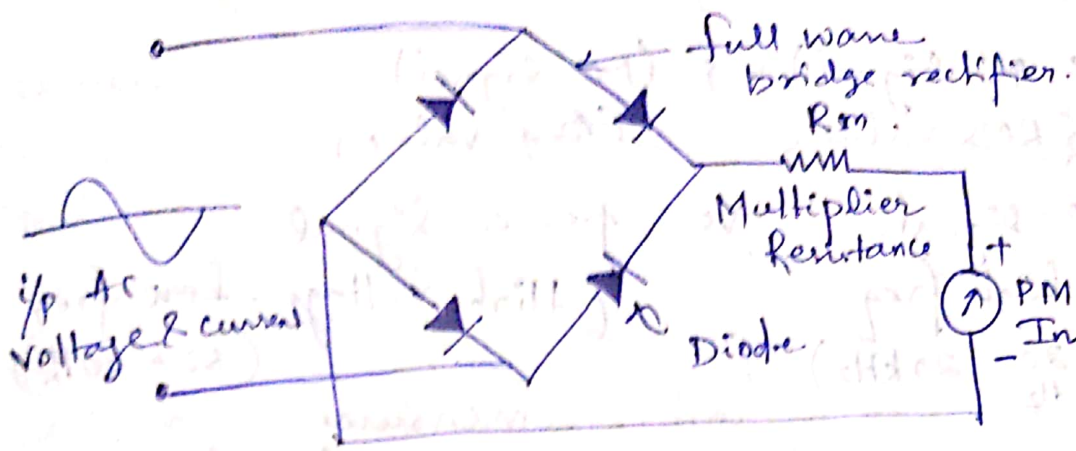
Case-III Wattmeter Connection

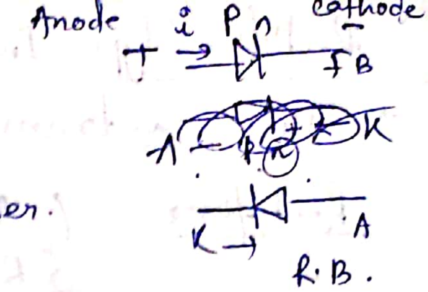
When the two coils are connected to parallel, the instrument can be used as a wattmeter. Fixed coil is connected in series with the load. Moving coil is connected in parallel with the load. The moving coil is known as voltage or pressure coil. and fixed coil is known as current coil.



$$\theta \propto VI\cos\phi$$

Rectifier Type Instrument





The instrument which uses the rectifying element for measuring the voltage and current is known as the rectifying instruments. The rectifying element converts the alternating current to the direct current which indicates by the DC responsive meter. The PMMC uses as an indicating instrument. The sensitivity of the rectifying instruments is high as compared to the moving coil and the emmc instrument. Thereby, it uses for measuring the current and voltage. The device uses the four diodes which act as a rectifying element. The multiplier resistance Rm uses for limiting the value of current so that their value does not extend more than the rating of the PMMC instrument.

$$T_m \propto \frac{1}{\pi}\int_0^{\pi} \phi_m \sin\theta\, I_m \sin(\theta-\alpha)\, d\theta$$

$$\Rightarrow T_m \propto \frac{\phi_m I_m}{\pi}\int_0^{\pi} \sin\theta \sin(\theta-\alpha)\, d\theta$$

$\sin A \sin B = \frac{\cos(A-B)-\cos(A+B)}{2}$

$$\Rightarrow T_m \propto \frac{\phi_m I_m}{\pi}\int_0^{\pi} \frac{\cos(\theta-\theta+\alpha)-\cos(2\theta-\alpha)}{2}\, d\theta$$

$$\propto \frac{\phi_m I_m}{2\pi}\int_0^{\pi} \{\cos\alpha - \cos(2\theta-\alpha)\}\, d\theta$$

$$\propto \frac{\phi_m I_m}{2\pi}\left[\int_0^{\pi} \cos\alpha\, d\theta - \int_0^{\pi} \cos(2\theta-\alpha)\, d\theta\right]$$

$$\propto \frac{\phi_m I_m}{2\pi}\left[\cos\alpha(\pi-0) - \int_0^{\pi} \cos(2\theta-\alpha)\, d\theta\right]$$

$$\propto \frac{\phi_m I_m}{2\pi}\left[\pi\cos\alpha - \int_{-\alpha}^{2\pi-\alpha} \cos x \frac{dx}{2}\right]$$

Let $2\theta - \alpha = x$

$$\Rightarrow \frac{dx}{d\theta} = 2$$

$$\Rightarrow d\theta = \frac{1}{2}dx.$$

$\theta = 0,\ x = -\alpha$

$\theta = \pi,\ x = 2\pi - \alpha$

$$\propto \frac{\phi_m I_m}{2\pi}\left[\pi\cos\alpha - \frac{1}{2}\sin x \Big|_{-\alpha}^{2\pi-\alpha}\right]$$

$$\propto \frac{\phi_m I_m \cos\alpha}{2} - \frac{\phi_m I_m}{4\pi}\left[\sin(2\pi-\alpha) - \sin(-\alpha)\right]$$

$$\sin(2\pi - \alpha) + \sin\alpha$$

$$= \underbrace{\sin 2\pi}_{0} \cos\alpha - \underbrace{\cos 2\pi}_{1} \sin\alpha + \sin\alpha$$

$$= 0 - \sin\alpha + \sin\alpha$$

$$= 0$$

$$\frac{\phi_m I_m}{4\pi} \times 0 = 0.$$

$$T_m \propto \frac{\phi_m I_m \cos\alpha}{2}$$

$$T_m \propto \frac{\phi_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} \cos\alpha$$

$$\Rightarrow \boxed{T_m \propto \phi_{rms} I_{rms} \cos\alpha}$$

At $\alpha = 90^\circ$, $T_m = 0$.

Hence, to obtain resulting torque it is necessary to produce an eddy current which is either less than or more than 90° out of phase with flux ϕ.

So, there must be some means in induction type instrument to prevent this phase angle from being 90°. We can achieve this by two methods below:-

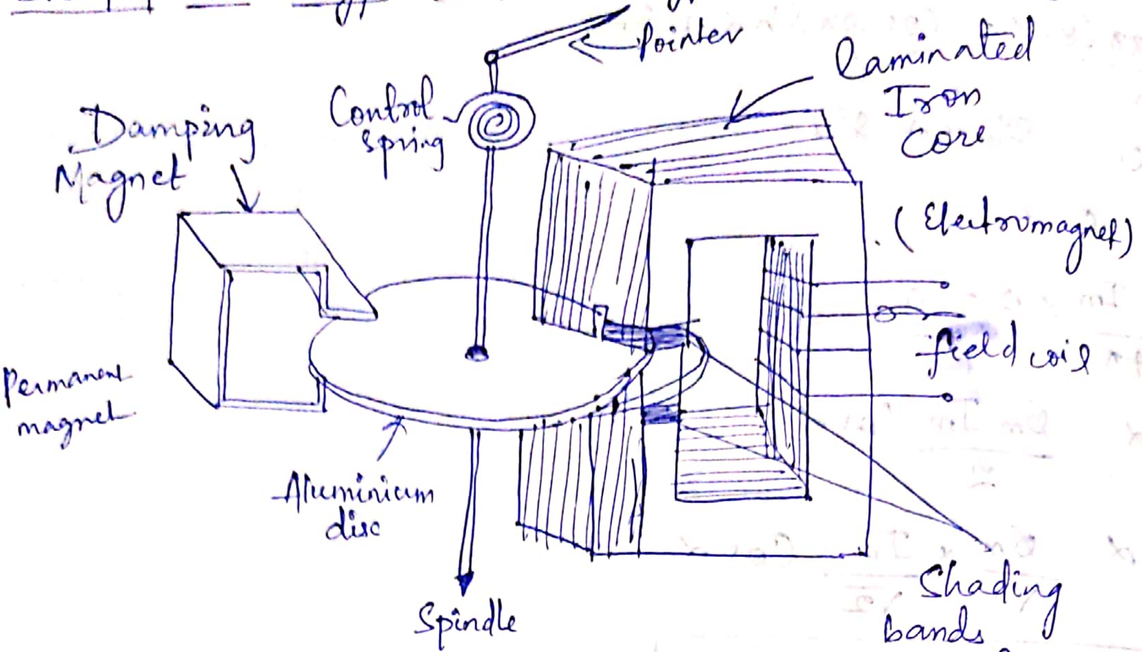
① Split phase type

② Shaded pole type

Split phase type Induction type Instruments

In this arrangement, there are two AC magnets P_1 and P_2 connected in series. The winding in P_2 is shunted by a resistance R. The current in the P_2 winding lags with respect to the total current. This helps to develop the necessary phase Angle α b/w the two fluxes. Eddy current damping is used in this type of instruments.

Shaded Pole Type Induction Type Instruments.



Shaded pole type Induction instrument uses a single winding to produce flux. The flux produced by this wdg is split up into two fluxes, having phase difference with respect to each other. The phase difference is usually 40 to 50 degrees and can be varied by varying the size of shading band. This is done by making a narrow slot in the poles of electromagnet. A copper strip is placed around the smaller of the two areas formed by the slot. This copper shading band acts as a short ckted secondary winding.

The exciting coil is placed on the poles and a the current or voltage being measured is passed through it. An aluminium disc which is mounted on a spindle is inserted in the air gap of the electromagnet. The spindle carries a pointer and has a control spring attached to it. The controlling torque is provided by this spring only.

→ Damping is provided by the permanent magnet placed at the opposite side of the electromagnet. So, that the disc can be used for the prodn of ~~don~~ both deflecting & Damping torque

CH-4. ENERGYMETERS AND MEASUREMENT OF ENERGY

- Energymeter. used to measure energy.
- An instrument that is used to measure the energy consumed by a consumer over a period is known as Energymeter.
- These are also called as watt hour meter.

Single phase Induction Type Energymeter.

Induction type instruments are most commonly used as energy meters. Energy meter is an integrating instrument which measures quantity of electricity. Induction type of energy meters are universally used for domestic and industrial applicatⁿ. These meters Record the energy in kilowatt-hours (kwh)

Principle.

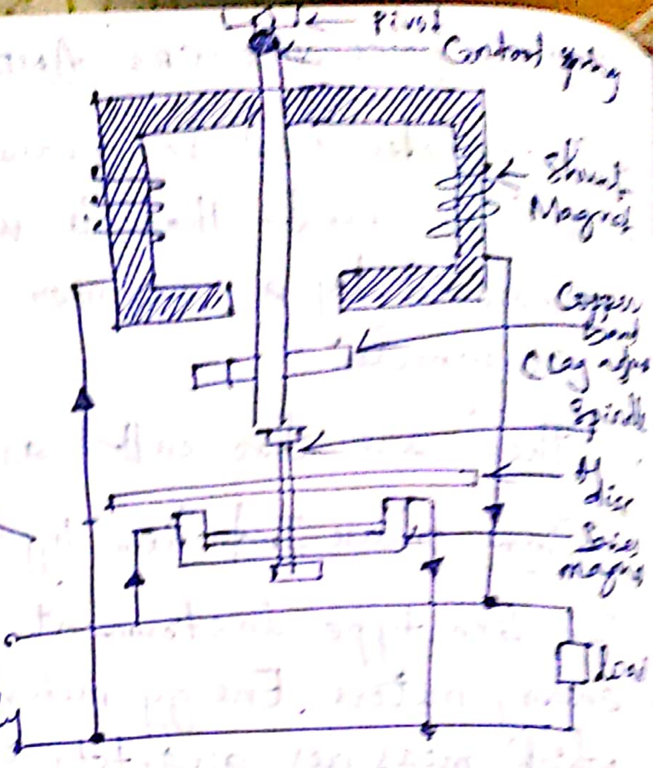
Induction type energy meter is used for single phase AC energy only. It works on the principle of induction i.e. on the production of eddy currents in the moving system by the alternating fluxes. These eddy currents induced in the moving system interact with each other to produce a driving torque due to which disc rotates to record the energy.

In energy meter, there is no controlling torque and thus due to driving torque only, a continuous rotatⁿ of the disc is produced. To have const speed of rotatⁿ braking magnet is provided.

Constructⁿ :-

Two laminated electromagnets, one is excited by the load current and is called the series magnet. while the other is excited by the current proportional to voltage is called the shunt magnet. The shunt magnet is in parallel with the load.

The alternating flux, produced by the series magnet, is directly ~~propor~~ proportional to the current and is in phase with it while the flux produced by shunt magnet lags behind the voltage by 90°. The series magnet has a few turns of thick copper wire, while the shunt magnet has a large no. of turns of thinnes wire.



→ A thin aluminium disc is mounted betn the two magnets so that its cut the leakage flux of both magnets, when the current flows in the two magnets.

→ In this instruments its absolutely esential that the shunt coil flux lags behind the voltage exactly by 90°. This is accomplished by making the shunt coil as inductive as possible by the adjustment of coppering (called lag adjuster) fitted on the central limb of the shunt magnet.

→ As it is an integrating type instrument, no control torque is provided. However, two brake magnets are positioned near edge of the aluminium disc to form the braking system. The aluminium disc moves in the field of this magnet and this provides a breaking torque.

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Constructⁿ

Constructⁿ :- It is mainly divided into four parts
(i) Driving system
(ii) Moving system
(iii) Braking system
(iv) Recording system

DRIVING SYSTEM

It consists of two electromagnets (a) Shunt Magnet
(b) Series Magnet

(a) Shunt Magnet.

→ It consists of numbers of M-shaped / E-shaped core made up of laminated silicon steel
→ A thin wire with large no. of turns is wound in the central limb
→ The coils resistance is high as well as inductance is also high.
→ This coil is connected in parallel with ~~to~~ the load.
→ In the system, this coil is known as PC / Pressure coil / VC.

(b) Series Magnet

→ It consists of a U-shapped core with laminated silicon steel.
→ A thick wire with less no. of turns are used
→ This coil is connected in series with load.
→ Coil is known as current coil

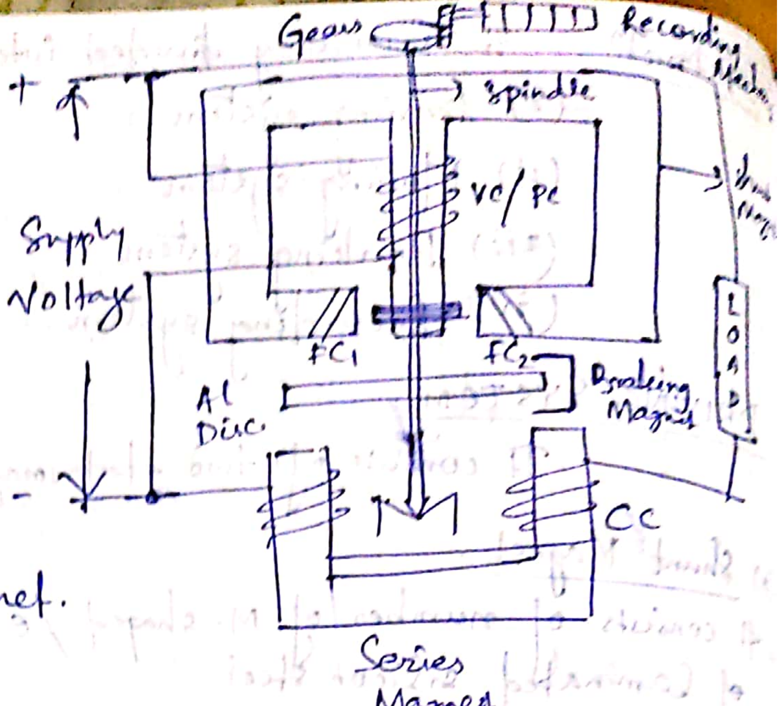
* Copper shading band are provided on the shunt magnet's central limb to get 90° phase displacement b/w shunt magnetic field & supply voltage.

MOVING SYSTEM

→ It consists of a light Aluminium disc mounted on the vertical spindle.
→ Induced magnetic flux by shunt or series magnets cut to the Al disc.
→ Due to inductⁿ, the eddy current is induced and therefore, the disc rotates.
→ Because disc is attached with spindle and spindle is attached with recording system through gear.

RECORDING SYSTEM

It record number of rotation of spindle and show the measured value in Kwh.



BRAKING SYSTEM.

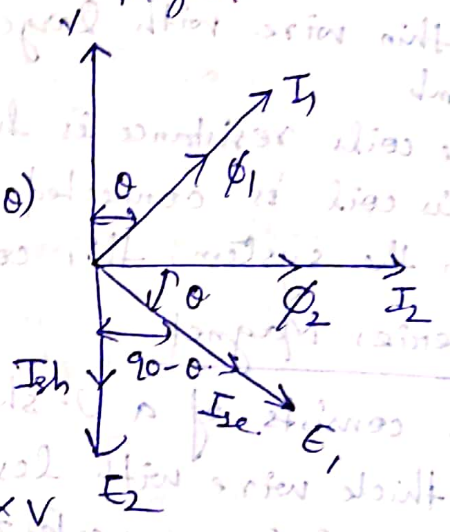
Damping of the disc is provided by a small permanent magnet.

Torque Eqⁿ

$$T_d \propto T_2 - T_1$$

$$T_d \propto \phi_2 I_{se} \cos\theta - \phi_1 I_{sh} \cos(180-\theta)$$

$$\Rightarrow T_d \propto \phi_2 I_{se} \cos\theta + \phi_1 I_{sh} \cos\theta$$



$$\Rightarrow \phi_2 \propto V, \quad E_2 \propto \phi_2 \propto V$$

$$I_{se} \propto \phi_1 \propto I_1 \qquad I_{sh} \propto \phi_2 \propto E_2 \propto V$$

$$T_d \propto VI_1 \cos\theta + VI_1 \cos\theta$$

$$T_d = K_1 VI_1 \cos\theta + K_2 VI_1 \cos\theta$$

$$T_d = (K_1 + K_2) VI_1 \cos\theta$$

$$T_d \propto VI_1 \cos\theta$$

I_{se} = Induced eddy current in series magnet/flux

I_{sh} = Induced eddy current in shunt magnet/flux

$$T_b \propto \phi_b I_b$$

$$T_b \propto \phi_b \frac{E_b}{R_b}$$

E_b = Induced emf

R_b = Resistance for eddy current

$$\Rightarrow T_b \propto \phi_b \frac{N\phi_b}{R_b}$$

$$T_b \propto \phi_b^2 \frac{N}{R_b}$$

$T_b \propto N$ (N = No. of Revolution) $\quad \phi_b, R_b$ = const

Measurement of Speed, Frequency & power factor

Tachometer

Tacho – Speed, Meter → to measure.

→ An instrument for measuring the speed is Tachometer.
→ Tachometer is a device which is used to measure rotational speed of a disk or a shaft of motors and other machines.
speed → in [RPM]
→ Inbuild or free hand device.
→ Also called as Revolution counter

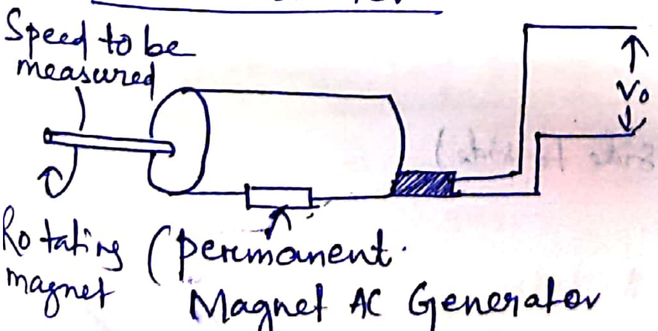
Working

The working principle of tachometer is that if there is a relative motion betn shaft of a device and magnetic field, then an electromotive force is induced in the coil placed inside the constant magnetic field of permanent Magnet. The developed emf is directly proportional to the speed of the shaft.

Types of Tachometer

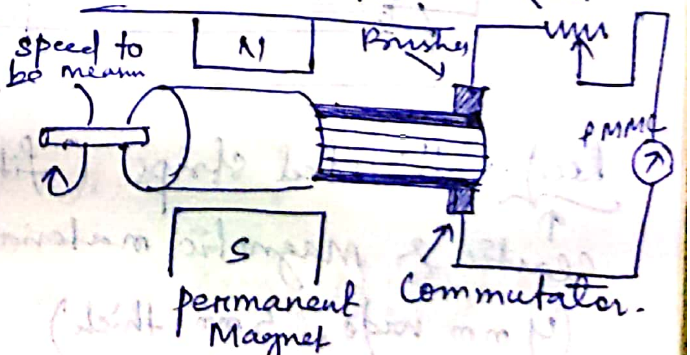
① Contact or Non-contact type Tachometer.
② AC or DC type Tachometer
③ Time measurement or freq Measurement type

AC tachometer



Amplitude & freq of emf. are $\propto$ to speed of Rotation

DC Tachometer



Armature is coupled to Machine whose speed needs to be measured.

Emf $\propto$ flux × speed
(Const)

Time Measurement

- The time measurement device calculates speed by measuring the time interval betn the incoming pulses

Freq Measurement

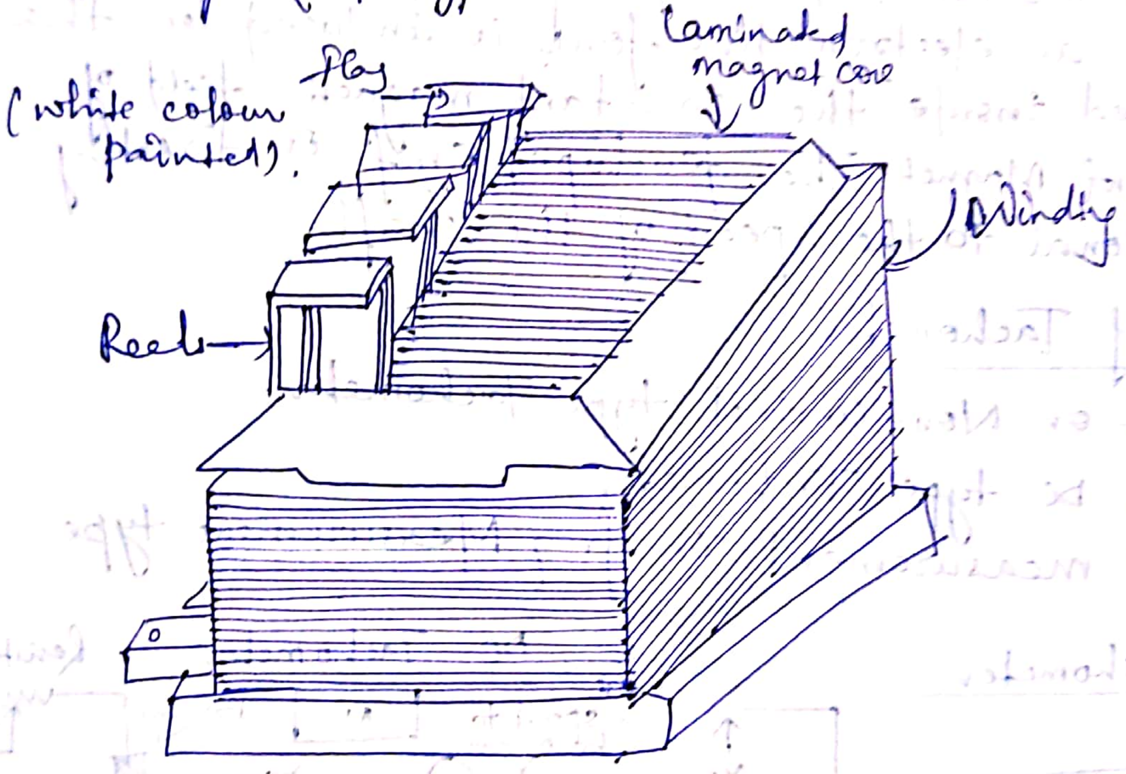
Calculates speed by measuring the freq of the ~~the~~ incoming pulses.

Measurement of Frequency

* Principle of operatn and construction of Mechanical and Electrical Resonance type freq meters.

Mechanical Resonance Type Frequency Meter

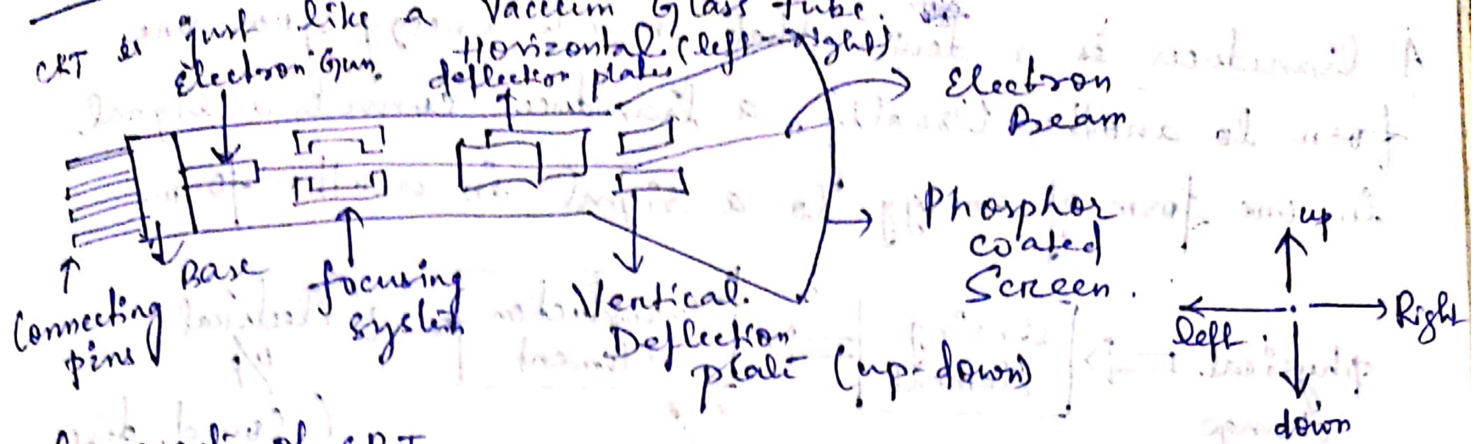
→ Vibrating Reed Type.



Reed → thin steel strips. (fitted side to side)
↑
Elastic & magnetic material.
(4 mm wide, 0.5 mm thick)

Cathode Ray Tube (CRT)

CRT is just like a Vaccum Glass tube.



Components of CRT

① **Electron Gun** :- Electron gun generates negatively charged electrons. Electron Gun consists of cathode and heating filament. When heat is supplied to cathode by a heating filament its ē become loose and gets emitted from cathode surface

② **Focusing System**

The purpose of focusing system in CRT is to force the electron beam to converge into small spots and travel in straight line.

③ **Deflectⁿ System**

The purpose of deflection system is to change the directⁿ of electron beam so that electron beam can be made to strike at diff. location.

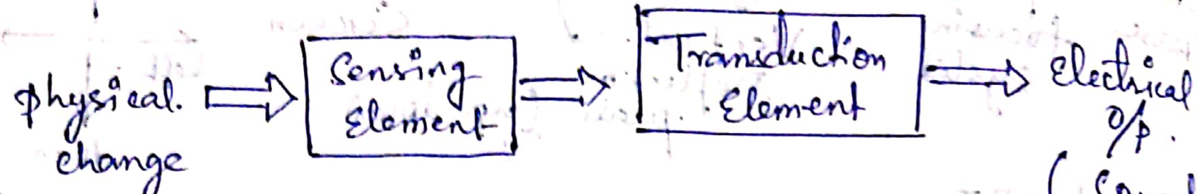
④ **Phosphor coated Screen**

The screen is coated with phosphorus ~~or~~ crystal called phosphors.

These phosphor crystal emits small spots of light when the ē beam strikes on them.

Transducer

A transducer is a device that converts energy from one form to another. Usually, a transducer converts a signal in one form of energy to a signal in another form.



{Resistance, inductance, Capacitance, stress/strain)

(Sound, dis pressure, voltage & current)

Sensor / Transducer

Both are used to sense a change within the environment they are surrounded by.

But sensor will give an output in the same format and a transducer will convert the measurement into electrical signal.

Sensor → Detector

Transducer → translator

Resistive Transducer

The transducer whose resistance varies because of the environmental effects. Such type of transducer is known as the Resistive transducer or Resistance transducer.

→ The resistive transducer is used for measuring the physical quantities like temp, pressure, disp, vibratⁿ etc.

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

Types of Resistive Transducer

1. Potentiometers (
2. Strain Gauge
3. Thermistors
4. Resistance Thermometers.