

UNIT - 1

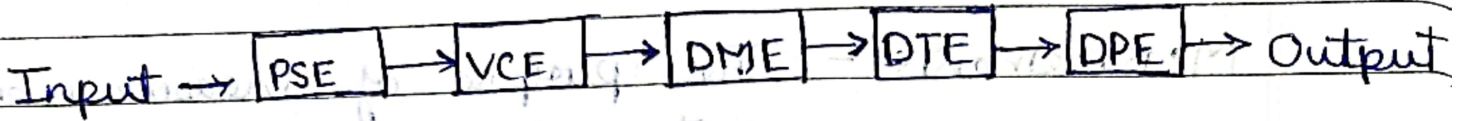
Measurements :- The purpose of measurement system is to present the observer with a numerical value constant numbers; the type of display preferred is digital type (BCD-7 segment). Digital display is more user friendly and easy to read. Any measurement has a :-

- (i) Constant value
- (ii) Unit
- (iii) Constant name & number

Note :- Measurement is the process of comparing the results of one value with another.

In Electrical Engineering the instrument that measure: Current, Voltage, Power, etc are called electrical instruments.

Block diagram of measuring system :-



(i) Primary Sensing element (PSE) :- It is an element which is in direct contact with the quantity to be measured.

Ex - Sensor, thermometer, thermocouple, transducer etc.

Note :- Transducer - It is a device that convert one form of energy to another form.
Ex - Photocell / PV-cell.

(ii) Variable Conversion element (VCE) :- It is an element that convert one form of signal to another form of signal. In this the nature of element is changed.

Ex - AC / DC converter, DC / AC converter
Digital / Analogic converter, Analogic / Digital converter.

(iii) Data Manipulation Element (DME):- It is an element that modify the level of signal without changing the nature of element. It can amplify or attenuate the level of signal.

Ex - Amplifier, Attenuator

(iv) Data Transmission element (DTE):- It is an element that is used for transmitting the data signal.

Ex - Optical Fiber, Channel

(v) Data Presentation element (DPE):- It is an element that is used to display data or can be used to store data for future analysis.

Ex - LED, LCD, CRO, etc

Classification of Measuring Instruments

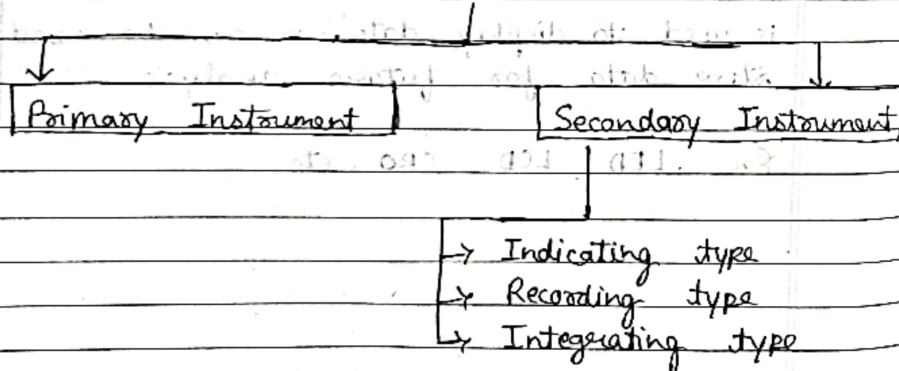
It can be classified into two types:-

- (i) Primary Instrument
- (ii) Secondary Instrument

Further the secondary instrument is divided into 3 types:-

- (i) Indicating Instrument
- (ii) Recording Instrument
- (iii) Integrating Instrument

Classification of Measuring Instrument



Indicating

Instruments → Torque → (i) Deflecting torque
(ii) Controlling torque
(iii) Damping torque

1) Primary Instrument:- Primary instrument only gives indication and does not give result. It can't be compared with others.
Ex - Tester

2) Secondary Instrument:- It gives indication as well as proper result of the measured quantity and can be compared with others.
Ex - Ammeter, Voltmeter, Ohmmeter, etc

(i) Indicating type instrument:- It is an instrument that gives result on the time of measurement when we give supply. When we turn off the supply it return back to its initial position or zero position. It contains a dial or pointer (Indicator).
Ex - Ammeter, Voltmeter, etc.

(ii) Recording type instrument:- It is an instrument that record the continuous variable variation of Electrical quantity.
Ex - ECG, Strip chart recorder, Data logger

Temperature data logger, temperature voltage pressure etc can be measured in data logger.

(ii) Integrating type instrument :- It is an instrument that gives the value of quantity such as power, current, voltage over a specific period of time.

Ex - Energy meter (Watt hour meters),
Ampere-hour meters

Torque -

(i) Deflecting Torque :- The part of instrument through which electric current or voltage is converted to physical force is called "Deflecting Torque". This creates motion in the moving system inside the instrument, causing the pointer to indicate the amount of current, voltage, etc.

(ii) Controlling Torque :- This is another essential part of an integrating type instrument which keeps the deflection of the pointer proportional to different values of currents. The controlling system or torque produces a force equal to and opposite to the deflecting torque of the deflecting system, this force is called controlling torque.

In absence of this ~~torque~~ controlling torque, the pointer of the deflecting system gets deflected to maximum limit of deflection by any amount of current or voltage. Not only that, once deflection occurs, it cannot return to the zero position.

Note :- Deflecting Torque is directly proportional to Controlling Torque but acts in opposite direction.

(iii) Damping Torque :- The damping system is the third essential part of an indicating type instrument. The force generated in this system is called damping torque. The damping torque is applied to stabilize the pointer.

In the absence of damping torque, the pointer would continue to oscillate for a long time on both sides of its final position after deflection, which would make it difficult to obtain result. The damping system acts like a brake, due to which the pointer stops at its final position without oscillation.

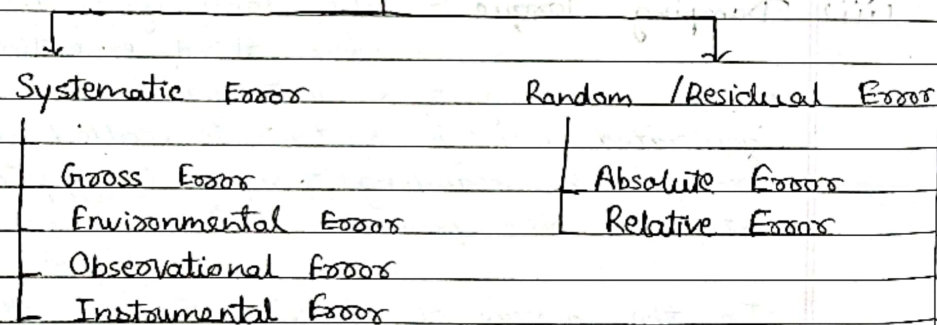
Error.

Error means estimated uncertainty. Mostly all measurements have error.

$$\text{Error} = \text{Measured Value} - \text{Actual Value}$$

Error is the difference between measured value and actual (true) value.

Types of Error



Systematic Error - Systematic error is a type of error which can be removed or corrected. This error is caused due to the fault of instrument, environment etc. or fixed procedural issues.

Ex- Ammeter always read 0.5 ampere high

Types of Systematic Error -

- (i) Gross Error - Gross error is mostly caused due to the misreading / misrecording of the observer.
- (ii) Environmental Error - The error which is caused due to the atmospheric pressure conditions such as temperature, pressure, magnetic field, heavy rain etc is called Environmental Error.
- (iii) Observational Error - This error is caused due to the observer. Error occurs when observer makes a wrong prediction or when the observer's line of sight doesn't directly align with the instrument's value.
- (iv) Instrumental Error - There is a chance of some errors in every instrument. caused due to manufacturing flaw, incorrect calibration etc. This error also occurs due to mechanical fatigue over time. Manufacturer provides some margin for calibration.

Random Error - Random Error is also called Residual Error. Even after correcting every systematic error if there is still some error left then, that error is called Residual Error. This error is caused by unpredictable and uncountable reasons. This error cannot be avoided and controlled but it can be reduced.

Ex - Fluctuating readings on a voltmeter

Types of Random Error -

- (i) Absolute Error - Absolute error is the maximum error which is equal to the difference of measured value and actual value of an object.

$$\text{Absolute Error} = \text{Measured value} - \text{Actual value}$$

- (ii) Relative Error - Relative error is the ratio of absolute error to the actual value of an object.

$$\text{Relative Error} = \frac{\text{Absolute error}}{\text{Actual value}}$$

Definitions (Short Notes)

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- (i) Sensitivity - Sensitivity is the property of a meter in which a very small amount of current may cause the meter to deflect at full scale.

The sensitivity of an instrument is defined as the ratio of change in output to the change in input.

$$\text{Sensitivity} = \frac{\text{Change in output}}{\text{Change in input}} = \frac{\Delta Q_0}{\Delta Q_1}$$

Ex - A Galvanometer is a highly sensitive instrument. Sensitivity is both desirable and essential for an instrument.

- (ii) Resolution - Resolution is the smallest change a measuring instrument can detect or display.

Ex - If the resolution of a voltmeter is 0.01 volt, then it can detect voltage changes of at least 0.01 volt.

(iii) Threshold - If the input of an instrument is increased very slowly, then the minimum value at which the instrument or system recognizes the change and starts giving output is called threshold.

Ex- If the threshold of a sensor is 2mV, then it does not give any output to signals less than 2mV.

(iv) Instrument Efficiency - The ratio of ^{the} power value measured at full scale to the power drawn by the instrument at full scale is called efficiency. It is denoted by η .

$$\text{Efficiency} = \frac{\text{Value measured at full scale (output)}}{\text{Power drawn at full scale (input)}}$$

Let in voltmeter,

R_m = Resistance of meter

E_{FS} = Reading of fullscale voltage

I_{FS} = Fullscale current

then,

$$\eta = \frac{E_{FS}}{P_{FS}} = \frac{\text{Output}}{\text{Input}} \quad \text{--- (i)}$$

$$P_{FS} = \frac{E_{FS}^2}{R_m} \quad \text{--- (ii)} \quad \left[V = E_{FS} \right]$$

$$P_{FS} = E_{FS} \cdot I_{FS} \quad \left[I = I_{FS} \right]$$

$$I_{FS} = \frac{E_{FS}}{R_m} \quad \left[R = R_m \right]$$

$$I_{FS} = \frac{E_{FS}}{R_m}$$

Putting value of I_{FS} in eq (ii)

$$P_{FS} = E_{FS} \times \frac{E_{FS}}{R_m}$$

$$P_{FS} = \frac{E_{FS}^2}{R_m}$$

Putting value of P_{FS} in eq (i)

$$\eta = \frac{E_{FS}}{\frac{E_{FS}^2}{R_m}}$$

$$\eta = E_{FS} \times \frac{R_m}{E_{FS}^2}$$

$$\eta = \frac{R_m}{E_{FS}}$$

(v) **Dead time** - The time (Δt) taken by the meter to respond is called dead time.

Dead time is defined as the time duration in a measurement when the instrument starts giving output after a change in input signal.

When a new input is given to a measuring system, the reading is not immediately visible but is visible after some time, then that delay is called dead time.

Ex- When measuring temperature with a thermometer, the result is not immediately visible, but after some time.

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(vi) **Accuracy** - Accuracy refers to the quality of a measured measurement that shows how close the measured value is to the true value.

Note - The ability of a measuring instrument to give results as close to the true value as possible is called accuracy.

$$\text{Accuracy} = \left(\frac{V_{\text{man}} - V_T}{V_T} \right) \times 100$$

V_{man} = Max value

V_T = True value

Imp

Precision - Precision in measurements refers to how closely repeated measurements of the same quantity agree with each other.

In simple terms, precision shows the consistency or repeatability of results.

Ex- The temperature at which water starts boiling is 100°C

Let the 4 readings measured by thermometer be

100.4°C

100.3°C

100.5°C

100.3°C

$$\text{Accuracy} = \left(\frac{V_{\text{man}} - V_T}{V_T} \right) \times 100$$

$$= \frac{100.5 - 100}{100} \times 100$$

$$= 0.5 \%$$

$$\begin{aligned}\text{Mean Reading} &= \frac{100.4 + 100.3 + 100.5 + 100.2}{4} \\ &= \frac{401.5}{4} \\ &= 100.375\end{aligned}$$

$$\begin{aligned}\text{So maximum deflection} &= V_{\text{max}} - \text{Mean Reading} \\ &= 100.5 - 100.375 \\ &= 0.125\end{aligned}$$

Tolerance - In measurement, tolerance is the acceptable value within which the measured or manufactured value is considered acceptable.

$$\text{Tolerance} = \frac{\text{Upper Limit}}{\text{Lower Limit}}$$

Different effects in measuring instruments

- (i) Magnetic effect - Generally used in voltmeter & ammeter
- (ii) Electromagnetic effect - used in voltmeter, ammeter, watt-meter
- (iii) Electrodynamic effect - used in voltmeter, ammeter, watt-meter
- (iv) Thermal effect - used in voltmeter & ammeter
- (v) Chemical effect - only used in DC ammeter-hour meter (power meter)
- (vi) Electrostatic effect - Photocopy machine, Laser printer, C.R.O., Air-Purifier etc.

Damping - The damping torque is applied to stop the pointer from oscillation after deflection. It stabilizes the pointer which makes it easier to find the readings.

Types of Damping -

There are three types of damping -

- (i) Air Friction Damping
- (ii) Fluid Friction Damping
- (iii) Eddy Current Damping

(i) **Air Friction Damping** -

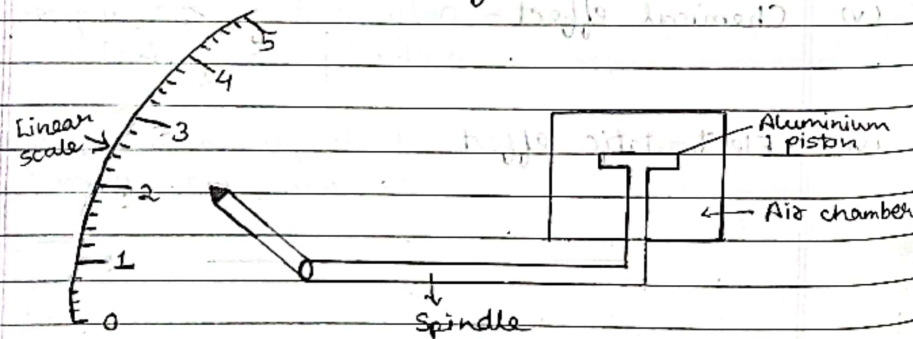


Fig - Air Friction Damping

Principle -

In this method, damping is produced by friction of air.

Construction -

A light piston (made of aluminium) is attached to the spindle and placed inside a closed air chamber. This chamber is fixed to the instrument frame, while the piston is connected to the pointer system.

Working - The piston is attached to the moving system. When the pointer deflects, the piston moves up and down inside the chamber. The air inside the chamber resists this motion, which produces a damping force.

The air resistance prevents continuous vibration of the pointer and helps it come quickly to rest at its correct final position.

Advantages -

1. The system is simple & reliable

2. It provides smooth, vibration-free pointer moves.

3. It does not affect the magnetic field of instrument.

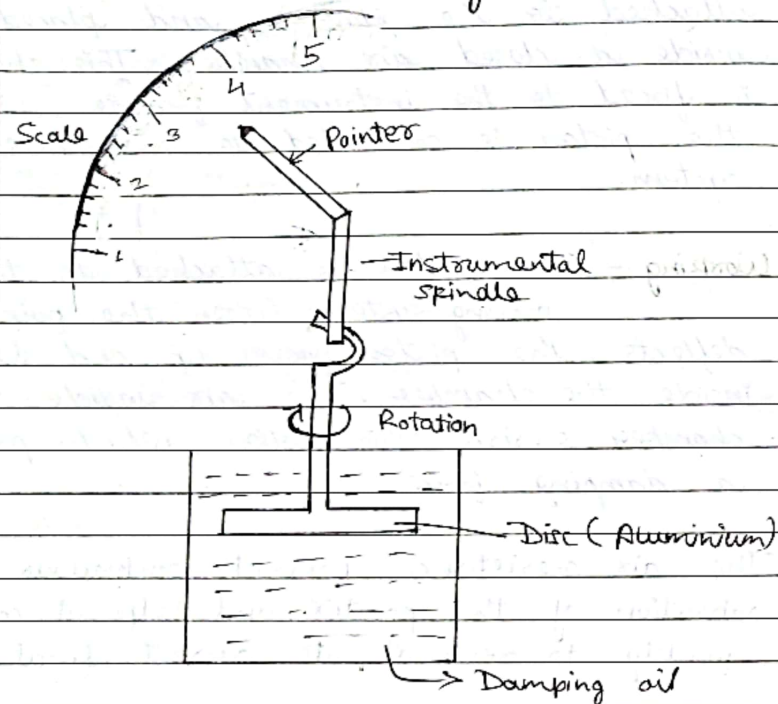
4. Longer life.

5. No leakage problem.

Disadvantages -

1. Difficult to adjust damping.
2. Less effective.

Fluid Friction Damping -



In this method of damping, oil is used to produce friction. This method is also similar to air friction damping, but here the viscosity of the fluid controls the damping. Damping takes place due to the viscous nature of the fluid.

Greater viscosity results in higher friction and more production of damping torque. In this method, when the moving system rotates, the disc also rotates. Because of rotation of

the disc, friction is produced, which creates the necessary damping torque. The disc is immersed inside the damping oil.

Characteristics of Oil -

The oil used in this system should have the following characteristics :-

1. The oil must not be sticky.
2. There should be no moisture in the oil.
3. The oil should not evaporate easily.
4. The viscosity of the oil should not change with temperature variation.
5. The oil should have good insulating properties.

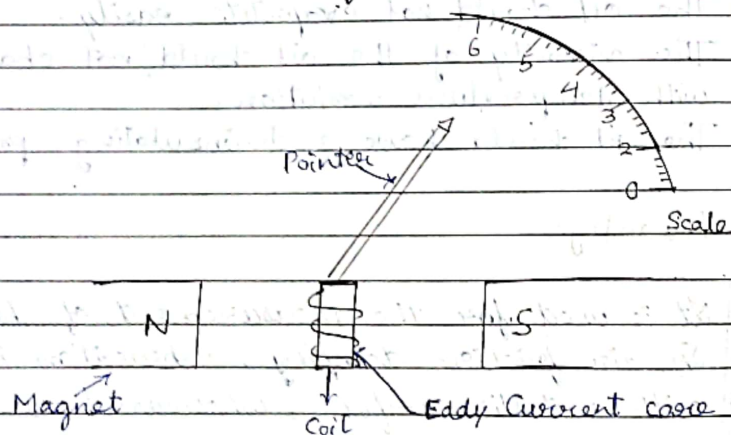
Advantages -

1. It is used for the measurement of high ratings.
2. In air friction damping, lubrication is required with metallic surfaces, whereas here no lubrication is needed.
3. It reduces the load on thrust bearing on the moving system.

Disadvantages -

1. It is mostly used only in vertical and highly damped instruments.
2. Due to the sticking or creeping effect of oil, error may occur in the readings of the instrument.
3. In such instruments, it is difficult to move the instrument.

Eddy Current Damping -



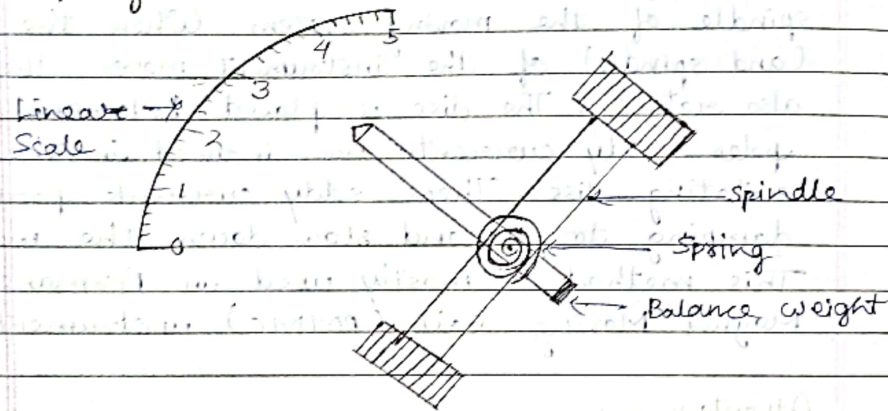
This method of damping is based on the principle that when a conducting material moves in a magnetic field, eddy currents are produced inside it. These eddy currents create a damping torque, according to Lenz's law which opposes the motion.

A rectangular aluminium disc is attached to the spindle of the moving system. When the pointer (and spindle) of the instrument moves, the disc also rotates. The disc is placed between the poles, eddy currents are induced in the rotating disc. These eddy currents produce damping torque and slow down the motion. This method is mostly used in Permanent Magnet Moving Coil (PMMC) instruments.

Advantage -

- This is the most efficient method of damping. The moving system stops quickly due to this method because eddy currents are produced in proportion to the speed of movement, and hence damping also increases with speed. So, the system comes to rest more quickly.
- Since the disc is made of a non magnetic material, it does not get attracted towards the magnet, and therefore its position does not get disturbed. Hence, no error occurs during observation.

Spring Control Method-



The deflection of a spring controlled instrument is proportional to the current, therefore the scale of instruments using spring control remains uniform.

Working- Spring control method is commonly used in most indicating instruments. In these method, there is a controlling spring of phosphorus attached to the moving system of the instrument along with the spindle. The spindle and spring provides support to the moving system.

On supplying current to the instrument, the spring turns in the opposite direction while deflecting & due to this the spring produces a controlling torque which is proportional

to the deflection angle. The controlling torque opposes the deflecting torque. When the controlling torque becomes equal to the deflecting torque, the pointer comes to rest.

T_d = deflecting torque

T_c = controlling torque

I = current, θ = angle

$T_d \propto I$, $T_c \propto \theta$

$T_d \propto T_c$ (at rest position)
 $I \propto \theta$

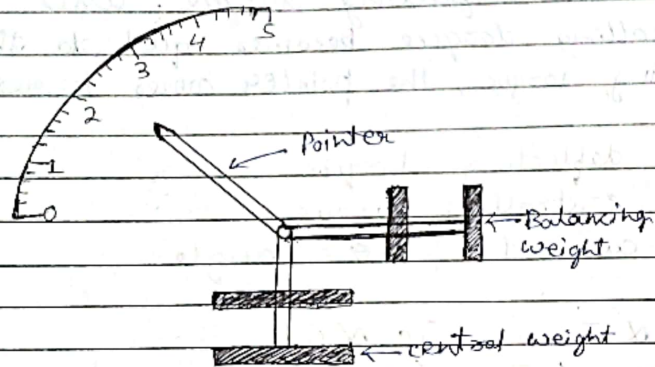
Advantage -

- 1) It is easy to use
- 2) It can be used vertically or horizontally
- 3) In this, the external force is not required control.
- 4) Use linear scale.

Disadvantage -

- 1) It is costly
- 2) Requires careful handling
- 3) It can depend on pressure & temperature.

Gravity Control Method



$$T_d \propto I \Rightarrow T_c \propto \sin \theta, T_d \propto T_c \Rightarrow I \propto \sin \theta$$

Working - In this method a small weight (w) is attached to the spindle of the moving system. The weight acts like a pendulum.

When the pointer deflects, the weight shifts position, creating a restoring torque proportional to the sine of the angle of deflection. This torque opposes the deflecting torque & stabilizes the pointer at the correct reading.

At zero mark, the controlling weight is positioned so that the no torque acts. As the pointer moves, gravity produces torque that increases with deflection, ensuring balance at a unique position.

Advantages -

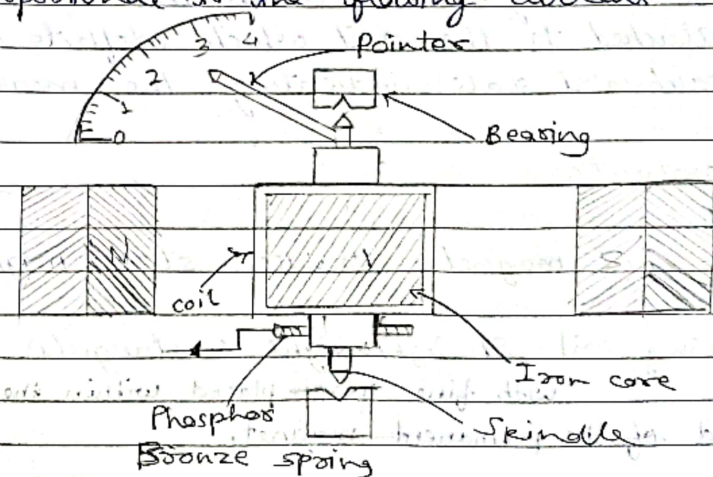
- 1) Simple design, no spring required.
- 2) Provides reliable restoring torque.

Disadvantages -

- 1) Works only when instrument is kept vertical.
- 2) Cannot be used in portable instruments.
- 3) Limited accuracy compared to spring control.

PMMC - Permanent Magnet Moving Coil -

PMMC instrument measures DC voltage or current using a coil suspended in a permanent magnetic field with the deflection of a pointer directly proportional to the flowing current.



Working Principle -

The PMMC instrument works on the principle that a current carrying conductor placed in a magnetic field and experiences a force and thus a torque, which causes it to move.

This torque is directly proportional to the current flowing through the coil. The PMMC instrument uses a rectangular coil of fine wire, wound on a light aluminium or copper wire with an iron core mounted between the poles of a permanent magnet.

When current flows through the coil, it produces a magnetic field that interacts with the permanent magnetic field resulting in the coil rotating. This rotation moves a pointer attached to the coil which deflects over a calibrated scale indicating the measurement.

Construction -

- Permanent magnet - Provides a steady magnetic field.
- Moving coil - A lightweight rectangular coil wound with fine wire, placed within the magnetic field of the permanent magnet.

- Iron core:- Positioned inside the coil to provide an easy path for the magnetic flux and to strengthen the magnetic field.

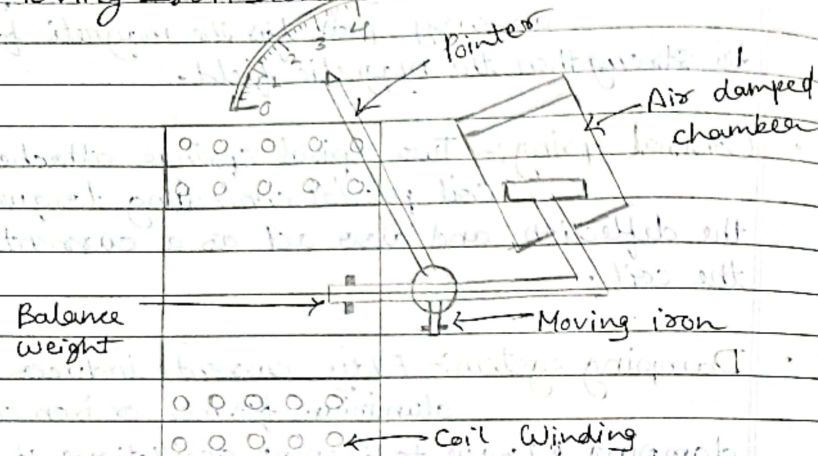
- Control spring:- Two spiral springs attached to the coil provide controlling torque opposing the deflection, and also act as a current leads to the coil.

- Damping system:- Eddy currents induced in the aluminium former or iron core provide damping torque to prevent oscillations of the pointer.

- Pointer & Scale:- The pointer is attached to the coil spindle & moves over a calibrated scale indicating the measured value.

To operation when current flows through the moving coil, it experiences a deflecting torque due to the interaction with the permanent magnet. This torque causes the coil & pointer to move. The controlling torque provided by the spiral springs opposes this motion & balances it at a certain angle. The damping torque ensures the pointer comes to rest quickly without oscillation. The amount of pointer deflection is directly proportional to the current flowing through the coil making the PMMC instrument accurate & linear for DC measurements. Its scale is uniform.

• Moving Iron Instrument :-



The moving part of this instrument is iron that's why it is known as moving iron instrument. This instrument is used for voltage measurement. It is divided into two parts according to construction.

- 1) Attraction type MI instrument
- 2) Repulsive type MI instrument

Working Principle :-

When a soft iron piece is placed in a magnetic field of a current carrying coil. It is attracted towards the centre of coil.

Construction:-

- When a current proportional to the voltage current to be measured flows through the coil, a magnetic field is produced along its axis, which magnetizes the ~~is~~ iron disc or piece. Due to the magnetic effect of the coil, the eccentric iron piece or disc is attracted towards the coil. But the force of attraction on the disc depends on the current flowing in the coil.

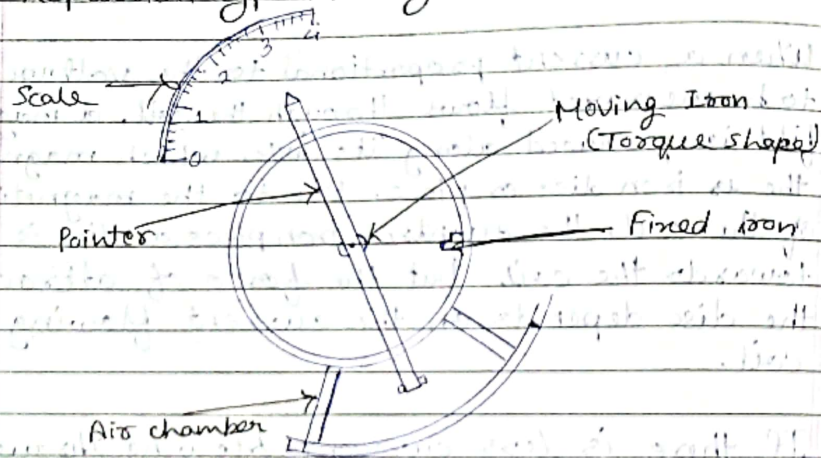
- If there is less current flowing through the coil, there will be less attraction force, and if there is more current flowing through it, there will be more attraction force. This attraction force does not depend on the direction of the current flowing through the coil. In other words, the direction of the current can be anywhere but the attraction force will continue to act. Does not depend on any direction.

The center eccentric iron piece is connected to a pointer or indicator and as the disc moves, the pointer shows a deflection on a calibrated scale. Damping is done by the air friction damping.

Therefore, attraction type Moving Iron instrument works on the principle of electromagnetic induction.

It works on both AC & DC. Its scale is non uniform.

Repulsion type Moving iron instrument



A repulsion type moving iron instrument works on the principle that when two soft iron pieces are magnetized with the same polarity by current flowing through a coil, they repel each other. This repulsion moves the pointer across a calibrated scale, allowing measurements of current or voltage in both AC & DC currents.

Principle of operation :-

When current flows through the coil, it produces a magnetic field.

Two soft iron pieces (a fixed vane & a movable vane) are placed inside the coil.

Both vanes get magnetized with the same polarity.

Because like poles repel, the movable vane is repelled or pushed by the fixed vane.

This mechanical movement is transferred to a pointer which deflects over a scale to indicate the magnitude of current or voltage.

Construction:- The repulsion type MI instrument is made of following.

- **Coil :-** A hollow cylindrical coil carries the current to be measured.
- **Fixed Iron vane :-** Stationary piece of soft iron inside the coil.
- **Movable iron vane :-** Attached to a spindle and pointer free to rotate.
- **Pointer & Scale :-** Pointer moves over a calibrated scale to show the reading.
- **Control mechanism :-** Springs provide controlling torque to balance deflection.
- **Damping :-** Air friction damping is usually employed to stabilize the pointer.

Working Characteristics

Deflection is proportional to the square of the current (I^2) meaning the instrument can measure both AC & DC since polarity doesn't matter.

The scale is non-linear, crowded at the lower end & more spread at the higher end.

Torque is produced by the repulsion force between the vanes balanced by spring control.

Advantages:

- It can measure both AC & DC.
- Simple & robust construction.
- Less affected by stray magnetic field compared to attraction type instruments.
- Low cost instrument.

Disadvantage:

- Pointer of this instrument is not completely vibrationless.
- It has non-uniform scale which is less accurate at low readings.

Requires careful calibration for accurate results.

Limited precision compared to other instrument like dynamometer or digital meters.

★ Difference between MI instrument & Moving coil instrument.

Moving Iron Instrument

It is used to measure AC & DC current.

Its scale is non linear / uniform.

It is robust in construction.

Its price is lower compared to moving coil instrument.

It is not completely vibration less.

DC measurement is less accurate.

Its value get affected by stray magnetic field.

Moving coil instrument

It is only used to measure DC current.

Its scale is uniform / linear.

It is not robust in construction.

Its price is high.

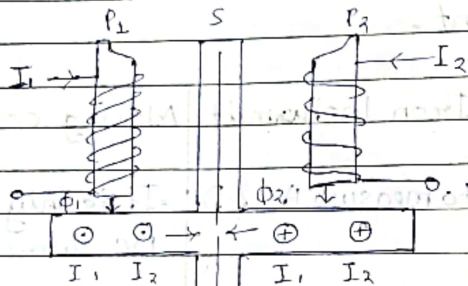
It is completely vibration less.

DC measurement is accurate than MI instrument.

It is not affected by external / stray magnetic field.

Induction type MI instrument

This is also based on the principle of Electromagnetic induction. This is used for measurement of AC quantity (AC current / AC voltage).



- Alternating current in the coil produces a changing magnetic field, which induces eddy currents in nearby iron or aluminium parts. The interaction between these induced currents & the magnetic field generates a torque that moves the pointer allowing measurement of AC quantities like current, voltage or power.

Working principle:-

- It is based on Faraday's law of electromagnetic induction. When AC flows through the coil, it creates a time-varying magnetic field. This field induces eddy currents in a metallic disk or cylinder (usually aluminium or iron).
- The induced currents interact with the original magnetic field, producing a repulsive torque. This torque moves the pointer over a calibrated scale proportional to the magnitude of AC quantity.

★ Construction:-

- This contains electro magnetic poles P & P. that are iron core.
- In these poles there are fixed coils present in which current I_1 flows from first one & current I_2 flows through another one. In both coils there is two alternating flux Φ_1 & Φ_2 produces.
- Coils:- Two or more fixed coils carry the alternating current.
- Iron/Aluminium Disc or Cylinder:- They are placed near the coils where the eddy currents are induced.

- **Moving system**:- The disc or cylinder is attached to a spindle and pointer.
- **Control mechanism**:- Springs provide controlling torque to balance deflection.
- **Damping**:- Air friction damping is used to stabilize the pointer.

Types:-

- 1) Induction type Ammeter.
- 2) Induction type Voltmeter.
- 3) Induction type Energy meter.

Advantage:-

- Rugged & simple construction.
- It is perfect for AC measurement.
- Suitable for measuring power & energy in AC circuits.

Disadvantages

- Cannot be used for DC measurement.
- Its construction is bit complicated.
- It depends on the temperature.
- Non-uniform scale make precise low-range reading difficult.

Applications:-

- Widely used in AC ammeters, volt meters, watt meters & energy meters.
- Common in household electricity meters. (Induction type energy meters)

CATHODE RAY OSCILLOSCOPE & DIGITAL STORAGE OSCILLOSCOPE

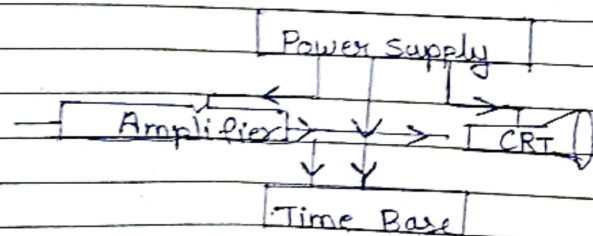
5.1: CATHODE RAY OSCILLOSCOPE

About it:-

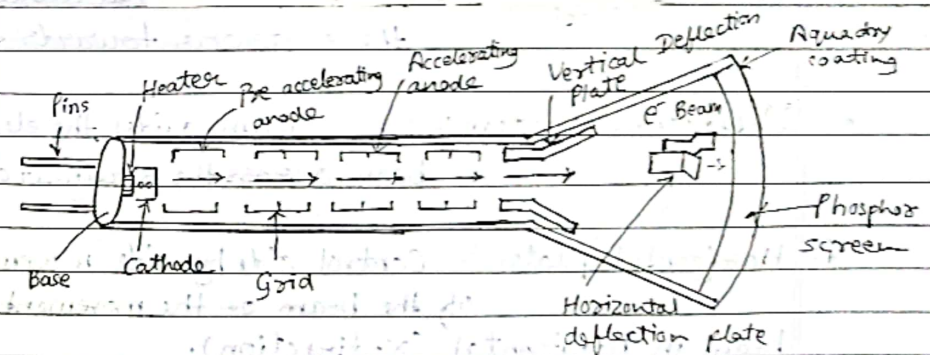
A CRO is an extremely useful instrument, it is mostly used for testing electrical & electronic circuits. Through it voltage, current, time, frequency & phase can be measured directly.

Fundamentally, a CRO creates the waveform of an AC voltage on the screen, which allows the functioning in the circuit to be easily predicted. The function in the circuit can be observed on the CRO screen by converting it into voltage.

Basic block diagram of CRO:-



- **Power Supply**:- Provides the required voltage for operation.
- **Vertical Amplifier**:- Controls the amplitude of the signal or amplify the signal in Y-axis.
- **Horizontal Amplifier & time base**:- Controls how fast the beam move horizontally or in X-direction in a time scale.
- **Trigger Circuit**:- It stabilizes the waveform so it doesn't move randomly.
- **C.R.T**:- Cathode Ray tube is the main display part where the waveform appears. It is also known as the heart of CRO.



Cathode Ray Tube (C.R.T.)

Date:

Page No.		

Electron Gun:- This is at the narrow end of the CRT and produces a focused beam of electrons. It typically consists of:

- i) Heater:- Heats the cathode to emit electrons.
 - ii) Cathode:- A negatively charged electrode that emits electrons when heated.
 - iii) Control Grid:- Controls the number of electrons reaching the screen, thus controlling the brightness of image.
 - iv) Focusing Anodes:- Electrodes that focus the electron beam into a tight spot.
 - v) Accelerating Anodes:- Electrodes that accelerate the electrons towards the screen.
- Deflection system:- This system guides the electron beam across the screen. It can be:
 - i) Horizontal plates:- Control side by side movement of the beam or the movement of beam in horizontal (X-direction).
 - ii) Vertical plates:- Control up & down movement of the beam or control the movement of beam in vertical direction (Y-axis).

- These plates are arranged inside the tube, with the electron beam passing btwn them.
- Applying a voltage difference across the plates creates an electric field that deflects the beam.
- Its purpose is to precisely steer the beam to trace waveform or pattern on the screen.
- Fluorescent Screen:- This is the front surface of the G.T. coated with phosphors. When the electron beam strikes the phosphors, they emit light, creating the image. Different phosphors emit different colours of light.
- Glass Envelope:- The evacuated glass bulb that encloses all the components - the vacuum is crucial to prevent the electrons from colliding with air molecules.
- Aquadag Coating:- An internal conductive coating (often graphite) that collects the electrons after they strike the screen & return them to the electron gun preventing charge buildup.
- Base:- Holds the electrical connections for the C.R.T. & connects the internal electrodes to external circuits.

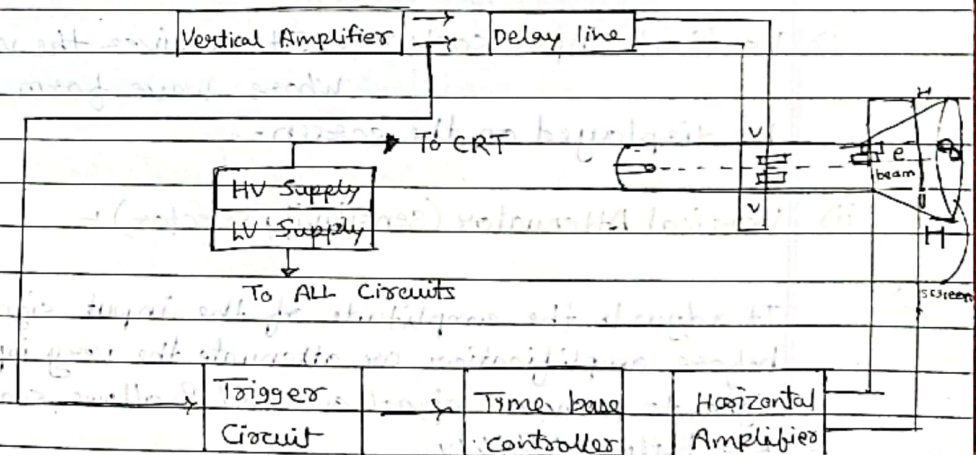
USES OF CRO

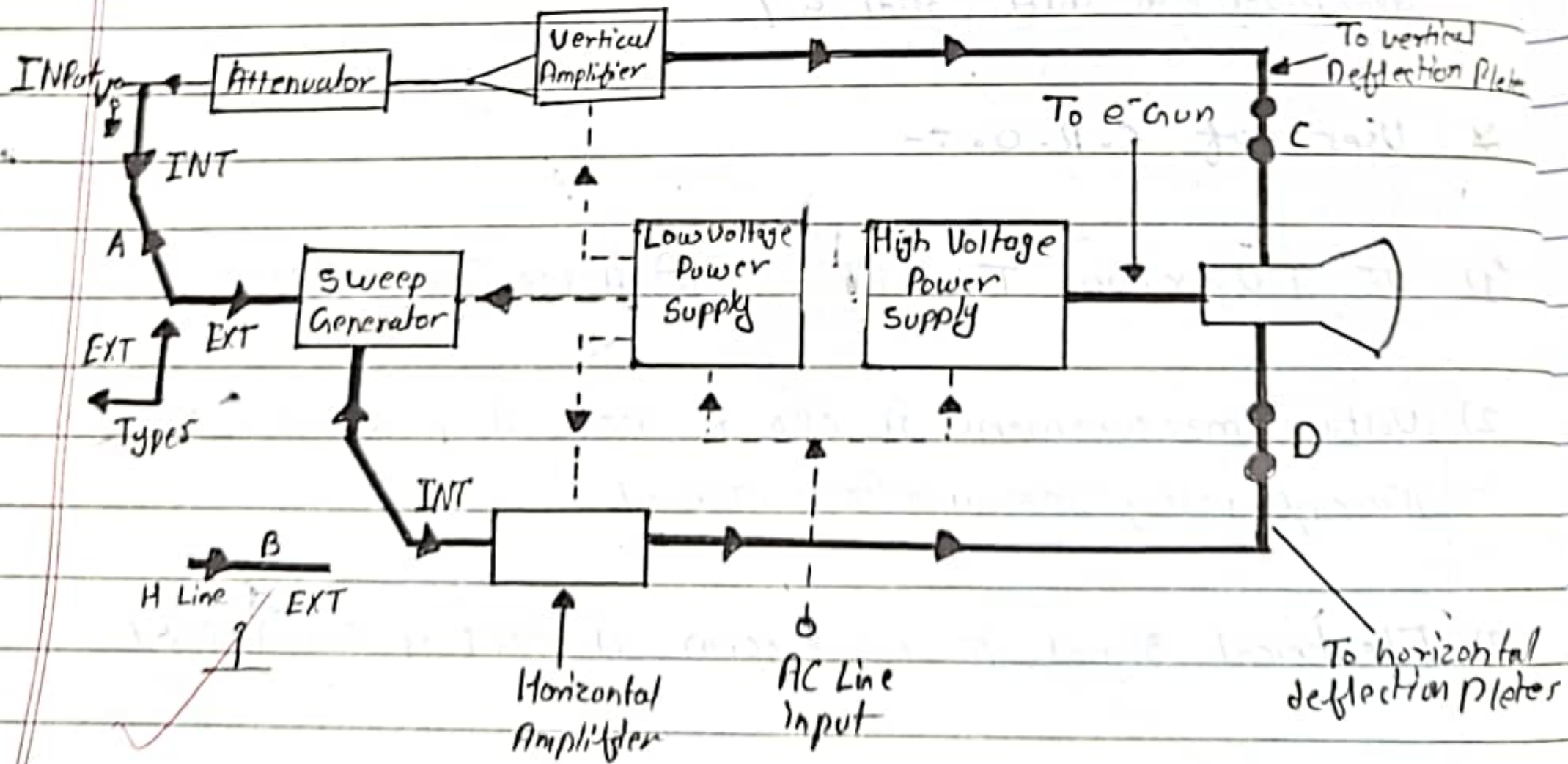
- It is used in measurement of voltage like its Peak value average & RMS value can be measured.
- It is also used in measurement of frequency & time period.
- It can also measure phase difference b/w two signals using dual-trace CRO.
- It is used for waveform analysis.
 - Displays the shape of signals (sine, square, triangular, etc.)
 - Detects distortion, noise or irregularities in circuits.
- Useful in amplifier & filter testing.
- It observes sudden changes in signals (switching, spikes, surges).
- Essential for studying digital circuits & pulse responses.

- It is commonly used in laboratories for teaching waveform behaviour.
- Used in physics & electronics experiments.
- CRO principles are applied in ECG machines to display heart signals. & also used in ECG for brain signal monitoring.

Block diagram of CRO:-

i) General purpose CRO block diagram.





Main diagram of C.R.O.

.. Main parts of CRO & their functions :-

i) Vertical input socket :- It receives the voltage whose wave form is to be displayed on the screen.

ii) Vertical Attenuator (Sensitivity selector) :-

It adjusts the amplitude of the input signal before amplification or attenuate the very input signal to prevent signal overload & allows scaling for better visibility.

iii) Vertical Amplifier :- Amplifies the input signal to a level suitable for deflection.

It make the signal strong enough to move the electron beam vertically on the screen.

- iv) Delay line:- It makes a slight delay in the vertical signal. Its purpose is to ensure the horizontal sweep starts before the signal reaches the screen so the beginning of the waveform is visible.
- v) Sweep generator:- It produces a ramp (sawtooth) voltage. This voltage moves the electron beam horizontally across the screen at a constant rate. It provides the X-axis (time) for the waveform display.
- vi) Synchronizer:- Synchronizes the sweep with the input signal. It stabilizes the waveform display so it doesn't drift or flicker.
- vii) H-Input:- Accepts the external signals for horizontal deflection.
- viii) Horizontal Amplifier:- It amplifies the sweep or horizontal input signal & it drives the horizontal deflection plates to control beam movement across the screen.
- ix) Cathode Ray tube:- It displays the waveform of the given input AC voltage or given voltage source.

iii) It contains:-

- Electron gun:- Generate & accelerate the beam.
- Deflection plate:- It makes the beam to move in X or Y direction or steer the beam.

Phosphor screen:- Glows when struck by the beam. It converts electrical signals to visible pattern. It is also known as the heart of CRO.

X) Power Supply:- It provides necessary voltages to all CRO components. Its purpose is to power the electron gun, amplifiers & sweep circuits.

CONTROLS ON CRO

1) Vertical centre:-

CRO is arranged in the vertical direction in such a way that its center remains perpendicular, so that its output is obtained correctly.

2) Horizontal centre:-

CRO is arranged in the horizontal direction in such a way that its center remains perpendicular, so that its output is obtained correctly.

3) Intensity:-

The intensity of the CRO waveform is very high. To control the intensity, a vertical amplifier is used. It controls the waveform going in the vertical direction. By controlling the waveform in this direction, the intensity also gets controlled.

4) Focus:-

To control the focus of the CRO, a horizontal amplifier is installed in it, which moves its focus in the horizontal direction and amplifies.

Note:- It sharpens the clarity of the waveform through

5) Course:-

To control its course, a swift generator is installed in its inner portion. Installing this generator prevents distortion on its inner side.

6) Fine:-

The CRO looks quite good, and to maintain its beauty special attention is given to its care & location. It is kept away from moist places so that no damage can occur to its inner part.

7) Synchronous Selector:-

The frequency of the CRO is well organized by the synchronous selector. The main work of this selector is to give the required points in vertical & horizontal directions in chunks to the sweep generator.

8) Synchronous Amplitude:-

By using synchronous amplitude, we can expand the amplitude of the CRT's electron gun & get a better output.

9) Horizontal Gain:-

Horizontal gain controls the deflection plates.

10) External synchronous input:-

The input of the CRO is controlled by external synchronous input.

11) Power indicator:-

It shows the incoming power supply of the CRO.

12) Power switch:-

Power switch is installed for the purpose of controlling the power supply, which can turn the power supply on or off when necessary.

13) On/off switch:-

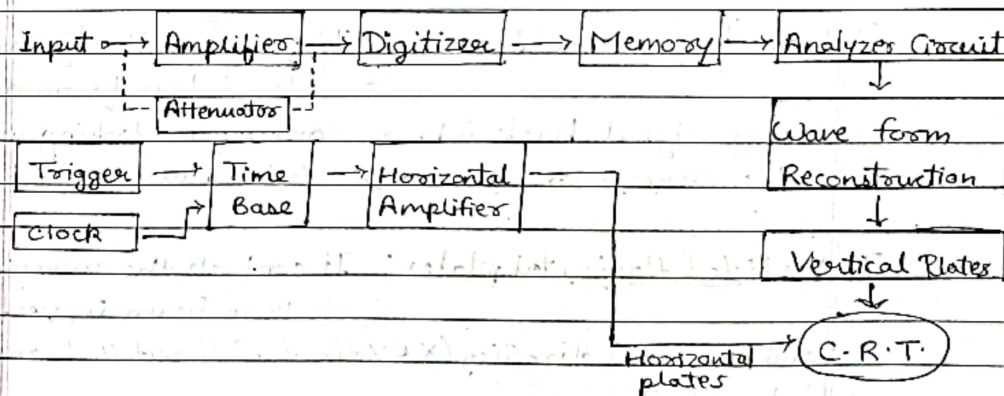
An on/off switch is also been used in CRO, which turns the alternating current going into it on or off. Installing this switch can protect the electronic circuit of the CRO.

DIGITAL STORAGE OSCILLOSCOPE

About it:-

A DSO is an instrument used to process, capture, analyze & display analog input signals in digital form storing the signal digitally in memory for later display & analysis. The DSO converts the input analog signal into digital format through an Analog to Digital Converter, stores the digital data in memory & reconstructs the waveform for display typically on a cathode ray tube (CRT) on modern display.

Block diagram



Main components of CRO:-

- 1) Input signal:- The analog signal to be analyzed is fed into the oscilloscope.

Qm) In given lissajous patterns what is the frequency of unknown frequency signal if frequency applied over the horizontal plate is 1000.

Formula:- Horizontal plate frequency $\times$

$$\frac{\text{No. of loop touching the x-axis}}{\text{No. of loop touching the y-axis}}$$



⇒ Given:-

Applied frequency on horizontal plate = 1000 Hz

then according to formula-

Horizontal plate frequency $\times$

$$\frac{\text{no. of loop touching X-axis}}{\text{no. of loop touching Y-axis}}$$

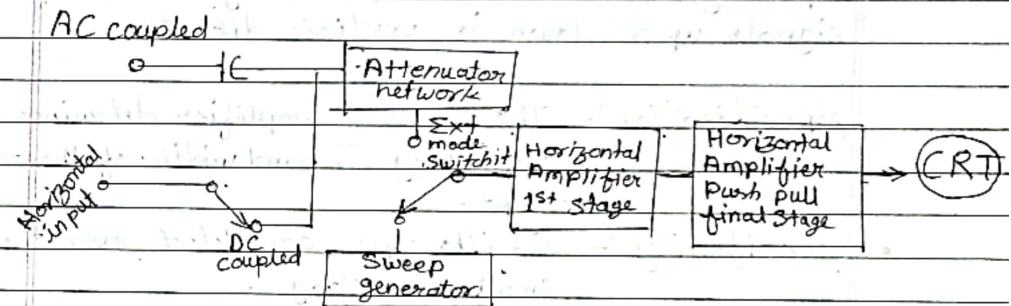
a) $[1000 \times \frac{1}{1} = 1000 \text{ Hz}]$

b) $[1000 \times \frac{1}{2} = 500 \text{ Hz}]$ Answer

X-Y AMPLIFIER

X-amplifier:- X-amplifier is responsible for moving the electron beam in horizontal direction or X-direction.

It amplifies the sawtooth signal and then connects it to the CRT's horizontal deflection plate so that the electron beam can move from left to right.



Inputs:- The x-amplifier is connected to an input sawtooth generator. This generator produces a ramp voltage that slowly increases over time and then suddenly drops causing the beam to continuously move from left to right.

~~The main objective of this is to~~

The main objective of this is to deflect the beam in the horizontal direction according to time to a certain distance. This shows the change of signal over the time on the screen.

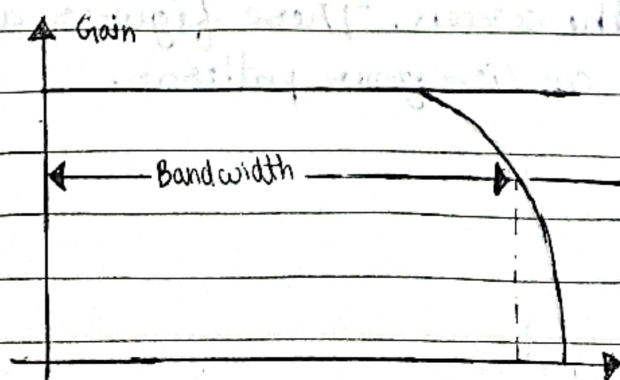
2) X-Y mode:- When the oscilloscope is in X-Y mode, the signal given from horizontal input terminal is amplified by it. In this mode, a Lissajous pattern is formed on the screen.

★ Vertical Amplifier:- Vertical amplifier is responsible for moving the electron beam in vertical or Y direction. This amplifier input signals like AC or DC voltage to move the signals up & down in vertical direction.

Specification:- The vertical amplifier determines the sensitivity & bandwidth of the oscilloscope.

- Sensitivity:- Oscilloscope can detect even the smallest voltage.
- Bandwidth:- Oscilloscope can accurately display the maximum bandwidth.

A vertical amplifier properly produces signals with low amplitude & high frequency & is useful for signals with a high rise time.



(Measurement using bridges / meters)

Bridges

Bridges are the special circuits used to determine unknown values of resistance, capacitance, inductance or other parameters with high accuracy.

They work by balancing two arms of a bridge network so that no current flows through the detector allowing precise calculation of the unknown component.

- A bridge circuit is formed by four arms (branches) connected in a loop, with a detector like galvanometer or voltmeter b/w two opposite junctions.
- Bridges are classified into DC bridges (operated with direct current, mainly used for resistance measurement) & AC bridges (operated with alternate current, mainly for capacitance, inductance & impedance measurement).

Classification of Resistance

Resistances are of three types:-

- 1) Low resistance
- 2) Medium resistance
- 3) High resistance

- Low resistance :- 1Ω or less than 1Ω resistances are come under this category. It is used in high current circuits where minimal opposition is required.
- Medium resistance :- Resistance from 1Ω to 100Ω resistance are come under the category of medium resistance.
- High resistance :- $100 \text{ k}\Omega$ or more the $100 \text{ k}\Omega$ resistance come under this category.

Methods for measurement of resistances.

1) Low resistance measurement

- a) Ammeter, voltmeter method
- b) Kelvin double bridge method
- c) Ohm meter method
- d) Potentiometer method

2) Medium resistance measurement

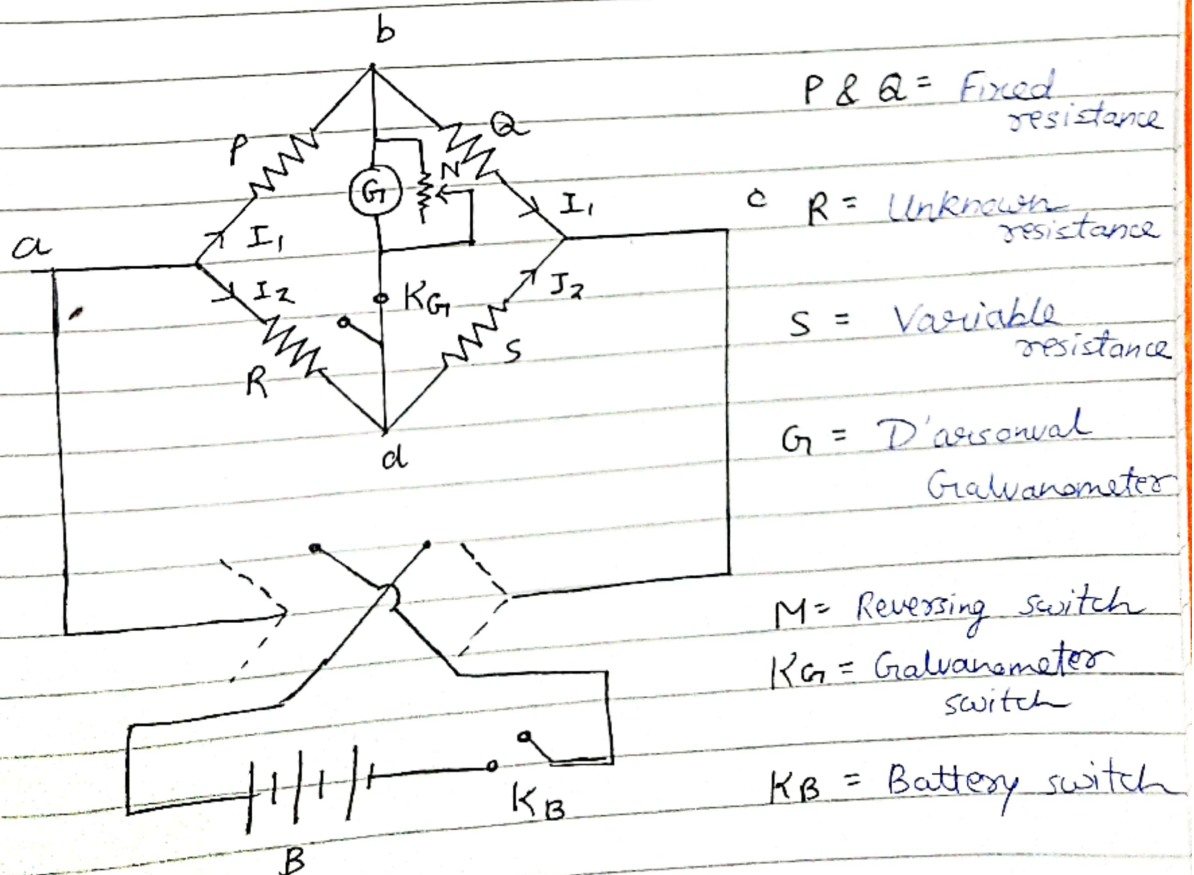
- a) Ammeter voltmeter method
- b) Direct deflection method or substitution method
- c) Wheat stone method

3) High resistance measurement

- Direct deflection method
- Iron loss method
- Bridge method
- Mega ohm bridge method (Megger)
- Electronic method

* Wheatstone bridge

A wheatstone bridge is an electrical circuit used to measure an unknown electrical resistance with high accuracy by balancing two legs of a bridge circuit. It is used for the measurement of medium resistance.



Derivation:-

Voltage drop at point a

$$I_1 P = I_2 R \quad \text{--- (1)}$$

Voltage drop at point b

$$I_1 Q = I_2 S \quad \text{--- (2)}$$

on dividing eqn (1) by eqn (2)

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

$$\left[\frac{P}{Q} = \frac{R}{S} \right] \text{ under balance condition}$$

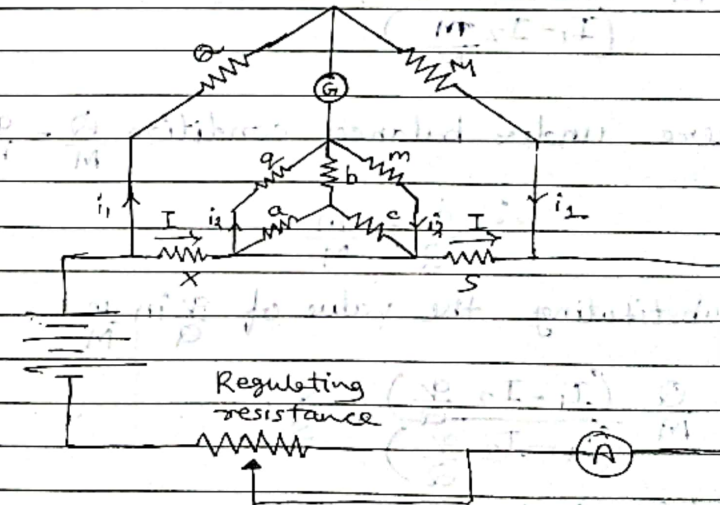
For finding unknown resistance R

$$R = \left(\frac{P}{Q} \right) \times S$$

★ Kelvin double bridge:-

Kelvin double bridge is the ~~best~~ method to measure low resistances. It is also the modified version of wheat stone bridge. In this method the error caused by contact or lead resistance are eliminated.

It uses a second set of ratio arms to eliminate error caused by lead & contact, which makes accurate low resistance measurements difficult with a standard WSB principle. The principle relies on maintaining a specific ratio between the two sets of arms to cancel out these parasitic resistances.



Kelvin Bridge

In loop ① Applying KVL

$$I_1 R - I_2 q - I_X = 0$$

$$I_1 R - I_2 q = I_X \quad \text{--- (1)}$$

Applying KVL in loop ②

$$I_1 M - I_S - I_2 m = 0$$

$$I_1 M - I_2 m = I_S \quad \text{--- (2)}$$

Dividing eqn ① from eqn ②

$$\frac{I_1 R - I_2 q}{I_1 M - I_2 m} = \frac{I_X}{I_S}$$

$$\frac{R}{M} \left(\frac{I_1 - I_2 \frac{q}{R}}{I_1 - I_2 \frac{m}{M}} \right) = \frac{X}{S}$$

$$\frac{R}{M} \left(\frac{I_1 - I_2 \frac{q}{R}}{I_1 - I_2 \frac{m}{M}} \right) = \frac{X}{S}$$

here under balance condition $\frac{R}{M} = \frac{q}{m}$

$$\therefore \frac{q}{R} = \frac{m}{M}$$

Substituting the value of $\frac{q}{R}$ in $\frac{m}{M}$

$$\frac{R}{M} \left(\frac{I_1 - I_2 \frac{q}{R}}{I_1 - I_2 \frac{q}{R}} \right) = \frac{X}{S}$$

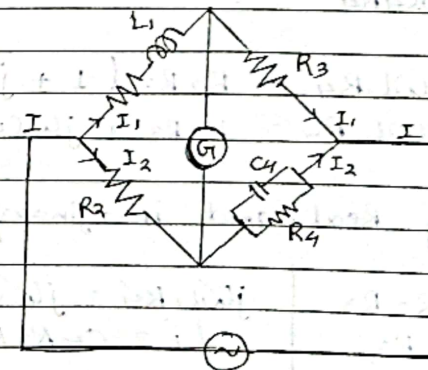
$$\left[\frac{R}{M} = \frac{X}{S} \right]$$

$$\left[X = \left(\frac{R}{M} \right) S \right] \text{ for finding unknown resistance}$$

✱ Maxwell's Induction bridge:-

This is also known as Maxwell's LC bridge. It is an AC bridge used to measure an unknown inductance by comparing it with known standard resistors & capacitors. It is a modified version of the wheat stone bridge that balances an unknown inductive impedance against a known capacitive impedance. the bridge is balanced when no current is flown through the detector, at which point the unknown inductance can be calculated from the values of others components.

It uses the principle of impedance composition, where the positive phase angle of the unknown impedance is compensated by the negative phase angle of the known capacitance in opposite arm.



Where,

$$Z_1 = R_1 + j\omega L_1$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_4 = \frac{1}{\frac{1}{R_4} + \frac{1}{j\omega C_4}} = \frac{R_4}{1 + j\omega C_4 R_4}$$

At Balance Condition

$$Z_1 Z_4 = Z_2 Z_3$$

$$(R_1 + j\omega L_1) \left(\frac{R_4}{1 + j\omega C_4 R_4} \right) = R_2 R_3$$

$$\frac{R_1 R_4 + j\omega L_1 R_4}{1 + j\omega C_4 R_4} = R_2 R_3$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 (1 + j\omega C_4 R_4)$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega C_4 R_2 R_3 R_4$$

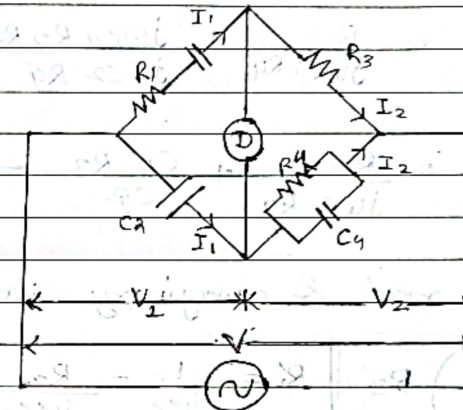
Comparing Real and imaginary part

$R_1 R_4 = R_2 R_3$	$j\omega L_1 R_4 = j\omega C_4 R_2 R_3 R_4$
$R_1 = \frac{R_2 R_3}{R_4}$	$L_1 = C_4 R_2 R_3$

$$Q \text{ Factor} = \frac{\omega L_1}{R_1}$$

Schering bridge :-

This method is used for the measurement of unknown capacitance, dielectric loss and low or high voltage power factor measurement.



At Balance Condition,

$$Z_1 = R_1 + \frac{1}{j\omega C_1} \quad (1)$$

$$Z_2 = \frac{1}{j\omega C_2} \quad (2)$$

$$Z_3 = R_3 \quad (3)$$

$$Z_4 = \frac{1}{\frac{1}{R_4} + j\omega C_4} = \frac{R_4}{1 + j\omega C_4 R_4} \quad (4)$$

$$\left(R_1 + \frac{1}{j\omega C_1}\right) \times \frac{R_4}{1 + j\omega C_4 R_4} = \frac{R_3}{j\omega C_2}$$

$$R_1 + \frac{1}{j\omega C_1} = \frac{R_3}{j\omega C_2} \left(\frac{1 + j\omega C_4 R_4}{R_4} \right)$$

$$R_1 + \frac{1}{j\omega C_1} = \frac{R_3}{j\omega C_2 R_4} + \frac{j\omega C_4 R_3 R_4}{j\omega C_2 R_4}$$

$$R_1 + \frac{1}{j\omega C_1} = \frac{R_3}{j\omega C_2 R_4} + \frac{C_4 R_3}{C_2} \quad (5)$$

Comparing real & imaginary part -

$$R_1 = \left(\frac{C_4}{C_2} \right) R_3$$

$$\frac{1}{j\omega C_1} = \frac{R_3}{j\omega C_2 R_4}$$

$$\frac{1}{C_1} = \frac{R_3}{C_2 R_4}$$

$$C_1 = \frac{C_2 R_4}{R_3}$$

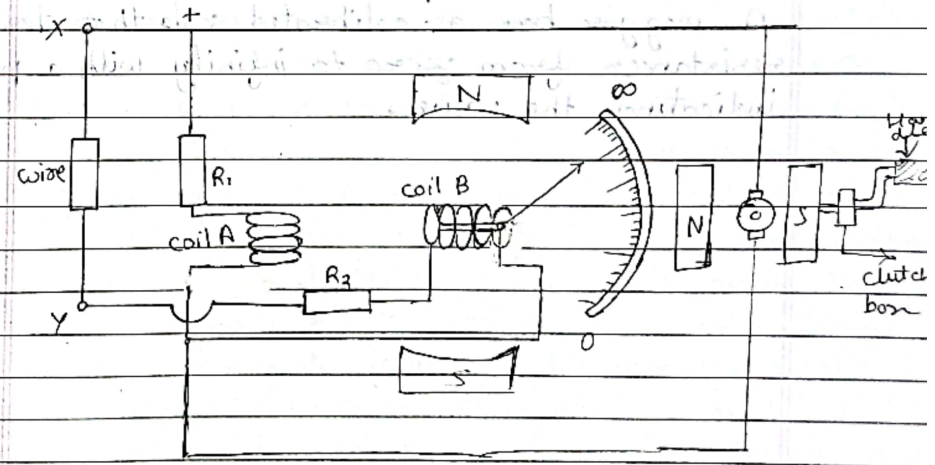
* Megger (Mega ohm meter)

Megger is the type of measuring instrument that is used to measure insulation resistance in power system.

- It works on the principle of comparison, the resistance of insulation is compared with known value of resistance.

• It has high accuracy compared to other types of instrument.

- If insulation resistance remain high the pointer deflected towards infinity (∞) & insulation resistance is low then pointer shows zero resistance.



Megger

coil A - current coil
coil B - potential coil

key features for high resistance measurement:-

High voltage source

Unlike an ohmmeter, a megger applies a high voltage to ensure a measurable current, even through very high resistance insulation.

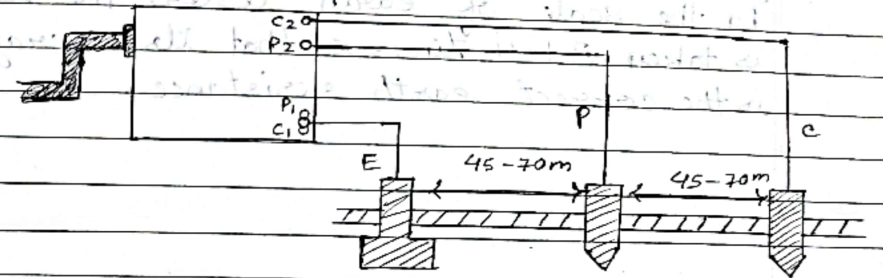
High sensitivity:-

It can measure currents in the nanoampere or microampere range, allowing it to accurately measure resistances in the giga ohms range.

• Scale:-

A megger has a calibrated scale that shows resistances from zero to infinity with a pointer indicating the value.

★ Measurement of earth resistance using earth tester megger



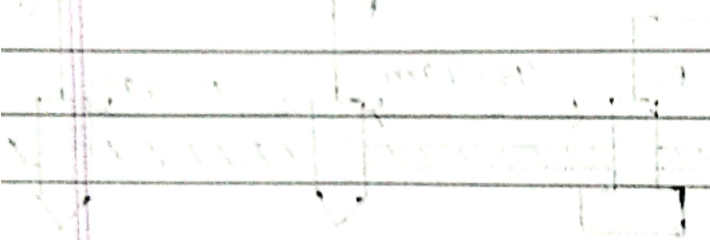
P = Potential electrode

C = Current electrode

E = Earth electrode

These four terminals are connected to E, P & C electrode, in which P & C are short circuited and connected to E electrode which is the earth electrode. P is connected to P₂ & C is connected to C₂. In this way, the connection is made & it is buried in the ground. The earth resistance is measured at the earth electrode (E) and (C) electrode, which is the current electrode, is buried in the ground at a distance of 90 to 140 meters from earth electrode (E). The (P) electrode, which is the potential electrode, is placed between the earth electrode (E) & current electrode (C), that is, it is buried at a distance of 45-70 meters from the earth electrode.

After this stage occurs, its hand-driven generator is operated, & the reading is noted by the scale of earth tester, the reading is taken 3 to 4 times so that its average value is the correct earth resistance.



These four terminals are connected as follows: (1) The terminal marked 'E' is connected to the earth. (2) The terminal marked 'P' is connected to the point to be tested. (3) The terminal marked 'C' is connected to the earth. (4) The terminal marked 'G' is connected to the earth. The reading is taken on the scale of the earth tester. The average of the readings is the correct earth resistance.