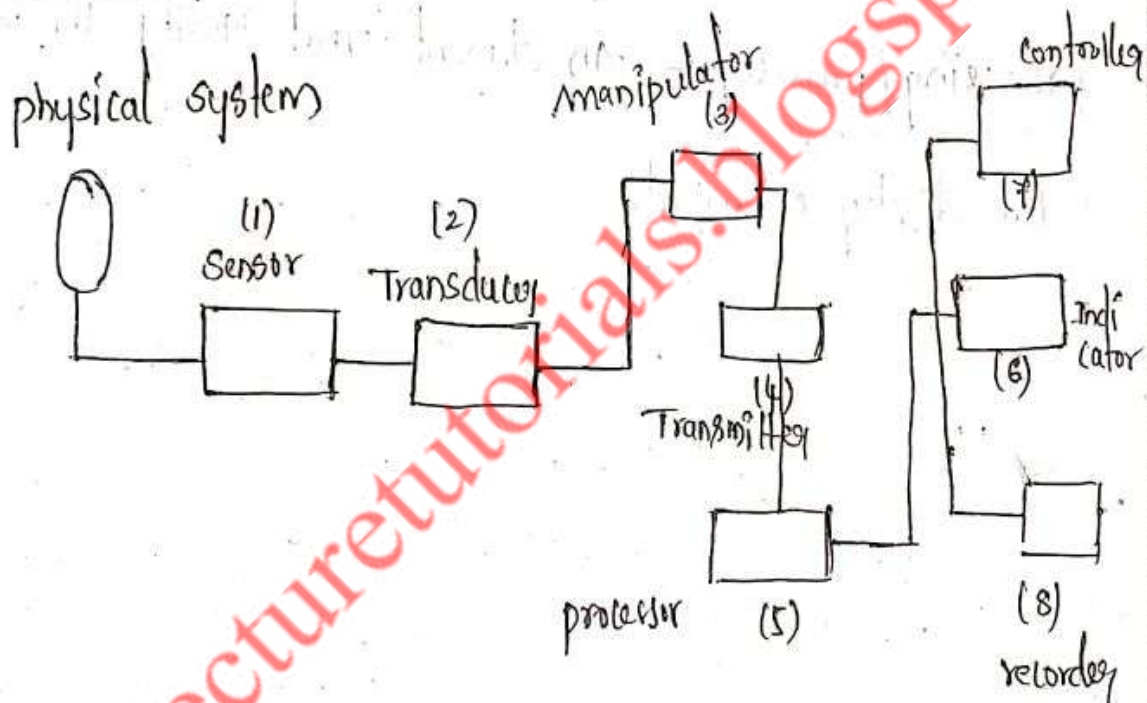


Measurement: - the word Measurement refers used to tell length, weight, Temperature and colour are changing one of this of the Materials.

Generalized system of Instruments / Generalized Measurement system:-



Sensor - An element that is sense to the Measured variables. It sense the condition state or value and produces output.

Transducer - An element that converts signals from one form to another form without changing the information. It may be electrical, Mechanical, optical, electronics.

Manipulator - It operates on the signal according to some Mathematical rule. $\text{input} \times \text{constant} = \text{out put}$

$$IXC = 0.$$

Transmitter - An element that transmits the signal from one location to another location.

eg - shafts and gears.

processing / processor - An element that modifies the data before display or record.

- i. Range and span
- ii. Accuracy, error and correction
- iii. calibration
- iv. hysteresis
- v. drift
- vi. Threshold and resolution
- vii. Tolerance
- viii. Sensitivity

Range and span — The region b/w the limits within an instrument for operate measuring indicating and recording is called range.

- Algebraic difference b/w the lower and upper values of the range is called span.

Accuracy, error and correction — Accuracy of an instrument define as closeness of Measured value to True value

eg — 98.1% of Accuracy

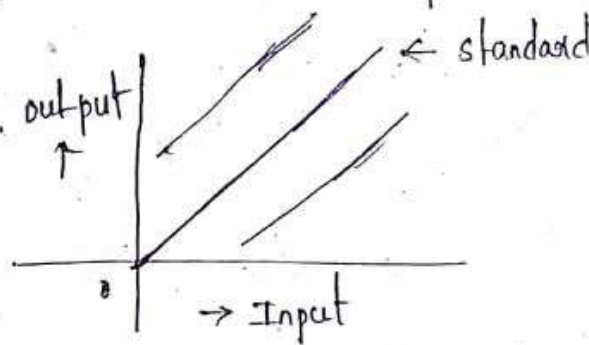
- Difference b/w Measure value and true value.
- Difference b/w True value and correction value.

$$E = \frac{V_m - V_t}{V_t - V_m}, E = -C$$

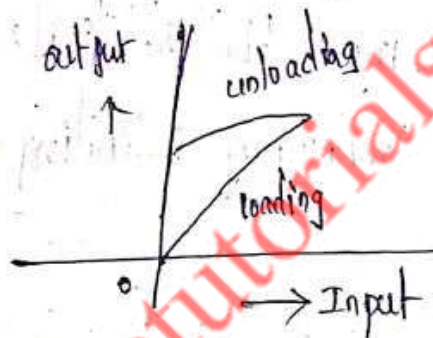
V_m — measure value
 V_t — True value

Error — E
Correction — C

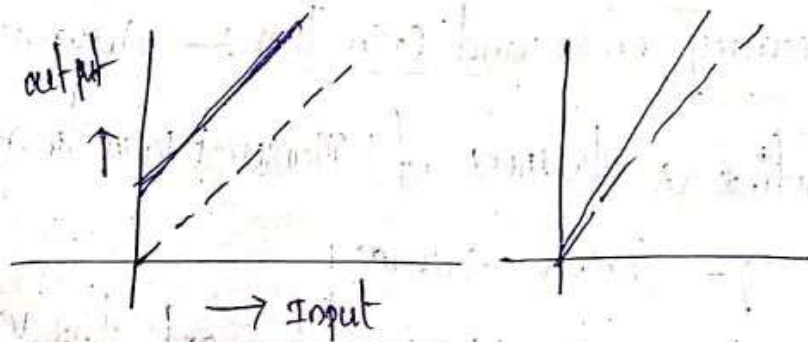
Calibration — The procedure laid down for making adjusting or checking by a scale so that readings of a instrument confirms to an accepted standard



Hysteresis :— The dependency of output upon previous input is called hysteresis



Drift :— An undesired gradual departure of the instrument output over a period of time is named as drift.



Sensitivity :— It is the ratio of the magnitude of change of output signal to input signal.

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Threshold and Resolution:- When the input of an Instrument is gradually increased from zero, there will be some Minimum value of input before which the instrument will not detect any output change. the Minimum value is called Threshold.

eg:-

Input	output
0	0
1	0
2	0
3	0.5

Threshold = 2.

- When Input is increased from non zero value repeat the above condition is named as Resolution

Input	output
1	0
2	0
3	0.5

Tolerance:- the range of accuracy which can be tolerated in Measurements of Instrumentation.

eg:- 10 bar pressure ± 0.01 bar, $10^{+0.01}$

- i) speed of response and the Measuring lag
- ii) Fidelity and dynamic error.
- iii) over shoot
- iv) dead time & dead zone

speed of response and Measuring lag -

→ It is defined as the repeatability which are instrument response to change in the value of quantity being Measure.

→ the delay of the response of instrument for a change in Input signal.

Fidelity and dynamic error:-

→ fidelity refers to the ability of the system to reproduce the output in same form as input

→ the difference b/w indicated value and true value of the time varying quantity.

overshoot

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Because of Mass and inertia and Moving parts the pointer of instrument doesn't immediately comes to the rest. in the final deflection position. i.e named as overshoot.

Dead time and Dead Zone:-

→ It is defined as time required for instrument to begin to respond to a change in the Measured quantities.

→ Which is instrument doesn't response due to friction,

~~Inter~~ Inertia ~~extra~~ etc.

Zero, first & second order Instrument system:-

The generalized Mathematical equation for any instrument is given below i.e

$$[A_n D^n + A_{n-1} D^{n-1} + \dots + A_1 D + A_0] \theta_0 =$$

$$[B_m D^m + B_{m-1} D^{m-1} + \dots + B_1 D + B_0] \theta_1$$

A_n & B_m are the constant.

D is differential parameter $D = \frac{d}{dt}$, $D^n = \frac{d^n}{dt^n}$

i) Zero order Instrument System

For zero order, $n=0$ & $A_n, A_{n-1} \dots A_1 = 0$

$m=0$ & $B_m, A_{m-1} \dots B_1 = 0$

θ_o - out put

θ_i - Input

Then

$$A_0 \theta_o = B_0 \cdot \theta_i$$

$$\theta_o = \frac{B_0}{A_0} \cdot \theta_i$$

$$K = \frac{A_0}{B_0}$$

$$\boxed{\theta_o = \frac{\theta_i}{K}}$$

mechanical levers, Amplifiers are obey's zero order Instrument system

ii) First order system -

For first order, Mercury glass thermometers, pressure gauges - bellows, network of resistance capacitance and inductors, velocity of free falling Mass are obey's first order

$n=1$ and $A_2, A_3, A_4 \dots A_0 = 0$ $D = \frac{d}{dt}$

$m=1$ and $B_2, B_3, B_4 \dots B_m = 0$, Then

$$(A_1 D + A_0) \theta_o = B_0 \theta_i$$

$$A_1 \frac{d\theta_o}{dt} + A_0 \theta_o = B_0 \theta_i$$

$$\frac{A_1}{A_0} \cdot \frac{d\theta_0}{dt} + \theta_0 = \frac{B_0}{\theta_0} \cdot \theta_1$$

$$Z \frac{d\theta_0}{dt} + \theta_0 = k \cdot \theta_1$$

$$(ZD+1) \theta_0 = k \theta_1$$

$$\frac{\theta_0}{\theta_1} = \frac{k}{(ZD+1)}$$

$$\left(\begin{aligned} \therefore Z &= \frac{A_1}{A_0} \\ \therefore k &= \frac{B_0}{A_0} \end{aligned} \right)$$

Displacement Transducers

Variable resistance Transistors

$$R = \rho \cdot \frac{l}{A}$$

Here R = resistance

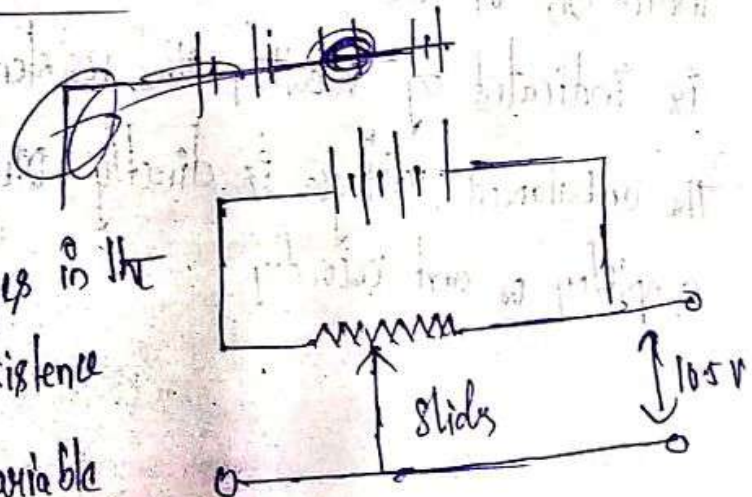
ρ - specific resistance

l - physical length

A - uniform cross sectional area

Linear displacement Transducers

These are convert the linear motion into changes in the resistance basically a resistance potentiometer are a variable resistors whose resistance varied by the Moment of slides



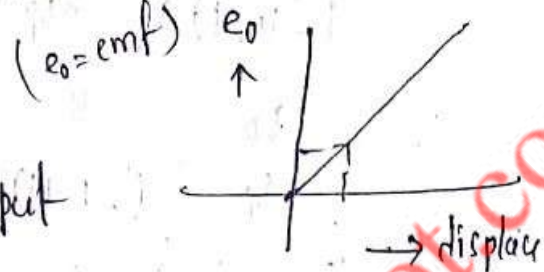
differentiate sizes, sizes and ranges are easily available

AC and DC both currents are used.

Insensitivity of vibration and Temperature

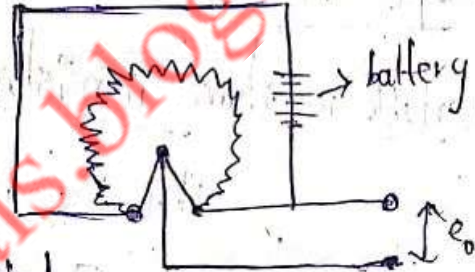
rough construction

less expensive, high output



Angular potentiometers:-

If the both the linear and rotary displacement potentiometer as the



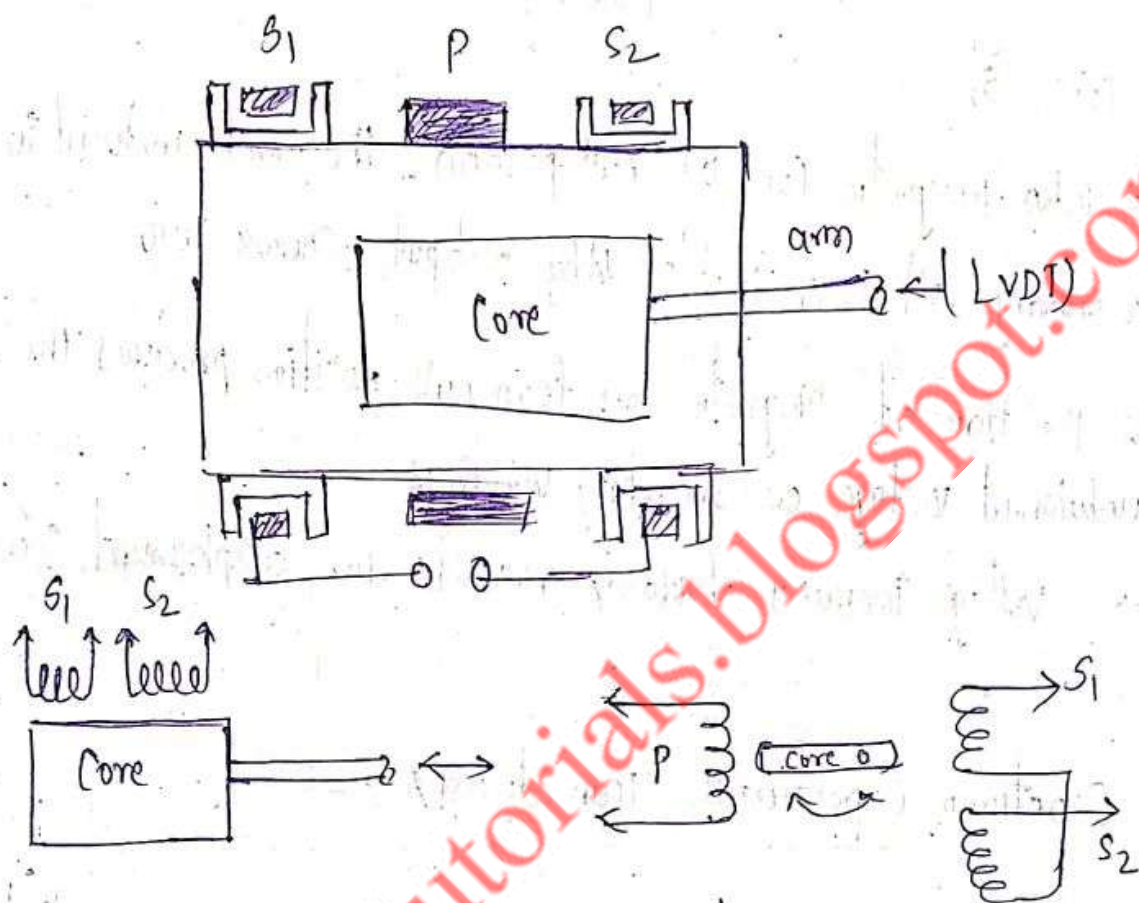
slider is powered by the Mechanical

part, on account of the arm moving the slider moves over the resistance element and the short out a portion of the

resistance. the resistance change in the potentiometer is the indication of the amount of motion and the direction of motion is indicated by whether the resistance increasing or decreasing

the unbalanced voltage is directly measured or sent to the amplifier or and recorder

LVDT - [linear variable differential Transformer]



→ one of most useful variable inductive transducers is linear variable differential transformer (LVDT)

→ the device as one primary coil (P), two secondary windings (S_1, S_2). one magnetic core free to move inside the coils

→ core is attached to the moving part on which displacement is

Measure

→ When AC current is supplied to the primary winding the magnetic flux generated which voltage is induced in secondary coil

→ The secondary winding is connected to a load

→ The output from the Transformer is the difference between voltages of secondary coil's, and secondary primary coil's

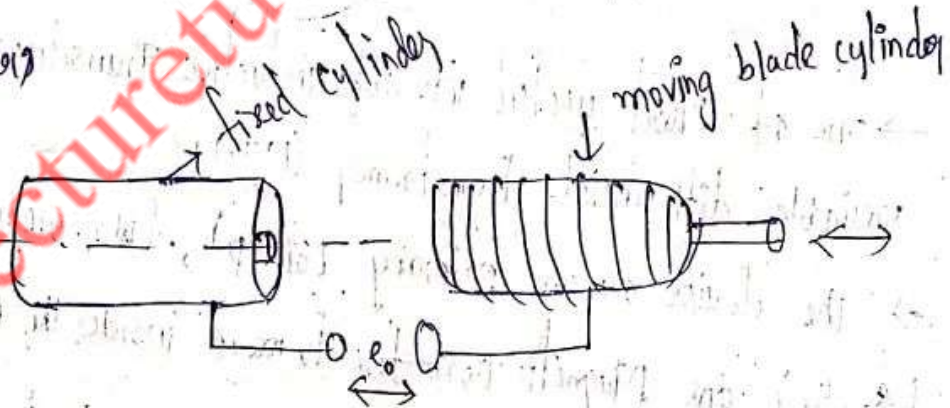
→ When magnetic core at null position, the emf induced in secondary coil is zero. That's why output shows zero

→ position of Magnetic Core from null position produces the unbalanced voltage on secondary windings

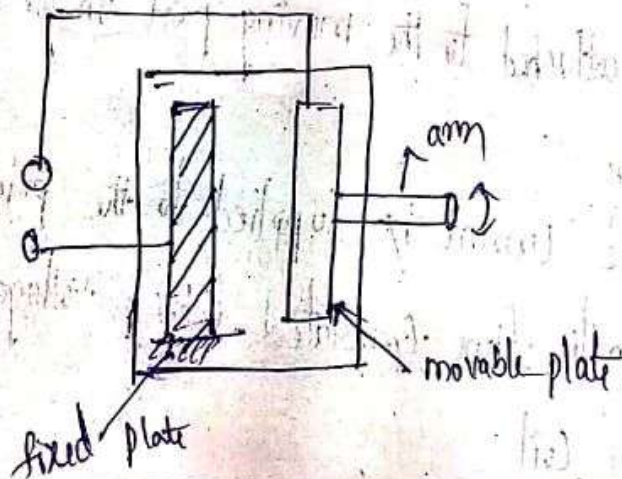
→ voltage increases towards results core displacement increases

Capacitive Transducers :-

Cylinders



plates



$$\rightarrow C = \epsilon_0 \epsilon_r \frac{A}{t} (N-1)$$

here C = capacitance

t - thickness b/w the plates [distance b/w plates]

N - No. of capacitor plates

ϵ_0 - permittivity b/w free plates

ϵ_r - relative permittivity

$C \propto$ effective area of plates $[A]$

$C \propto$ Inversely proportional to thickness of free space
(or) distance b/w two plates $\left[\frac{1}{A}\right]$

$C \propto$ no. of plates

ϵ_0, ϵ_r are capacitance constants.

~~piece~~ $\rightarrow$ Capacitor comprises two (or) more metal plates separated by an insulator

$\rightarrow$ Voltage is applied across the plates equal and opposite electronic charges are generated

$\rightarrow$ A capacitance transducer operates on the principle of variation in capacitance produced by the physical quantity being measured.

→ the capacitance can be vary by $\epsilon, \epsilon_r, A, t, N$

→ the detector can be measure up to $2.5 \times 10^6 \text{ m}$

Advantages of parallel plates capacitive transducers:-

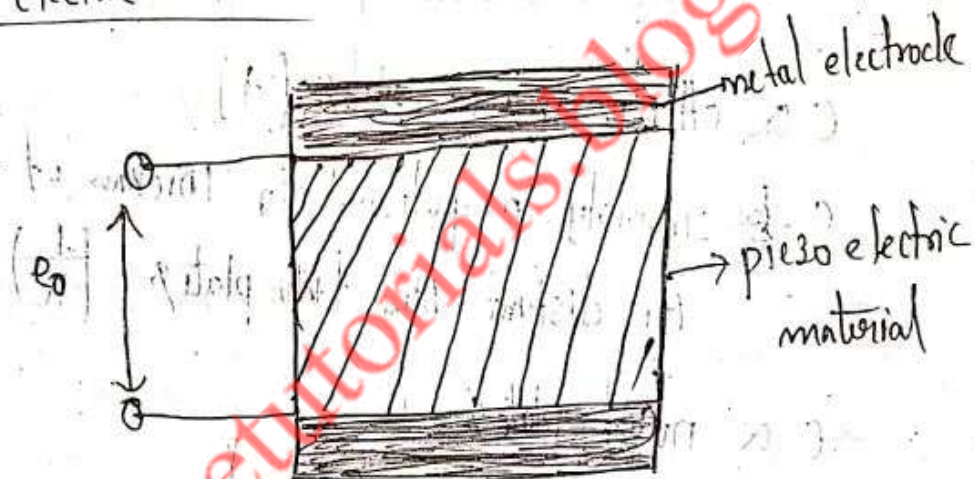
→ easy fabrication

→ High frequency response

→ ability to measure static and dynamic quantity

→ low initial cost & maintainance cost.

piezo electric Transducers:-



$$F = Ay \left(\frac{\Delta t}{t} \right)$$

Where F - force generated / applied

A - clb area of the plate

y - effective length

Δt - change in thickness

t - Thickness

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- It represents the property of crystal atoms that cause the crystal to develop potential difference when subjected to mechanical forces along specific planes
 - Metal electrodes are attached to the select phase of crystal in order to detect the electric charge developed.

Advantages

- high frequency response (beyond $20\text{Hz} - 20\text{KHz}$)
- High output
- Rugged construction
- ~~phase~~ Negligible phase shift

Advantages of Natural piezo electric crystals:-

- very low electrical value
- It withstands for high Temp
- ~~High output~~
- ~~Rugged construction~~ [flexible construction]
- ~~Negligible phase shift~~
- operating at low frequency
- with stand for high mechanical strain (high mech force)
- artificial crystals.

These are three Types [measure the displacement]

- (i) photo emission cell
- (ii) photo conductive cell
- (iii) photo voltaic cell

(i) photo emission cell -

→ These operates on photo emission effect, When certain type of materials are exposed to light, electrons flow is emitted and current is produced.

→ light information is converted into current

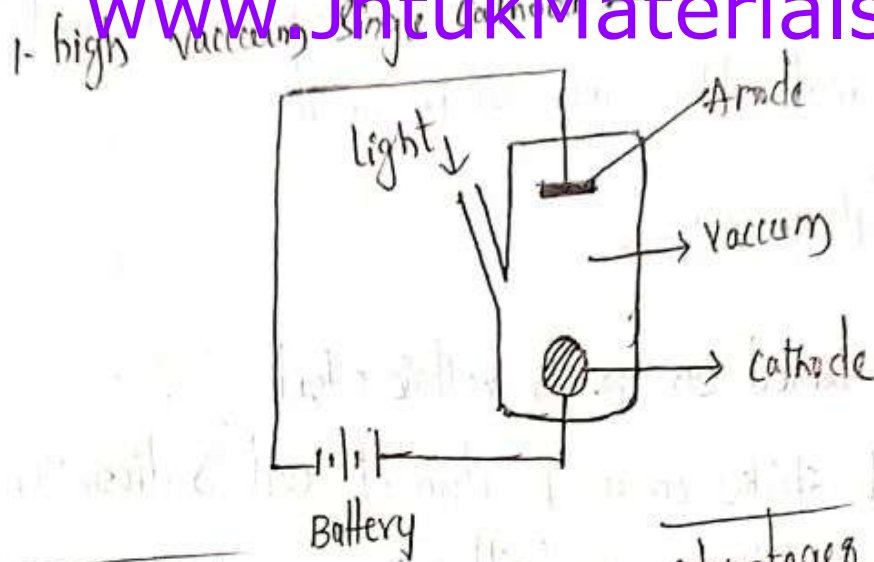
→ light emission cell has photo cathode has a mix of silver, selenium, cesium. light strikes on cathode electrons emission is results

→ There are 3 Types of photo emission shells

1. high vacuum single cathodes

2. gas filled

3. multiplier Tubes



Applications-

- In control engineering
- precision measuring devices
- photo expo meters
- Rockets and satellites

Advantages

- No direct contact is required
- Infrared radiation also

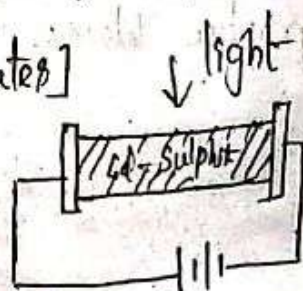
(2) photo conductive cell:-

- photo conductive cell operates on principle of photo conductive effect

- some special materials (Semiconductor) change their resistance when exposed to light

light information $\longleftrightarrow$ current information
 $\longleftrightarrow$ resistance information

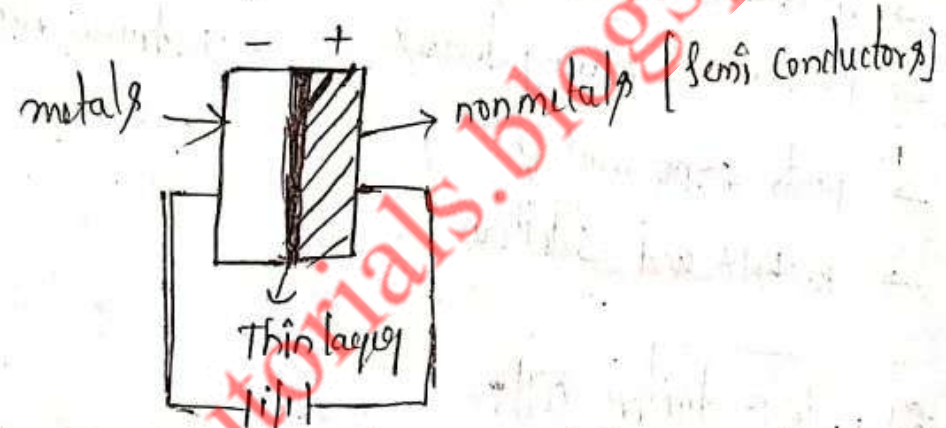
- Materials are Cadmium, Sulphite [in the form of thin coating on glass plates]



→ light strikes on the material resistance of the material decreases. current flow increases in circuit

(iii) photo voltaic cell :-

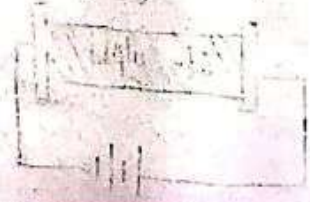
- It works based on photo voltaic effect
- When light strikes on a Junction of certain dissimilar metals potential difference is built-up
- light information → emf information



- It contains base metal plate, non metal semiconductor.
- the layer formed with a technique of spread of a thicker thin metals and non metals
- It requires no voltage source
- no vacuum or gas is required

Application :-

- light expo photographic works.



11 Sources of error, classification of errors, correction of errors

1. Instrument error
2. Transilation error and Transmission error
3. Observation error
4. environmental error
5. operational errors
6. System interaction error.

1. Instrument errors -

- Many factors in the design and construction of instrument
- poor Maintenance of instruments
- Wear, friction, rust, yielding of supports
- physical phenomenon. Capillary attraction (surface Tension)
- Assembly errors

ex - Scales are not fit initial to zero

Correction of errors

- Assembly errors are easily corrected by fit into correct position
- Friction is corrected by lubricating oil by gentle topic

Source of errors

→ When instrument assembly condition and working condition are not same

→ Temp results on elastic constant of Materials, dimension of scale, resistance value of Materials -- etc

Correction of errors

→ caution about working condition is same as assembly condition

→ use automatic compensation values for final readings

3. Translational and Transmission errors :-

→ Instrument Magnot Cells to read the measuring effect with complete fidelity

→ Falls due to resonance.

→ Due to inertia and coil losses (induction) these results unwanted noise, line pickup humb etc

Correction:-

→ Monitoring systems at 1 or more points along the Transmission

4. path / Observational Error :-

Due to parallel error (line of vision not $\perp$ to scale)

→ Inaccurate definition of any units, means and standard deviation

→ Inaccurate conversion of units

→ personal bias

Correction

→ avoid inexperience and careless observers

→ arrange two or more observers for that

5. operational error :-

→ pre-requisite [To precise instrument is that should be properly used

ex- Thermometer will not read accurately if sensitive portion is insufficiently immersed (or) radiating to heat portion.

Correction

→ Conduct Experiments on pre-requisite instrument.

6. System interaction errors :-

→ The act of measurement may effect the condition of instrument thus leads uncertainty in the measurements
reading of hand Tachometer should vary with pressure with which it pressed against the shaft

Correction - repeat the measurement under different conditions and different equipments.