UNIT - 1

MEASUREMENT & INSTRUMENTATION

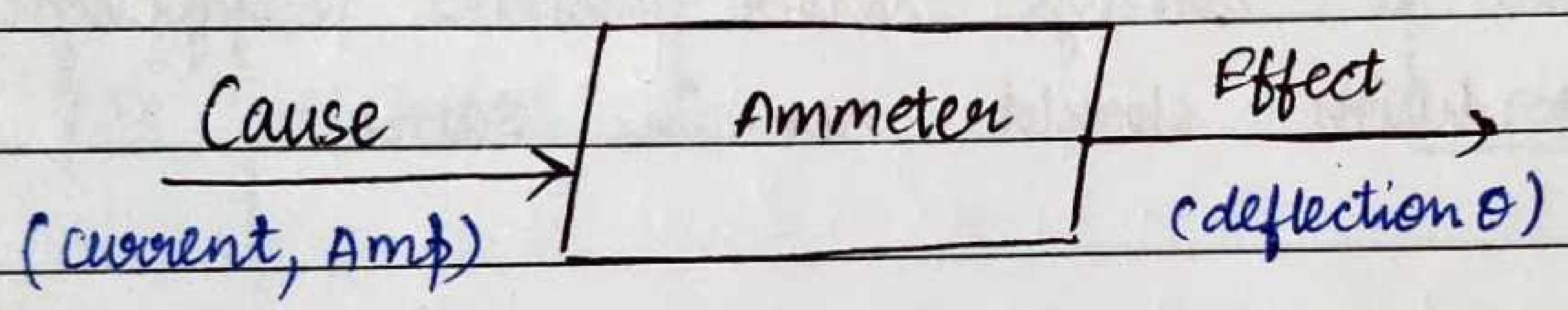
Definition-

* Measurement-

It is defined as the process of comparison or cause and effect phenomenon.

Or

Measurement of a given quantity is the result of a quantative comparison between an unknown quantity and a pre-defined standard quantity



$$i \propto \underbrace{\boxed{NBA}}_{\text{constant}} \theta$$

* Instrumentation-

Device for measuring the value of a magnitude of a quantity or variable.

→ Important points-

- Power drawn by ckt should be zero
- Perfect measurement theoritically is impossible
- Null method is always better than deflection me
- Circuit condition should remain same.

* CLASSIFICATION OF MEASUREMENT-

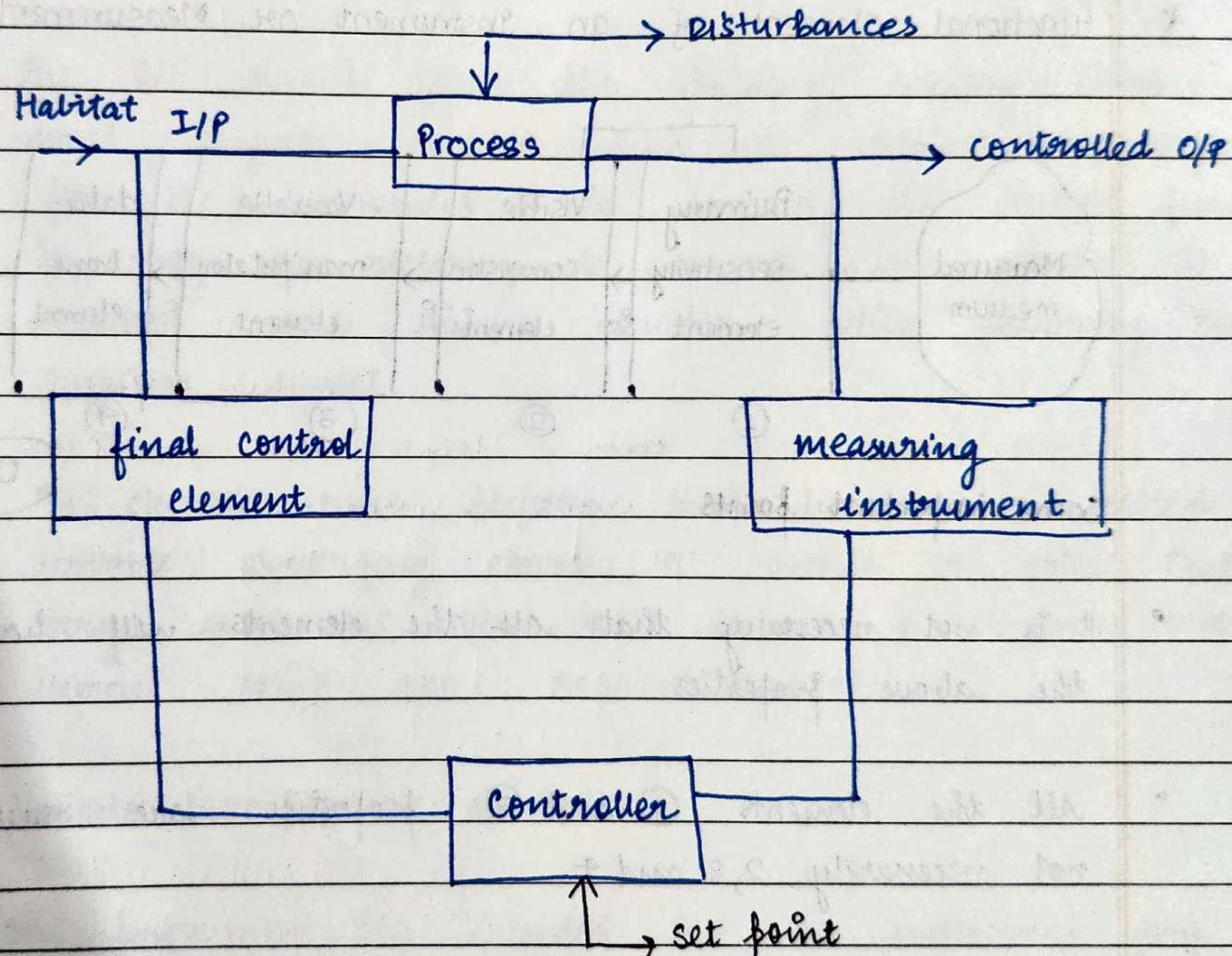
Based on application classification should be of three types-

(i) Monitoring of a process and operation
(ii) Control of a process and operation
(iii) Experimental engineering analysis

(i) Monitoring of a process and operation-

Example- Film badges
↳ Monitor exposes at radiation of hazard rays.

(ii) Control of a process and operation-



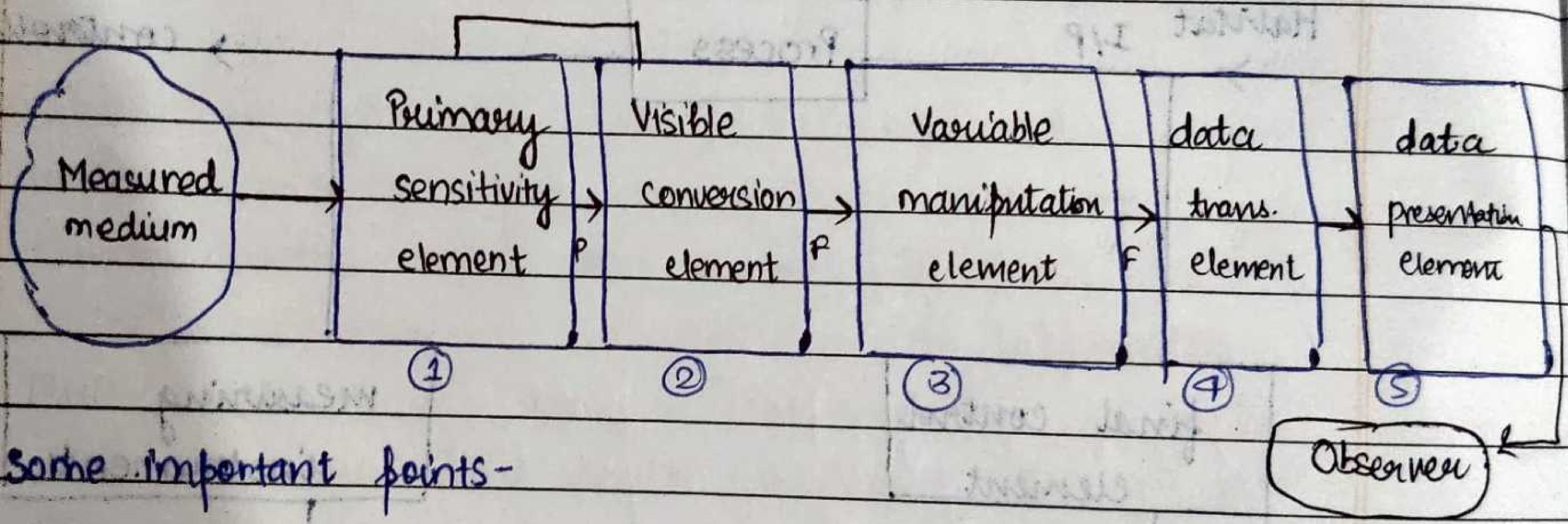
(iii) Experimental Engineering Analysis-

- Theoratical approach
- Practical approach

Some more basic classification of a measurement are-

- Deflection method - a scale and pointer arrangment
- Null method - always better than deflection method
- Direct method - measurement is in direct contact with instrument
- Indirect method - vice-versa above.

* Functional element of an Instrument or Measurement System-



Some important points-

- It is not necessary that all the elements will have all the above properties.
- All the elements 1 and 5 properties are must but not necessarily 2, 3 and 4
- Elements should not appear in order but 1 & 5 are fixed.

1 Primary Sensitivity element-

It is a element which receives energy from measured medium and produces an O/P depending in someway on the measured quantity.

It is important to note that an instrument always extracts some energy from measured medium. Thus measured quantity is always disturbed by this act of measurement. theoritically is impossible. Good instruments are designed to minimize the effects but it is always presenting some degree

② Visible conversion element-

The O/P signal from the primary sensory element is some physical variable such as displacement / voltage. for the instrument is to perform the desired function it may be necessary to convert this variable to another were suitable variable, while preserving the original signal.

An element which perform such function is called variable converging element. It should be noted that every instrument need not include a variable converging element while some required several.

③ Variable Manipulation element-

In performing the intended task, an instrument may required that the single represented by the physical variable be manipulated in some way. By manipulation here we mean a specifically a change in the numerical value, according to some definite rules but the preservation of the physical nature of the variable.

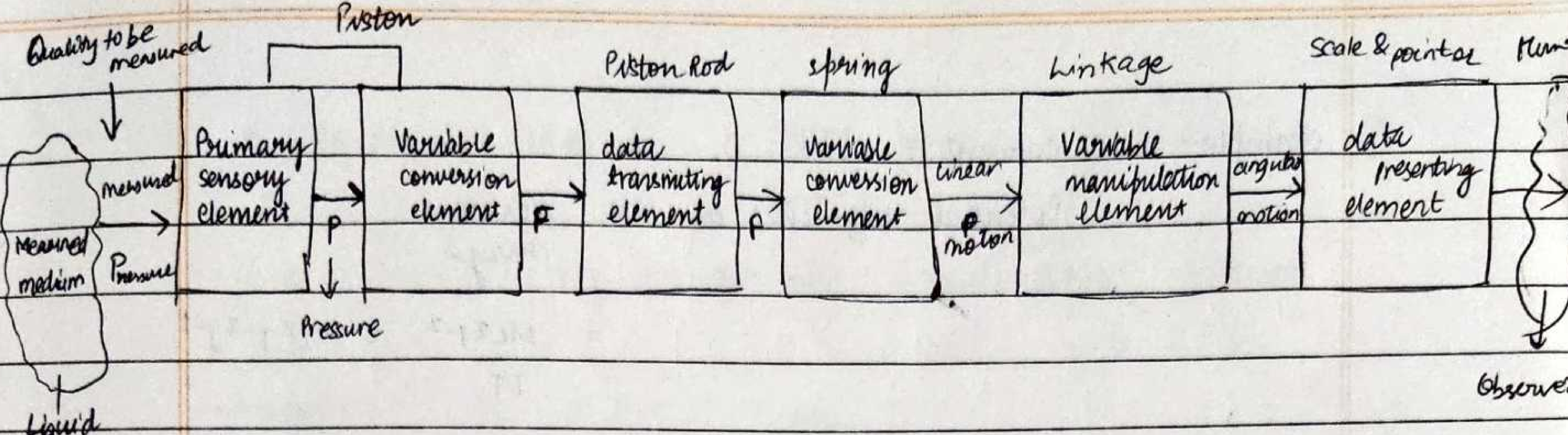
A variable manipulation element doesn't necessarily follow a variable converging element, but it may proceed it or may appear somewhere else or may not appear at all.

(4) Data Transmission element-

When the actual physical quantities are physically separated, it becomes necessary to transmit the data from one place to another. This may be a very simple system or may be very complicated such as meter / generator set, telematory system etc.

(5) Data Presentation element-

It may be a digital display, analog display, analog circuit, storage device, recording anything.



* UNITS, DIMENSIONS AND STANDARDS-

Units-

Units are the integral part of M and I

(i) Fundamental

(ii) Derived

→ Seven fundamental units are there-

- Mass - kg
- Length - metre
- Time - sec
- Current - Amp
- Luminous Intensity - cd
- Amount of substance - Mol
- Temperature - °K

MKS - (mass, length, sec)

CGS - (cm, gm, sec)

FPS - (foot, pound, sec)

SI - System International

ISI - Indian Std. Insti

BIS - Buren of Indian Standards

MKSI (I → current)

Dimensions-

→ Dimensional equation help as follows-

- In conversion of one system unit to another
- In derivation of equation for physical quantities
- In checking the accuracy of the equation

example- current = [I]

Potential difference or V = $\frac{\text{Workdone}}{\text{charge}}$

$$= \frac{ML^2T^{-2}}{IT} = ML^2T^{-3}I^{-1}$$

Charge Q = I[T]

Velocity v = LT^{-1}

Acceralation = LT^{-2}

Force = MLT^{-2}

Power = ML^2T^{-3}

Resistance $v = IR \Rightarrow V/I$

$$R = \frac{ML^2T^{-3}I^{-1}}{I} = ML^2T^{-3}I^{-2}$$

Capacitance C = ? $Q = CV \Rightarrow C = Q/V \Rightarrow TT = C.$

There are two types of systems-

(a) Electrostatic - path covered by current

(b) Electromagnetic - path covered by magnet.

examples-

- Flux = $\frac{V}{T} = \frac{ML^2T^{-3}I^{-1}}{T}$

$$= ML^2T^{-2}I^{-1}$$

- mmf = [I]
- magnetic ~~current~~ force = $\frac{\text{mmf}}{\text{length}} = \frac{I}{L} = IL^{-1}$
- Reluctance = $\frac{\text{mmf}}{\text{flux}} = \frac{I}{ML^2T^{-2}I^{-1}} = M^{-1}L^{-2}T^2I^2$

uncertainty
spring dome

- Coulomb's law $F = \frac{Q_1 Q_2}{\varepsilon_0 d^2}$

(ε_0 = absolute permittivity)

- Ampere's law - $F = \frac{m_1 m_2}{\mu_0 d^2}$

(μ_0 is absolute permeability)

Einstein's equation → $\boxed{\mu_0 \varepsilon_0 = 1/c^2}$ where c= velocity of light.

Absolute unit-

- An absolute system of unit is defined as a system in which the various units are all expressed in terms at a small numbers of fundamental unit.

- It involves the measurement of unit in terms of physical quantity which are measured practically.

Standards-

The standard is the physical representation of unit and measurement. The term standard is applied to a piece of equipment having no measure of physical quantity. ~~having~~ They are used for the purpose of other equipment by comparison method.

Some of its type are as follows-

International Standard-

Agency- International Bureau of weight and measurement
By France
↓
Paris
↓
SEVRES

Primary Standard-

Maintained at national level. In India: New Delhi at National Physical laboratory.
Pussa road - 100024

(9192631770 Hz) Cs atom

Secondary standard-

In big country, there are secondary standards, which are maintained by
- IL KOTA
- BHEL
- NTPC
- BHEL etc.

Working standard-

Leading technical institute of India
- IIT'S
- NIT'S

International Standards -

These are defined on the basis of international agreement. They present the unit of measurement, they which are (IEEE 488) closest to the possible accuracy attainable, with the present day technological and scientific method.

These standards are checked and evaluated regularly against absolute instruments of measuring. These standards are not useful for ordinary uses for caliberation or comparing.

* Special features at primary standard -

- Few in number
- Must have highest possible accuracy
- Low temperature coefficient.
- Have stability
- Shouldn't be attached by moisture, humidity or environmental change.
- Rigidity or machining should have proper
- Should be periodically calibrated against the higher standard.

IEEE - Institute of electrical and electronics engineer's Headquarters New York

IEEE-488, is one of the important organisation which deals with the digital interface for programmable instrument.

* Performance characteristics of Instrument (M&I)

There are three types of characteristics-

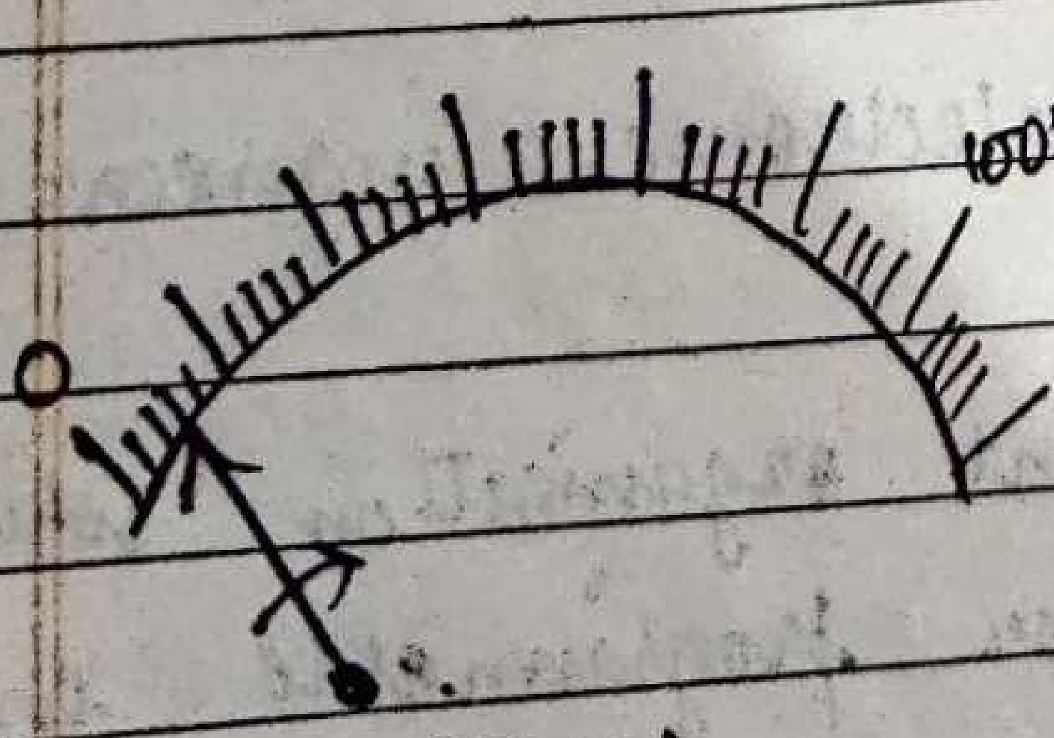
- Static Performance Characteristic
- Dynamic Performance Characteristic
- Environmental Performance Characteristic.

(i) Static Performance characteristic-

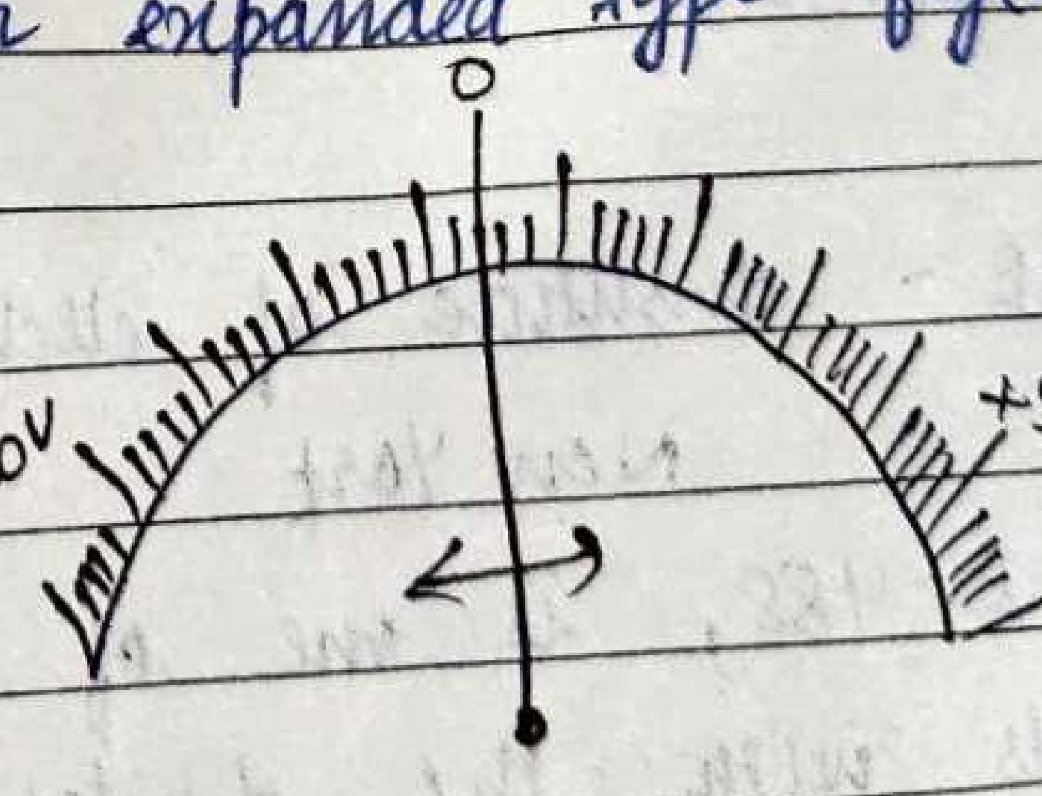
When I/P is Kept constant (or) not varied w.r.t time or Known value.

- **Range-**
  - → upper bound (FSD- full scale deflection)
  - → Lower bound

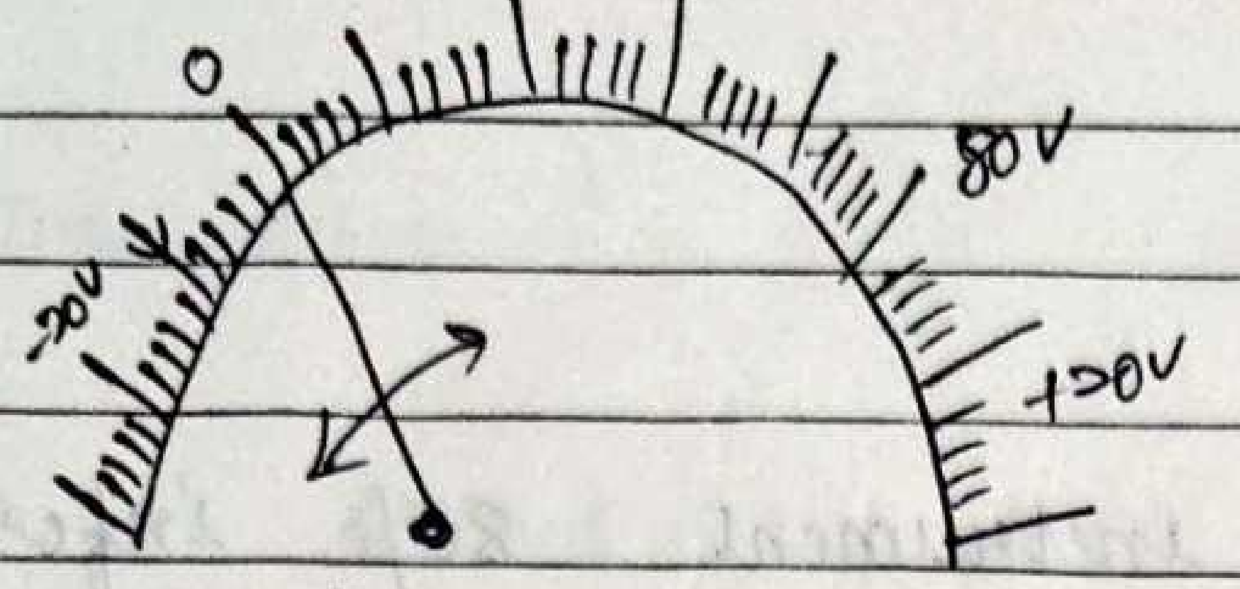
- **Scale-**
  - → unidirectional fig(a)
  - → Bidirectional fig(b)
  - → Assymetrical bidirectional fig(c)
  - → zero suppressed or expanded type fig(d)



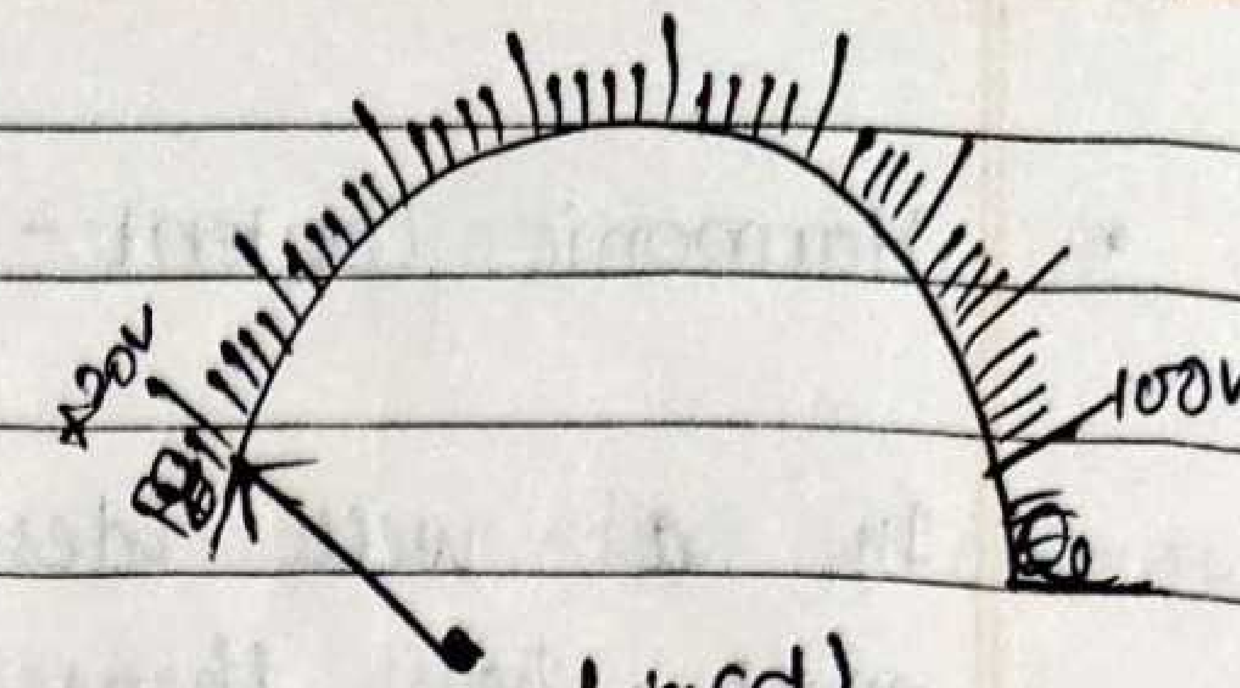
fig(a)



fig(b)



fig(c)



fig(d)

- **Span-**

  Span = ~~copper~~ upper bound - lower bound

- **outputs-**

  There are three types of outputs
  - analog O/P
  - Discrete O/P
  - coded O/P

- **Inputs-**

  There are three types of ~~O/P~~ I/P.-
  - Desired I/P - Those I/P for which the instrument is intentionally sensitive
  - Interfering I/P - Instrument is unintentionally sensitive
  - Modifying I/P - May modify the cause and effect relationship.

eg-

Cause (I/P) (I) —— Ammeter —— effect (O/P) (θ → displacement)

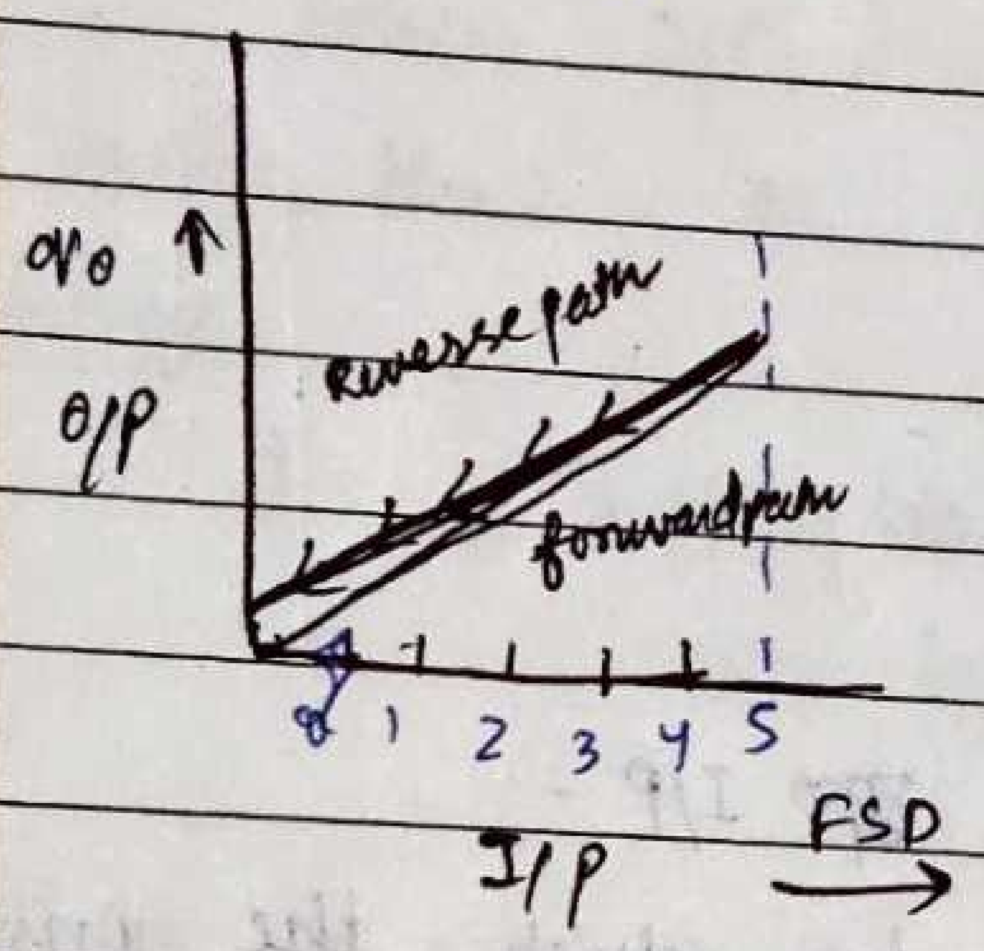
- **Impedance-** Three types of impedances-
  - I/P impedance - as high as possible
  - O/P impedance - as low as possible
  - Load impedance - No loading is required / proper impedance matching

- Harmonic Content -

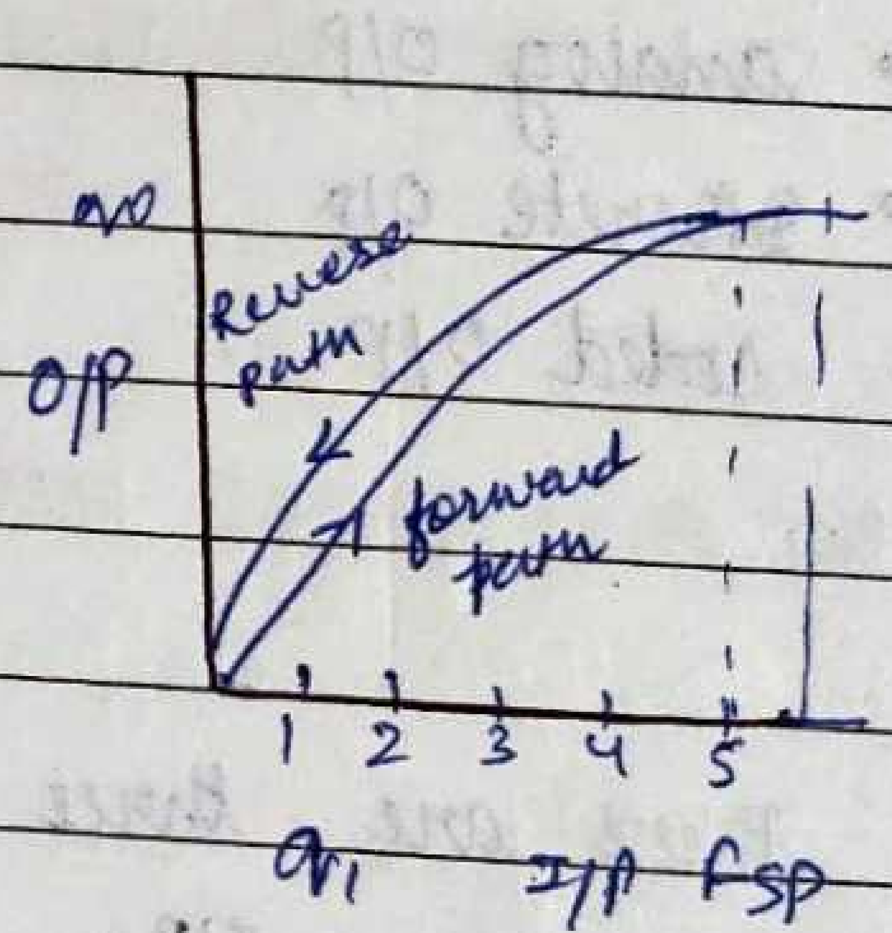
In a well designed instrument 80% information must be there with fundamental and rest 20% may be with higher harmonics.

- Hysteresis -

The forward and reverse path will not be the same. The deviation is due to the second law of thermodynamics.

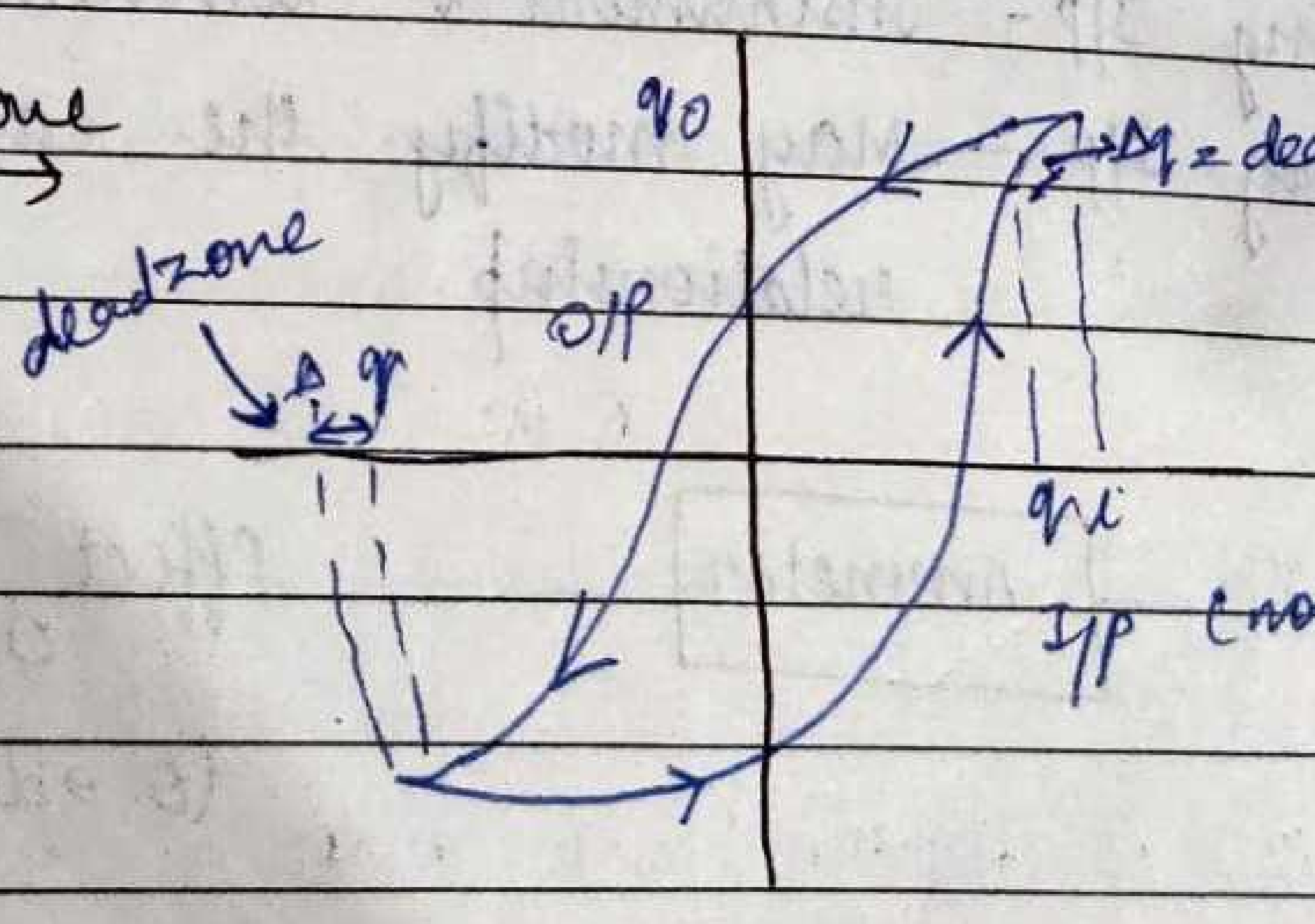


(Linear unidirectional)



(Non-linear unidirectional)

* Deadzone
fig →



(non-linear bidirectional).

- Dead zone -

It is defined as for small change in I/P, there is no change in I/P.

- True value -

It is defined as the standard value with minimum or least error at the different levels.

- Accuracy -

It is defined as closeness to the true value.
More closer value → more accurate
Less closer value → less accurate.

- Precision -

The degree of reproducibility (repeating the same reading)

- Error -

Defined as (δA) = measured value − True value

$$\boxed{\delta A = A_1 - A}$$

- Correction -

δC = True value − measured value

$$\boxed{\delta C = A - A_1}$$

$\boxed{\delta A = -\delta C}$ → Relationship b/w error & correction.

$$\boxed{\%\ \text{error} = \frac{\text{measured value} - \text{true value}}{\text{True value}} \times 100}$$

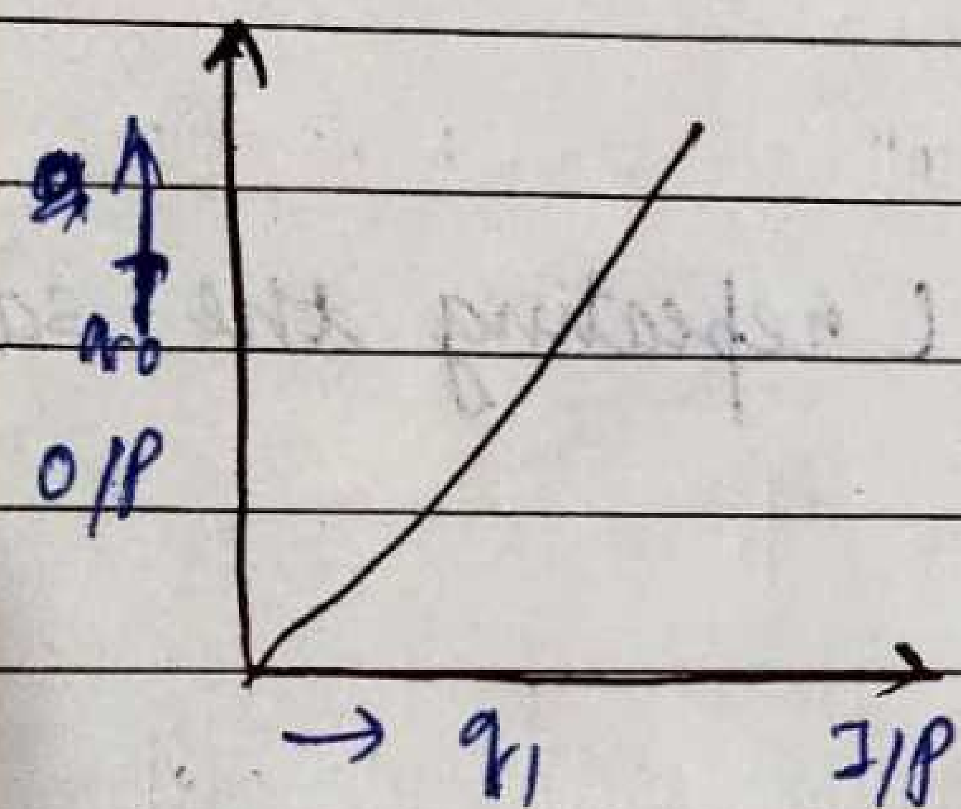
- Sensitivity / Static sensitivity -

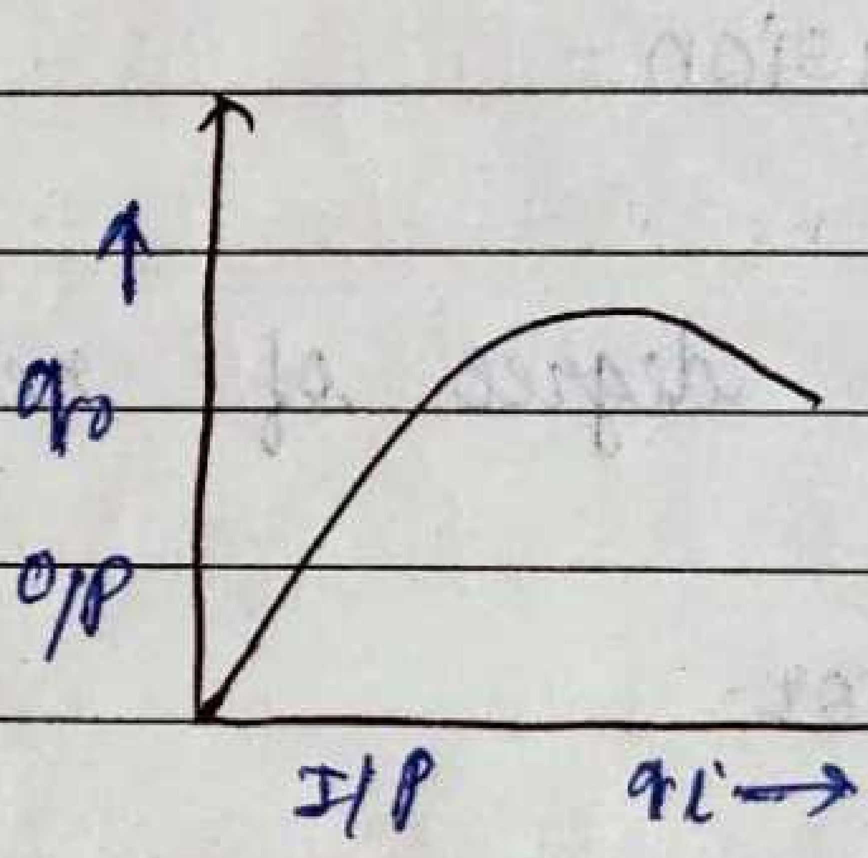
It is defined as (S) change in O/P w.r.t to change in I/P.

$$S = \frac{\text{Change in O/P}}{\text{Change in I/P}}$$

$$= \frac{\Delta q_o}{\Delta q_i}$$

$$= \frac{O/P}{I/P}$$





eg-	A	B
current	2.53 A	2.54 A
Deflection	40°	40°
	↓ more sensitive b'coz it is taking less current	↓ less sensitive than A.

- Resolution / Discrimination / Least count -

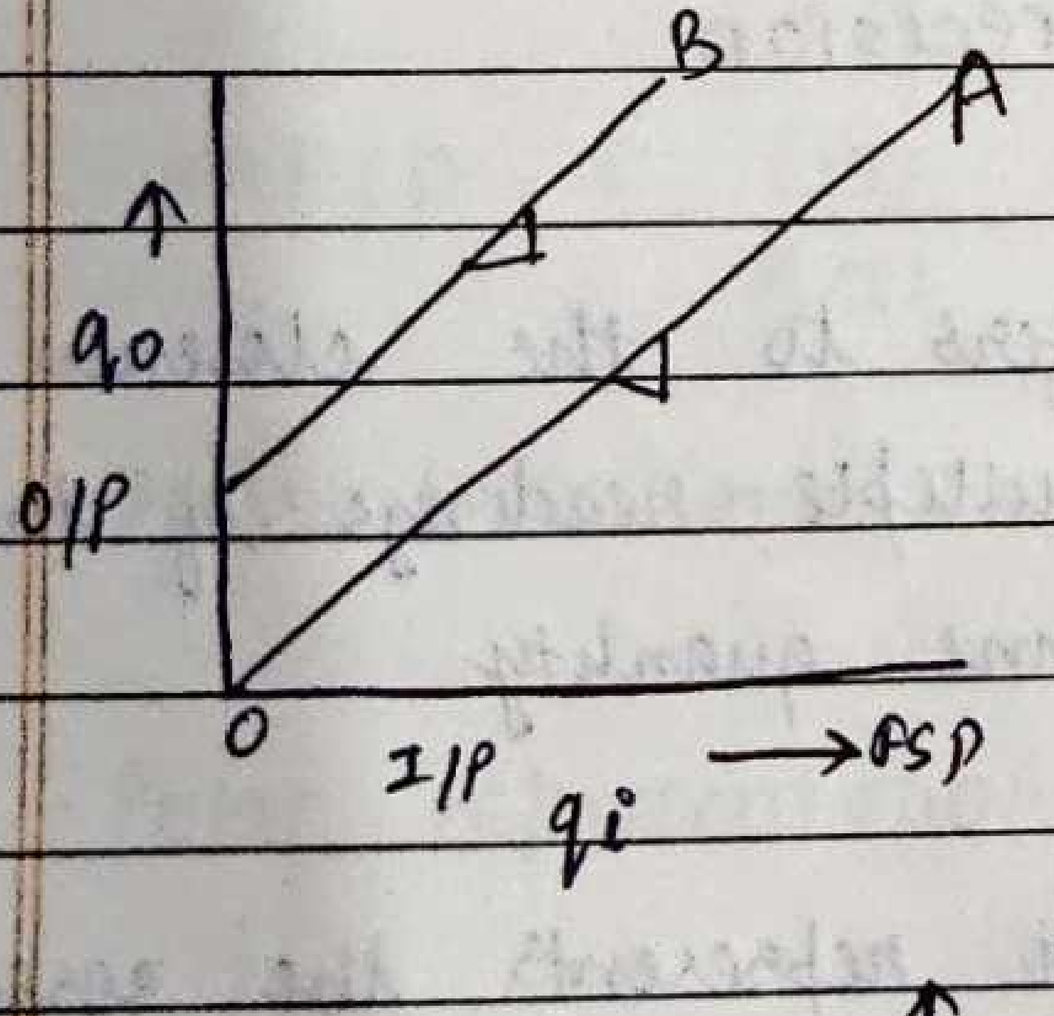
It is defined as the minimum value which can be measured by the instrument with certainity

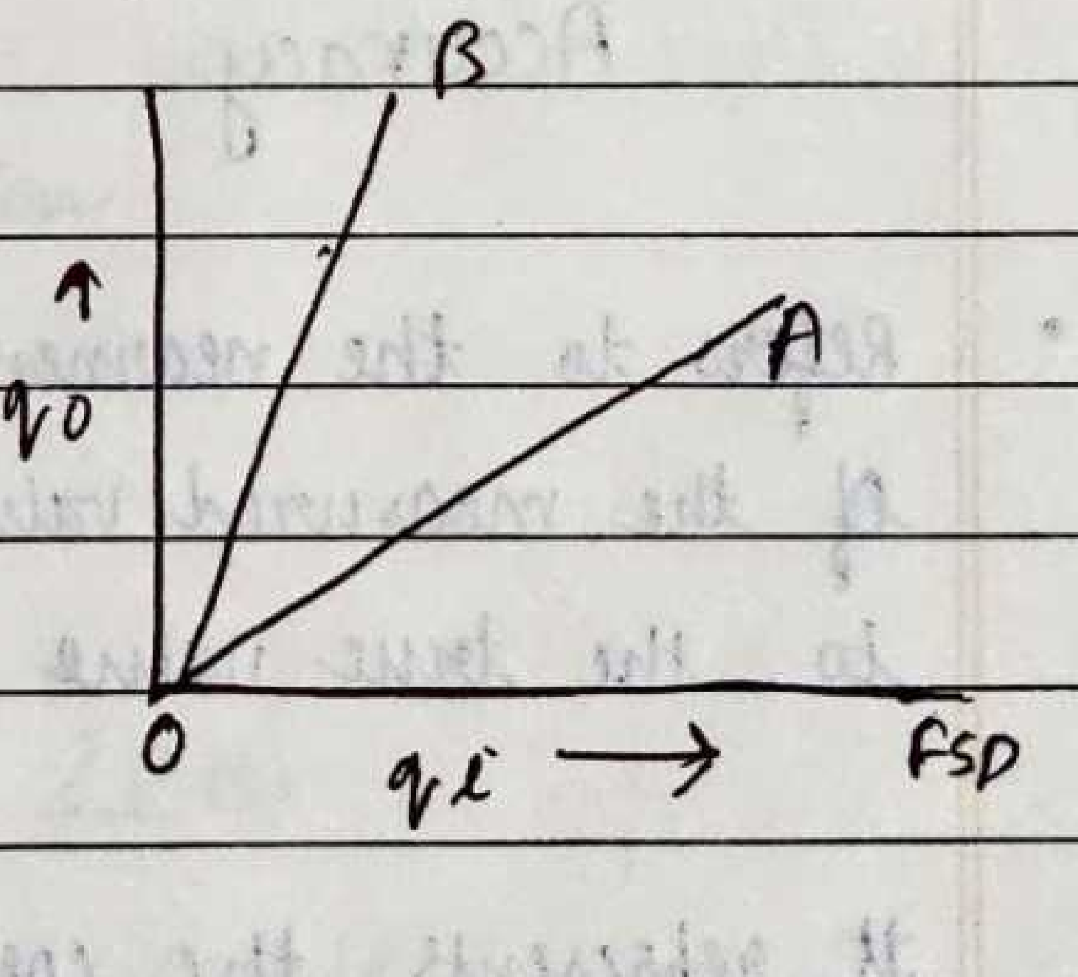
- Drift-

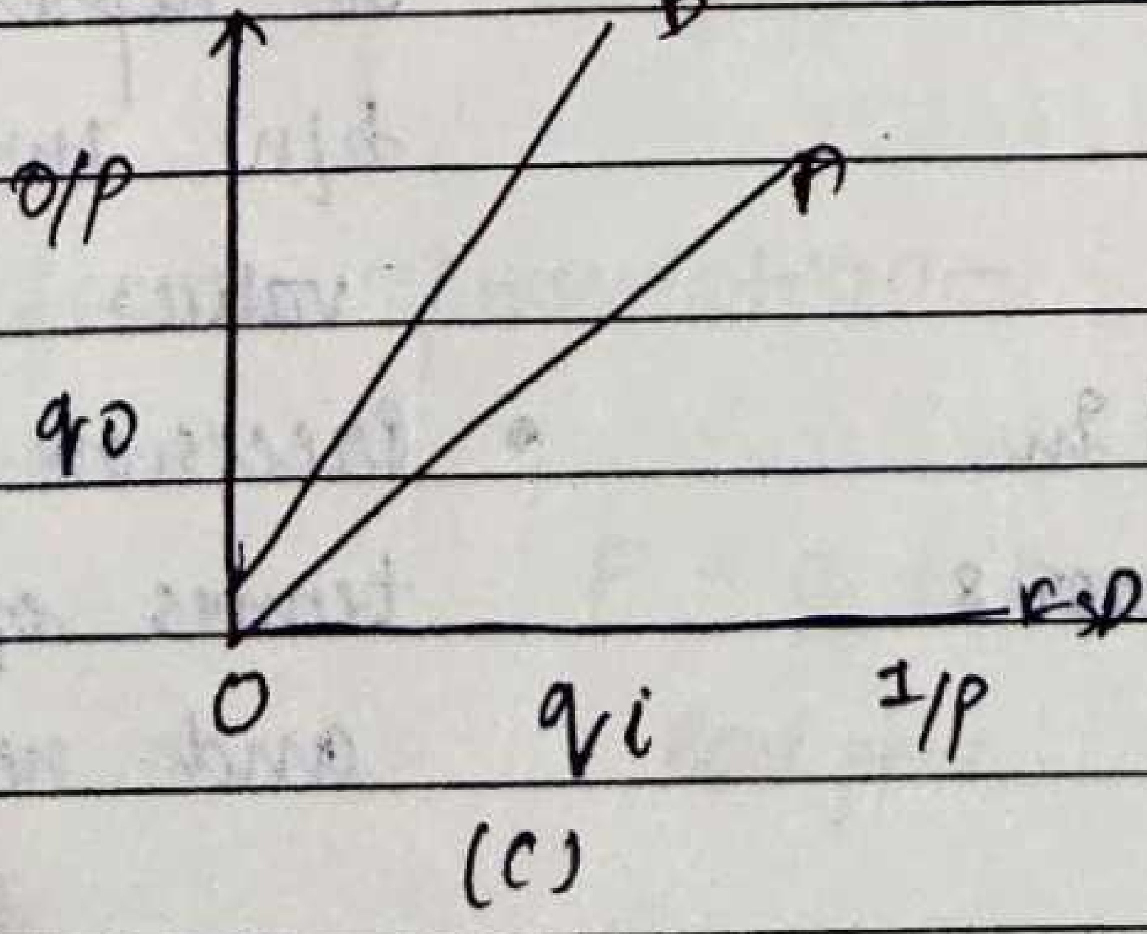
It is of two types-

Zero drift - sensitivity is same but zero has been dritted [fig (a)]

Sensitivity drift - fig (b) is more sensitive as 'B' has more slope.







(C)

Slope is parallel in fig (a) → so it is more sensitivity

- **Readibility -**
  - Clarity of marking
  - Thickness of scale
  - Thickness of pointer

- **Efficiency -**

Instrument efficiency = $\frac{FSD}{\text{Power required for FSD}}$

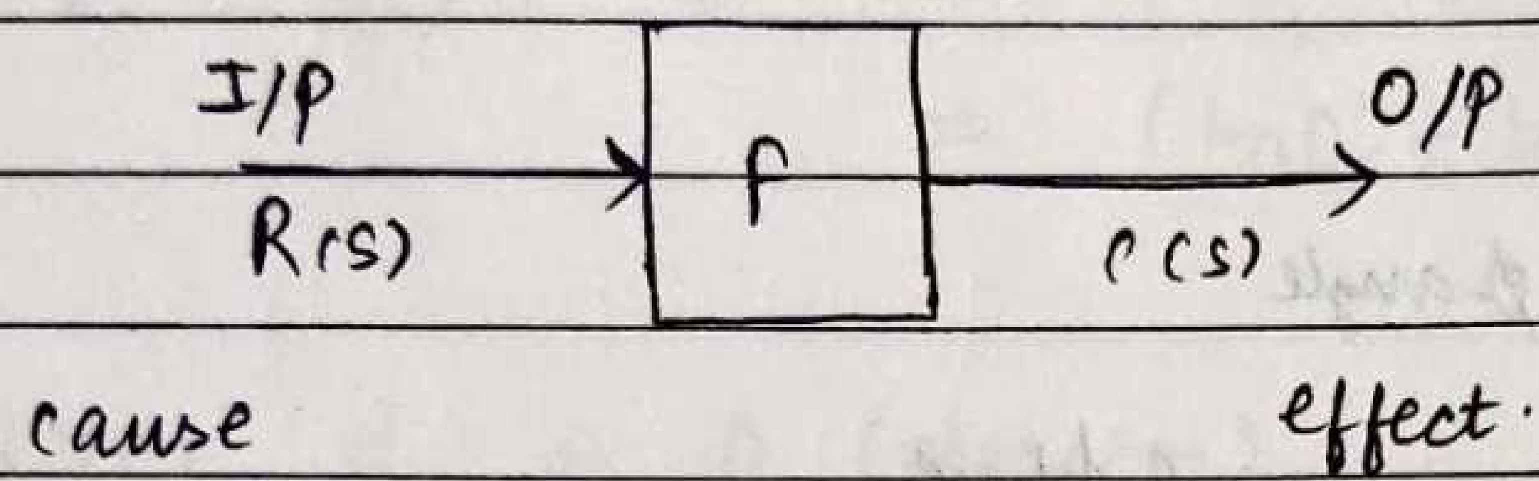
* Difference b/w Accuracy & Precision -

Accuracy	Precision
• Refers to the nearness of the measured value to the true value	• Refers to the closeness of multiple readings of the same quantity
• It represents the correctness of the measurement	• It represents the agreement b/w two or more measured values
• Accuracy is expressed in terms of absolute error & relative error	• Precision is expressed in terms of absolute deviation and relative deviation
• It can be determined by a single measurement	• Several measurements are required to determine precision
• High accuracy implies small error	• High precision implies the reproducibility of readings

* DYNAMIC PERFORMANCE CHARACTERSTICS -

Under this, the I/P is varying
or
Measurement is varying

(i) frequency domain analysis-



Frequency is being altered

$$T.F = \frac{O/P}{I/P}$$

$$F(s) = \frac{C(s)}{R(s)}$$ ~~Representation~~

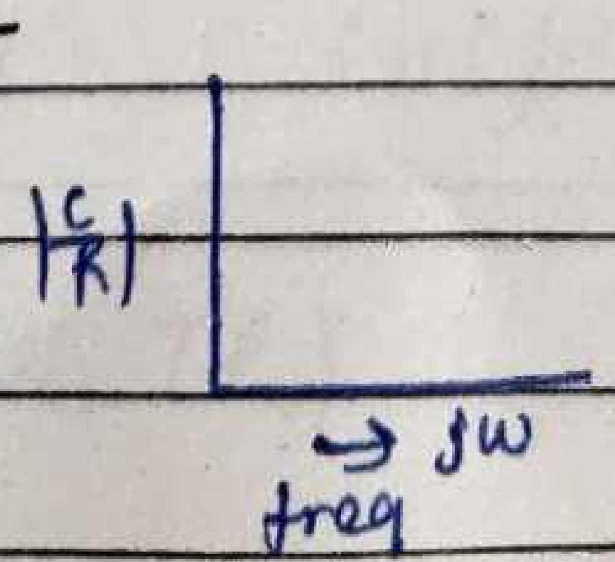
representation-

- Polar representation- $|F(s)|$ amplitude $\angle F(s)$ angle

- Rectangular form representation-

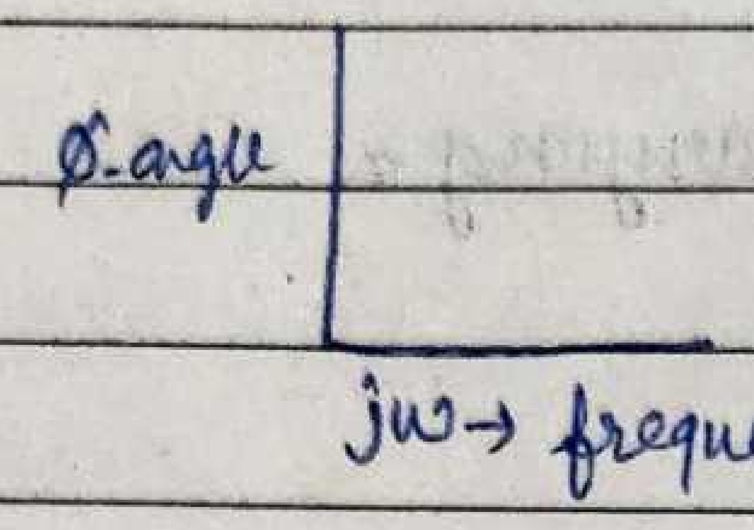
$F = a + ib \rightarrow$ imaginary part.
a: Real part

- Amplitude Plot-



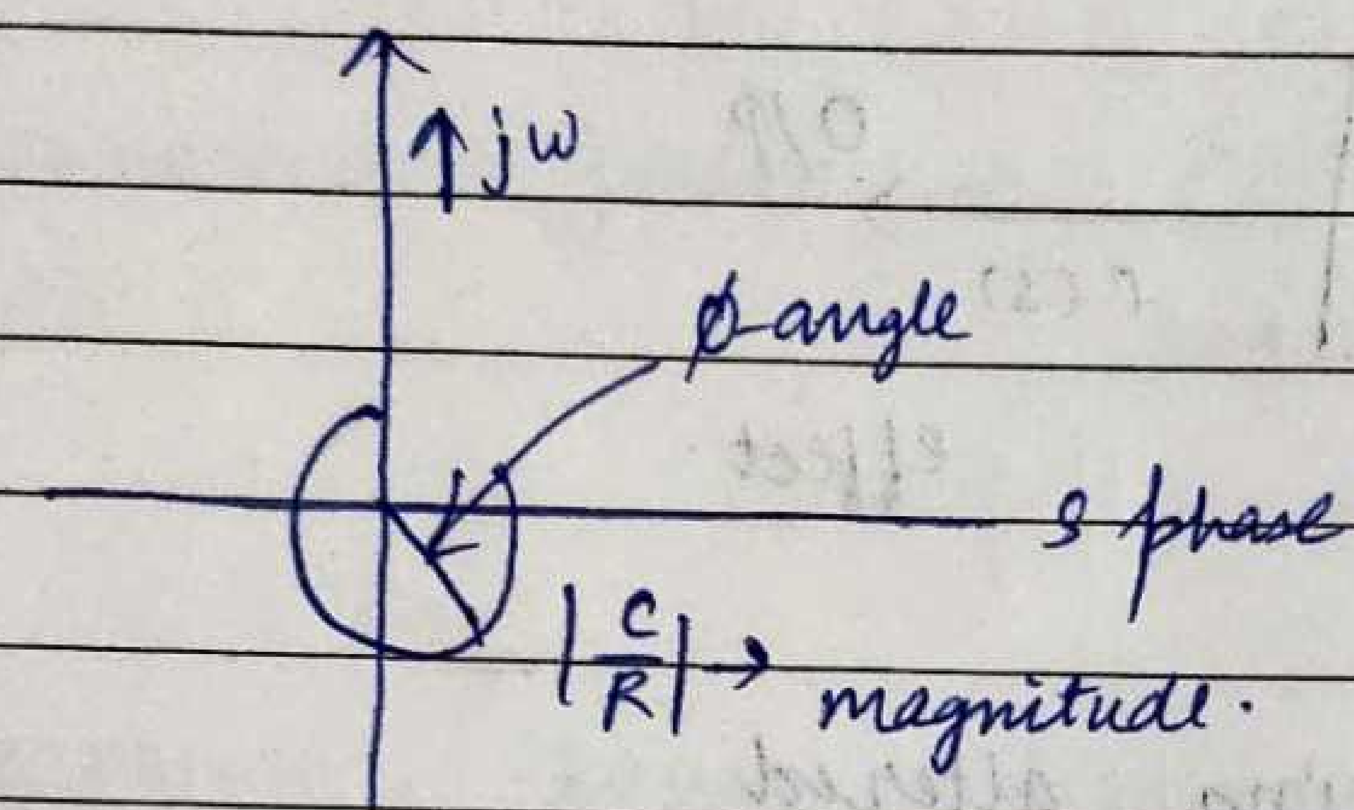
graph b/w freq & amplitude.

- Phase angle plot/ BODE plot -

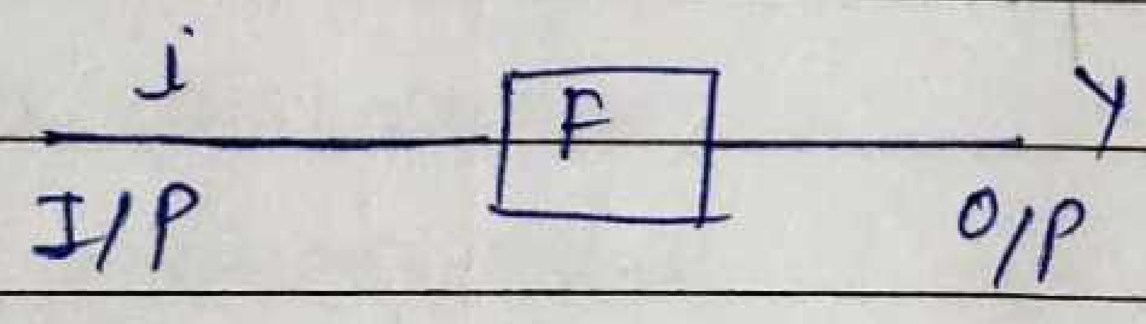


graph b/w ϕ angle & frequency

- Polar Plot / Nyquist Plot -



- Time domain analysis -



$F = \frac{o}{i} = \frac{y}{i} \Rightarrow y = Fi$

$y(t) = F(t)\, i(t)$

T.F may be represented in 3- ways

- operational T.F
- Laplace T.F
- Sinusoidal T.F

* General Dynamic differential equation of study of dynamic characterstics of n^{th} order -

$$a_n \frac{d^n y}{dt^n} + a_{n-1} \frac{d^{n-1} y}{dt^{n-1}} + \dots\dots + a_1 \frac{dy}{dt} + a_0 y$$

$$= b_n \frac{d^n z}{dt^n} + b_{n-1} \frac{d^{n-1} z}{dt^{n-1}} + \dots + b_1 \frac{di}{dt} + b_0$$

$$(a_n D^n + a_{n-1} D^{n-1} + \dots\dots + a_1 D + a_0) y$$

$$= (b_n D^n + b_{n-1} D^{n-1} + \dots + b_1 D + b_0) i$$

Replace $\frac{d}{dt} \Rightarrow D$ (operator)

$$\boxed{F(t) = \frac{y(t)}{i(t)} = \frac{b_n D^n + b_{n-1} D^{n-1} + \dots + b_1 D + b_0}{a_n D^n + a_{n-1} D^{n-1} + \dots + a_1 D + a_0}}$$

$$\boxed{F(t) = \frac{y(t)}{i(t)} = \frac{y(s)}{i(s)} = \frac{b_0}{a_n D + a_{n-1} D^{n-1} + \dots a_1 D + a_0}}$$

↳ operational T.F deals with time domain

Replace D by s

$$\boxed{F(s) = \frac{y(s)}{i(s)} = \frac{b_0}{a_n s^n + a_{n-1} s^{n-1} + \dots a_1 s + a_0}}$$

↓ laplace T.F

Replace $s = j\omega$

$$\boxed{F(j\omega) = \frac{y(j\omega)}{i(j\omega)} = \frac{b_0}{a_n (j\omega)^n + a_{n-1} (j\omega)^{n-1} + \dots + a_1 (j\omega) + a_0}}$$

↓

(Sinusoidal T.F)

$y(t) = F(t) \cdot i(t)$
$y(s) = \alpha^{-1} [F(t) \cdot i(t)]$

Conclusion -

- Operational T.F. is preferred over time domain
- Sinusoidal is preferred over O.T.F
- Laplace is prefered over all.

eg -

(i) $T.F = \dfrac{1.5}{3D^2+2D+6}$ (ii) $T.F \ \dfrac{3}{6s+1}$

Order = 2 Order = 1

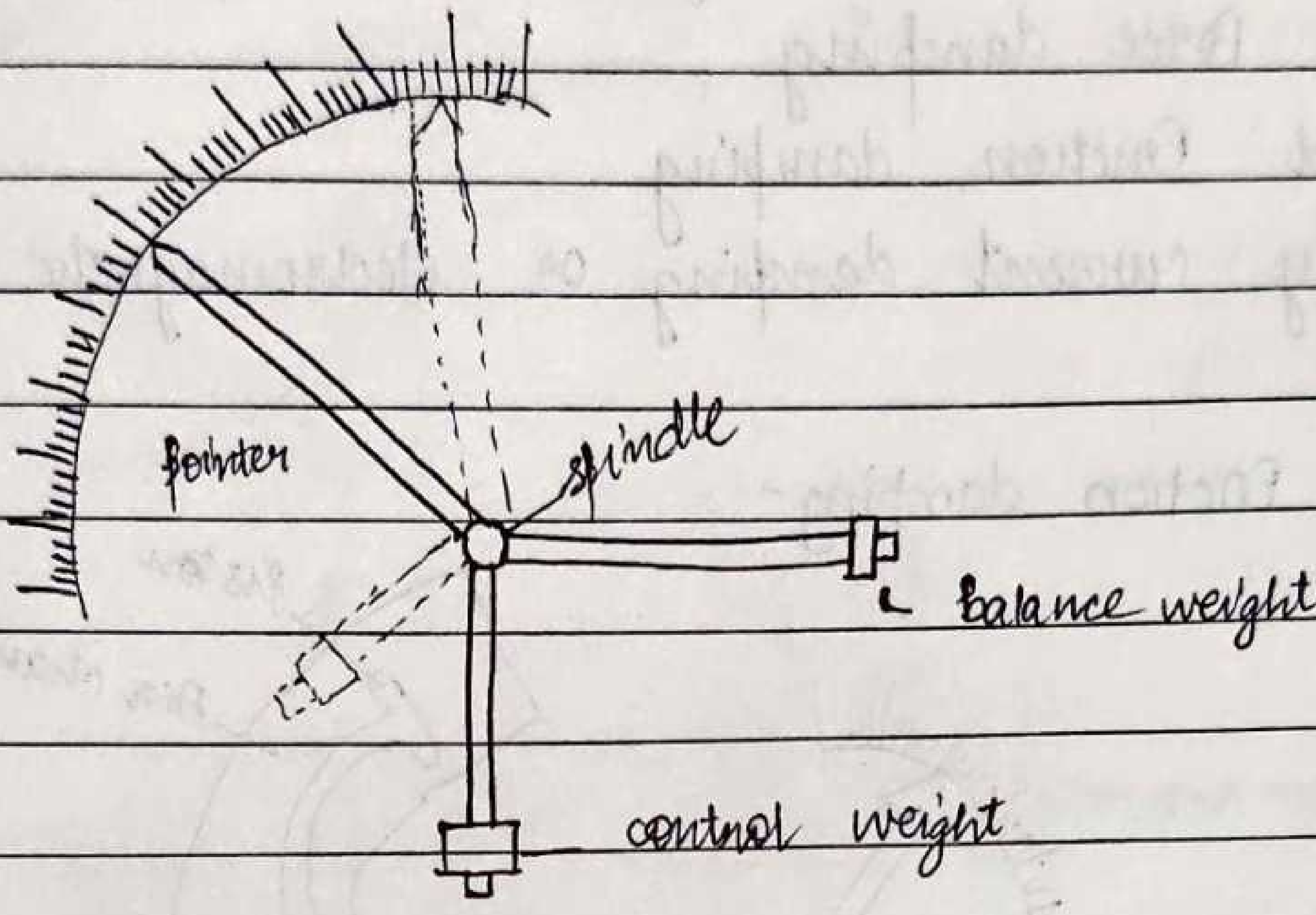
- Time constant -

Time taken by the system to reach 63.3% to the final steady state value, if there is no oscillation - (I^{st} order)
time req. from '0' to 63% of its steady state value.
(response of I^{st} order)

21 / 11 / 2022

Gravity control-

Figure-



From figure-

$T_d \propto I$

$T_c \propto \sin\theta$

At balance $T_d = T_c$

$I \propto \sin\theta$

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

$\boxed{I \propto \theta}$ (spring)

Advantages-

- It is cheap
- No aging
- Only two adjustable weights
- are required
- No effect of temperature
- No fatigue

Disadvantages-

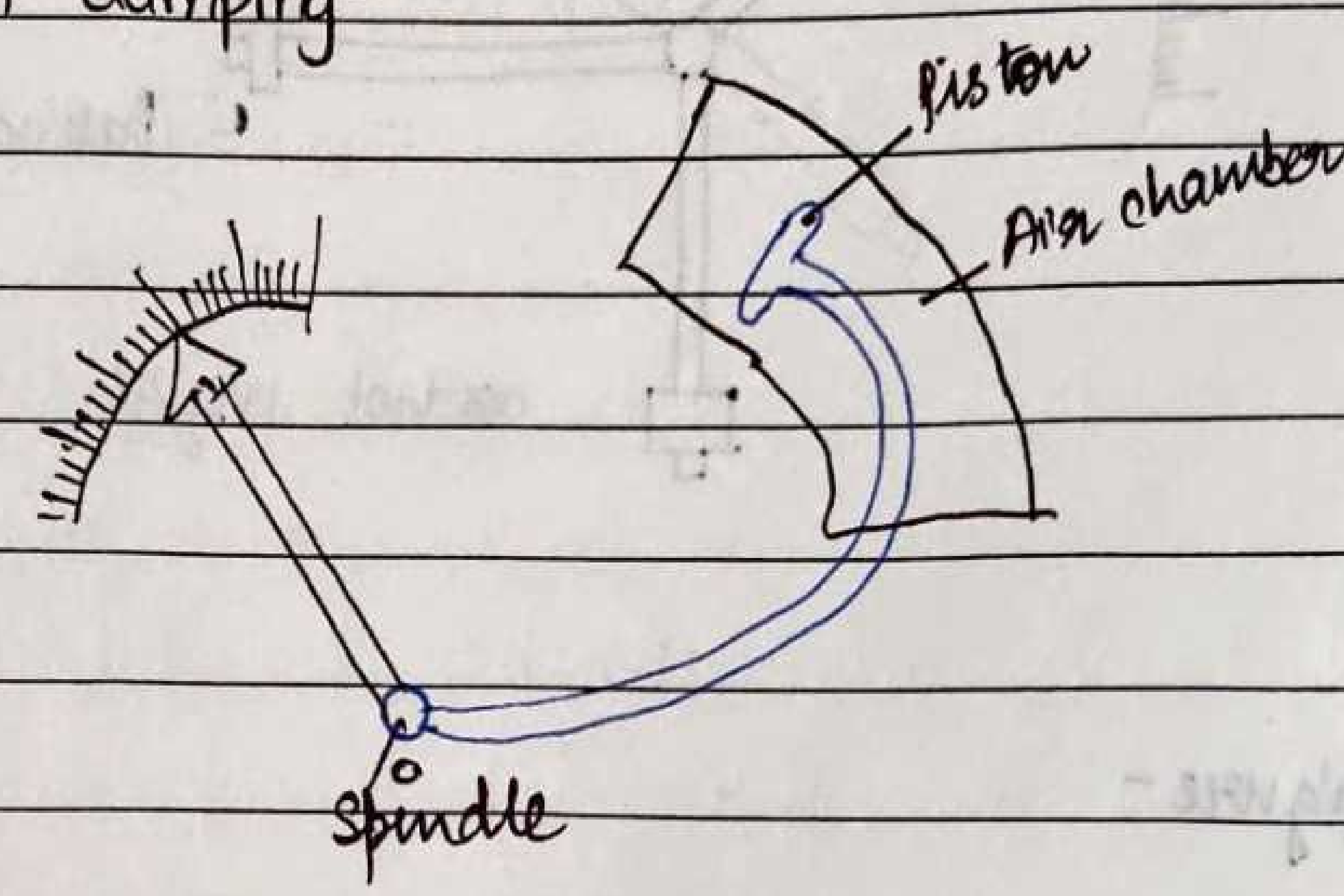
- Kept vertical
- Cramped scale

Damping Torque / Force-

There are three types of damping Torque / force-

- Air Force damping
- Fluid Friction damping
- Eddy current damping or electromagnetic damping

Air friction damping-

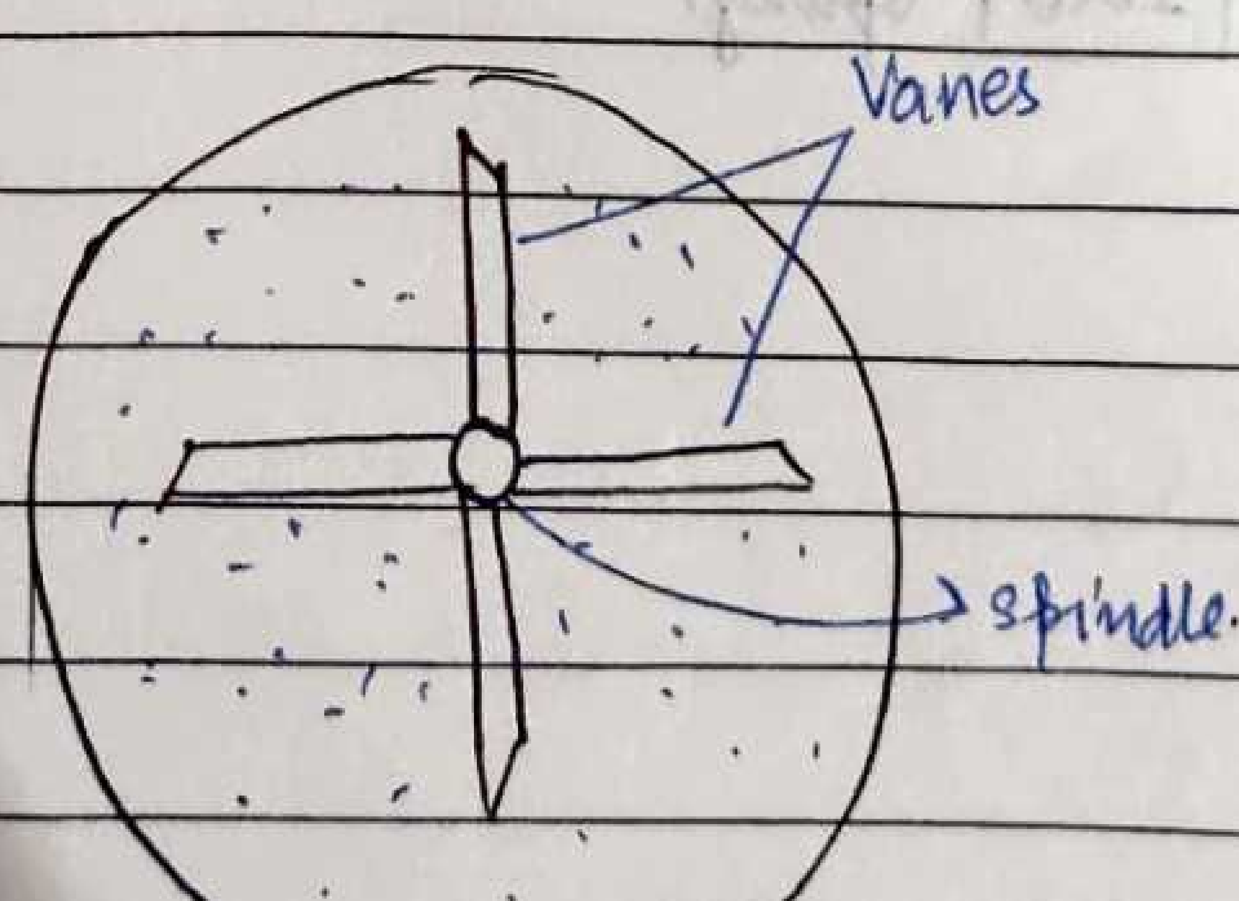


Used in-

- Electrodynometer type
- Thermocouple
- Hot wire and Mi

Mi
EDM
eletrodynometer type
hot wire
thermocouple

Fluid friction damping-

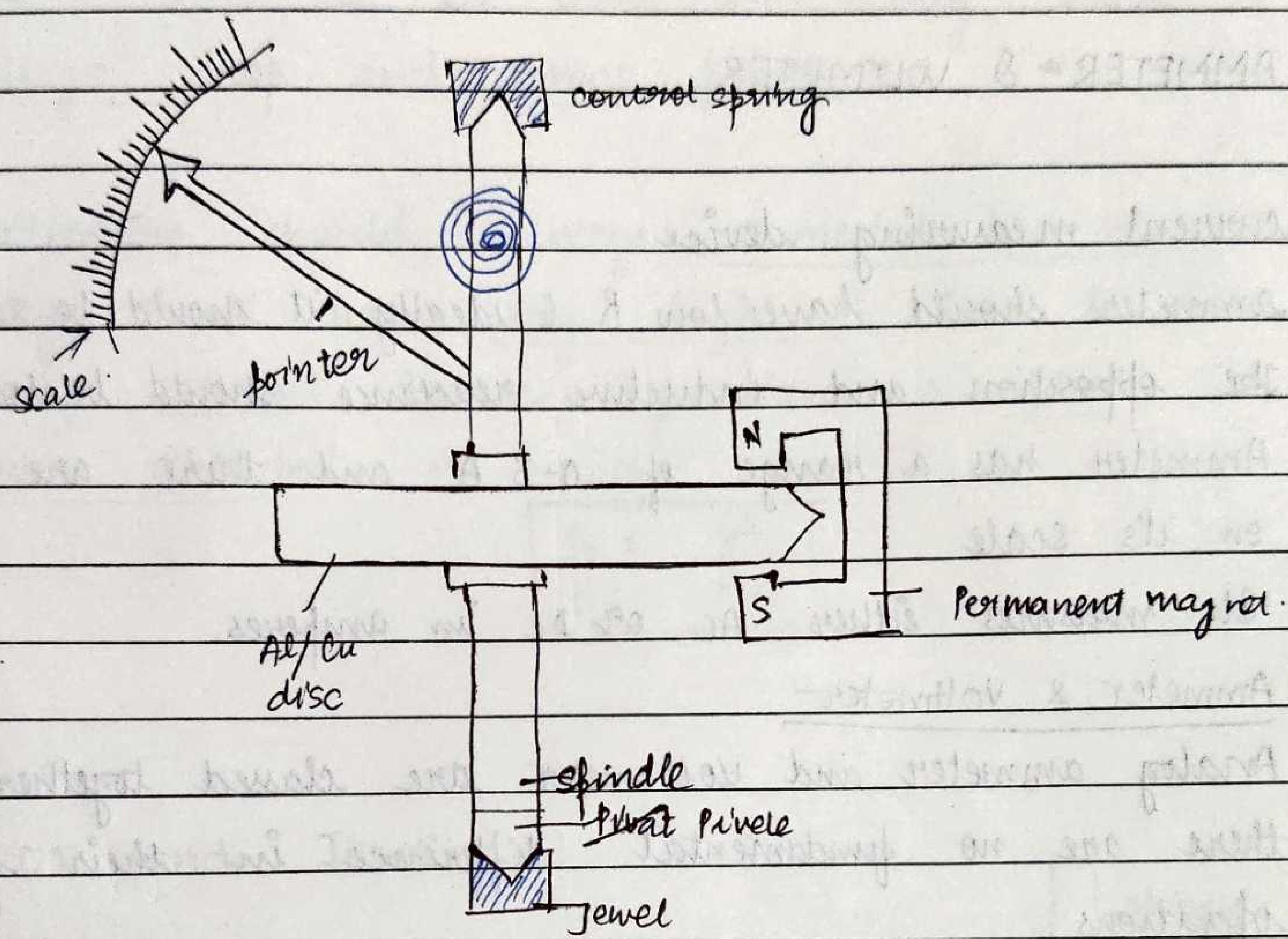


used in-

- It is rarely used
- Electrostatic type
- Changing the different fluid viscosity

it's cooling also
V decide insulation thick
I decided thickness of

Eddy current damping / EM damping -



- Al frame move in a mag field, emf induced, I produced, Lenz's law oppose & moving system

used in:-

- Permanent Magnet moving coil (PMMC)
- Hot wire

→ Imp points from above three damping Torque -

Loads r connected in ||r.

SC → zero impedance
OC → high impedance
Power drawn by instrument ...
It shouldn't alter or change the ckt condition

* MEASUREMENT (analog) OF ELECTRICAL QUANTITIES Like AMMETER, VOLTMETER, ~~WATTMETER~~, POWER and FREQUENCY.

(1) AMMETER & VOLTMETER

- current measuring device
- ammeter should have low R (ideally it should be zero but o...
- The opposition and inductive reactance should be low
- Ammeter has a range of 0-3 A and there are 30 divisions on it's scale
- It measures either AC or DC in amperes.

Ammeter & Voltmeter-

- Analog ammeter and voltemeter are classed together as there are no fundamental difference in their principle of operations

- In an ammeter the deflecting T is produced by the current to be measured and in voltmeter this Torque is produced by a current which is proportional to the voltage to be measured (electrostatic type)

- Thus all the voltmeters and ammeters are basically a current measuring device.

Imp

Any measuring instrument will have two basic requirements

(a) It shouldn't alter or change circuit condition
alter means nature of ckt.

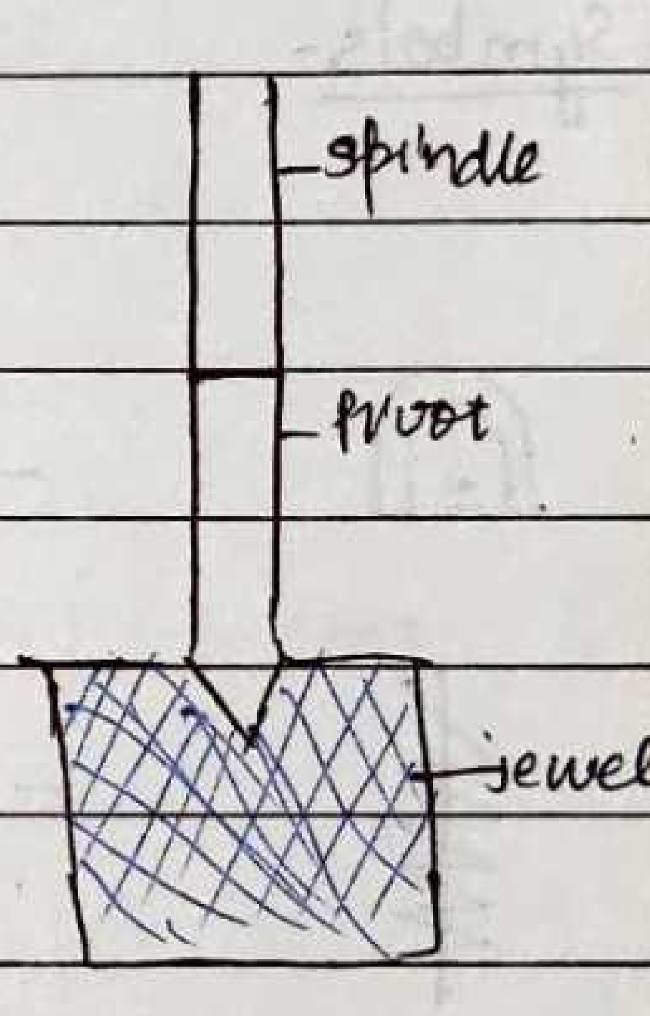
(b) Power consumed by measuring instrument (Mi) should be as minimum as possible

- Ammeter should always connected in series in circuit Therefore they should have very low electrical resistance. ~~The~~ This is in order that they cause a small voltage drop and small power.

- Voltmeters should always connected in ||r with circuit They should have very high R. This is in order that, current drawn by them is small and hence Power absorbed is small.

$$\boxed{P_V = \frac{V^2}{R_V}}$$

(2) PIVOT and JEWEL –



Pivot – 6
Jewel – 9

diff materials used for Pivot & Jewel

Pivot →
- stub silver
- Steel silver

Jewel →
- Diamond
- Blue sapphire
- Red stone (Rubby)

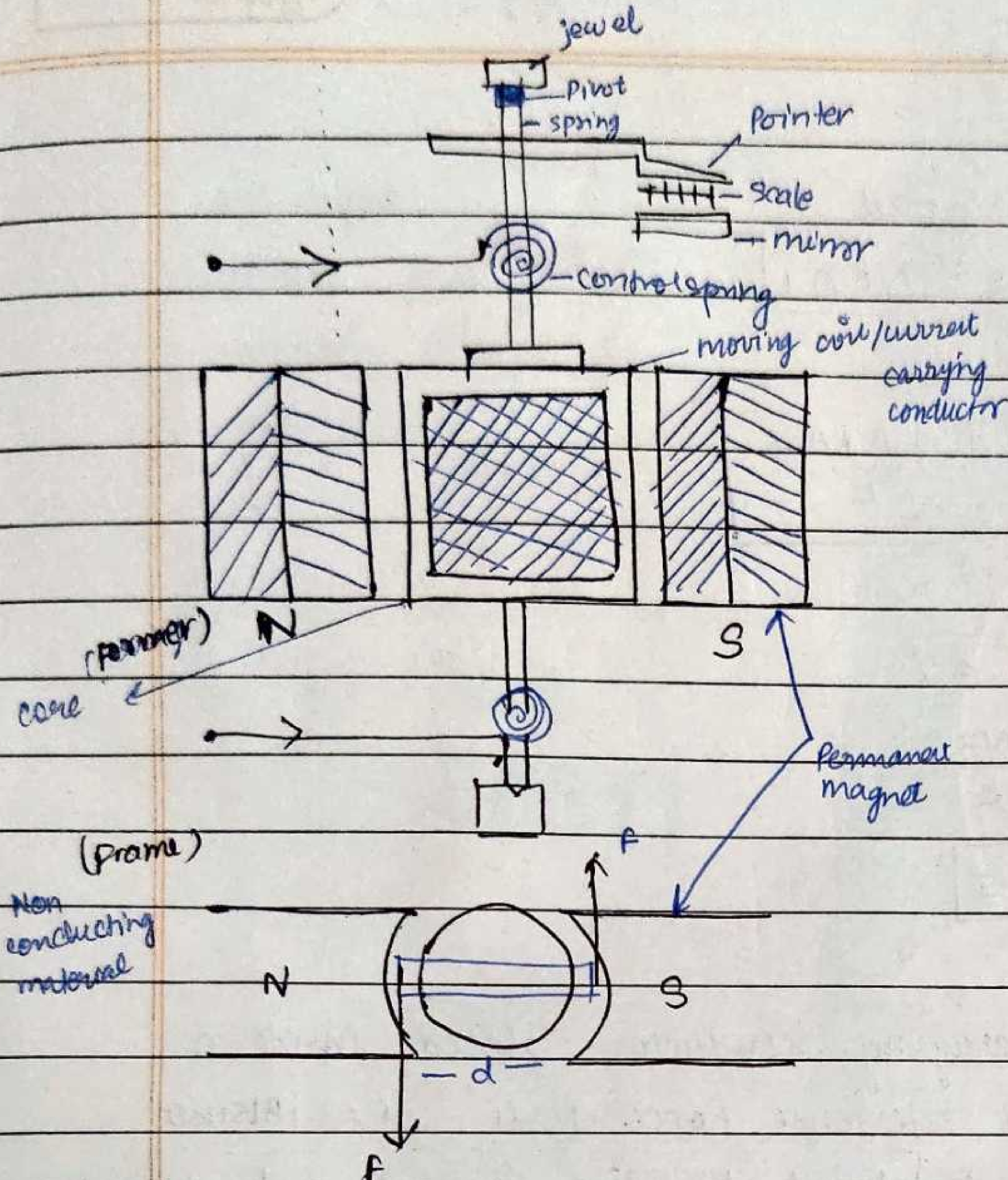
* TYPES OF AMMETERS & VOLTMETERS

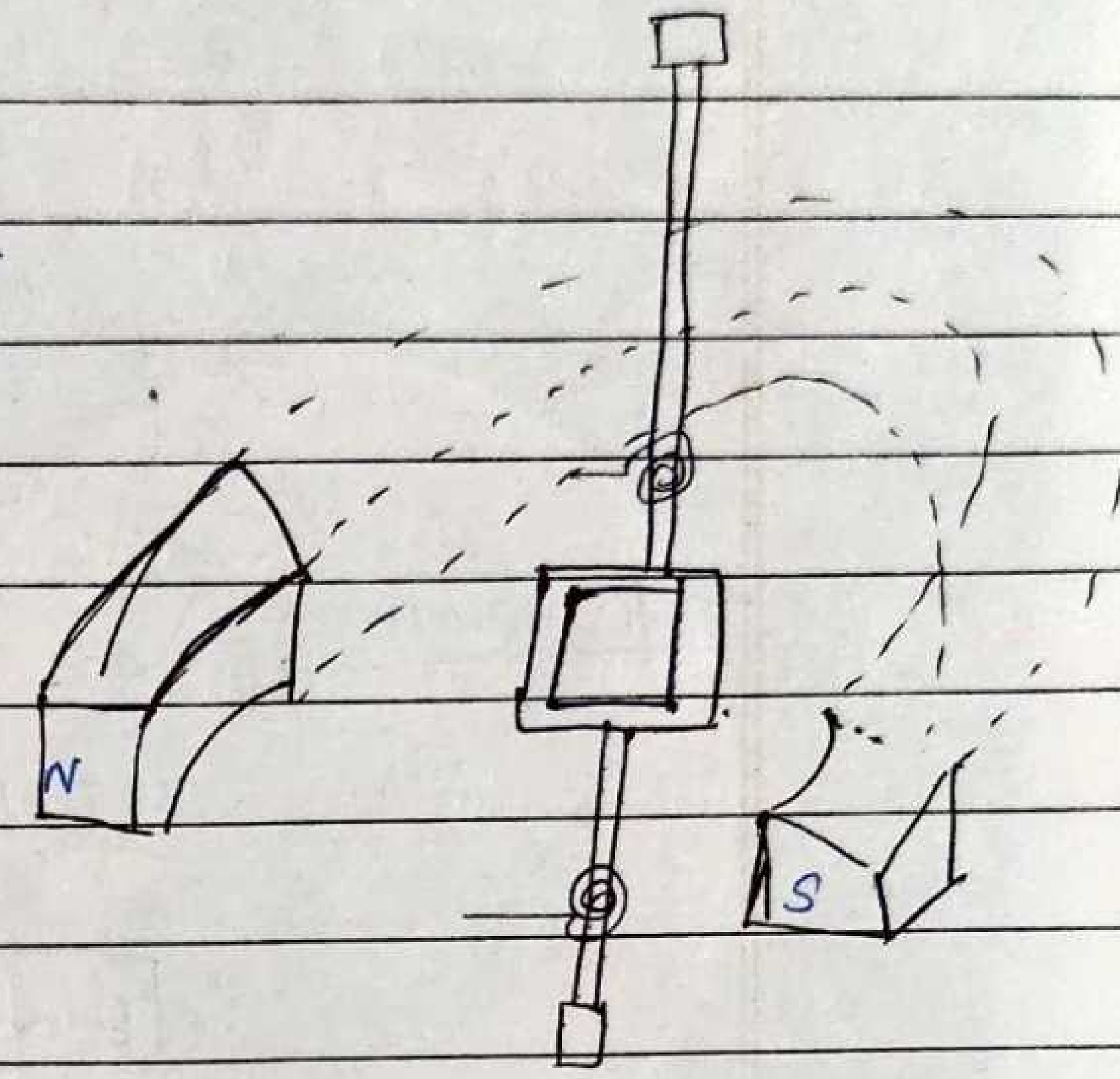
- Permanent Magnet Moving coil (PMMC) or Moving coil Type (MC) (D.C only)
- Moving Iron Type (MI) — Attraction type MI, Repulsion type MI — (AC/DC)

Generator - Right hand Fleming rule
Motor - Left Rule
dirn of force -

PMMC / DC motor working principle of n is same

(a) PMMC :- Working Principle, Construction, Torque eqn -





Permanent magnent (ALNICO)

fig - PMMC

~~N = no. of turns of coil~~

l = vertical length of coil (m)

d = Horizontal length of coil (width) in (m)

B = flux density

i = current to be measured

K = spring constant $\left(\frac{Ebt^3}{12l}\right)$

θ = deflection

Working Principle PMMC -

- If a current carrying conductor placed inside a magnetic field, it will experience a force, $\boxed{F = N i B l \sin\theta}$ and direction is known of F is given by Fleming's left hand rule -

Deflecting torque - $T_d = F \times d$

$= NiBl \times d$

F will be N no of turns

$T_d = NiBA$

$= K\theta$

τ_c div by 2 b'coze spring are 2
τ_c div by 1 " " is 1

At balance $\tau_c = \tau_d$

$$\boxed{K\theta = NBAi}$$

$$\Rightarrow \boxed{\theta = \frac{NBAi}{K}}$$

for numerical $\rightarrow$ $\theta = Gi$

$$G = \frac{NBA}{K}$$

i.e, $\boxed{\theta \propto I}$

- If a current carrying conductor placed inside a mag field, it will experience force F & $F = iBl\sin\theta$. The F is directly propotional to the current and direction of F can be find out with the Fleming's left hand rule

Construction-

- As the name indicates the instrument consist of rectangular coil and permanent mag of many turns wound on a light Aluminium or copper former (frame) inside which an iron core is placed.

- The power 'U' shaped permanent mag is made of 'ALNiCO', actually it is of cylindrical shape whose function is as follows-

(a) ~~who~~ To make the field radial & uniform
(b) To decrease the reluctance of the path b/w the pole i.e, increase the flux.
(C) The ~~fore~~ core is rectangular coil of many turns wound on

a light Aluminium frame which is supported by delicate jewel bearing, a pointer is attached to that control the is obtained by 2 phosphour bronze spring and eddy current damping is involved.

Note:-

For ammeters-

0-5 μA to 200 mA (PMMC) internal alone.

0- 200 A internal shunt

0 - 5000 A external shunt

For voltmeters-

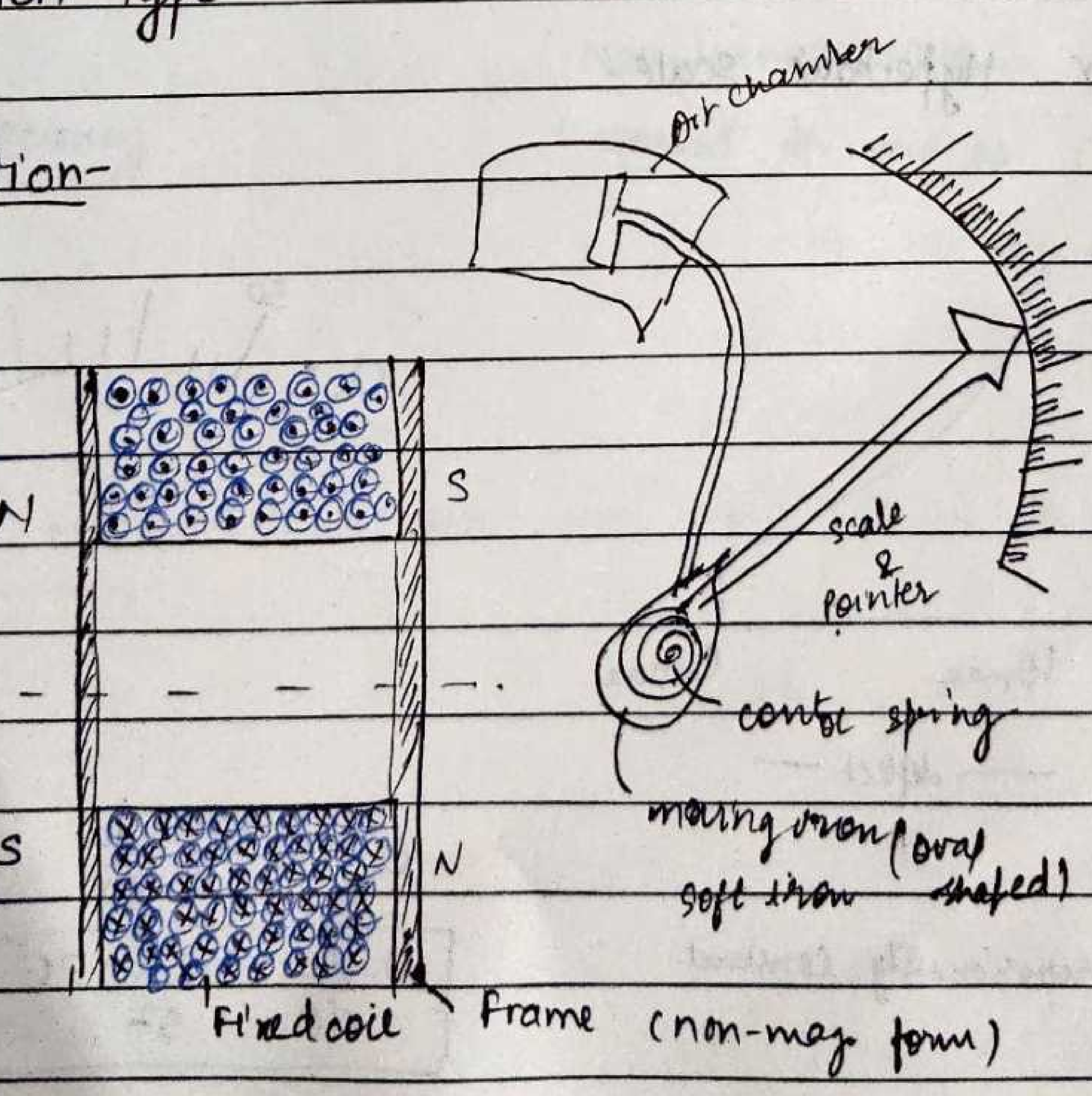
0-5 mV to 0-1000 mV

Multiplexer.

(b) MOVING IRON TYPE (Mi type)-

(i) Attraction type-

Construction-



- most commonly used
- For academic & industry
- most suitable at freq 50Hz.

⊙ - current coming out

⊗ - current going out

Law of conservation of energy applicable here

Torque equation -

Mechanical work done = electrical energy stored in coil

$$T_d \times d\theta = \frac{1}{2} I^2 dL$$

$$\boxed{T_d = \frac{1}{2} I^2 \frac{dL}{d\theta}}$$

$$\boxed{T_c = K\theta}$$

K ↳ spring constant

At balance condn-

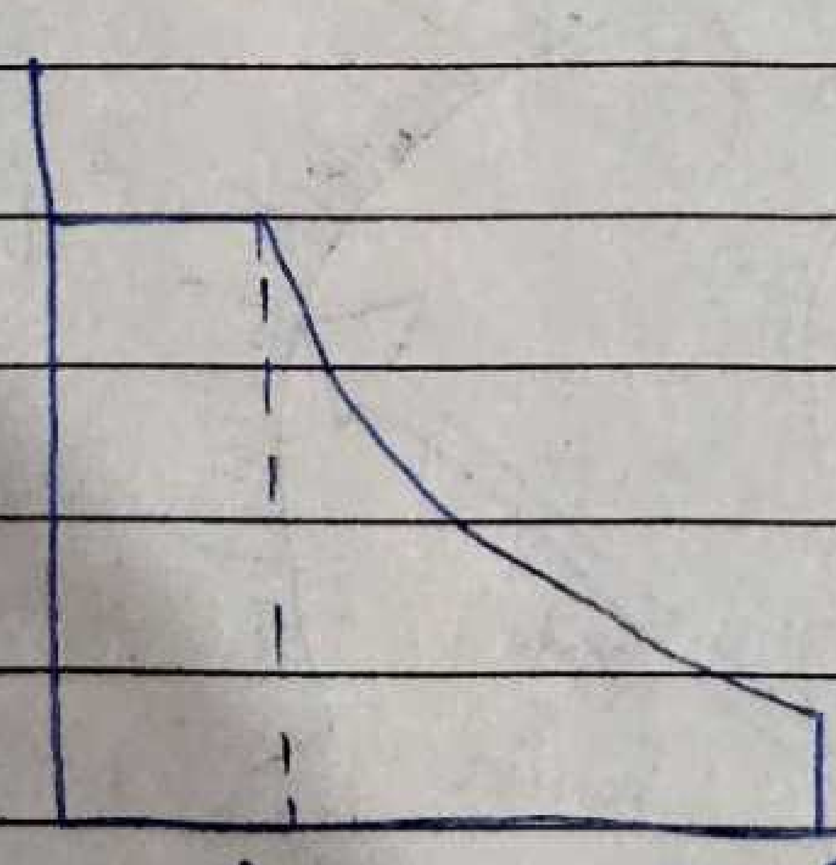
$$T_c = T_d$$

$$K\theta = \frac{1}{2} I^2 \frac{dL}{d\theta}$$

$$\boxed{\theta = \frac{1}{2} \frac{I^2}{K} \frac{dL}{d\theta}}$$

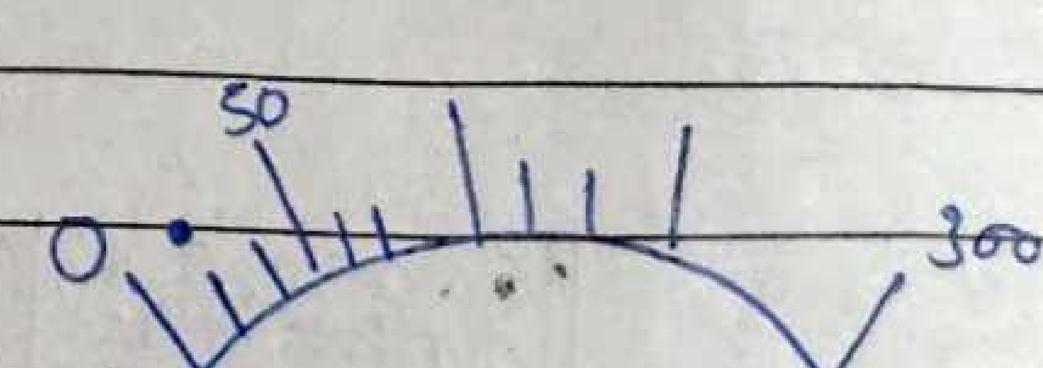
$$\boxed{\theta \propto I^2}$$

Rectangular Hyperbolic scale-



$I\theta_{max}$ θ_{max}

— deflect —



$I \propto \theta$

$I = S\theta$ ↳ proportionality constant

$$\theta = \frac{1}{2} \frac{S^2\theta^2}{K} \frac{dL}{d\theta}$$

$$\boxed{\theta \cdot \frac{dL}{d\theta} = \frac{2K}{S^2} = C}$$

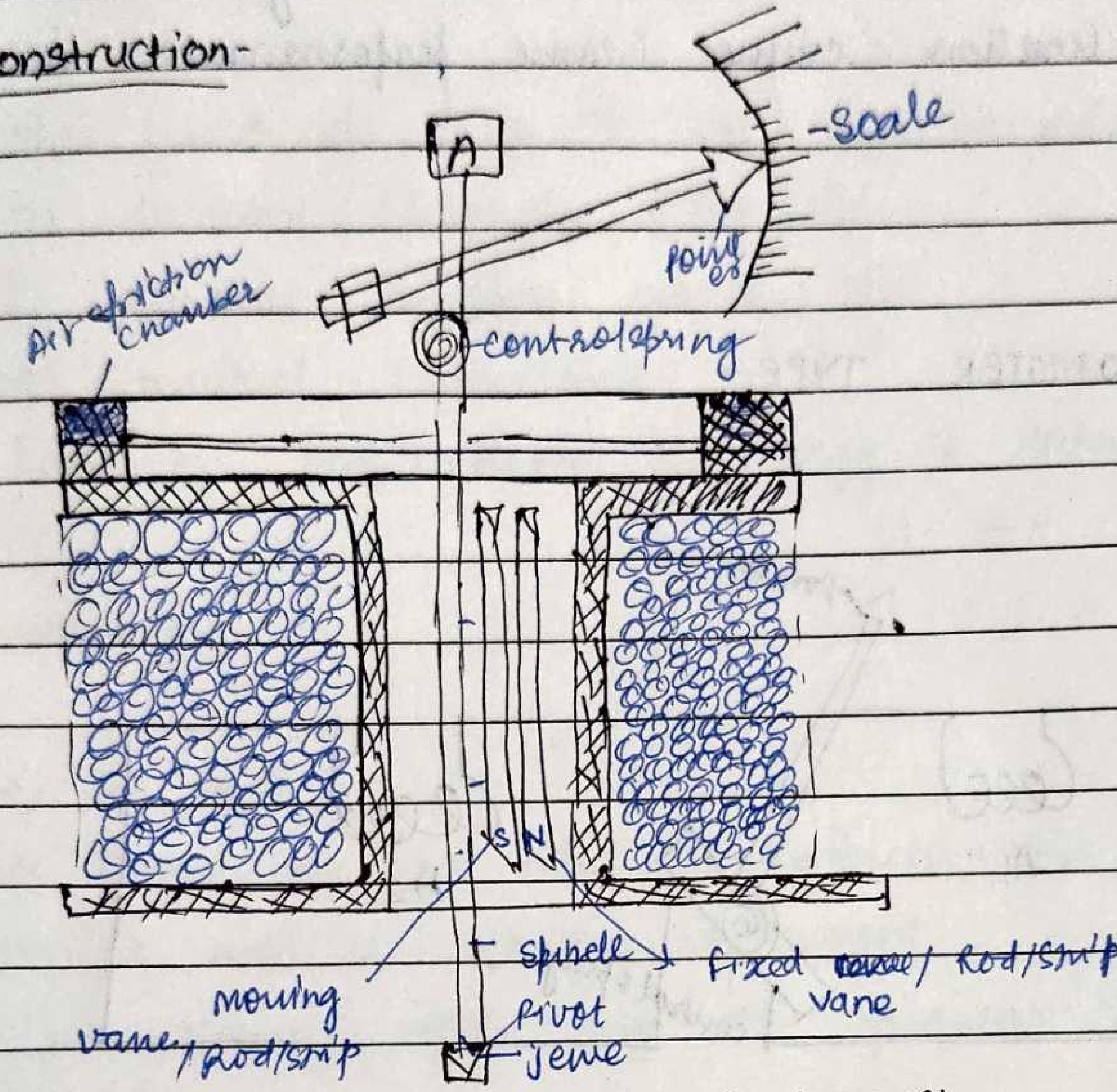
$\uparrow T_W = H$

$\frac{F}{T} = H$

$\frac{\text{signal}}{\text{noise}} = \text{High}$

(ii) Repulsion type -

Construction -



Advantages -

- robust and cheap
- less power
- AC/DC both
- $T_W = H$
- High efficiency

Disadvantages -

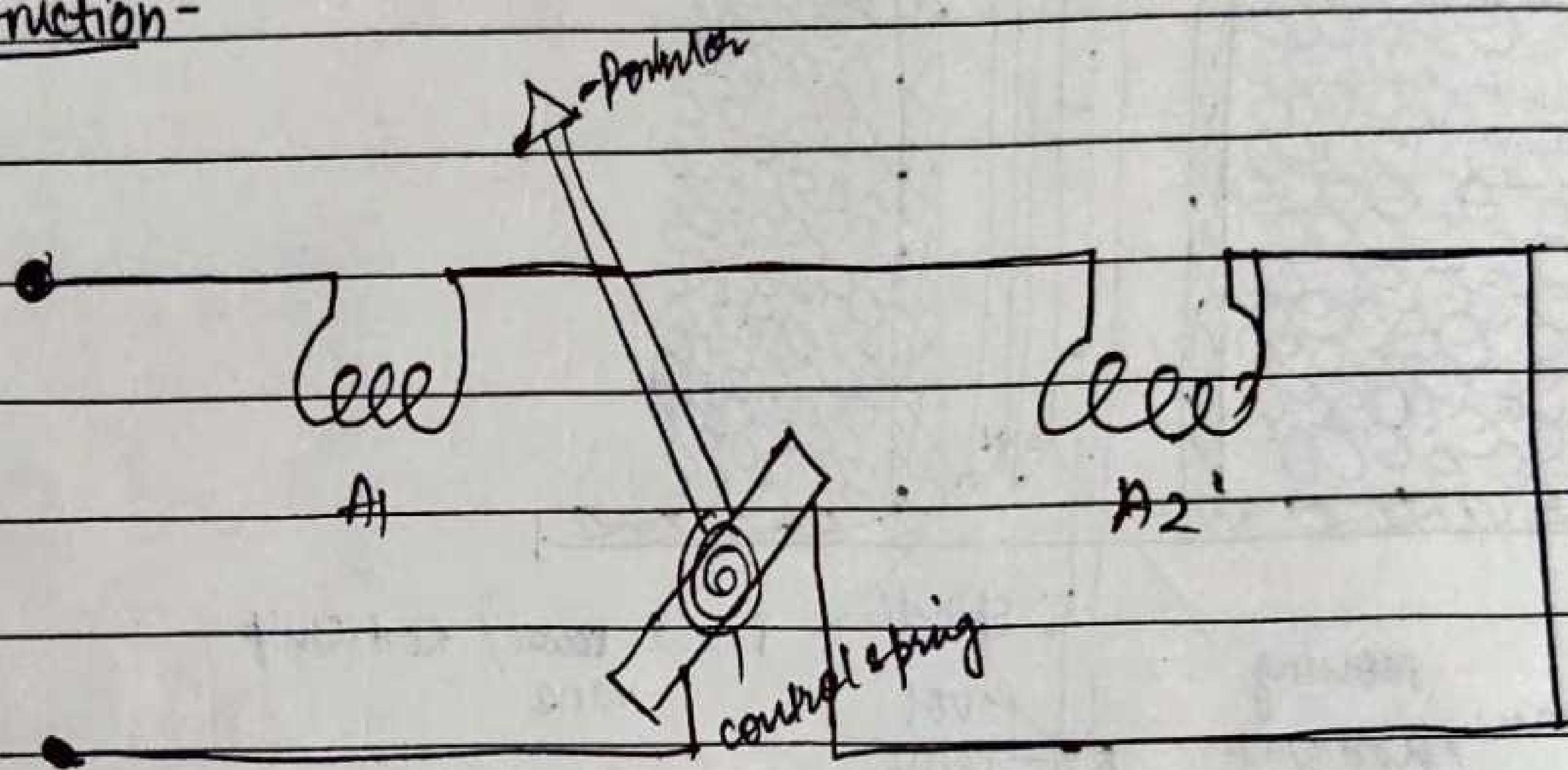
- Less accuracy
- Sensitive to frequency (AC only)
- Additional loss
- Non-linear scale
- cannot be used as T/F instrument

Transfer instrument-

A instrument which have same accuracy with same and calliberation curve (same performance) with AC and DC.

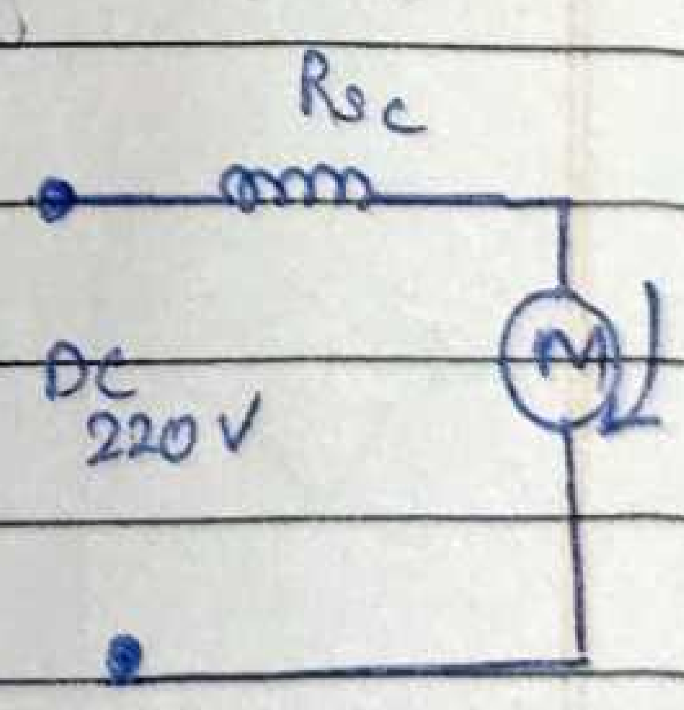
(c) ELECTRODYNOMOTER TYPE-

Construction-



- It can be used as transfer instrument
- Same performance with AC and DC
- Can be used for audio freq range i.e. 20Hz - 20kHz

Working Principle-



From above fig -

Here A_1 and A_2 are two half fixed coil

B is moving coil

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

At balance

$\hookrightarrow T_c = K\theta$

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

(I_1, I_2 are in series that's why there are simultaneously unidirectional)

$\frac{d(m)}{d\theta} \rightarrow$ mutual inductance

$\therefore \theta \propto I^2$ (It follows square law) (i.e. rectangular & hyperbolic scale)

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

- The fixed coil are Air core, light weight and paper core.
- I_1 current through fixed coil
- I_2 current through moving coil
- M mutual inductance
- Law of conservation of energy is taken here ($\tau_c = K\theta$)

Advantages-

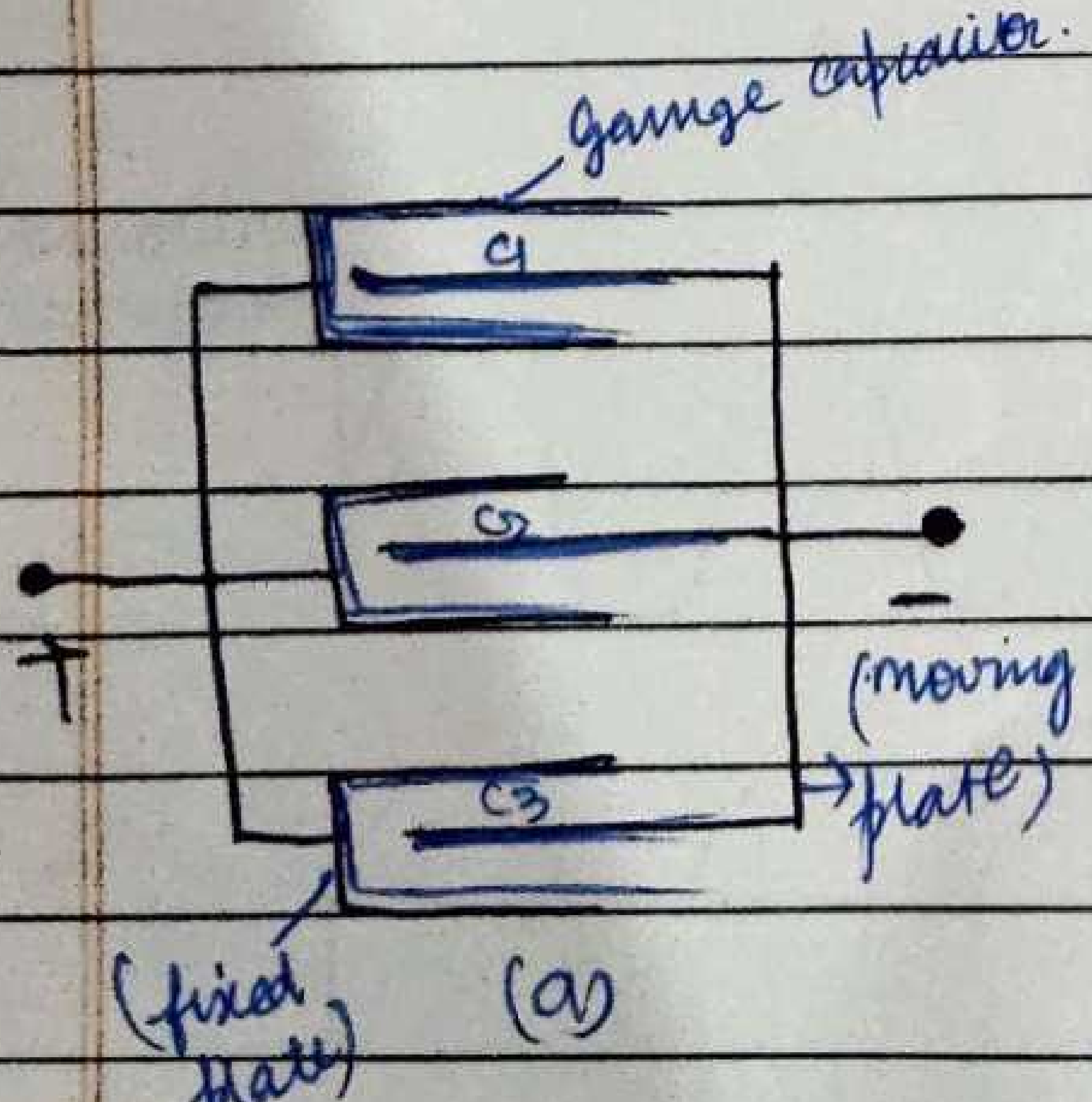
- AC/ DC both.
- Free from We and Wh (hysteresis = Wh, We = eddy)
- Can be used as Transfer instrument
- It is covering wide range of frequence (audio range).

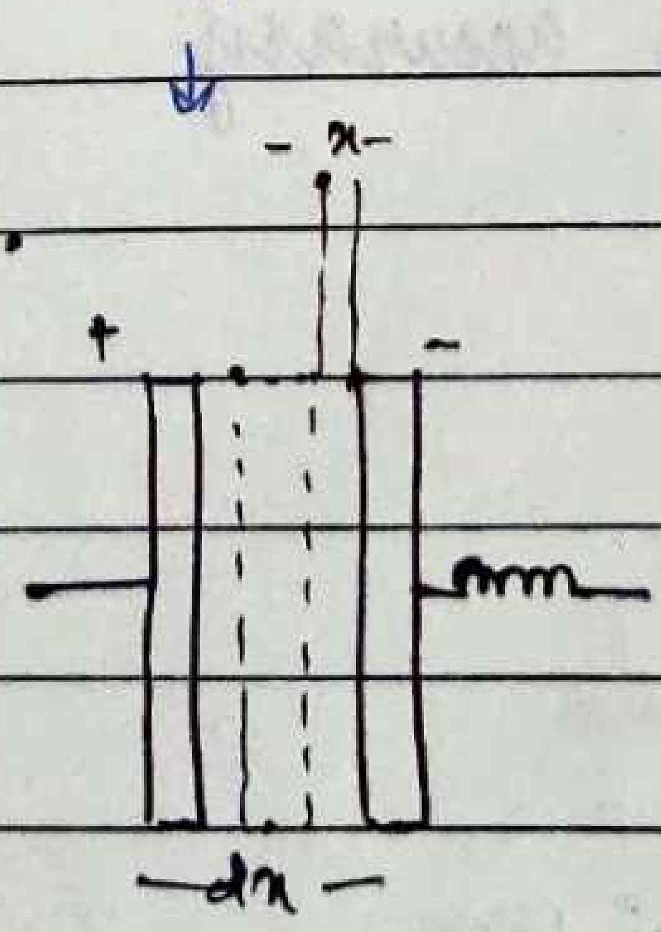
Disadvantages-

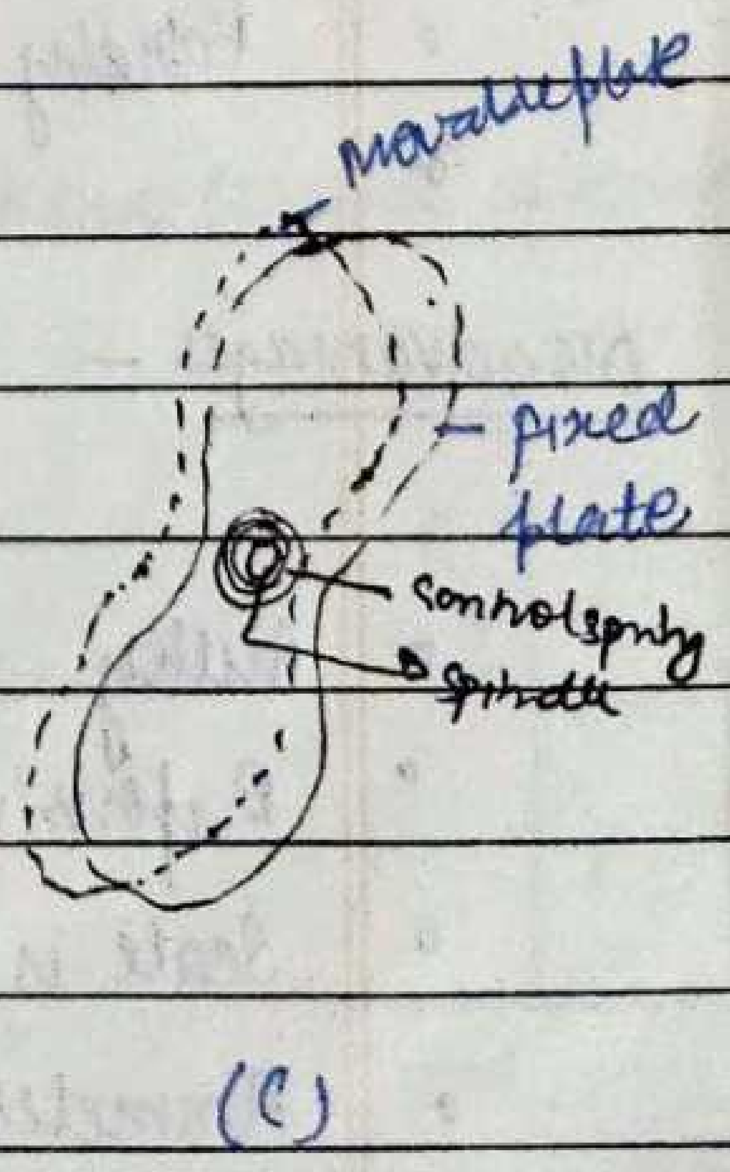
- Torque/W $= \frac{T}{W}$ is low
- Scale is not uniform.

(d) ELECTROSTATIC TYPE-

$C = \frac{\epsilon_r \epsilon_0 d}{A}$







$T_d \propto \frac{1}{d\theta} = \frac{1}{2} V^2 \frac{dc}{d\theta}$.

Working principle depends upon it's charge'

→ Mechanical work done by instrument = electrical energy stored

$T_d \times d\theta = \frac{1}{2} V^2 dc$

$T_d = \frac{1}{2} V^2 \frac{dc}{d\theta} \Rightarrow \boxed{\tau_c = k\theta}$

At balance

$\tau_c = \cancel{k\theta}\ \tau_d$

$k\theta = \frac{1}{2} V^2 \frac{dc}{d\theta}$

$$\boxed{\theta = \frac{1}{2} \frac{V^2}{K} \frac{dc}{d\theta}}$$

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

Adv →

- follows square law
- used for AC / DC both
- Non uniform scale
- Rectangular hyperbolic scale.
- Suitable for high voltage
- We, Wh is not present
- No waveform effect
- Fairly good accuracy

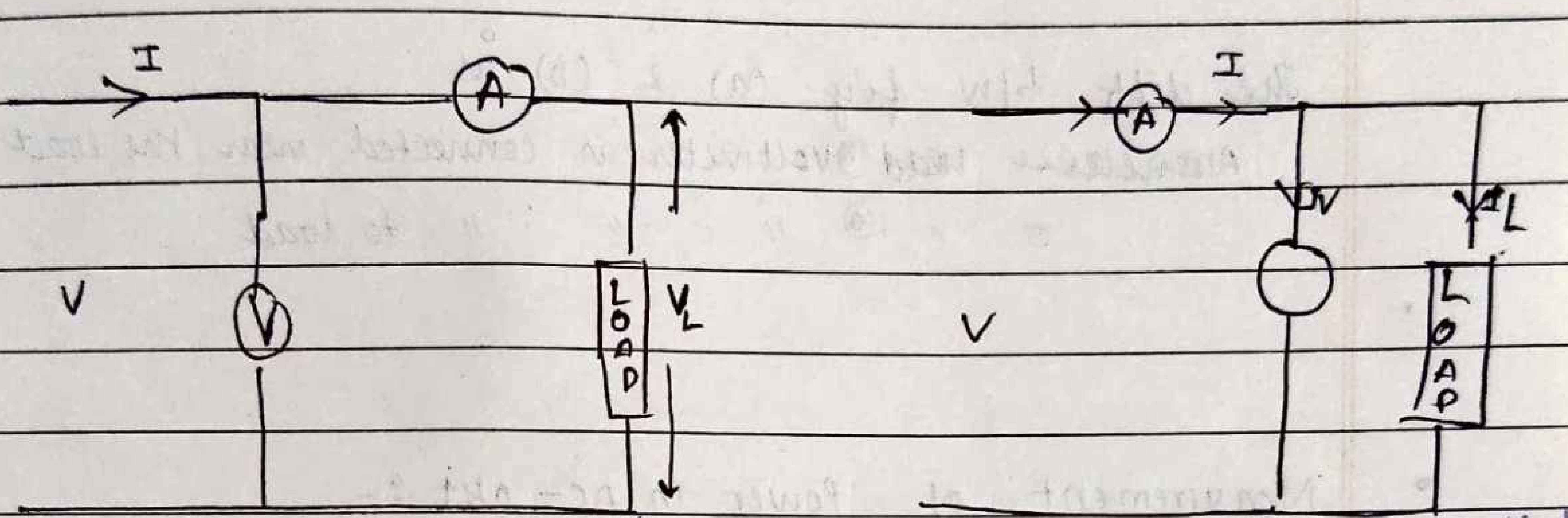
Disadvantages –

- Bulky
- Expensive
- Scale is not uniform
- Ammeters are less popular
- Fluid friction damping

(2) MEASUREMENT OF POWER-

→ Measurement of Power in DC ckt
→ Measurement of Power in AC ckt:

• Measurement of Power in DC ckt-



(a) (This ckt considered for low I meas)

(b) (This ckt considered for high I)

For fig (a)

→ Power consumed by the load =

$$= V_L I$$
$$= (V - V_a) I$$
$$= VI - V_a I$$
$$= VI - I^2 R_a$$

⇒ Power consumed by the load = Indicated power − Power loss in ammeter

⇒ Indicated power / actual power = Power consumed by load + Power loss in ammeter

for fig b -

Power consumed by load $= VI_L$

$$= V(I - I_V)$$
$$= VI - VI_V$$
$$= VI - \frac{V^2}{R_V}$$

Power consumed by load = Power indicated by instrument − Power loss in voltmeter

(I) Ameter-Series
(V) Voltmeter - ||r.

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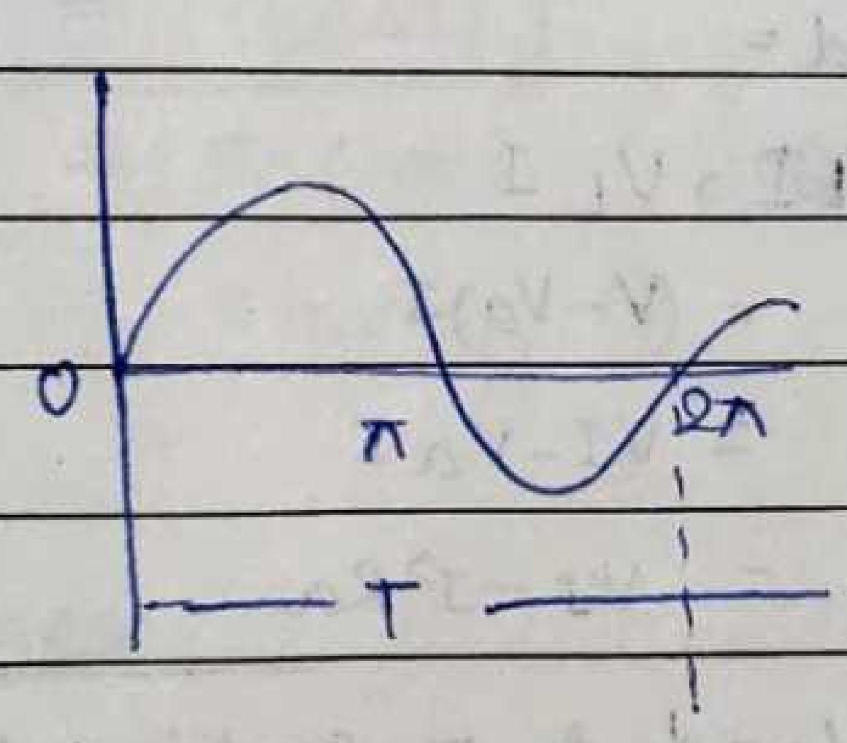
* $\boxed{\text{Power indicated by instrument = Power consumed + Power loss in V}}$

*** Note- Power indicated by instrument = Power consumed by load + power loss in the inst. connected near the load

The diff b/w fig (a) & (b) is
~~Ammeter~~ ~~load~~ ⓐ Voltmeter is connected near the load
ⓑ " " " to load

- Measurement of Power in AC-ckt :-



v - instantaneous
V - rms
V_{max} - max
i - inst.
I - rms
I_m - max.

$p = vi$

$v = V_m \sin \omega t$

$i = I_m \sin(\omega t - \phi)$ $\phi \rightarrow$ angle b/w v & I

$p = V_m I_m \sin\theta\,(\sin\theta - \phi)$

$= \frac{V_m I_m}{2}\, 2\sin\theta\,\sin(\theta - \phi)$

$p = \frac{V_m I_m}{2} \cos\phi\,(\cos(2\theta - \phi))$

$p = \frac{V_m I_m}{2} \int_0^{2\pi} \cos\phi . \cos(2\theta - \phi) . d\theta$

$P = \frac{V_m I_m}{2} \cos\phi$

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Numerical -

① A temp sensing device can be modelled as a first order system with a time constant of 8 sec. It is suddenly subjected to a step i/p of 25°C - 150°C what temp will be indicated in 12 sec.

① soln -

given

$\theta_f = 150°C$

$\theta_{in} = 25°$

Time cons. $\tau = 8$ sec

Therefore the temp after 12 sec.

$$\theta = \theta_f + (\theta_{in} - \theta_f)\, e^{-t/\tau}$$
$$= 150 + (25 - 150°)\, e^{-12/8}$$
$$= 122.18°C$$

② A linear Resistance POT is 50mm long and uniformly wound wire with a wire of total R 5000Ω. under normal condition the slider is at the centre of the potentiometer, Determine the linear displacement when the R at the POT as measured by wheatstone bridge is 1850Ω.

② sol -

$l_1 = 50mm$

$R_1 = 5000\Omega$

$R_0 = \frac{5000}{2} = 2500\Omega$

$l_0 = ?$

when $R_0' = 1850\Omega$.

$$\therefore V_0 = V_i \frac{R_0}{R_1} = V_i \frac{\Delta R_0}{R_1} = V_i \frac{l_0}{l_1}$$

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$$\frac{\Delta R_0}{R_1} = \frac{l_0}{l_1}$$

$$l_0 = \frac{\Delta R_0}{R_1} l_1 \qquad \boxed{l_0 = \frac{R_0 - R_0'}{R_1} \times l_1}$$

$$l_0 = \frac{(2500 - 1850) \times 50}{5000}$$

$$= 6.5 \text{ mm}$$

OR

(i) R of POT wire per unit length $= \frac{5000}{50} = 100\ \Omega/\text{mm}$

(ii) chang in R of POT its normal position $= 2500 - 1850$
$= 650\ \Omega$

Displacement $= \frac{650}{100} = 6.5$ mm

(3) The wire in a strain gauge is 0.1 m long has an initial R of 12Ω. on app of force wire length increased by 0.1 mm & R increases by 0.21Ω, Determine G.F?

given →
$l = 0.1 m$
$R = 12\Omega$
$\Delta l = 0.1 mm = 0.1 \times 10^{-3} m$
$\Delta R = 0.21\ \Omega$

$$G_f = \frac{\left(\frac{\Delta R}{R}\right)}{\left(\frac{\Delta l}{l}\right)} \quad \text{--- (1)}$$

$$\Rightarrow \frac{0.21/12}{\frac{0.1 \times 10^{-3}}{0.1}} = 17.5 \text{ Ans}$$

(4) The deflecting τ of an ammeter varies as the square of current passing through it. If current 5 A produces a deflection 90°, what deflection will occur for a I 3A. when this is (a) spring control & (b) gravity control.

(4) Deflecting τ:

$\tau_d = K_d I^2$

(a) spring control →

$\tau_c = K\theta$

at eq $\tau_c = \tau_d$

$K\theta = K_d I^2$

$\theta = \frac{K_d}{K} I^2$

let deflection for current I_1 & I_2 be θ_1 & θ_2

$\frac{\theta_1}{\theta_2} = \frac{I_1^2}{I_2^2}$

$\theta_2 = \theta_1 \left(\frac{I_2}{I_1}\right)^2$

deflection produced by current 3A, $\theta_2 = 90 \times \left(\frac{3}{5}\right)^2$

$= 32.4$

(b) gravity control

$\tau_c = K_1 \sin\theta$

$\frac{\sin\theta_1}{\sin\theta_2} = \frac{I_1^2}{I_2^2}$

$= \sin 90° \times \left(\frac{3}{5}\right)^2$

$= 0.36$

$\theta_2 = \sin^{-1} 0.36 = 21.1°$