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1. Measuring Instruments

Measurement:- The result obtained by comparing unknown quantity with known quantity is called Measurement

Measuring Instruments:- The Instruments used for measurements are called measuring Instruments

→ The electrical quantities like power, current, voltage, Resistance are to be measured with the help of measuring instruments.

Necessary Requirements:-

→ With the introduction of the instrument, the circuit parameters shouldn't be altered in the circuit.

→ The instrument must and should consume less amount of power.

Classification of Measuring instruments:-

The measuring instruments are classified as follows

classification

- Absolute Instruments
  - Ex: Tangential Galvanometer
- Secondary Instruments
  - Indicating Instruments — Ex: Ammeter, voltmeter, wattmeter
  - Recording Instruments — Ex: X-Y plotter
  - Integrating Instruments — Ex: Energy meter.

Absolute Instruments:- These instruments are used in laboratories. The unknown quantity is measured in terms of instrument parameter.

ex: Tangential Galvanometer.

Secondary Instruments

the instruments which are used for indicating the magnitude of measured quantity.

① **Indicating Instruments**:- It consists of a standard dial & pointer. The pointer moves on standard dial the unknown quantity is calculated

Ex: Ammeter, voltmeter & wattmeter

→ the instruments which are used to record the circuit conditions at a particular interval of time.

② **Recording Instruments**:- The unknown quantity is measured & recorded (i) in the graph w.r.t time.

ex: X-Y. plotter.

→ the instruments which is used to measure the total energy supplied at a particular interval of time.

③ **Integrating Instruments**:- The unknown electricity is measured over a period of time.

ex: Energy meter, watt-hour meter

Essential requirements of any Indicating Instruments:-

① Deflecting system: $T_d \to F$

② controlling: T_c → opposite direction to deflecting torque

③ Damping: To avoid oscillations

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① Deflecting system → It produces deflecting torque (T_d)

② Controlling system → It produces controlling torque (T_c)

③ Damping system → It avoids the oscillations of a pointer.

→ The deflecting torque acting on the pointer to move in forward direction from its zero position. The deflecting torque can be produce in any of the following methods.

(i) Magnetic effect
(ii) Electrostatic effect
(iii) Induction effect
(iv) Thermal effect.

(i) Magnetic effect:-

Whenever a current carrying conductor is placed in uniform Magnetic field there exists a force on the conductor. this effect is used in Ammeters, Voltmeters, Wattmeters.

(ii) Electrostatic effect:-

When two charged plates are brought nearer there exists a force. This type of effect is used in electrostatic voltmeters.

(iii) Induction effect:-

When AC supply is given to the magnets alternating current flows which cuts the disc. An emf is induced in it. Disc is closed path, current flows through it, interaction of disc flux & magnetic flux, the disc rotates. It is used in Induction type Energy meters.

(iv) ~~Dissin~~ Thermal effect:-

When two dissimilar materials joined together to form a closed loop, these metals are maintained with different temperatures, an emf is induced in it and the current will be flow. This current is used to produce a torque.

2) Controlling system:-

The controlling system provides controlling torque which serves two functions,

① when the supply is removed, pointer bring backs to original zero position.

② It provides equal and opposite torque to make pointer at definite value.

There are 2 methods for controlling system

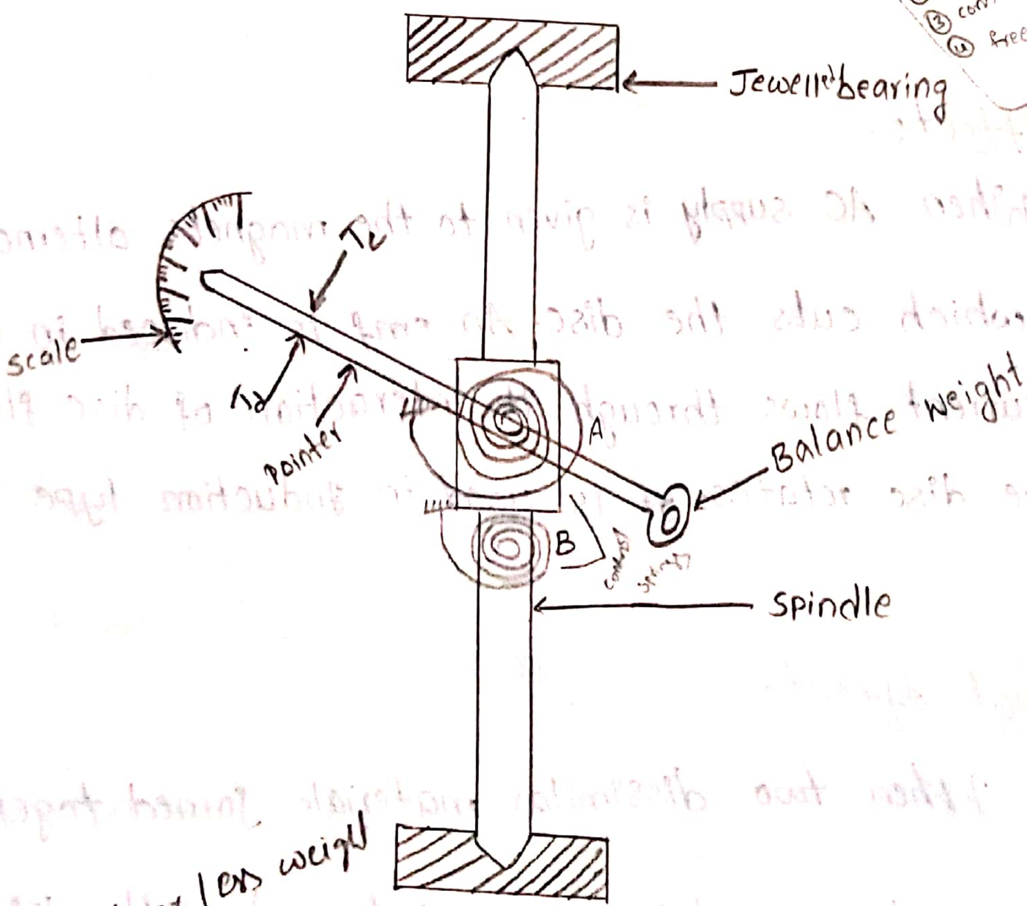
① Spring control method → it is best

used if vertical position → ② gravity control method.

① Spring control method:- phosphorous Bronze

mostly used

Spring should have following quantities
① low resistance temp co-efficient
② It should be non-magnetic
③ consists of small resistance, sufficient cross sectional area
④ free from mechanical stress



used bcoz less weight

The controlling torque

$$\boxed{T_c = \frac{E b t^3}{12 l} * \theta} \quad N\text{-}m$$

→ where, E = young's modulus of a material N/m^2

b = Depth of spring

t = thickness of spring

l = Length of spring

D = Deflection

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

→ The deflecting torque,

$$\boxed{T_d = K \cdot I}$$

At equilibrium condition,

$$T_d = T_c$$

$$K_s \theta = K I$$

$$\boxed{\therefore I \propto \theta} \rightarrow \text{uniform Scale}$$

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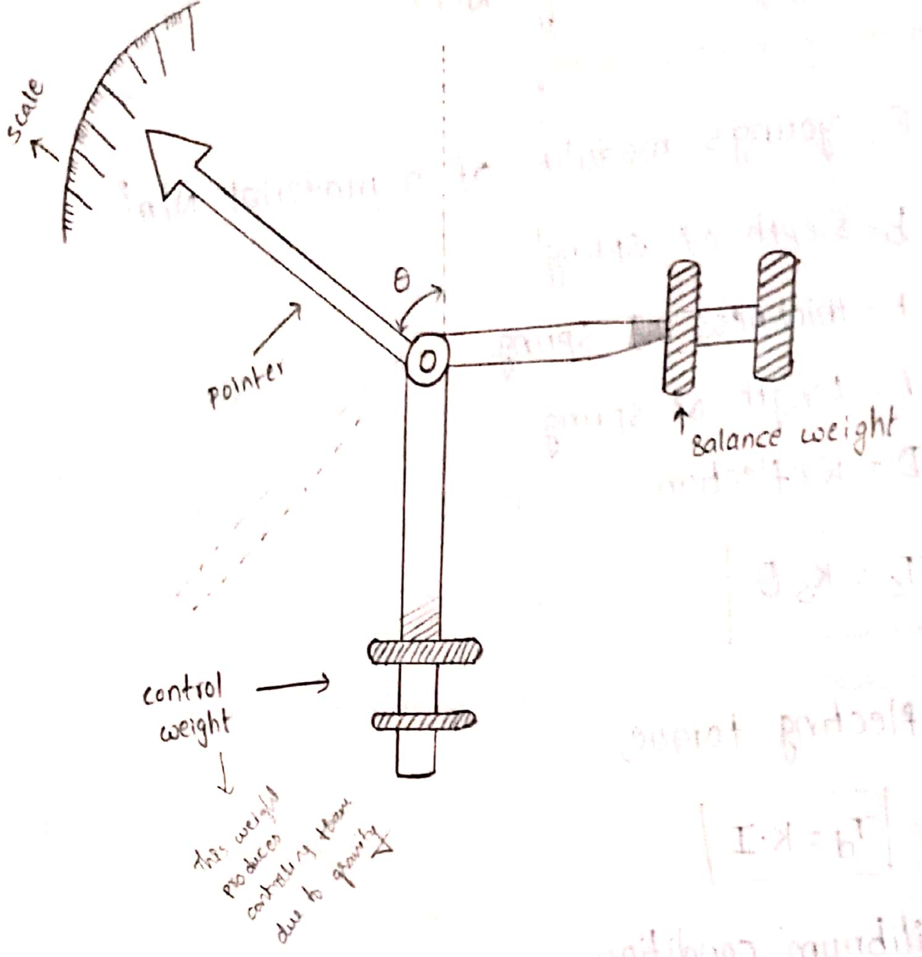
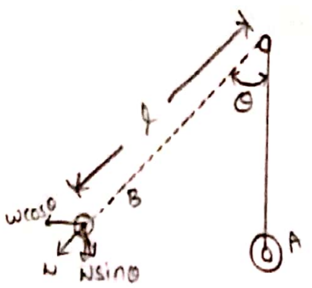
(2) Gravity control method:—

It is used for vertically mounted instruments.

The control weight is also adjustable but the scale is non-uniform





Advantages of gravity control

1. Time Independent
2. Temperature Independent
3. controlling torque is varied by varying control weight
4. Simple & cheap

Disadvantages

1. Scale non-uniform
2. used only for vertically mounted instruments
3. Requires proper leveling, otherwise causes serious errors.

→ The controlling torque

$$\boxed{T_c = W\sin\theta * l}$$

where $K = W * l$

∴ controlling torque $T_c = K\sin\theta$

Deflecting torque $T_d = KI$

At equilibrium condition

$$T_d = T_c$$

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

scale is non-uniform.

Differences between spring control & gravity control.

Spring control (phosphor bronze springs are using) $T_c = \frac{Ebt^2}{12l}\theta$	Gravity control. $T_c = W\sin\theta\, l$
1. scale is uniform i.e., $I \propto \theta$	1. scale is non-uniform i.e., $I \propto \sin\theta$
2. It is used in all Instruments	2. It is only used in vertically mounted Instruments.
3. control weight is fixed	3. control weight is adjustable by adjusting wt of system
4. This method gives accurate values.	4. The readings taken are not an accurate values.
5. This method involves more cost.	5. cost is less
6. Leveling is not required	6. proper levelling is required to get accurate values

with help of spring the pointer backs to original system even supply is not there

with gravity force it will bring back to zero position

Damping system:—

There are 3 types of Damping systems

1. under damped system
2. over damped system
3. critically damped system.

Under Damping system:— In this system, the pointer will takes some time to settle at final position.

Over Damped system:— In this system, the pointer is sluggish & lazy. takes more time to settle at final steady position

Critically Damped system:— In this system, the pointer placed at final steady position rapidly & quickly.

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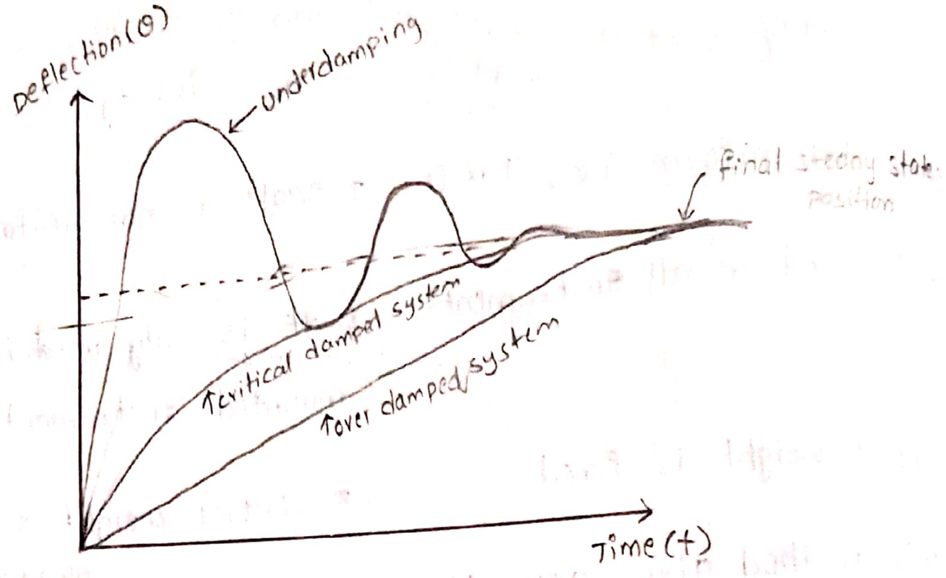
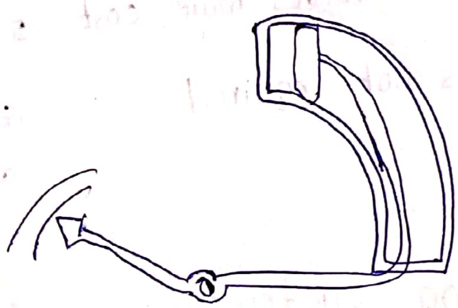
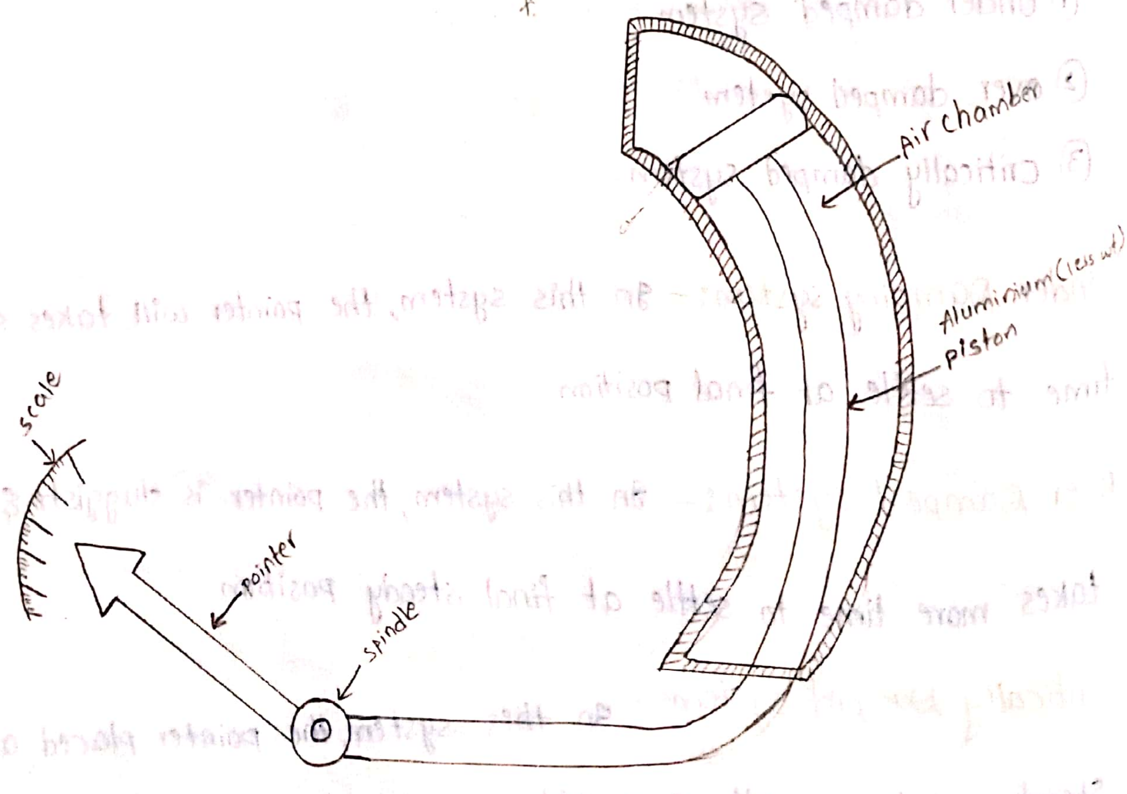


* There are three methods to provide the damping torque

1. Air friction Damping
2. oil/Fluid friction Damping
3. Eddy current Damping
   ↓ it is best



1. Air friction Damping:-

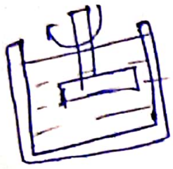


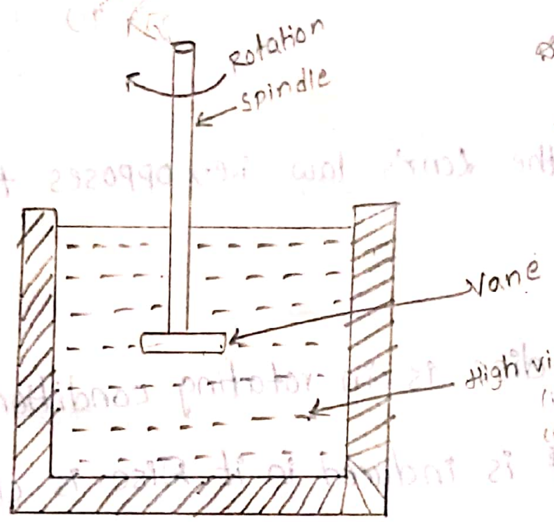
→ It consists of a light aluminium piston in the air chamber. The clearance between Air chamber and piston is very less.

→ When the piston moves outside the chamber (fro motion) outside air opposes a piston direction.

→ When the piston moves into the chamber, air inside is compresses. Therefore, for to and fro motions piston reciprocates in the air chamber. Hence, oscillations are avoided.

2. Fluid / oil Friction Damping:-





The high viscosity has following properties.

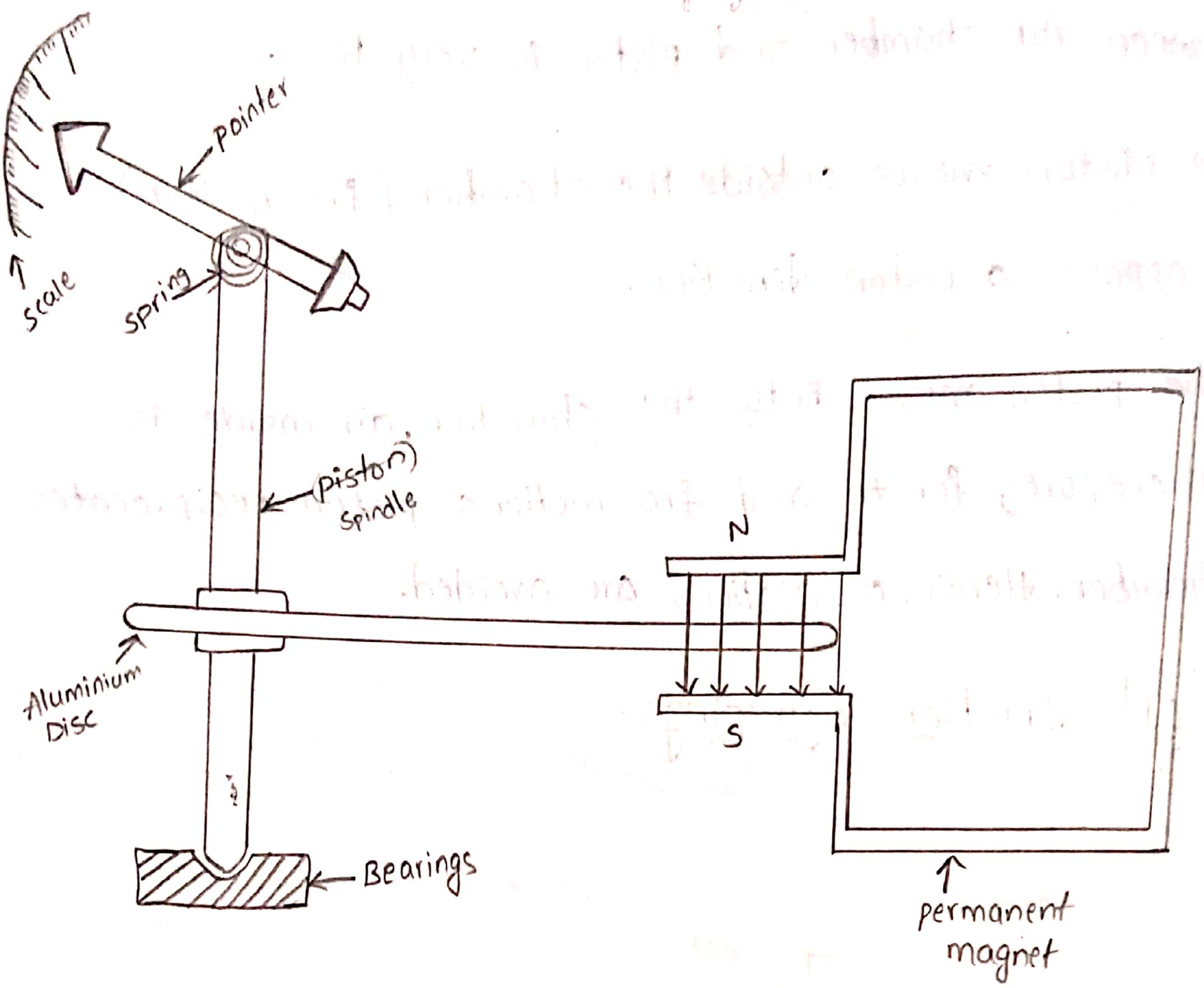
(i) It is acting as a insulating medium for inner parts.

(ii) It provides cooling

(iii) Due to upthrust of a oil, the bearings are free from frictional losses.

→ When the vane is rotating the direction is opposed by high viscosity oil. Hence, the oscillations are avoided.

3. Eddy current Damping:—



→ It works on the Lenz's law i.e., opposes the cause of producing it.

→ When the disc is in rotating condition, it cuts the magnetic flux lines, an emf is induced in it. Disc is closed path, hence currents are produces. These currents are called Eddy currents.

→ The Eddy currents opposes the rotation of disc. Hence, oscillation are avoided.

→ It is the most effecient & effective method of Damping system.

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→ It is unipolar device.

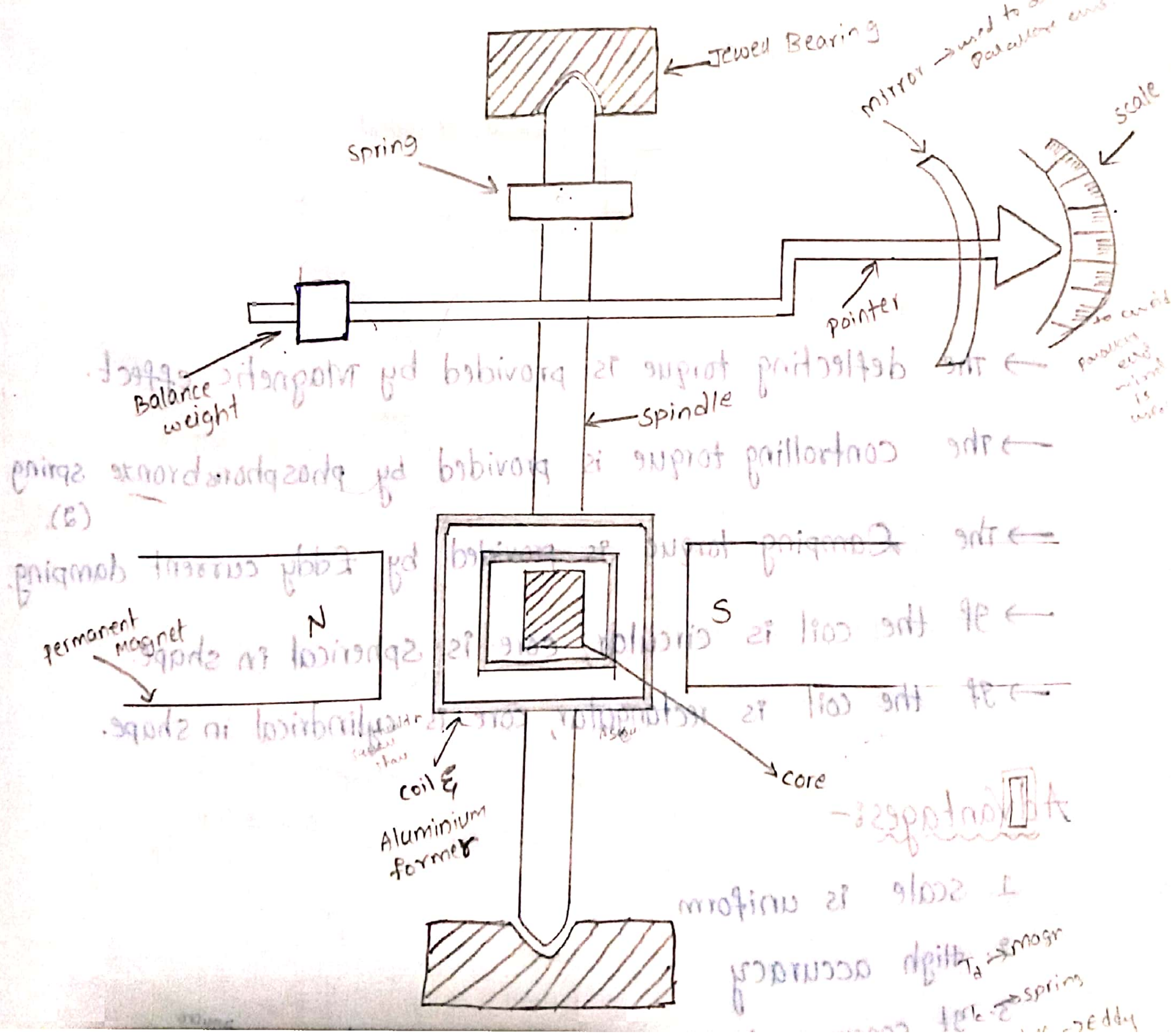
[8M]

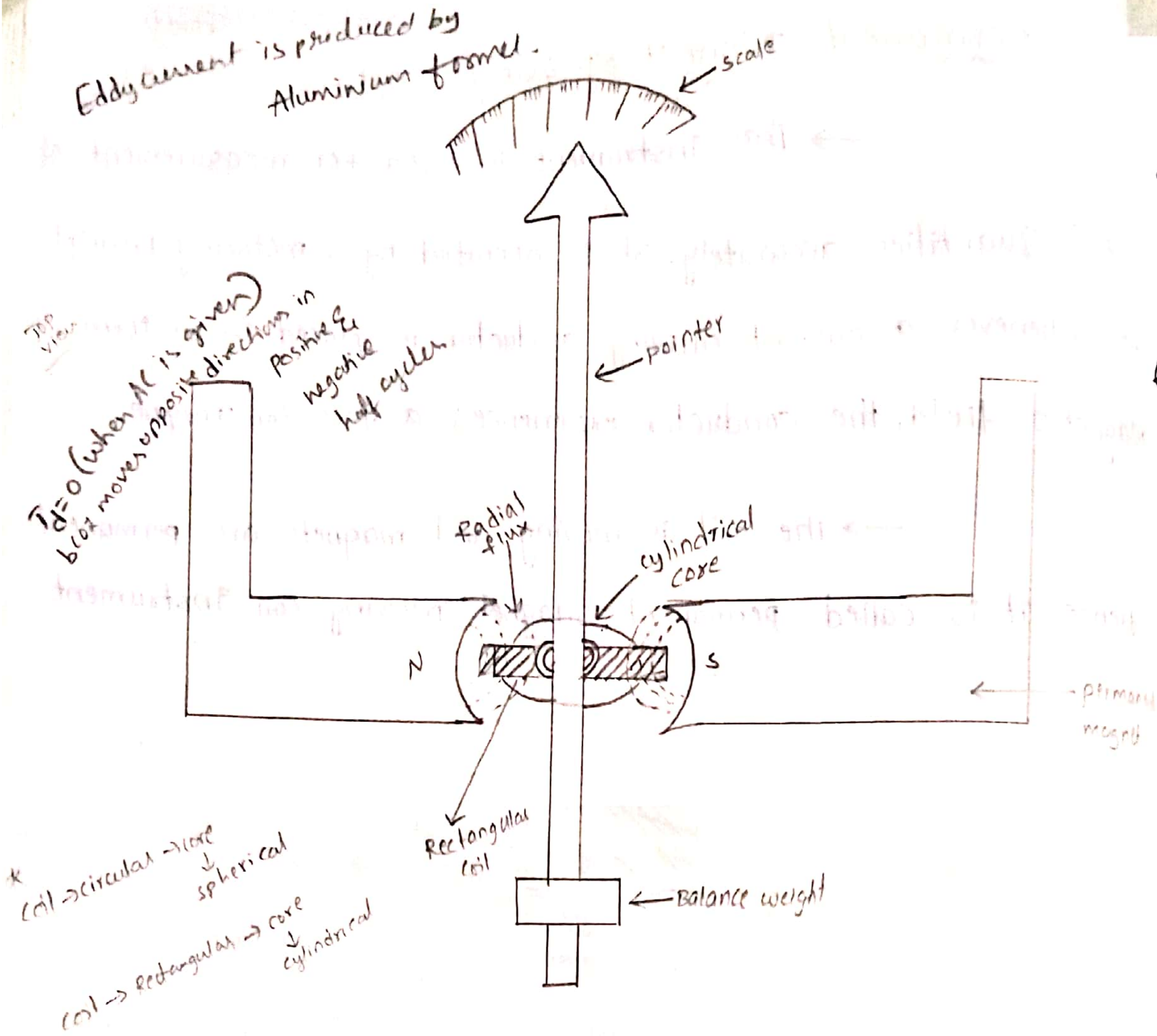
Permanent Magnet Moving coil :— [PMMC]

①

→ This instrument is used for measurement of DC quantities accurately. It is operated by a motoring principle. i.e., whenever a current carrying conductor is placed in uniform Magnetic field, the conductor experiences a force (or) Torque.

→ The coil is moving and magnets are permanent Hence it is called permanent Magnet Moving coil Instrument.





→ The deflecting torque is provided by Magnetic effect.

→ The controlling torque is provided by phosphorus bronze spring (s).

→ The Damping torque is provided by Eddy current damping.

→ If the coil is circular, core is spherical in shape.

→ If the coil is rectangular, core is cylindrical in shape.

for radial flux

Advantages:-

1. Scale is uniform
2. High accuracy
3. It consumes less power i.e., 25 μW to 200 μW
4. Torque to weight (T/w) ratio is ~~less~~ high, hence frictional errors are avoided.

Disadvantages:-

1. cost of instrument is high
2. Due to aging of springs, errors are produces
3. It is only suitable for measurement of DC quantities, not for AC.

Torque Equation:-

The deflecting torque

$$\boxed{T_d = NBAI} \quad N\text{-}m$$

where, T_d = Deflecting torque in N-m

N = Number of turns on a coil

B = Flux Density in wb/m^2 (or) Tesla

A = Area of cross-section of coil in m^2.

I = current through the coil in Amperes.

$$\boxed{T_d = G I} \longrightarrow (1)$$

G = NBA = constant [Displacement constant].

→ The controlling Torque

$$\boxed{T_c = K_s \theta} \longrightarrow (2)$$

where, K_s = spring constant in Nm/rad (or) Nm/Degree

$$K_s = \frac{Ebt^3}{12l}$$

→ At final steady position

$$T_d = T_c$$

$$G I = K_s \theta$$

$$\therefore \text{Deflection } (\theta) = \left[\frac{G}{K_s}\right] I$$

Here, $K = K_s$

$$\boxed{\therefore I \propto \theta} \longrightarrow \text{scale is uniform.}$$

① A PMMC has a coil of dimensions 10mm X 8mm. The flux density in the air gap is 0.15 wb/m². If the coil is wound for 100 turns carrying 5mA. calculate the deflecting Torque. calculate the deflection if the spring constant (K_s) is 0.2×10^{-6} Nm/degree.

$T_d = NBAI$

Sol: Given Data,

Area (A) = 10 mm X 8mm

$= 80 \text{ mm}^2$

$= 80 \times 10^{-6} \text{ m}^2$

Flux Density in the air gap (B) = 0.15 wb/m².

Number of turns (N) = 100

current (I) = 5 mA

$= 5 \times 10^{-3}$ A

Spring constant (K_s) = 0.2×10^{-6} Nm/degree.

Formula:-

→ Deflecting Torque is given by

$$T_d = NBAI$$

$$= 100 \times 0.15 \times 80 \times 10^{-6} \times 5 \times 10^{-3}$$

$$\boxed{T_d = 6 \times 10^{-6} \text{ N-m}}$$

→ Deflection $(\theta) = \left[\frac{G}{K}\right] I$

$$= \left[\frac{NBA}{K_s}\right] I$$

$$= \left[\frac{100 \times 0.15 \times 80 \times 10^{-6}}{0.2 \times 10^{-6}}\right] 5 \times 10^{-3}$$

$$\boxed{\theta = 30^\circ \Rightarrow 30 \text{ degrees}}$$

② The following data refers to a moving coil voltmeter.
DC

Resistance = 10,000 Ω ; Dimensions of a coil = 30 mm × 30 mm ;

No. of turns of coil = 100 ; Flux density in air gap = 0.08 wb/m² ;

Spring constant (K_s) = 3×10^{-6} Nm/degree. Find the deflection produced

for voltage of 200 volts.

$\theta = \frac{NBAI}{K_s}$ $V = IR$ $I = \frac{V}{R}$

Sol: Given Data,

$R = 10{,}000\ \Omega$

$A = 900 \times 10^{-6}\ m^2$

$N = 100$

$B = 0.08\ wb/m^2$

$K_s = 3 \times 10^{-6}$ Nm/degree

$V = 200$ V

$\therefore I = \frac{V}{R} = \frac{200}{10{,}000} = 0.02$ A

$T_d = NBAI$

$T_c = K_s\theta$

$NBAI = K_s\theta$

$I = \frac{V}{R} = \frac{200}{10{,}000}$

$100 \times 0.08 \times 30 \times 30 \times 10^{-6} \times \frac{200}{10000}$

$= 3 \times 10^{-6}$ Nm/deg $\times\ \theta$

→ $T_d = NBAI$

$= 100 \times 0.08 \times 900 \times 10^{-6} \times 0.02$

$\boxed{T_d = 144 \times 10^{-6}\ N\text{-}m}$

→ Deflection (θ) = $\left[\frac{G}{K_s}\right] I$

$= \frac{144 \times 10^{-6}}{3 \times 10^{-6}}$

$\boxed{\theta = 48\ \text{degrees.}}$

$T_d = NBAI$

$T_c = K_s\theta$

$NBAI = K_s\theta$

$\theta = \frac{NBAI}{K_s}$

③ The Deflecting torque (T_d) of an Ammeter varies as the square of the current passing through it. If a current of 5 Amps produces a deflection of 90 degrees, what will be the deflection for current of 10 Amps when the instrument (i) Spring controlled

(ii) Gravity controlled.

Sol: Given data,

1st condition: Current $(I) = 5$ Amps; Deflection $(\theta) = 90$ degrees

$$\boxed{T_d = K I^2} \quad N\text{-}m$$

(i) Spring control method:-

$T_d = K_1 I^2 \quad ; \quad T_c = K_2 \theta$

At equilibrium

$T_d = T_c$

$K_1 I^2 = K_2 \theta$

$K_1 (5)^2 = K_2 (90^\circ)$

$$\boxed{\frac{K_1}{K_2} = 3.6 = K}$$

$T_d = I^2$

→ $T_d = K_1 I^2 \quad ; \quad T_c = K_2 \theta$

$= 3.6 \times (10)^2$

$\cancel{T_d = 360\ N\text{-}}$

At equilibrium

$K_1 I^2 = K_2 \theta$

$K_1 (10)^2 = K_2 (\theta)$

$\theta = 3.6 \times 100$

$$\boxed{\theta = 360^\circ}$$

(ii) Gravity control method:-

$$T_d = KI^2 \; ; \; T_c = w \sin\theta \times l$$

$$T_c = K_g \sin\theta$$

At equilibrium,

$$KI^2 = K_g \sin\theta$$

$$\frac{K}{K_g} I^2 = \sin\theta$$

$$\sin\theta = 3.6 \times (10)^2$$

$$= \text{Math error}$$

In this control, if 10Amp of current is applied, the measurement is not possible.

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Errors in PMMC Instrument:—

The following are the sources of errors

1. Frictional errors
2. Temperature errors
3. Aging of Magnet & control springs.

⟶ The frictional errors are caused due to improper bearings. To avoid the frictional errors, T/w ratio must be high.

⟹ when the instrument is under operating condition, it causes/produces heat to avoid temperature errors. Large series resistance with low temperature co-effecient is used for voltmeters. /shunt resistance for Ammeters.

⟹ Aging of permanent magnet and control springs causes the errors. of magnet is weak. it produces less deflection. (because less flux)

If the control spring is weaken, it produce large deflection. To reduce these errors, proper material is used during manufacturing.

Moving Iron Instruments :—

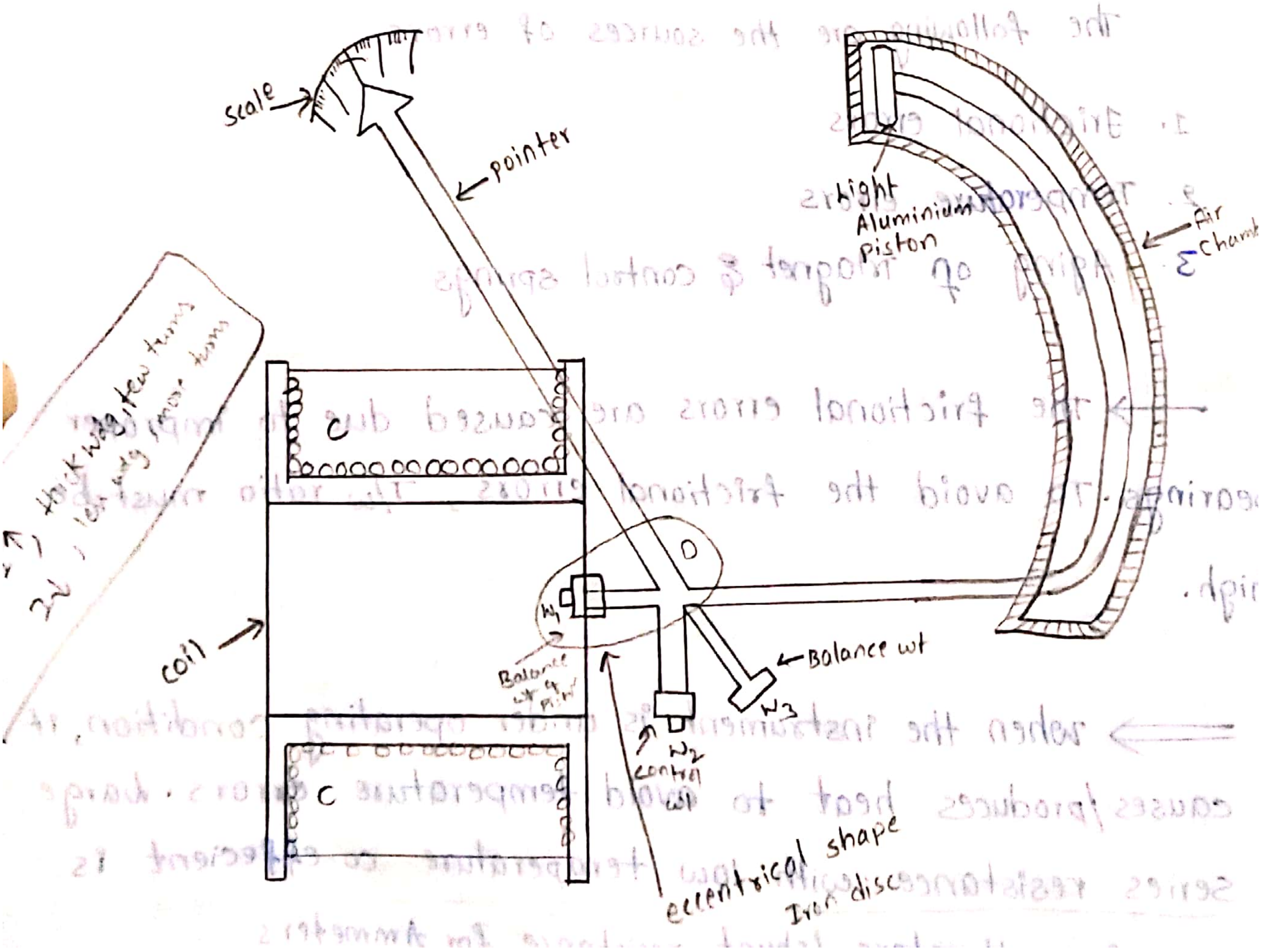
→ Based on the working principle, these are classified as two types.

for DC, performance is less.

(3) (i) Moving Iron attraction type.

(4) (ii) Moving Iron repulsion type.

(i)



→ It works based on force of attraction principle i.e., whenever a iron piece is bought nearer to the magnet, it attracts.

→ The deflecting torque is produced by force of attraction.

→ The controlling torque is produced by either spring control (or) Gravity control method.

→ The Damping torque is provided by Air friction Damping

→ It is used for AC quantities.

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⊛ Torque Equation of MI Instruments:-

Consider small increment current supplied to a coil of the instrument. Due to this current, the deflection is "$d\theta$" and the deflecting torque is "T_d". Hence, the mechanical work done

$$\therefore \text{Mechanical workdone} = T_d \cdot d\theta \longrightarrow (1)$$

Work = Force × distance
MWD = $T_d \cdot d\theta$

let "I" is initial current, "θ" is deflection, "L" is Induction (Inductance) of coil.

EE = stored Energy + Mechanical Work
↓
Electro magnetic [Inductance]

dI = change in current

$d\theta$ = change in deflection

dL = change in Inductance.

Due to the change of voltage, the current increases.

$$\rightarrow e = \frac{d}{dt}[LI] \rightarrow \text{voltage eq}^n \text{ of coil}$$

$$e = L\frac{dI}{dt} + I\frac{dL}{dt} \longrightarrow (2)$$

→ Electrical Energy input

$$e\,i\,dt = \left[L\frac{dI}{dt} + I\frac{dL}{dt}\right] I\,dt$$

$$\text{Ele input} = LI\,dI + I^2 dL \longrightarrow (3)$$

→ The Energy stored in a coil is $\frac{1}{2}LI^2$ increases to

$$\frac{1}{2}(L+dL)(I+dI)^2$$

→ change in stored Energy

$$\Rightarrow \frac{1}{2}[L+dL][I+dI]^2 - \frac{1}{2}LI^2$$

$$= \frac{1}{2}[L+dL][I^2 + 2I\,dI + dI^2] - \frac{1}{2}LI^2$$

$$= \frac{1}{2}\cancel{LI^2} + LI\,dI + \frac{1}{2}\cancel{L\,dI^2} + \frac{1}{2}I^2 dL + I\,dI\,dL + \frac{1}{2}dL\,dI^2$$

$$- \cancel{\frac{1}{2}LI^2}$$

→ Neglecting higher order terms

$$= LI\,dI + \frac{1}{2}I^2 dL \longrightarrow (4)$$

$\therefore$ Electrical Energy input = change in stored Energy + Mechanical work done

$$LI\cancel{dI} + I^2 dL = LI\cancel{dI} + \frac{1}{2}I^2 dL + T_d \cdot d\theta$$

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

$$\boxed{\therefore T_d = \frac{1}{2}I^2\frac{dL}{d\theta}} \longrightarrow (5)$$

→ controlling Torque $T_c = K\theta$ → (6)

→ At equilibrium condition, $T_d = T_c$

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

$$\boxed{\therefore \text{Deflection } (\theta) = \frac{1}{2}\frac{I^2}{K}\frac{dL}{d\theta}}$$

scale non-uniform.

Q: The Inductance of a moving Iron instrument is given by $L = (12 + 6\theta - \theta^2)\mu H$, where "$\theta$" is deflection in radians from zero position. The spring constant is 12×10^{-6} Nm/radians. Calculate the deflection for a current of 8 Amps.

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

Sol: Given Data,

$$L = [12 + 6\theta - \theta^2]\mu H$$

$$K = 12 \times 10^{-6} \text{ Nm/radians}$$

$$\therefore \text{Deflection } (\theta) = \frac{1}{2}\frac{I^2}{K}\frac{dL}{d\theta}$$

$$= \frac{1}{2} \times \frac{(8)^2}{12 \times 10^{-6}} \times \frac{d(12 + 6\theta - \theta^2)\mu}{d\theta}$$

$$= \frac{1}{2} \times \frac{64}{12 \times \cancel{10^{-6}}} \times (6 - 2\theta)\cancel{\mu}$$

$$= 2.666[6 - 2\theta]$$

$$\theta = 16 - 5.332\theta$$

$$\theta = \frac{16}{6.332}$$

$$\therefore \theta = 2.526 \text{ radians}$$

$$\boxed{1 \text{ rad} = \frac{180}{\pi} \text{ de}}$$

$$2.526 \times \frac{180}{\pi}$$

$$= 144.72 \text{ degrees}$$

2. The Inductance of a moving iron instrument is given by $L = [10 + 5\theta - \theta^2]\,\mu H$. where "$\theta$" is the deflection in radians from zero position. the spring constant is 12×10^{-6} Nm/radians. Estimate the deflection for a current of 5Amps.

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

Sol: Given Data,

$L = [10 + 5\theta - \theta^2]\,\mu H$

$K = 12 \times 10^{-6}$ Nm/rad

$I = 5\,A$

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

$\theta = \frac{1}{2}\left(\frac{25}{12 \times 10^{-6}}\right)(5 - 2\theta)$

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

$$\theta = \frac{1}{2} \times \frac{(5)^2}{12 \times 10^{-6}} \cdot [5 - 2\theta]\,\mu$$

$$\theta = 1.0416\,[5 - 2\theta]$$

$$\theta + 2.0832\theta = 5.208$$

$$\therefore \theta = 1.689 \text{ radians.}$$

In degrees $\left(\frac{\pi}{180}\right)$ → not exact. $\frac{180}{\pi}$

$\cancel{\theta = 0.029}$

(ii) Moving Iron Repulsion type Instruments :-

These are classified as two types.

(i) Radial Vane type

(ii) Co-axial Vane type (or) Concentric Vane type.

(i) Radial Vane type MI Instrument :-

⟶ It consists of two Vanes [fixed & Movable].

Fixed vane is attached to coil & movable vane is attached to spindle.

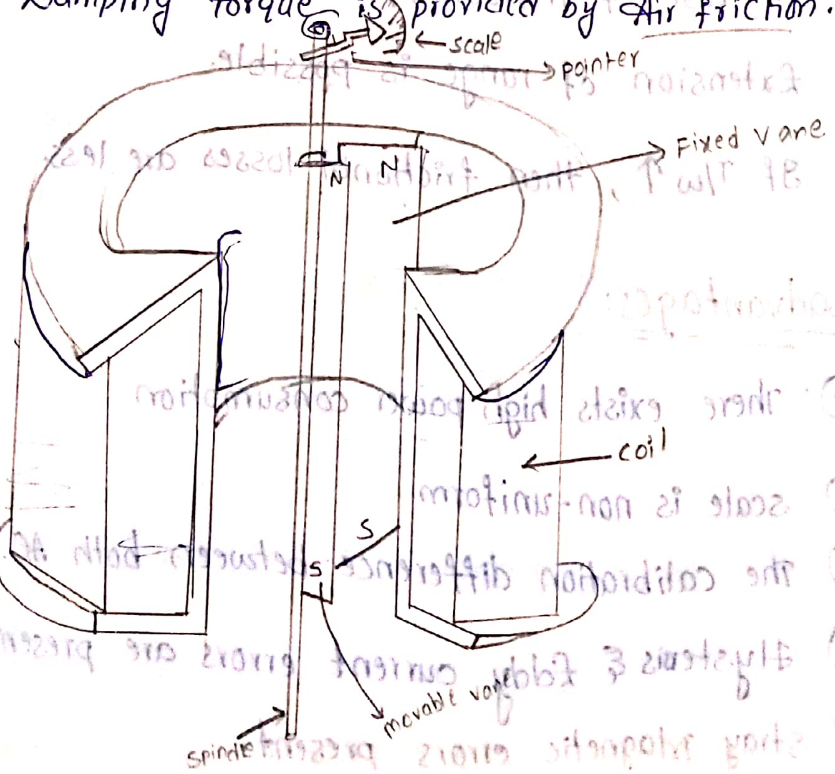
⟶ When the supply is given to the instrument on both the vanes same magnetic poles are created. Hence, the repulsive force is produced in between two vanes.

⟶ The movable vane rotates, attached spindle rotates and the pointer deflects on the scale.

⟶ Deflecting torque (T_d) is produced by Repulsive force.

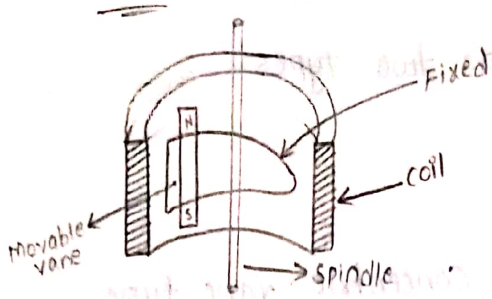
⟶ Controlling torque (T_c) is provided by spring control./gravity

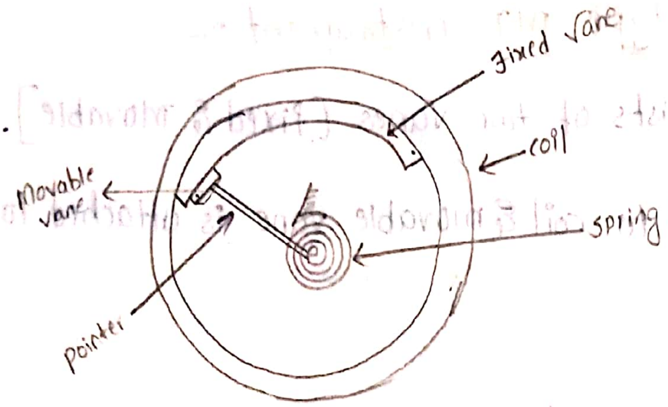
⟶ Damping torque is provided by Air friction.



(ii) Co-axial vane type (or) concentric:

T equation, "θ" is same as Attraction for Repulsive type





Same operation as radial type. Attraction type equation are same.

Advantages:-

① It is used for measurement of both AC & DC quantities.

② Its construction is rigid & reliable.

③ The cost of instrument is less.

④ Extension of range is possible.

⑤ If T/w ↑, then frictional losses are less.

Disadvantages:

① There exists high power consumption

② scale is non-uniform

③ The calibration difference between both AC & DC quantities.

④ Hysteresis & Eddy current errors are present.

⑤ stray Magnetic errors present.

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Errors in Moving Iron Instruments:-

The following are the sources of Errors

1. Temperature Error
2. Square stray Magnetic field Error
3. Hysteresis Error
4. Eddy current Error
5. Frequency Error.

1. When the instrument is under working condition, heat will be produces. This heat raises the temperature. To avoid these ~~temp~~errors, coil is connected with resistance of low temperature coeffecient.

Stray Magnetic field Error

2. Outside flux effects the useful flux. So the deflecting torque reduces which causes errors. To avoid this, instrument is provided with shielding (or) casing.

3. Hysterisis error:-

When the instrument is supplied with AC supply it undergoes magnetization and Demagnetization. It is called Hysterisis effect. For quick Demagnetization small iron pieces are attached to coil.

4. Eddy current Error:-

These depends on the frequency error.

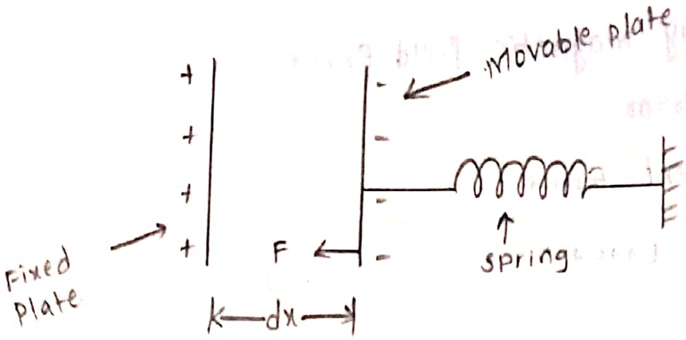
5. Frequency Error:-

→ When the frequency changes, $[X_L = 2\pi f L]$; reactance changes, current decreases, Deflecting torque (T_d) decreases, ∴ Error ...

avoid this maintain constant frequency.

Electrostatic Voltmeter → for measuring high voltage.

It is used only for voltages



→ It consists of two charged plates. one is fixed and the other one is movable plate. It works based on Electrostatic effect.. i.e., whenever two charged plates are brought nearer there exists force of attraction between them. To provide controlling torque, spring control method is used, Damping torque is provided by Air friction Damping.

→ Mechanical workdone $= F \times dx$ ⟶ ①

Let C = capacitance
V = voltage
θ = Deflection
dC = change in capacitance
dV = change in voltage
$d\theta$ = change in Deflection

→ change in current $i = \frac{dq}{dt} = \frac{d}{dt}[CV]$

$\therefore i = C\frac{dV}{dt} + V\frac{dC}{dt}$ ⟶ ②

→ Electrical Energy input = $vi\,dt$.

$$= v\left[c\frac{dv}{dt} + v\frac{dc}{dt}\right]dt$$

∴ Electrical Energy input = $cv\,dv + v^2 dc$ ⟶ (3)

→ Energy stored in a capacitor $= \frac{1}{2}cv^2$ which is increases to $\frac{1}{2}(c+dc)(v+dv)^2$

→ change in stored Energy $= \frac{1}{2}(c+dc)(v+dv)^2 - \frac{1}{2}cv^2$

$$= \frac{1}{2}(c+dc)(v^2+2v\,dv+(dv)^2) - \frac{1}{2}cv^2$$

$$= \cancel{\frac{1}{2}cv^2} + cv\,dv + \underbrace{\frac{1}{2}c\,dv^2}_{\text{Negle}} + \frac{1}{2}v^2dc + \underbrace{v\,dv\,dc}_{\text{Neglect}}$$

$$+ \underbrace{\frac{1}{2}dc(dv)^2}_{\text{Neglect}} - \cancel{\frac{1}{2}cv^2}$$

change in stored Energy $= cv\,dv + \cancel{v\,dv\,dc}\ \frac{1}{2}v^2dc$ ⟶ (4)

∴ Electrical Energy input = change in stored Energy + Mechanical work done

$$c\cancel{v}dv + v^2 = \frac{1}{2}v^2dc + c\cancel{v}dv + F_x\,dx$$

$$\frac{1}{2}v^2dc = F_x\,dx$$

The linear motion is converted into a circular (or) Rotational

Hence, $F \longrightarrow T_d$; $dx \longrightarrow d\theta$

$$\therefore \frac{1}{2}v^2dc = T_d\,d\theta$$

Deflecting torque $= \therefore T_d = \frac{1}{2}v^2\frac{dc}{d\theta}$ ⟶ (5)

$\rightarrow$ controlling torque $(T_c) = K\theta \rightarrow (6)$

At equilibrium, $T_d = T_c$

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

$$\boxed{\therefore \text{Deflection}(\theta) = \frac{1}{2} \frac{V^2}{K} \frac{dC}{d\theta}}$$

30/11/19

1. An electrostatic voltmeter reading upto 2000 volts. It is controlled by a spring with a constant of 5×10^{-6} Nm/radians. has a full ~~thou~~ scale deflection 90 degree. The capacitance at zero voltage is 15PF. what is capacitance when pointer indicates 2000 volts.

Sol: Given Data,

voltage = 2000 volts

$K_s = 5\times10^{-6}$ Nm/radians

θ = 90 degree

C = 15 PF

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

$\boxed{\pi r = 180^\circ}$

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

$$\frac{dC}{d\theta} = \frac{2\times5\times10^{-6}}{(2000)^2} \times \frac{\pi}{2} \text{ (}\theta\text{ in radian)}$$

$$\frac{dC}{d\theta} = 3.926 \text{ PF/radians}$$

To get only in "PF" without radians.

$\downarrow$
C

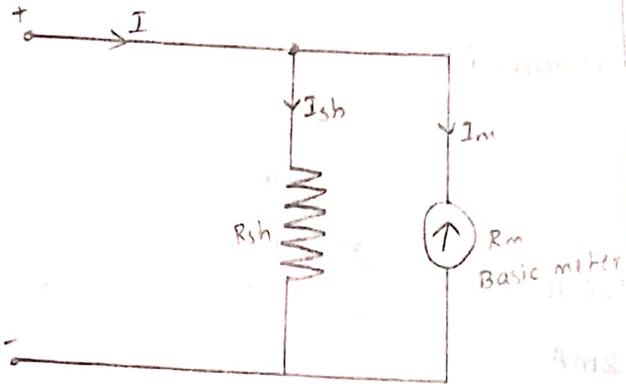
capacitance (C) $\rightarrow$ 0 - 2000V $\Rightarrow 3.926 \times \frac{\pi}{2}$ PF

$= 6.16$ PF

At 2000 V, C = 15 + 6.16 = 21.16 PF.

Basic D.C Ammeter :-

for small winding, less current flows.
for large currents, high amount of current should be by passed i.e., shunt resistance.



→ Let I_m = full scale deflection current

R_m = Internal resistance of coil/meter.

R_{sh} = shunt resistance

I = Total current

I_{sh} = shunt current

→ voltage across both resistances must be same.

$$R_{sh} I_{sh} = I_m R_m$$

$$\therefore R_{sh} = \frac{I_m R_m}{I_{sh}} \longrightarrow (1)$$

from diagram, $I = I_{sh} + I_m$

$$\therefore I_{sh} = I - I_m \longrightarrow (2)$$

(2) in (1)

$$R_{sh} = \frac{I_m R_m}{(I - I_m)} \; ; \quad \boxed{m = \frac{I}{I_m}}$$

$$\boxed{\therefore R_{sh} = \frac{R_m}{m-1}}$$

Note: To increase the range of Ammeter "m" times, shunt required is "$\frac{1}{(m-1)}$" times the meter resistance.

① A 2mA meter with an internal resistance of 100 ohms is to be converted 0 to 150mA Ammeter. Calculate the value of shunt resistance required.

$R_{sh} = \frac{R_m}{m-1}$ $m = \frac{I}{I_m}$

Sol: Given Data,

$R_m = 100\,\Omega$

$I_m = 2mA$

$I = 150mA$

$R_{sh} = ?$

$\therefore R_{sh} = \frac{I_m R_m}{I_{sh}}$

$I_{sh} = I - I_m = 148\,mA$

$R_{sh} = \frac{2\times10^{-3} \times 100}{148\times10^{-3}}$

$\therefore R_{sh} = 1.35\,\Omega$

$I_m R_m = I_{sh} R_{sh}$

$R_{sh} = \frac{I_m R_m}{I_{sh}}$

$R_{sh} = \frac{2\times10^{-3}\times100}{(150-2)}$

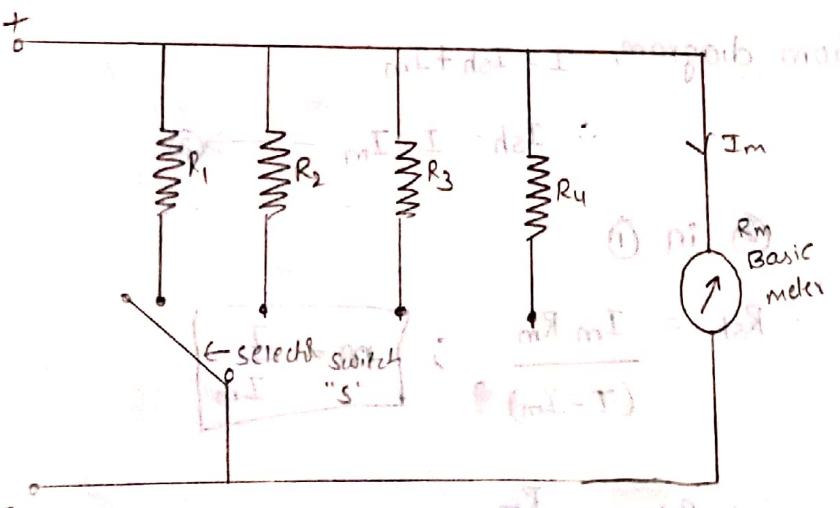
$m = \frac{150}{2} = 75$

$R_{sh} = \frac{100}{75-1} = \frac{100}{74}$

$\boxed{R_{sh} = 1.35\,\Omega}$

Multi Range Ammeter:-

Make before break type switch is used



→ To consider accurate measurement, the working of each element is required. In selector switch, the operation of "S" on any resistance is done, by closing the Resistance on which switch is existing. So, that every element is calculated which is not present in normal switching.

→ where R_1, R_2, R_3, R_4 are shunt resistances corresponding currents are I_1, I_2, I_3, I_4 respectively

$$R_1 = \frac{R_m}{m_1 - 1} \quad ; \quad m_1 = \frac{I_1}{I_m}$$

$$R_2 = \frac{R_m}{m_2 - 1} \quad ; \quad m_2 = \frac{I_2}{I_m}$$

$$R_3 = \frac{R_m}{m_3 - 1} \quad ; \quad m_3 = \frac{I_3}{I_m}$$

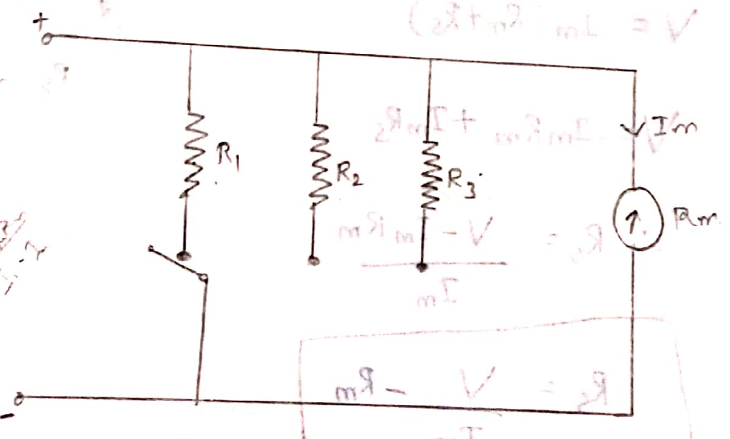
$$R_4 = \frac{R_m}{m_4 - 1} \quad ; \quad m_4 = \frac{I_4}{I_m}$$

2/12/19

Design a multirange DC milli Ammeter with a basic meter having a resistance of 75 ohms and full scale deflection for the current of 2mA. The required ranges are (0 to 10mA), (0-50mA) and (0-100mA).

$R_m = 75\Omega$, $I_m = 2mA$

Sol:



Given data,

$R_m = 75\,\Omega$

$I_m = 2mA$

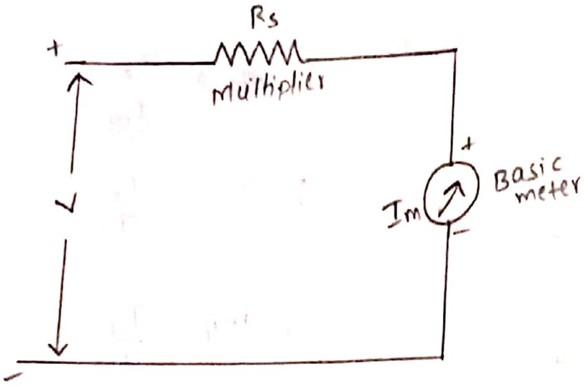
$$R_{sh} = \frac{I_m R_m}{I_{sh}} = \frac{I_m R_m}{I_1 - I_m} = \frac{R_m}{m_1 - 1} \quad ; \quad m = \frac{I_1}{I_m}$$

$$\rightarrow R_1 = \frac{I_m R_m}{I_1 - I_m} = \frac{2\times10^{-3}\times 75}{(10-2)\times10^{-3}} = 18.75\ \Omega$$

$$\rightarrow R_2 = \frac{I_m R_m}{I_2 - I_m} = \frac{2\times10^{-3}\times 75}{(50-2)\times10^{-3}} = 3.125\,\Omega$$

$\rightarrow R_3 = \dfrac{I_m R_m}{I_3 - I_m} = \dfrac{2\times10^{-3}\times 75}{(100-2)\times10^{-3}} = 1.530\,\Omega$

Basic DC voltmeter :-



$\rightarrow$ It consists of a series resistance called Multiplier. and internal resistance of voltmeter is "R_m"

Let R_s = Multimeter Multiplier

R_m = Meter Resistance

I_m = Full scale Deflection current

V = Voltage to be measured.

$$V = I_m(R_m + R_s)$$

$$V = I_m(R_m+R_s)$$

$$R_s = \frac{V}{I_m} - R_m$$

$$V = I_m R_m + I_m R_s$$

$$\therefore R_s = \frac{V - I_m R_m}{I_m}$$

$$\boxed{R_s = \frac{V}{I_m} - R_m}$$

$\rightarrow$ m = multiplying power = $\dfrac{\text{voltage to be measured}}{\text{Voltage drop across coil}} = \dfrac{V}{v}$

$$m = \frac{I_m R_m + I_m R_s}{I_m R_m}$$

$$m = 1 + \frac{R_s}{R_m}$$

$$\boxed{\therefore R_s = (m-1) R_m}$$

Q. A moving coil instrument gives a full scale deflection for a current of 20 mA with a potential difference of 200 mV across it. Calculate (i) shunt required to use it as an Ammeter to get a range of of (0-200) A.

(ii) Multiplier required to use it as an voltmeter of range (0-500) V.

$I_m = 20mA$

$V_m = 200 mV$

$V_m = I_m R_m$

$R_m = \frac{V_m}{I_m} = \frac{200\times10^{-3}}{20\times10^{-3}} = 10$

Sol: Given data,

$I_m = 20mA \quad ; I = 200$

$V_m = 200mV = I_m R_m$

$$\therefore R_m = \frac{\cancel{200}^{10} \times 10^{-3}}{\cancel{20}\times10^{-3}}$$

$$\boxed{\therefore R_m = 10\Omega}$$

$R_{sh} = \frac{I_m R_m}{I_{sh}} = \frac{I_m R_m}{I - I_m}$

$= \frac{20\times10^{-3}\times10}{(200-20)10^{-3}}$

$= 1 \times \Omega$

$V = I_m R_s + I_m R_m$

$R_s = \frac{V}{I_m} - R_m$

$R_s = \frac{500}{20\times10^{-3}} - 10$

$= 24990\Omega$

$= 24.990 k\Omega$

(i) $R_{sh} = \frac{I_m R_m}{I - I_m} = \frac{20\times10^{-3}\times10}{(200-20)\times10^{-3}} = \cancel{1.111}\Omega$

$= 1.000\times10^{-3}\Omega$

$= 1m\Omega$

(ii) $R_s = \frac{V}{I_m} - R_m = \frac{500}{20\times10^{-3}} - 10 = 24,990\Omega$

$= 24.990 k\Omega$

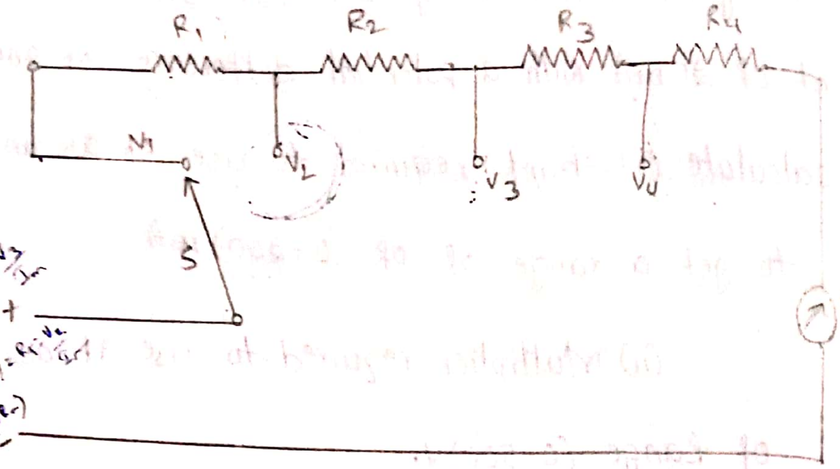
$V = I_m R_s + I_m R_m$

$\frac{V}{I_m} - R_m = R_s$

V = voltage to be measured

v = voltage across coil

Multi Range Voltmeter :-



$R_T = \frac{V_4}{I_m}$ $\therefore R_4 = R_T - R_m$ $R_T = \frac{V_3}{I_m}$ $R_3 = R_T - (R_m + R_4)$ $R_2 = R_T - (R_m + R_3 + R_4)$ $R_1 = R_T - (R_2 + R_3 + R_4 + R_m)$

→ It consists of R_1, R_2, R_3 and R_4 are the multipliers connected in series.

→ The voltages V_1, V_2, V_3 & V_4 are the voltages corresponding to multipliers.

→ 4th position of "S" :-

$$R_T = \frac{V_4}{I_m}$$

$$\therefore R_4 = R_T - R_m$$

$R_T = \frac{V_4}{I_m}$ $R_T = \frac{V_4}{I_m}$ $R_4 = R_T - R_m$ $R_{T_4} = R_T - R_m$ $R_T = \frac{V_4}{I_m}$ $R_3 = R_T - (R_4 + R_m)$ $R_T = \frac{V_3}{I_m}$

→ 3rd position of "S" :-

$$R_T = \frac{V_3}{I_m}$$

$$\therefore R_3 = R_T - (R_m + R_4)$$

$R_T = \frac{V_3}{I_m}$ $\therefore R_3 = R_T - (R_m + R_4)$

$R_T = \frac{V_2}{I_m}$ $\therefore R_2 = R_T - (R_3 + R_4 + R_m)$

→ 2nd position of "S" :

$$R_T = \frac{V_2}{I_m}$$

$$\therefore R_2 = R_T - (R_m + R_4 + R_3)$$

$R_T = \frac{V_1}{I_m}$ $\therefore R_1 = R_T - (R_2 + R_3 + R$

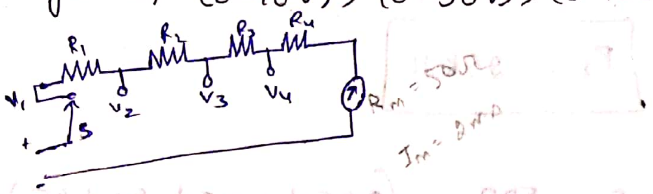
→ 1st position of "S" :

$$R_T = \frac{V_1}{I_m} \quad \therefore R_1 = R_T - (R_m + R_4 + R_3 + R_2)$$

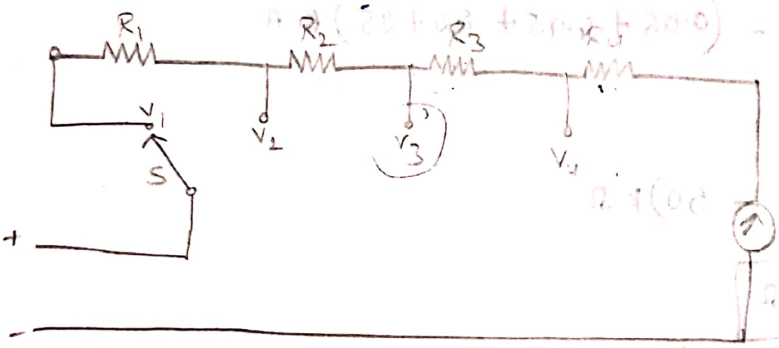
PMMC

Q: The basic D'Arsonval Galvanometer with an internal resistance of 50Ω & full scale deflection current of 2mA is used as a multirange voltmeter. Design a series string of multipliers to obtain the voltage ranges of (0-10V); (0-50V); (0-100V) & (0-500)V.

$R_m = 50\Omega$
$I_m = 2mA$



Sol:



$R_4 = R_T - R_m$

$R_T = \frac{V_4}{I_m}$

$R_3 = R_T - (R_m + R_4)$

$R_T = \frac{V_3}{I_m}$

Given Data,

As $V = IR$

$V \uparrow ; R \uparrow$

$\therefore V_1 = (0-500)V$

$V_2 = (0-100)V$

$V_3 = (0-50)V$

$V_4 = (0-10)V$

⟶ Internal Resistance $(R_m) = 50\Omega = 0.05 K\Omega$

⟶ Fullscale deflection current $(I_m) = 2mA$

⟶ 4th position of S:

$$R_T = \frac{V_4}{I_m} = \frac{\cancel{500}}{2\times10^{-3}} = 250\times10^3\ \Omega$$

$$= 5K\Omega$$

$R_4 = R_T - R_m$

$R_T = \frac{V_4}{I_m} = \frac{10}{2\times10^{-3}}$

$$\therefore R_4 = R_T - R_m$$

$$= 250\times10^3 - 50 \Rightarrow [5 - 0.05] K\Omega$$

$$\boxed{R_4 = 4.95K\Omega}$$

⟶ 3rd position:

$R_3 = R_T - (R_4 + R_m)$

$R_T = \frac{V_3}{I_m} = \frac{50}{2\times10^{-3}}$

$$R_3 = R_T - (R_m + R_4)$$

$$= \frac{50}{2\times10^{-3}} - [0.05 + 4.95]1000$$

$$= 25K\Omega - 5K\Omega$$

$$\boxed{R_3 = 20K\Omega}$$

$\rightarrow R_2 = \frac{100}{2\times10^{-3}} - (0.05 + 4.95 + 20)\,1000$

$= 50\,K\Omega - (25)\,K\Omega$

$\boxed{R_2 = 25\,K\Omega}$

$\rightarrow R_1 = \frac{500}{2\times10^{-3}} - (0.05 + 4.95 + 20 + 25)\,K\Omega$

$= (250 - 50)\,K\Omega$

$\boxed{\therefore R_1 = 200\,K\Omega}$

$I_m = 10\,mA$

A moving coil instrument gives full scale deflection of 10 mA, when potential difference across it terminal is 100 mV; calculate

$V_m = 100mV \quad \frac{V_m}{I_m} = R_m = 10\,\Omega$

(i) Shunt resistance for a full scale deflection corresponding to 100A.

$R_{sh} = ? \quad I = 100A \quad R_{sh} =$

$I_m R_m = I_{sh} R_{sh}$

$R_{sh} = \frac{I_m R_m}{I_{sh}} = \frac{I_m R_m}{I - I_m} = \frac{10 \times 10}{100}$

(ii) The series resistance for a full scale reading of 1000V.

$R_m =$

$V = I_m R_m + I_m R_s$

(iii) The power Dissipation in each case.

$R_{sh} = \frac{1}{m-1} R_m \quad R_s = \frac{V}{I_m} - R_m$

$R_s = (m-1) R_m$

$I_m = 10mA$

$V_m = 100mV$

$= \frac{I_m R_m}{I - I_m} \quad = \frac{1000}{10\times10^{-3}} - 10$

Sol: Given Data,

$I_m = 10\,mA$

$V = I_m R_m + I_m R_s$

$R_s = \frac{V}{I_m} - R_m$

$I_m R_m = 100\times10^{-3}$

$R_m = 10\,\Omega$

$V = I_m R_m = 100\,mV \quad \Rightarrow \frac{100\times10^{-3}}{10\times10^{-3}} = R_m$

$\boxed{\therefore R_m = 10\,\Omega}$

(i) $R_{sh} = \frac{I_m R_m}{I - I_m}$

$= \frac{10\times10^{-3} \times 10}{100 - 0.01} = 1.0001\times10^{-3}$

$R_{sh} = 1\,m\Omega \quad \Rightarrow 1.0001\times10^{-3}\,\Omega$

(ii) $R_s = \dfrac{V}{I_m} - R_m$

$= \dfrac{1000}{10\times10^{-3}} - 10$

$$\boxed{R_s = 99{,}990\,\Omega}$$

(iii) power Dissapation (i) $= I^2 R_{sh}$

$= (100)^2 \times 1.0001\times10^{-3}$

$$\boxed{P = 10.001\,W}$$

(ii) $P = I^2 R_s$ (or) $\dfrac{V^2}{R_s}$

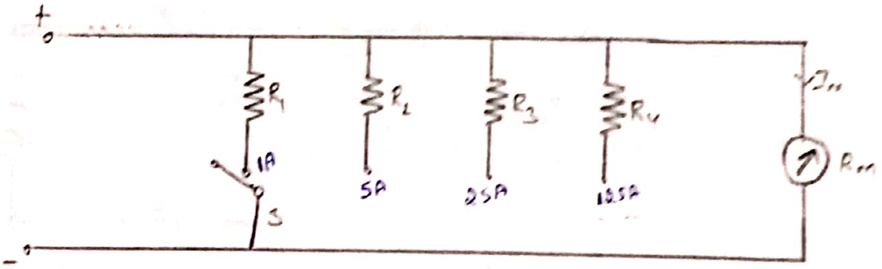
$= (100)^2 - (99990)$

$$\boxed{P = 10.001\,W}$$

Design a multirange ammeter with ranges of 1A, 5A, 25A & 125A. A D'Arsnual Galvanometer with internal resistance of 730Ω & full scale current of 5mA.

$R_m = 730\,\Omega$
$I_m = 5\,mA$

Sol:



when 'S' is at R_1 all resistances are considered which has high ~~current~~ resistance so, less current flows i.e., 1A

$\rightarrow R_1 = \dfrac{R_m}{m_1 - 1}$

$m_1 = \dfrac{I_1}{I_m} = \dfrac{1}{5\times10^{-3}} = 200$

$\therefore R_1 = \dfrac{730}{200-1} = 3.668\,\Omega$

$\rightarrow R_2 = \dfrac{R_m}{m_2 - 1}$

$m_2 = \dfrac{I_2}{I_m} = \dfrac{5}{5\times10^{-3}} = 1000$

$$\rightarrow R_2 = \frac{730}{1000-1} = 0.7307\,\Omega$$

$$\rightarrow R_3 = \frac{R_m}{m_3-1} \quad ; \quad m_3 = \frac{I_3}{I_m} = \frac{25}{5\times10^{-3}} = 5000$$

$$\therefore R_3 = \frac{730}{5000-1} = 0.1460\,\Omega$$

$$\rightarrow R_4 = \frac{R_m}{m_4-1} \quad ; \quad m_4 = \frac{I_4}{I_m} = \frac{125}{5\times10^{-3}} = 25,000$$

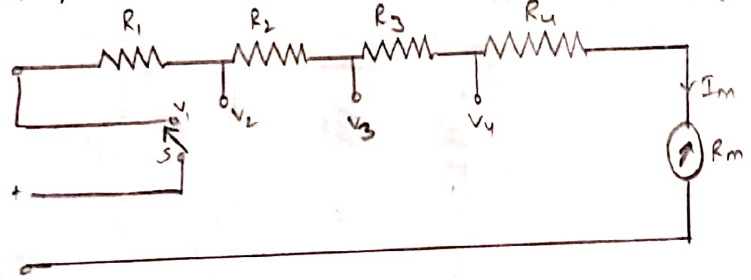
$$\therefore R_4 = 0.0292\,\Omega$$

A Basic D'Arsunnal Galvanometer with full scale reading of $50\mu A$ and an internal resistance of 1800Ω. It is to be converted into $(0-1)V$, $(0-5)V$, $(0-25)V$; $(0-125)V$. Multirange voltmeter using individual multipliers. calculate the values of individual multipliers.

$V = IR$

For high resistance, it gives high voltages

Sol:



→ 4^{th} position of "S"

$$R_4 = R_T - R_m \qquad \left[\because R_T = \frac{V_4}{I_m} = \frac{1}{50\times10^{-6}}\right]$$

$$= 20,000 - 1800$$

$$= 18,200\,\Omega$$

→ 3^{rd} position of "S":-

$$R_3 = R_T - (R_m + R_4) \qquad \left[\because R_T = \frac{V_3}{I_m} = \frac{5}{50\times10^{-6}} = 100000\right]$$

$$= 100000 - (1800 + 18,200)$$

$R_3 : 80,000\,\Omega$

→ 2nd position of "S"

$R_2 = R_T - (R_m + R_3 + R_4)$ $\left[\because R_T = \frac{V_2}{I_m} = \frac{25}{50\times10^{-6}} = 5\times10^5\right]$

$= 500000 - (1800 + 18,200 + 80,000)$

$R_2 = 4,00,000\,\Omega$

→ 1st position of "S":

$R_1 = R_T - (R_m + R_3 + R_4 + R_2)$ $\left[\because R_T = \frac{V_1}{I_m} = \frac{125}{50\times10^{-6}} = 25\times10^5\right]$

$= 25\times10^5 - 5\times10^5$

$= 20\times10^5$

$R_1 = 2\,M\Omega$

precautions to be taken for an "Ammeter":-

→ polarities must be observed correctly. otherwise, it leads to negative mechanical work, which damages the instrument.

→ Ammeter consists low resistance, hence it must be connected in series with the load circuit

→ While using multirange Ammeters, highest range is measured and going on low values are measure.

3/12/19 precautions to be taken for "voltmeter": —

→ As the resistance of voltmeter is high, it must connected across (or) parallel to circuit.

→ polarities must be observed correctly.

→ In Multirange voltmeter, first take highest voltage range and then lowest.

Requirements of shunt & Multiplier:-

→ shunt & Multiplier must be low temperature coeffecienct.
Temp ↑, doesn't show any effect on instrument

→ Either Manganine (or) constantan are used while designing.

→ while soldering, it doesn't produce any thermal effect emf's

Sensitivity :— [S]

$S = \frac{R_T}{V}$ It is defined as the ratio of total resistance to the voltage range. remains same.

(or) reciprocal of full scale deflection current.

$\boxed{S = \frac{1}{I_m}}$

$$\text{Sensitivity (S)} = \frac{1}{I_m} \ \Omega/V \ \text{(or)}\ k\Omega/V \qquad \text{(or)}\ S = \frac{R_T}{V}$$

$S = \frac{1}{I_m}$

$R_T = \frac{V}{I_m}$

$I_m = \frac{V}{R_T}$

$\frac{1}{I_m} = \frac{R_T}{V}$

example:- R_1, R_2, R_3, R_4 are multipliers ; V_1, V_2, V_3, V_4 are corresponding voltages, the multipliers interms of senstivity is

$$R_4 = SV_4 - R_m \qquad \left[\because S = \frac{1}{I_m}\right]$$

$$R_3 = SV_3 - (R_m + R_4)$$

$$R_2 = SV_2 - (R_m + R_4 + R_3)$$

$$R_1 = SV_1 - (R_m + R_4 + R_3 + R_2)$$

$R_4 = R_T - R_m$

$R_T = \frac{V_4}{I_m}$

$\therefore R_4 = SV_4 - R_m$

$R_4 = R_T - R_m$

$= \frac{V_4}{I_m} - R_m$

$= SV_4 - R_m$

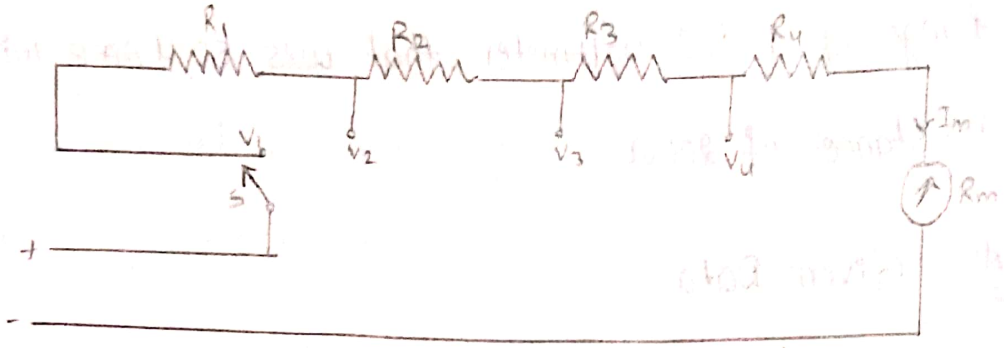
$R_3 = R_T - (R_4 + R_m)$

$R_T = \frac{V_3}{I_m}$

$R_3 = SV_3 - (R_4 + R_m)$

① The Basic D'Arsonval Galvanometer with an Internal resistance of 50Ω & full scale deflection current of 2mA (I_m) is used as multirange voltmeter. Design the string of multipliers to obtain (0-10)V ; (0-50)V ; (0-100)V ; (0-500)V interms of sensitivity.

Sol:



$\rightarrow$ Sensitivity $(S) = \frac{1}{I_m} = \frac{1}{2 \times 10^{-3}} = 500\ \Omega/V$

At 4th position:

$R_4 = SV_4 - R_m$

$= 500(10) - 50$

$R_4 = 4950\ \Omega$

$\boxed{R_4 = 4.950\ K\Omega}$

At 3rd position:-

$R_3 = SV_3 - (R_m + R_4)$

$= 500(50) - (50 + 4950)$

$= 20,000\ \Omega$

$\boxed{R_3 = 20\ K\Omega}$

At 2nd position:

$R_2 = SV_2 - (R_m + R_4 + R_3)$

$= 500(100) - (50 + 4950 + 20,000)$

$= 25000\ \Omega$

$\boxed{R_2 = 25\ K\Omega}$

At 1st position:

$R_1 = SV_1 - (R_m + R_4 + R_3 + R_2)$

$= 500(500) - (50 + 4950 + 20,000 + 25000)$

$\boxed{R_1 = 200\ K\Omega}$

② Calculate the value of multiplier Resistance on the 500V Range of a DC voltmeter that uses 50μ Amp with internal resistance of 200Ω.

Sol: Given Data,

$V = 500V$

$I_m = 50\mu$

$R_m = 200\Omega$

$$\therefore R_s = \frac{V}{I_m} - R_m \quad \text{(or)} \quad SV - R_m \Rightarrow 20{,}000(500) - 200$$

$$= 9999.8K\Omega$$

$$= \frac{\cancel{500}^{10}}{\cancel{50}\times 10^{-6}} - 200$$

$$R_s = 9999800\ \Omega$$

$$R_s = 9.9998\ M\Omega \quad \text{(or)} \quad 9999.8K\Omega$$

③ The meter "A" has a range of (0-100)V & Multiplier resistance of 25KΩ. Meter "B" has a range of (0-1000)V and multiplier resistance of 150KΩ. Both meters has basic resistance of 1KΩ. which meter is more sensitive.

Sol: WKT, $R = SV - R_m$

$\rightarrow R_A = SV_A - R_m$

R_s

$25\times10^3 = S(100) - (1\times10^3)$

$$\boxed{S_A = 260\ \Omega/V}$$

$R_B = SV_B - R_m$

R_s

$25\times10^3 = S(1000) - (1000)$

$$\boxed{S_B = 151\ \Omega/V}$$

Here, Meter "A" is high value. Therefore Meter "A" is more sensitive than Meter "B".

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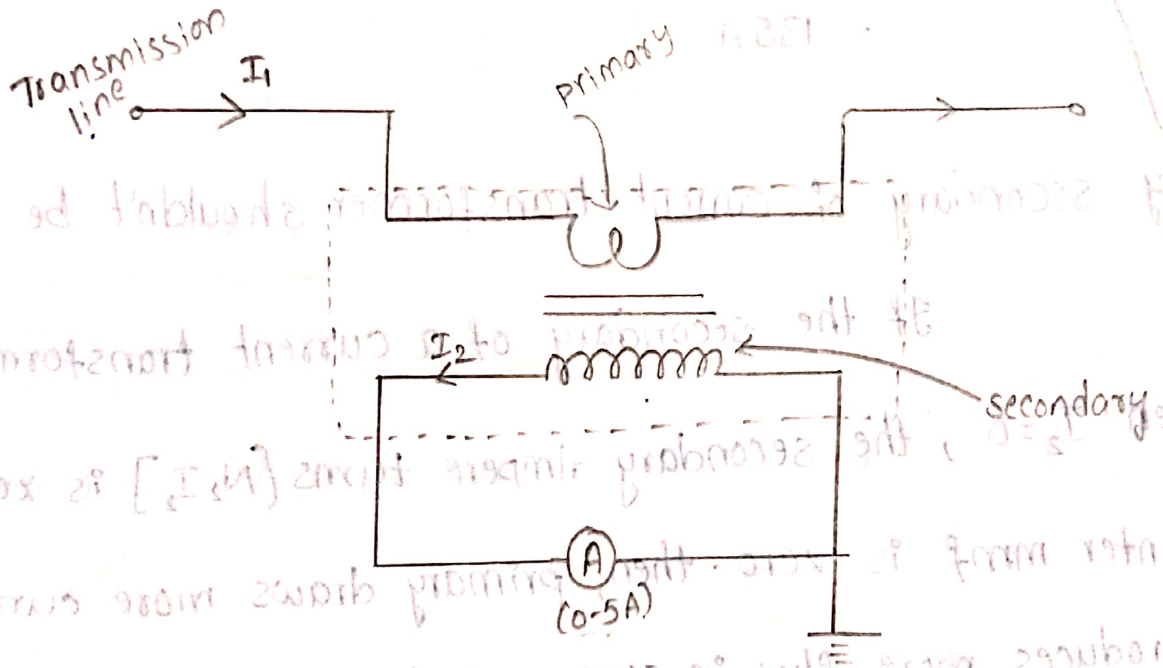
Instrument Transformers:—

To measure high range of currents & voltages Instrument Transformers are used.

1. Current Transformer [C.T]
2. Potential Transformer [P.T]

1. Current Transformer:-



less turns, Thick, High area

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

$\therefore R \downarrow$

step up but it step down curre

where, I_1 = primary current

I_2 = secondary current

N_1 = Number of primary turns

N_2 = secondary winding turns

$$\boxed{\frac{I_1}{I_2} = \frac{N_2}{N_1}}$$

If secondary open, $I_2 = 0$, counter mmf" then high primary curre high flux, high en which increases heat temp. T/F burns ou

Remedy: Ammeter is used (or) grou

Example:

① A 250:5 current transformer is used along with an ammeter, if ammeter reading is 2.7 Amp. Estimate line current.

Sol:

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

$$\frac{I_1}{2.7} = \frac{250}{5}$$

$$I_1 = \frac{2.7 \times 250}{5}$$

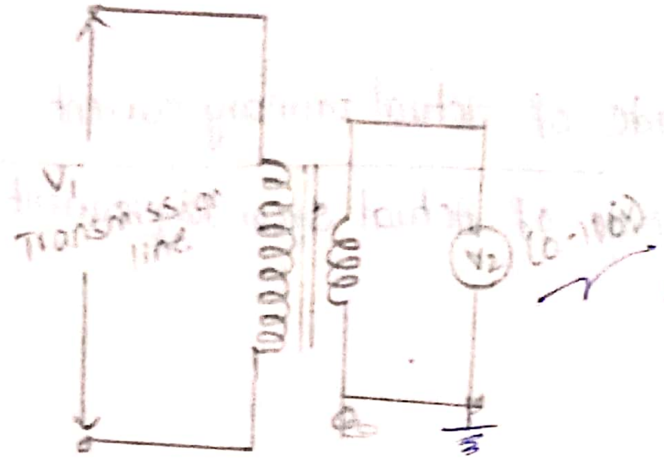
$$= 135\,A$$

② why secondary of current transformer shouldn't be open?

If the secondary of a current transformer is open $I_2 = 0$, the secondary Ampere turns $[N_2 I_2]$ is zero (or) counter mmf is zero. then, primary draws more current which produces more flux in core, so induces more emf in secondary, heat will be dissipated more which causes rise of temperature and transformer may be burn out. It is very dangerous from operator point of view.

Note:- Secondary of current transformer should be connected with Ammeter (or) grounded with low resistance.

Potential Transformer :— [P.T]



where, N_2 = secondary no. of turns

N_1 = primary no. of turns

V_1 = primary voltage

V_2 = secondary voltage

$$\boxed{\frac{V_2}{V_1} = \frac{N_2}{N_1}}$$

example:

A 11000 : 110 V potential transformer is used along with an voltmeter. If voltmeter reading is 87.5 V. Estimate line voltage.

N_1 N_2

sol:

$$\frac{N_1}{N_2} = \frac{V_1}{V_2}$$

$$V_1 = \frac{N_1}{N_2} \times V_2$$

$$\frac{N_2}{N_1} = \frac{V_2}{V_1}$$

$$V_1 = V_2 \times \frac{N_1}{N_2}$$

$$= \frac{11000 \times 87.5}{110}$$

$$= 8750$$

$$= 87.5 \times \frac{11000}{110\cancel{00}}$$

$$= \cancel{0.875} \Rightarrow 8750$$

I_1

Ratio's in Instrument Transformers :-

① **Actual Ratio :- [R]**

$$R = \frac{\text{Magnitude of Actual primary current}}{\text{Mangnitude of Actual secondary current}}$$ for C.T

for potential T/F :-

$$R = \frac{\text{Magnitude of Actual primary voltage}}{\text{Magnitude of Actual secondary voltage}}$$

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② **Nominal Ratio :- [K_n]**

$$K_n = \frac{\text{Rated primary current}}{\text{Rated secondary current}}$$ for C.T

Actual > Rated
on meter (or) fixed on plates
↓
on running the machines

for potential T/F :-

$$K_n = \frac{\text{Rated primary voltage}}{\text{Rated secondary voltage}}$$

③ **Turns Ratio :- [n]**

$$n = \frac{\text{No.of turns in secondary wdg}}{\text{No.of turns in primary wdg}}$$ for C.T

for potential T/F :-

$$n = \frac{\text{No.of turns in primary wdg}}{\text{No.of turns in secondary wdg}}$$

④ Ratio of correction factor (R.C.F) :—

It is defined as actual ratio to the nominal ratio.

$$\text{Ratio of correction factor} = \frac{R}{K_n}$$

$$\therefore R = \text{Ratio of correction factor} \times K_n$$

⑤ Total Burden (Load) of secondary winding :—

$$\text{Total Burden of } 2^\circ \text{ wdg} = \frac{\text{secondary induced voltage square}}{\text{Impedance due to } 2^\circ \text{ wdg \& load}}$$

$$= \frac{V^2}{Z_S + Z_L} \longrightarrow [\text{potential T/F}]$$

(or)

$$= I_S^2 [Z_S + Z_L] \longrightarrow [\text{current T/F}]$$

= secondary current square into (×) Total impedance due to 2° wdg & load.

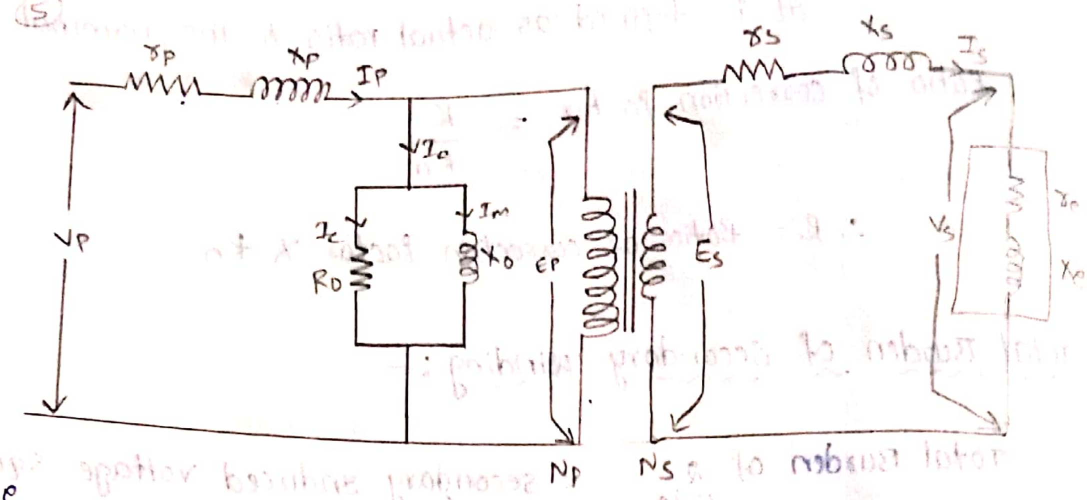
(ii) Secondary Burden due to load = $\frac{\text{Secondary Induced voltage square}}{\text{Impedance due to load}}$

(or)

= secondary current square × Impedance due to load

i.e., $\frac{V^2}{Z_L}$ (or) $I_S^2 Z_L$

Equivalent circuit of a current Transformer



Here,

V_p = primary voltage

r_p = primary Resistance

X_p = " Reactance

I_p = " current

I_o = No load current

I_c = core component of current

I_m = Magnetising current

R_o = No load resistance

X_o = No load reactance

E_p = primary Induced Emf

N_p = primary no. of turns

E_s = secondary Induced Emf

N_s = secondary no. of turns

r_s = secondary resistance

X_s = " reactance

I_s = " current

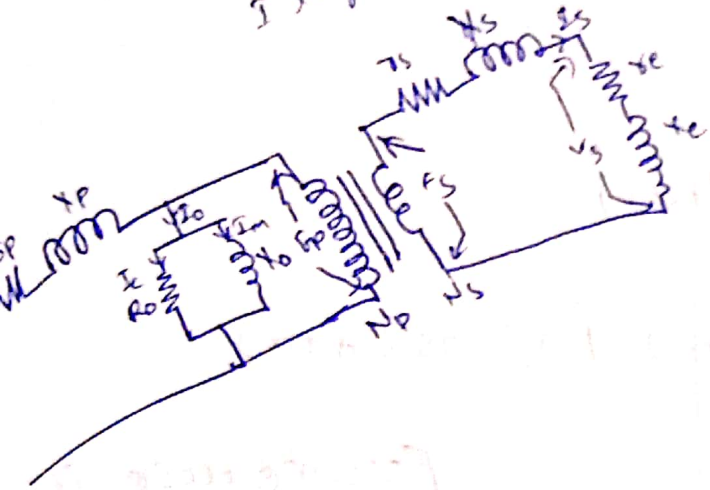
V_s = " voltage

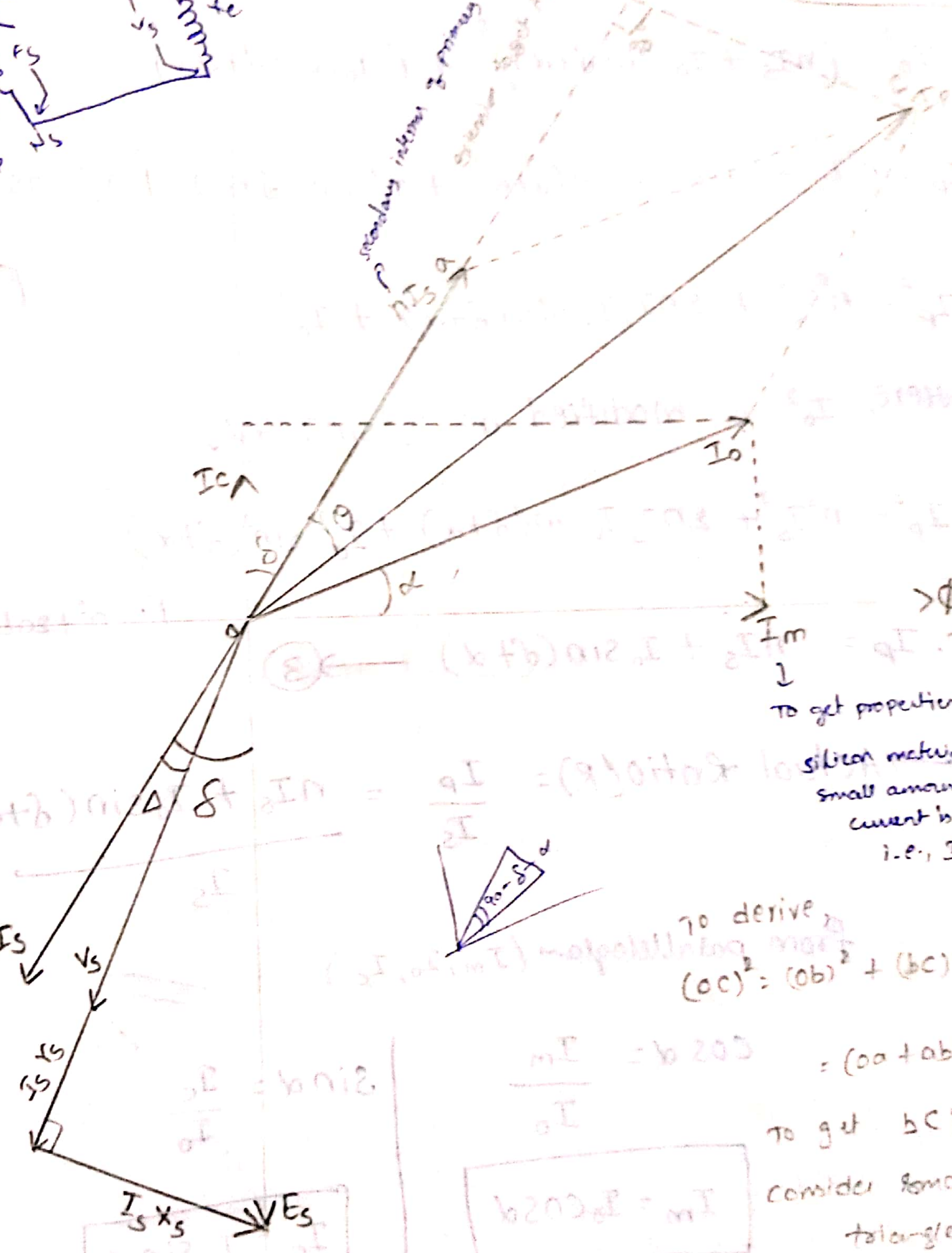
r_e = Load resistance

X_e = Load reactance.

Derivation for Actual Ratio [R]:-

lagging pf
↓
I lags V





To get properties

silicon metal

small amount

current

i.e.,

$\boxed{V_s + I_s r_s + I_s X_s}$

To derive

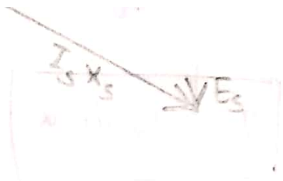
$(oc)^2 = (ob)^2 + (bc)^2$

$= (oa + ab$

To get bc

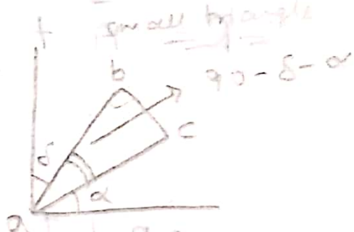
consider some

triangle



Consider $\angle bac$,

$\rightarrow \sin(90-\delta-\alpha) = \dfrac{bc}{ac}$; $ac = I_0$, $oa = nI_s$, $oc = I_p$



$$\sin[90-(\delta+\alpha)] = \frac{bc}{ac}$$

$$\cos(\delta+\alpha) = \frac{bc}{ac}$$

$$\boxed{\therefore\ bc = I_0\cos(\delta+\alpha)} \longrightarrow 1$$

$\rightarrow \cos(90-\delta-\alpha) = \dfrac{ab}{ac}$

$$\boxed{\therefore\ ab = I_0\sin(\delta+\alpha)} \longrightarrow 2$$

Large triangle

consider $\angle obc$

$$(oc)^2 = (ob)^2 + (bc)^2$$

$$(oc)^2 = (oa+ab)^2 + (bc)^2$$

$$I_p^2 = (nI_s + I_0 \sin(\delta+\alpha))^2 + (I_0 \cos(\delta+\alpha))^2$$

$$I_p^2 = n^2 I_s^2 + 2nI_s I_0 \sin(\delta+\alpha) + I_0^2 \sin^2(\delta+\alpha) + I_0^2 \cos^2(\delta+\alpha)$$

$[\because \sin^2\theta + \cos^2\theta = 1]$

$$I_p^2 = n^2 I_s^2 + 2nI_s I_0 \sin(\delta+\alpha) + I_0^2$$

Here, I_0^2 is modified as $I_0^2 \sin^2(\delta+\alpha)$ $[\because \sin(\delta+\alpha) << I_0]$

since less value it doesn't have any impact

$$I_p^2 = n^2 I_s^2 + 2nI_s I_0 \sin(\delta+\alpha) + I_0^2 \sin^2(\delta+\alpha)$$

$[\because a^2 + 2ab + b^2 = (a+b)^2]$

$$\therefore I_p = nI_s + I_0 \sin(\delta+\alpha) \longrightarrow (3)$$

$\rightarrow$ Actual Ratio(R) = $\dfrac{I_p}{I_s} = \dfrac{nI_s + I_0 \sin(\delta+\alpha)}{I_s}$

from parallelogram (I_m, I_0, I_c)

$\cos\alpha = \dfrac{I_m}{I_0}$	$\sin\alpha = \dfrac{I_c}{I_0}$
$\boxed{I_m = I_0 \cos\alpha}$	$\boxed{I_c = I_0 \sin\alpha}$

$$\therefore R = n + \frac{I_0}{I_s} \sin(\delta+\alpha)$$

$[\because \sin(A+B) = \sin A \cos B + \cos A \sin B]$

$$= n + \frac{I_0}{I_s}[\sin\delta \cos\alpha + \cos\delta \sin\alpha]$$

$I_m = I_0 \cos\alpha$

$I_c = I_0 \sin\alpha$

$$* \quad \boxed{R = n + \frac{I_m \sin\delta + I_c \cos\delta}{I_s}} \quad *$$

where $\delta = +ve \rightarrow$ lagging pf

$\delta = -ve \rightarrow$ leading pf

(ii) Phase angle "θ" :-

Consider $\angle obc$,

$$\tan\theta = \frac{bc}{ob} = \frac{bc}{oa+ab} = \frac{I_0\cos(\delta+\alpha)}{nI_s + I_0\sin(\delta+\alpha)}$$

$$\tan\theta \simeq \theta = \frac{I_0\cos(\delta+\alpha)}{nI_s}$$ [Here, Neglect $I_0\sin(\delta+\alpha)$]

$$\theta = \frac{I_0}{nI_s}\left[\cos\delta\cos\alpha - \sin\delta\sin\alpha\right]$$

* $$\boxed{\theta = \frac{I_m\cos\delta - I_c\sin\delta}{nI_s}}$$ * radians

$I_c = I_0\sin\alpha$

$I_m = I_0\cos\alpha$

$$\boxed{\therefore \theta = \frac{180}{\pi}\left[\frac{I_m\cos\delta - I_c\sin\delta}{nI_s}\right]}$$ degree

Approximate Results:-

In practical $\delta = 0^\circ$; $\sin\delta = 0$; $\cos\delta = 1$

$$\boxed{R = n + \frac{I_c}{I_s}} \; ; \; \boxed{\theta = \frac{180}{\pi}\frac{I_m}{nI_s}} \text{ degrees}$$

Errors in current Transformers:-

There are two types of errors

① Ratio Error

② phase Angle Error

① Ratio Error:-

In practical, the ratio $\frac{N_s}{N_p} = \frac{I_p}{I_s}$ are not equal.

Hence the errors are produced. these errors are called Ratio error.

$$\% \text{ error} = \frac{\text{Nominal ratio} - \text{Actual Ratio}}{\text{Actual Ratio}} \times 100$$

$$\% \text{Error} = \frac{K_n - R}{R} \times 100$$

② **Phase angle error:—**

In practice, the phase angle difference between E_p & E_s is not 180° i.e., ∠180°. Hence, the errors are produced is called phase angle error.

$$\theta = \frac{180}{\pi}\left[\frac{I_m \cos\delta - I_c \sin\delta}{n I_s}\right]$$

Example: A current T/F ~~with 5 primary turns~~ has no load components are magnetising component = 102 A ; core loss component = 38 A, current T/F ratio is $\frac{1000}{5}$ A. Calculate the Approximate ratio error at full load.

Sol: Given Data,

$I_m = 102\,A$

$I_c = 38\,A$

$\frac{I_1}{I_2} = \frac{N_2}{N_1}$

current T/F

Magnetising $I_m = I_0 \cos\alpha = 102\,A$

Core loss comp $I_c = I_0 \sin\alpha = 38\,A$

$I_m = I_0 \cos\alpha$

$I_c = I_0 \sin\alpha$

$$n = \frac{N_s}{N_p} = \frac{I_p}{I_s} = \frac{1000}{5} = 200$$

Approximate Results:-

(i) $R = n + \frac{I_c}{I_s}$

$= 200 + \frac{38}{5}$

$\boxed{R = 207.6}$

(ii) $\theta = \frac{180}{\pi}\left[\frac{I_m}{n I_s}\right]$

$= \frac{180}{\pi}\left[\frac{102}{200 \times 5}\right]$

$= 5.8°$

$$\% \text{ Error} = \frac{K_n - R}{R} \times 100$$

Here, $K_n = \frac{I_P}{I_s} = 200$

$$= \frac{200 - 207.6}{+207.6} \times 100$$

$\%$ Error $= -3.66\%$

A current T/F has a single turn primary & 400 secondary turns. The magnetising current is 90 A. While coreloss current is 40 Amps secondary circuit phase Angle is 28°. calculate the Actual primary current & ratio error when secondary carries 5 Amp current.

$N_1 = 1$; $N_s = 400$ $\quad R = ?$

$I_m = 90A = I_0 \cos\alpha$ $\quad \% = \frac{K_n - R}{R} \times 100$

$I_c = 40A = I_0 \sin\alpha$ $\quad K_n = \frac{I_P}{I_s}$

$n = \frac{N_s}{N_P} = \frac{I_P}{I_s}$

Sol: Given,

$N_P = 1$; $N_s = 400$

$I_m = 90A$; $I_c = 40A$

$I_s = 5 Amp$

$\delta = 28°$

$n = \frac{I_P}{I_s} = \frac{N_s}{N_P} = \frac{400}{1}$

$\boxed{n = 400}$

Find:- Actual primary current = ?

Ratio error = ?

Ratio error $= \frac{K_n - R}{R} \times 100$

$\delta = 28°$

$\sin(28°) = 0.469$

$\cos(28°) = 0.882$

$$\rightarrow R = n + \frac{I_m \sin\delta + I_c \cos\delta}{I_s}$$

$$= 400 + \frac{[90(0.469)] + [40(0.882)]}{5}$$

$K_n = \frac{I_P}{I_s}$

$\boxed{R = 415.498}$

$n = \frac{I_P}{I_s}$

$I_P = 400 \times 5$

$I_P = 2000 A$

$$\rightarrow R = \frac{\text{Actual primary current}}{\text{Actual secondary current}}$$

$\rightarrow n = \dfrac{I_p}{I_s}$

$I_p = n I_s$

$= 400 \times 5$

$$\boxed{I_p = 2000A}$$

$\rightarrow K_n = \dfrac{\text{Rated primary current}}{\text{Rated secondary current}} = \dfrac{2000}{5}$

$$\boxed{K_n = 400}$$

$\rightarrow$ Ratio error $= \dfrac{K_n - R}{R} \times 100$

$= \dfrac{400 - 415.498}{415.498} \times 100$

Ratio error $= -3.814\ \%$

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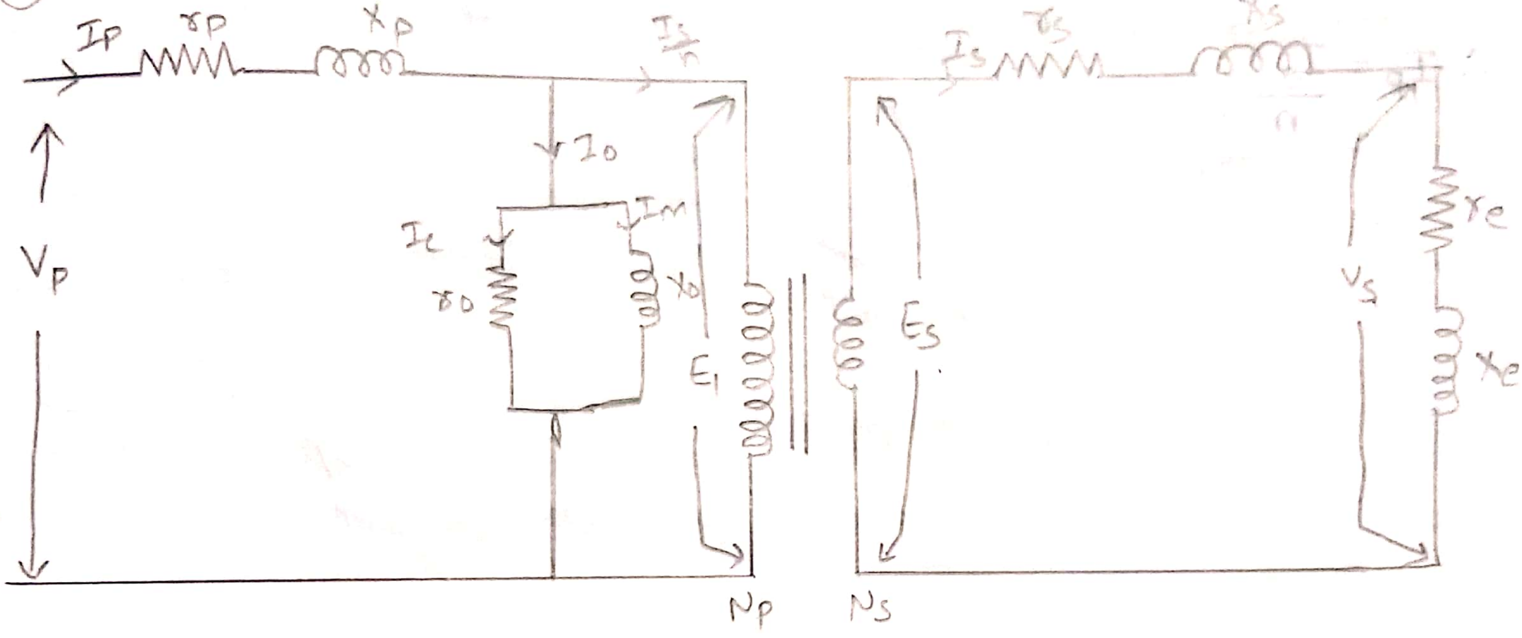
⑥ Equivalent circuit of potential Transformer:-



where Terms explanation,

where, Terms explanation.

V_p = primary voltage

I_p = primary current

r_p = primary resistance

x_p = primary reactance

I_o = No load current

I_c = core component of current

I_m = Magnetising current

r_o = No load resistance

X_o = No load reactance

E_1 = primary induced emf

N_p = primary no.of turns

N_s = secondary no.of turns

E_s = secondary induced emf

r_s = secondary resistance

X_s = secondary reactance

V_s = secondary voltage

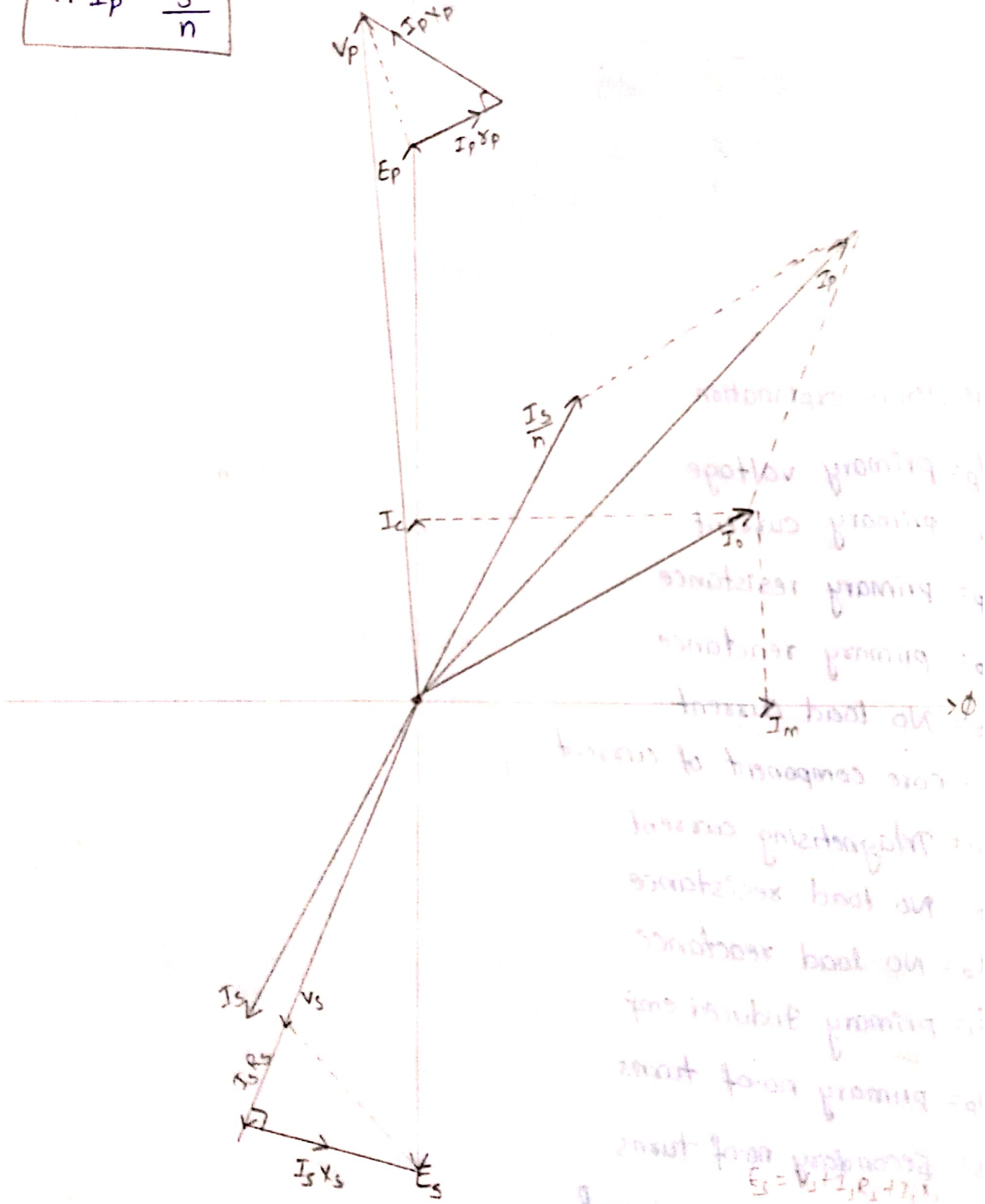
r_e = load resistance

X_e = load reactance.

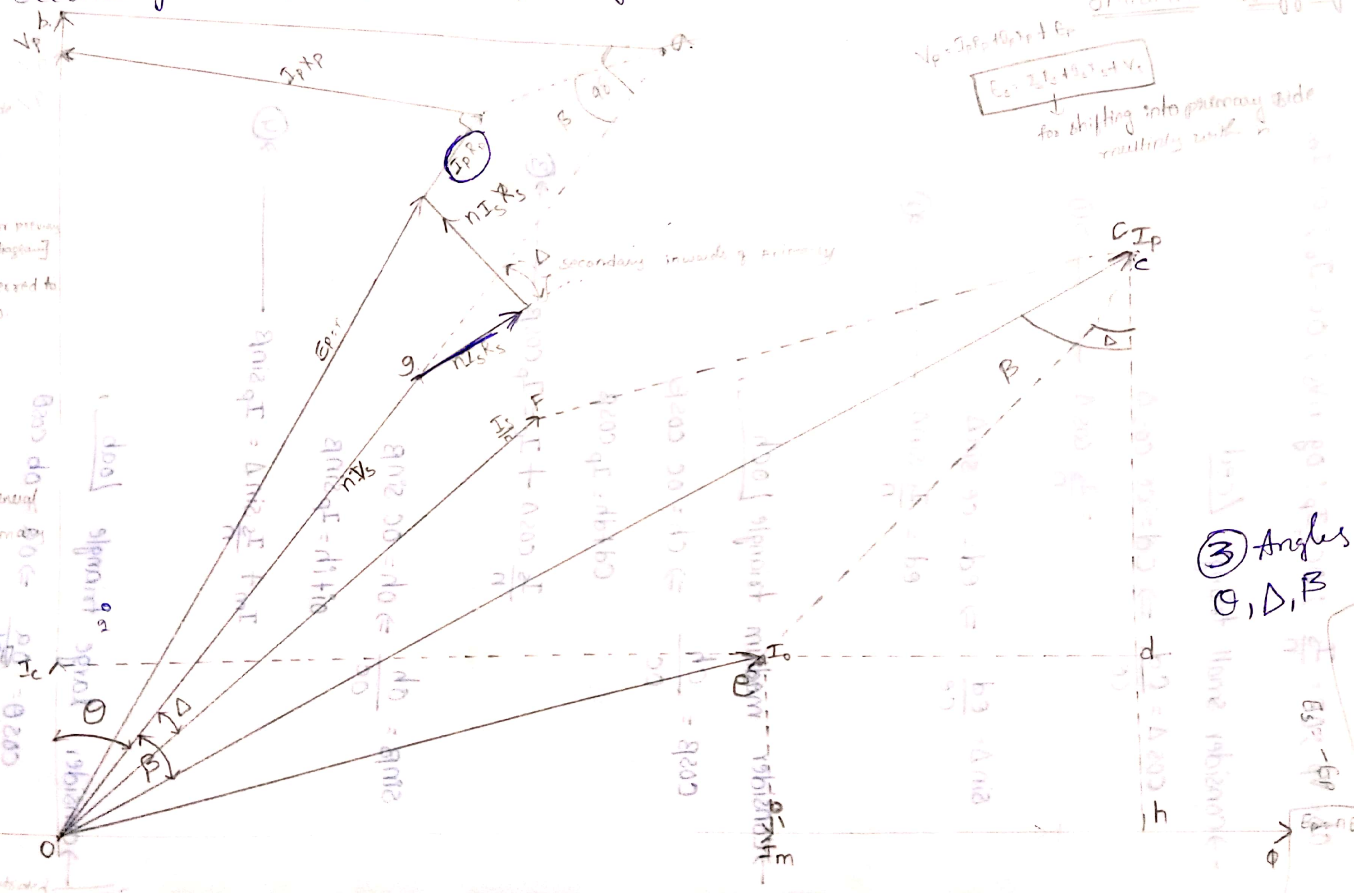
According to potential T/F,

$$n = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$$

$$\boxed{\therefore I_P = \frac{I_S}{n}}$$



secondary are transferred to primary.



$ce = \frac{I_s}{n}$

From Diagram,

$ob = V_p \; ; \; OF = \frac{I_s}{n} \; ; \; oc = I_p \; ; \; og = nV_s \; ; \; oe = I_o \; ; \; oi = I_m$

→ consider small triangle $\angle ced$

$\cos\Delta = \frac{cd}{ce} \Rightarrow cd = ce\cos\Delta$

$= \frac{I_s}{n}\cos\Delta \longrightarrow (1)$

$\sin\Delta = \frac{ed}{ce} \Rightarrow ed = ce\sin\Delta$

$ed = \frac{I_s}{n}\sin\Delta \longrightarrow (2)$

→ consider medium triangle $\angle och$,

$\cos\beta = \frac{ch}{oc} \Rightarrow ch = oc\cos\beta$

$cd + dh = I_p\cos\beta$

$\frac{I_s}{n}\cos\Delta + I_c = I_p\cos\beta \longrightarrow (3)$

$\sin\beta = \frac{oh}{oc} \Rightarrow oh = oc\sin\beta$

$oi + ih = I_p\sin\beta$

$I_m + \frac{I_s}{n}\sin\Delta = I_p\sin\beta \longrightarrow (4)$

→ consider large triangle $\angle oab$,

$\cos\theta = \frac{oa}{ab} \Rightarrow oa = ob\cos\theta$

$oa = V_p\cos\theta$

$V_p\cos\theta = \underbrace{oa}_{(og+ga)}$ [w into striling, multiply with cos & sin]

∴ oa becomes from sle

$V_p\cos\theta = nV_s + nI_s r_s\cos\Delta + nI_s X_s\sin\Delta + I_p r_p\cos\beta + I_p X_p\sin\beta \longrightarrow (5)$

$\theta \simeq \cos\theta = 1$

$$V_p = nV_s + nI_s r_s \cos\Delta + nI_s X_s \sin\Delta + I_p r_p \cos\beta + I_p X_p \sin\beta$$

"β" in terms of "Δ"

$$V_p = nV_s + nI_s r_s \cos\Delta + nI_s X_s \sin\Delta + \left[\frac{I_s}{n}\cos\Delta + I_c\right] r_p + \left[I_m + \frac{I_s}{n}\sin\Delta\right] X_p$$

[$\because$ from (3) & (4)]

$$V_p = nV_s + I_s \cos\Delta\left[n r_s + \frac{r_p}{n}\right] + I_s \sin\Delta\left[n X_s + \frac{X_p}{n}\right] + r_p I_c + X_p I_m$$

by taking "n" as lcm ; $n^2 r_s + r_p = R_{01}$

lly $n^2 X_s + X_p = X_{01}$

$$V_p = nV_s + \frac{I_s}{n} R_{01} \cos\Delta + \frac{I_s}{n} \cdot X_{01} \sin\Delta + r_p I_c + X_p I_m$$

$$V_p = nV_s + \frac{I_s}{n}\left[R_{01}\cos\Delta + X_{01}\sin\Delta\right] + I_c r_p + I_m X_p$$

$\therefore$ Actual Ratio $R = \frac{V_p}{V_s}$

referred to primary

$$\boxed{R = n + \frac{\frac{I_s}{n}\left[R_{01}\cos\Delta + X_{01}\sin\Delta\right] + I_c r_p + I_m X_p}{V_s}}$$

→ Actual Ratio referred to secondary

$$\boxed{R = n + \frac{nI_s\left[R_{02}\cos\Delta + X_{02}\sin\Delta\right] + I_c r_p + I_m X_p}{V_s}}$$

for phase angle, (θ)

consider $\underline{\angle oab}$; $\tan\theta = \dfrac{ab}{oa}$

$\tan\theta \simeq \theta$

Deviation in str. line with the flow [a-b] + [c-d]

$$\theta = \frac{I_p X_p \cos\beta - I_p r_p \sin\beta + nI_s X_s \cos\Delta - nI_s r_s \sin\Delta}{nV_s + \underbrace{nI_s r_s \cos\Delta + nI_s X_s \sin\Delta + I_p r_p \cos\beta + I_p X_p \sin\beta}_{\text{neglected}}}$$

$$\theta = \frac{I_p X_p \cos\beta - I_p r_p \sin\beta + nI_s X_s \cos\Delta - nI_s r_s \sin\Delta}{nV_s}$$

"β" interms of "Δ"

$$\theta = \frac{X_p\left[\frac{I_s}{n}\cos\Delta + I_c\right] - r_p\left[\frac{I_s}{n}\sin\Delta + I_m\right] + nI_s X_s\cos\Delta - nI_s r_s \sin\Delta}{nV_s}$$

$$\theta = \frac{I_s\cos\Delta\left[\frac{X_p}{n} + nX_s\right] - I_s\sin\Delta\left[\frac{r_p}{n} + nr_s\right] + I_c X_p - r_p I_m}{nV_s}$$

"ccm"

$$\theta = \frac{\frac{I_s}{n} X_{o_1}\cos\Delta - \frac{I_s}{n} R_{o_1}\sin\Delta + I_c X_p - r_p I_m}{nV_s}$$

$$= \frac{\frac{I_s}{n}\left[X_{o_1}\cos\Delta - R_{o_1}\sin\Delta\right] + I_c X_p - I_m r_p}{nV_s}$$

$$\therefore \theta = \frac{180}{\pi}\left(\frac{\frac{I_s}{n}\left[X_{o_1}\cos\Delta - R_{o_1}\sin\Delta\right] + I_c X_p - I_m r_p}{nV_s}\right) \text{ degrees}$$

There are two types of erros

1. Ratio error
2. phase Angle error.

$$\% \text{ Ratio error} = \frac{K_n - R}{R} \times 100$$

where, $R = n + \dfrac{\frac{I_s}{n}\left[R_{0_1}\cos\Delta + X_{0_1}\sin\Delta\right] + I_c r_p + I_m X_p}{V_s}$

$$\text{phase angle error}(\theta) = \frac{180}{\pi}\left(\frac{\frac{I_s}{n}\left[X_{0_1}\cos\Delta - R_{0_1}\sin\Delta\right] + I_c X_p - I_m r_p}{n V_s}\right)$$

11/12/19 $n = \frac{N_2}{N_1} = \frac{I_1}{I_2}$ - 399

A current T/F has turns ratio 1:399 and is rated as 2000/5A. The core loss component is 3A & magnetising component is 8A under full load conditions. Find phase angle and ratio errors if secondary circuit power factor is 0.8 leading.
(-)

Sol: Given data,

$$n = \frac{N_s}{N_p} = \frac{I_s}{I_p}$$

$$n = \frac{N_s}{N_p} = \frac{399}{1}$$

primary high current
secondary less curr.

$$\rightarrow K_n = \frac{I_p}{I_s} = \frac{2000}{5} = 400$$

$I_c = 3A$

$I_m = 8A$

$$\theta = \frac{180}{\pi}\left[\frac{I_m \cos\delta - I_c \sin\delta}{n I_s}\right]$$

$I_c = 3A$; $I_m = 8A$

Find: $\theta = ?$

$$\rightarrow \text{\% Ratio error} = \frac{K_n - R}{R} \times 100$$

$$\rightarrow \cos\delta = 0.8 \text{ lead}$$

$$\delta = -36.86$$

$$\rightarrow \text{Actual Ratio } (R) = n + \frac{I_m \sin\delta + I_c \cos\delta}{I_s}$$

$$= 399 + \frac{(8)(-0.6) + (3)(0.8)}{5}$$

$$\boxed{R = 398.52}$$

$\cos\delta + I_m \sin\delta$

$$\% \text{ Ratio error} = \frac{K_n - R}{R} \times 100$$

$$= \frac{400 - 398.52}{398.52} \times 100$$

$$= 0.371\%$$

$\rightarrow$ phase angle $(\theta) = \frac{180}{\pi}\left[\frac{I_m \cos\delta - I_c \sin\delta}{n I_s}\right]$

$\cos\delta = 0.8$
$\delta = -0.6$

$$= \frac{180}{\pi}\left[\frac{8(0.8) - (3)(-0.6)}{399 \times 5}\right]$$

$n = \frac{N_s}{N_p} = \frac{399}{1}$

$$= 0.235^\circ \simeq 13.46'$$

A current T/F with 5 primary turns ($N_p = 5$) has a secondary burden (Load) consisting of a resistance of 0.16 ($r_e = 0.16$) & Inductive reactance of 0.12Ω ($X_e = 0.12\Omega$). When the primary current is 200A ($I_p = 200$). The magnetising current is 1.5A ($I_m = 1.5A$). The core loss current is 0.4A ($I_c = 0.4$). Find the no. of turns on secondary (N_s) needed to make the current ratio 100:1 and phase angle.

$I_s = 1.99$

Sol: Given data,

$N_p = 5$ turns

$R_e = 0.16\Omega$; $X_e = 0.12\Omega$

$I_p = 200A$

$I_m = 1.5A$; $I_c = 0.4A$

$n = \frac{I_p}{I_s} = \frac{N_s}{N_p}$

$N_s = \frac{I_p \times N_p}{I_s}$

$n = \frac{5 \times}{1.99}$

$\frac{N_s}{N_p} = \frac{I_p}{I_s}$

$N_s = 100 \times 5$

$\frac{N_s}{N_p} = \frac{I_p}{I_s}$

$N_s = \frac{I_p \times N_p}{I_s}$

$\frac{200 \times 5}{1.991}$

Find:- $N_s = ?$

$\Rightarrow \delta = \tan^{-1}\left(\frac{X_e}{R_e}\right) = \tan^{-1}\left[\frac{0.12}{0.16}\right] = 36.86^\circ$

$\Rightarrow \frac{I_P}{I_S} = 100.1$

$\boxed{I_S = 1.998\,A}$

$\Rightarrow \frac{N_S}{N_P} = n \Rightarrow 100.1$

$N_S = N_P \times 100.1$

$\boxed{N_S = 500.5}$ turns

$\cos(36.86)$

$\Rightarrow \theta = \frac{180}{\pi}\left[\frac{I_m \cos\delta - I_c \sin\delta}{n I_S}\right]$

$= \frac{180}{\pi}\left[\frac{1.5 \times 0.8 - 0.4 \times 0.6}{100.1 \times 1.998}\right]$

$\boxed{\theta = 0.275^\circ}$

A current T/F of turns ratio of 1:199 is rated as 1000/5A, 25 VA. The core loss is 0.1 W & magnetising current is 7.2A. Determine phase angle & ratio errors for rated load & rated secondary current (i) at 0.8 power factor lagging. (ii) at 0.8 " " leading.

$n = \frac{I_p}{I_s}, \frac{N_s}{N_p} = \frac{199}{1}$

$K_n = \frac{1000}{5}$

$n = \frac{N_S}{N_P} = \frac{199}{1}$

$P_c = 0.1W \; ; \; I_m = 7.2A$

Sol: Given Data:-

$n = \frac{N_S}{N_P} = \frac{199}{1} = 199$

$\rightarrow 1000/5A \Rightarrow K_n = \frac{I_P}{I_S} = \frac{1000}{5} = 200$

In T/F, power is same. But voltage & current ↑ (or) ↓

$\rightarrow$ power Rating $= 25\,VA$

$\rightarrow$ core loss power $= 0.1\,W$

$I_m = 7.2\,A$

Find:-

$\theta = ?$

$\% R = \frac{K_n - R}{R}$

process to find :-

In Transformer, power is same i.e.,

$$\boxed{E_p I_p = E_s I_s = 25\,VA}$$

$\therefore E_p I_p = 25\,VA$ | $E_s I_s = 25\,VA$

$E_p = \frac{25}{1000} = 0.025$ | $E_s = \frac{25}{5} = 5\,V$

To know the core component current (I_c), core loss power is 0.1W. core loss present at pimary. so take relation as

Core loss power $= E_p I_e$

$$\therefore I_c = \frac{0.1}{0.025} = 4A$$

$$\boxed{\therefore I_c = 4A}$$

(i) Actual Ratio

$$R = n + \frac{I_m \sin\delta + I_c \cos\delta}{I_s}$$

[condition 0.8 lagging (+)]

$\cos\delta = 0.8$

$\delta = 36.86$

$\sin(36.86) = 0.6$

$$= 199 + \frac{(7.2 \times 0.6 + 4 \times 0.8)}{5}$$

$$\boxed{R = 200.504}$$

$$\% \text{ Ratio error} = \frac{K_n - R}{R} \times 100$$

$$= \frac{200 - 200.504}{200.504} \times 100$$

$$= -0.251\,\%$$

$$\rightarrow \theta = \frac{180}{\pi}\left[\frac{I_m \cos\delta - I_c \sin\delta}{n I_s}\right]$$ (2)

$$= \frac{180}{\pi}\left[\frac{7.2\times 0.8 - 4\times 0.6}{199\times 5}\right]$$

$$\boxed{\theta = 0.193^\circ}$$

(ii) 0.8 leading (−)

$\sin(-36.86) = -0.6$

$\cos(36.86) = 0.8$

$\delta = -36.86$

$$R = n + \left[\frac{I_m \sin\delta + I_c \cos\delta}{I_s}\right]$$

$$= 199 + \left[\frac{7.2(-0.6) + 4\times 0.8}{5}\right]$$

$$\boxed{R = 198.78}$$

% Ratio err8 = 0.615%.

Phase Angle(θ) = 0.469°

lagging (+ve)

$\cos\delta = \text{Ans}$

$\delta = \cos^{-1}(\text{Ans})$

$\sin\delta = \sin[\cos^{-1}(\text{Ans})]$

leading (−ve)

$\cos\delta = \text{Ans}$

$\delta = -\cos^{-1}(\text{Ans})$

$\sin\delta = \sin(-\cos^{-1}(\text{Ans}))$

I_P/I_S

(2) At its rated load of 25VA, 100/5 current transformer has. Iron loss of 0.2 W, and magnetising current is 1.5 A, calculate its ratio error & phase angle when supplying rated output to a meter having a ratio of resistance to reactance of 5.

Sol: **Given Data:-**

power rating = 25VA

$K_n = \frac{100}{5} A = \frac{I_P}{I_S}$

$n = \frac{I_P}{I_S} = \frac{100}{5} = 20$

Iron loss = 0.2 W

$I_m = 1.5 A$

$\frac{I_P'}{I_S} = \frac{N_S}{N_P}$

$\rightarrow$ In T/F ; $E_P I_P = E_S I_S = 25VA$

$n = 20 = \frac{N_S}{N_P}$

$E_P I_P = 25$	$E_S I_S = 25$
$E_P = \frac{25}{100}$	$E_S = \frac{25}{5}$
$= 0.25$	$E_S = 5$

$E_P I_P = E_S I_S = 25VA$

$I_C = 0.2 W$

$I_m = 1.5 A$

$\rightarrow$ Iron loss power $= E_P I_C$

$I_C = \frac{0.2}{0.25} = 0.8 A$

$\boxed{I_C = 0.8 A}$

$\rightarrow \frac{R_e}{X_e} = 5$

$\delta = \tan^{-1}\left(\frac{X_e}{R_e}\right) = \tan^{-1}\left(\frac{1}{5}\right)$

$\boxed{\delta = 11.309^\circ}$

$\cos\delta = \cos(11.309) = 0.98$

$\sin\delta = \sin(11.309) = 0.196$

$$\therefore R = n + \frac{I_m \sin\delta + I_c \cos\delta}{I_s}$$

$$= 20 + \frac{1.5 \times 0.196 + 0.8 \times 0.98}{5}$$

$$\boxed{R = 20.2156}$$

$$\text{Ratio error} = \frac{K_n - R}{R} \times 100$$

$$= \frac{20 - 20.2156}{20.2156} \times 100$$

$$\boxed{\text{Ratio error} = -1.066\%}$$

$$\theta = \frac{180}{\pi}\left[\frac{I_m \cos\delta - I_c \sin\delta}{n I_s}\right]$$

$$= \frac{180}{\pi}\left[\frac{1.5 \times 0.98 - 0.8 \times 0.196}{20 \times 5}\right]$$

$$\boxed{\theta = 0.752^\circ}$$