Date: 25/09/19 LECTURE NO 1

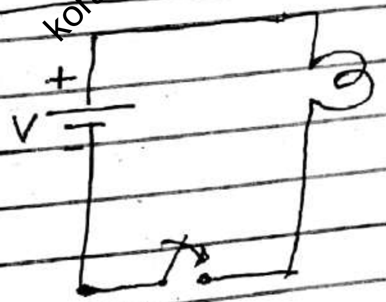
ELECTRICAL MEASURMENT INSTRUMENTATION

Course Outlines:-

- Principle, Operation working and construction of Different Analog and Digital Meters.
- Oscilloscope and its Measurments.
- Recording Instruments and signal generators
- Transducers.

~~OBE~~(

Electrical:

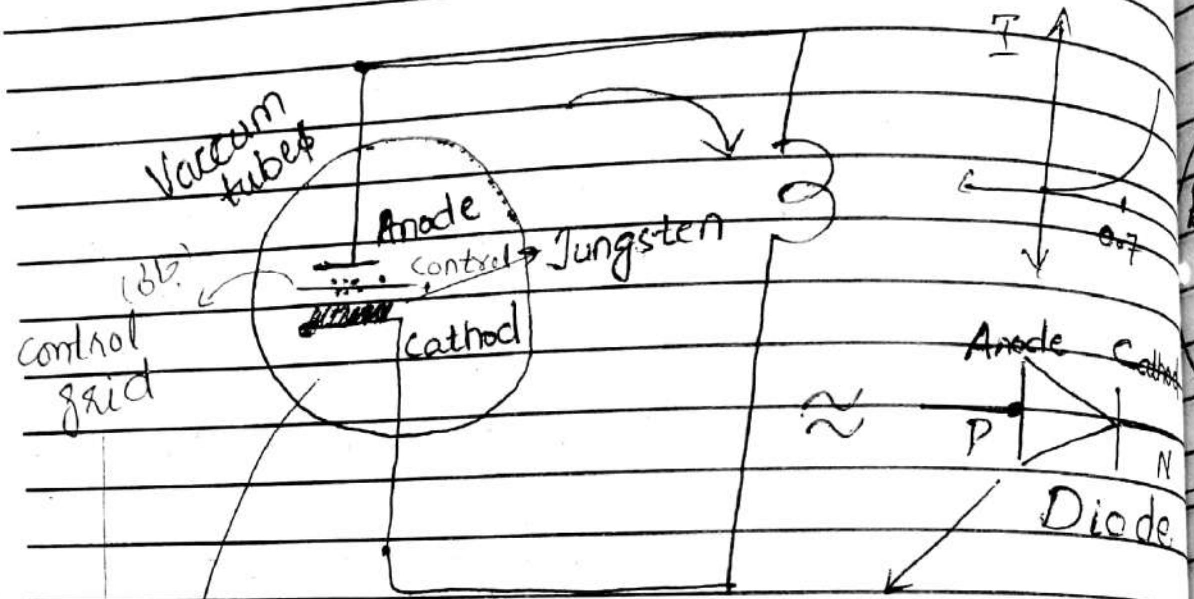


Electronics: If Bulb is control with remote is called electronics.

Vaccum Tube:

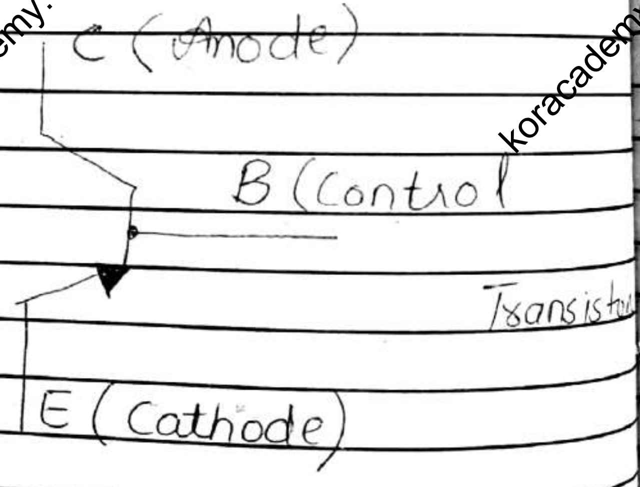
High work ftn: A metal is called of high work ftn if less amount of heat is require to free outer ēs.

Tungsten is of high work ftn.



Thermionic Emission

These two are Equivalent



Δ There is a non-uniform flow of es which produces noise.

To measure = to determine the magnitude or extend or degree of the condition of system in terms of some standard

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All the natural phenomenos follow mathematical model so can be mathematical modelled.

Bernoulli Equation is mathematical model of ~~fluid~~ natural fluid flow.
→ e.g Blinking of Eye and breathing.

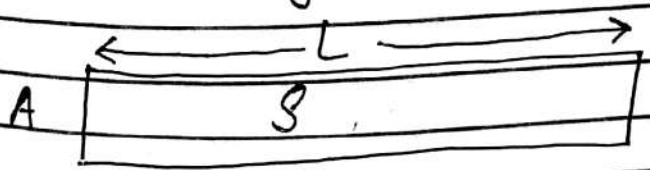
~~Metering~~ Meter: Instrument used to indicate or record measured value.

Instrument
1) Sensing 2) Detecting 3) Measuring
4) Recording 4) Controlling 5) Communicating.

SIR FAROOQ:-

Measured Value is the value calculated using a measurment system/instrument.

True value is the value calculated from the ratted values.
ratted (given)



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

Accuracy Vs Precision:-

Accuracy is define as degree of closeness of the measured value with true value is known as accuracy.

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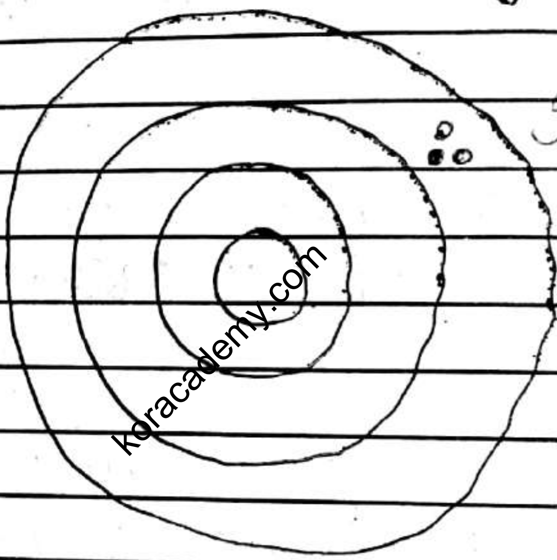
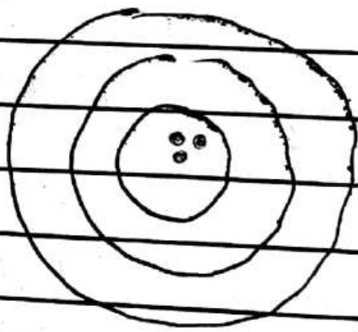
If Actual value = True value
the Accuracy is 100%

Precision
Degree of Closeness of measured values among themselves

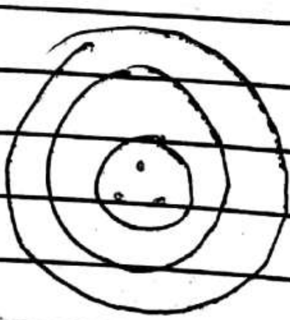
Bird Eye target



Inaccurate & precised



Accurate & precised



Accurate but not precised.

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Sensitivity: The ratio of change in output signal/responce of system to change of input variable

$$S = \frac{\Delta output}{\Delta input}$$

Input → pressure → 0 – 100 PSI
output → 0 – 5V

PSI → Pound per square inch.

$S = \frac{~~100~~\ 5}{100} = \frac{1}{20}\ \frac{V}{PSI}$

Resolution:- Smallest change in the input that can be detected.

~~100.001~~

100.00

Resolution is .01

0.006 and if it can round off then its resolution is .05

→ 100.01

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SIGNIFICANT FIGURES:-

1) Any non-zero digit is significant figure.

2) Any zero in between two non zeros is a sig. figure

3) Any zero before a non zero is not a significant figure

4) Any zero after non-zeros are not sig figure iff the given number has no decimal point

5) Any zero after non zero are significant fig if given number has decimal point

If there is decimal point in the number zeros after non zeros is sig.

	Number	# of Sig fig
1)	17	2
	132.856	6
2)	101	3
	2,000,009	7
3)	0.5	1
	0.000305	3
4)	5000	1
	Eg 5000m = 5Km or 5×10^3 m	
	10,000	1
	$500\bar{0}$	4
	$5\bar{0}00$	2
	$50\bar{0}0$	3
5)	370.	3.70×10^2
	0.003205300	7

Imp

Bilal Register

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Addition and Subtraction of Sig figure:-

کھرب ارب

One trillion 2 billions Nine thousand.

2325.2358

- 1000's, 100's, 10's, 1's
- 10th, 100th, 1000th → 10,000th

1) Math first sig figs after.

N_1 → more accurate
N_2 → less accurate
+
N_3 → less accurate.

a) If both numbers has decimal point

```
  1 5 0 . 0        → 1 digit after decimal
      0 . 7 0 2    → 3 digit after decimal
+
  1 5 0 . 7 0 2
```

So Answer should have 1 digit after decimal.

1 5 0 . 7

No of Sig figs ∝ Accuracy

Bilal Regist...

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$$\begin{array}{r} 0.854 \rightarrow 3ad \\ -\ 0.0594 \rightarrow 4ad \\ \hline 0.7946 \end{array}$$

So answer will have three digit after decimal

$\boxed{0.796}$

$0.7996 \xrightarrow{\text{Round-off}} 0.800$

b) If one digit has decimal point & the other number has no decimal pt

$$\begin{array}{r} 4.51 \\ 3 \\ \hline 7.51 \end{array}$$

Ans ⇒ 1's

8 (after round-off)

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1000

12,000 → 100's

3,500

7,500 → 8000

Ans ⇒ 1000's

Last Sig fig → position → highest position

کس کی ہے؟

Answer should not have significant figure after highest position (1000's)

Example:-

500.0 → 10th 10's ← 90 410.0 ↓ **410**	500 -90 410 ↓ **400**

12,000
+ 3,500
15,500

Ans 16,000

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Multiplication & Division:-

1) Math first

815.991 → 6SF

324.6 → 4SF

264,870.6786

Ans ⇒ S.F = 4

264,900

12

× 3

36

Ans ⇒ 40

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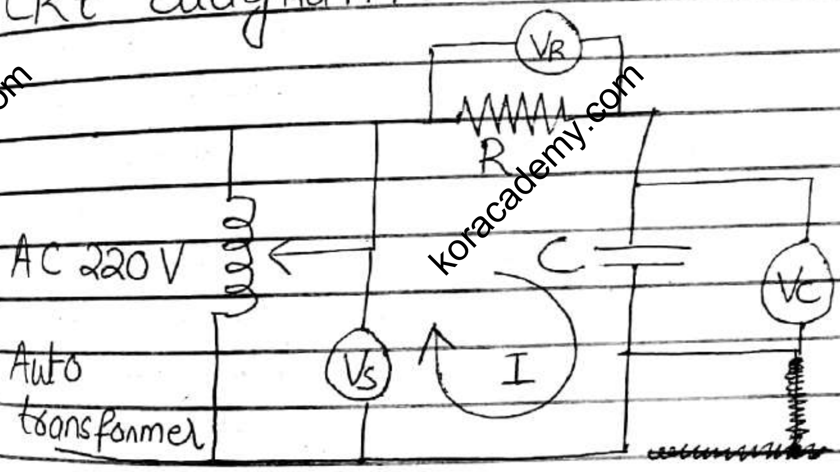
LAB # 01 :-

To find the unknown capacitance using three voltmeters Method

Apparatus:-

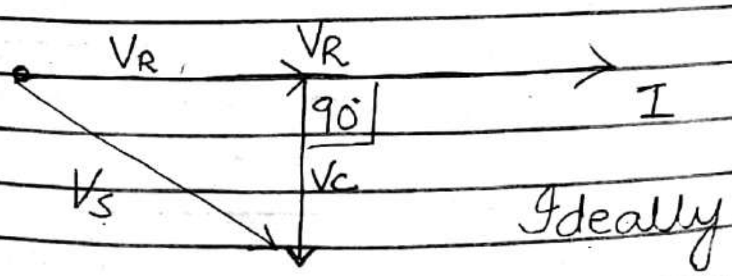
Auto transformer, rheostat, voltmeter capacitor and wires

Ckt diagram:-



Applying KVL

$V_S = V_R + V_C$ (Phasor sum)



Practically there will be some resistance of capacitor

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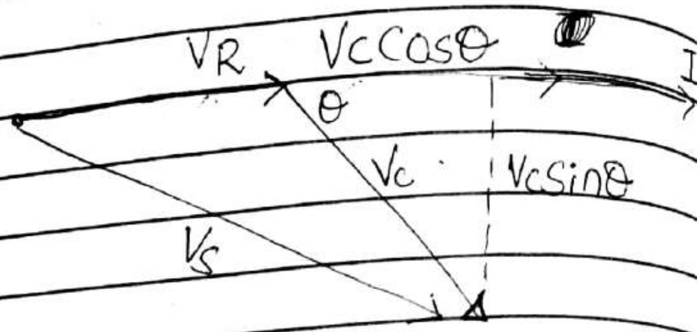

$$V_C \sin\theta = I \cdot X_C \quad \text{—— (A)}$$

$$V_R = I \cdot R \Rightarrow I = \frac{V_R}{R}$$

$$X_C = \frac{1}{\omega C}$$

$$V_C \sin\theta = \frac{V_R}{R} \cdot \frac{1}{2\pi f C}$$

$$C = \frac{V_R}{V_C \sin\theta \cdot R \cdot 2\pi f}$$

S.No	Vs	VR	Vc	C	θ	Error
1	100V	60V	40V		85°	

Scale :- 10V = 1cm

100V = 10cm

66V = 6cm

40V = 4cm

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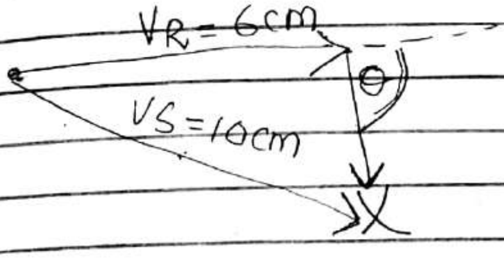
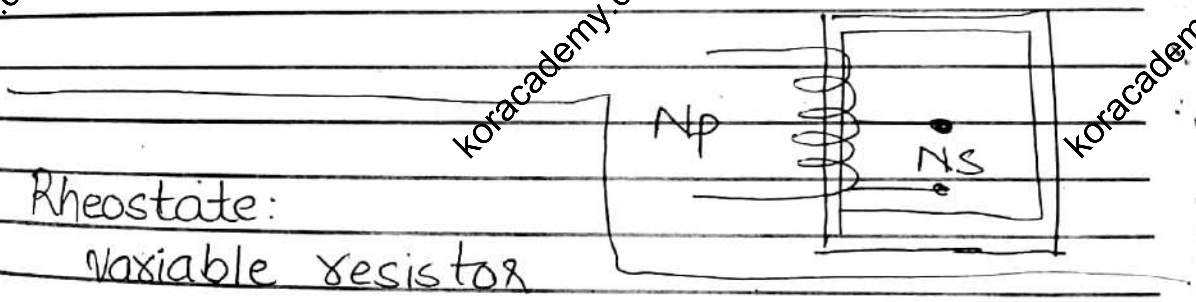


Auto transformer has one winding & a portion of which is use for primary & secondary. It can step Up and step down the given voltage.



Rheostate:

variable resistor

Error = Measured value − True value

Limiting Error or Relative Static Error:

$$\% L.E \text{ or } \% R.S.E = \frac{\text{Error}}{\text{True value}} \times 100$$

Accuracy = 100 − % L.E / R.S E

Date: 02/oct/2019 LECTURE # 2

If we take many readings from the same instruments and there is no change in reading so we called this instrument as precise.

Precision is composed of two characteristics:

1) Conformity

2) the number of significant figures to which a measurment may be made.

①	
2.0	
2.15	
2.157	
2.1578	→ significant figs

$$\text{Error} = x_m - x_T$$

Gross Error = Human Error.

Through proper training of operator gross error will reduce.

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Random Error: Random Error are those error due to unknown reasons.

100.00V
100.01V

We can reduce this error (Random Error) by taking multiple readings.

~~Statistical Error:-~~

Statistical Analysis:-

1) Arithmitic Mean:

$x_1, x_2, x_3, x_4, \ldots\ldots x_n.$

$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_4 \ldots\ldots + x_n}{n}$$

This may be the most probable value of the measured value.

2) Deviation from the mean:-

$$d_1 = x_1 - \bar{x} \quad , \quad d_2 = x_2 - \bar{x}$$

$$\vdots$$

$$d_n = x_n - x$$

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Exple: 2, 4, 3, 3, 2

$\bar{x} = 2.8$

$d_1 = -0.8$ $d_2 = 1.2$
$d_3 = 0.2$ $d_4 = 0.2$
$d_5 = -0.8$

3) Average Deviation :-

$$D = \frac{|d_1| + |d_2| + |d_3| + \cdots |d_n|}{n}$$

$D = 0.64$ → $+0.64$, -0.64

Sum of deviations will be zero. Therefore we take mode.

4) Standard Deviation:-

It is define as

RMS Deviation.

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + d_3^2 + \cdots + d_n^2}{n}}$$

$d_1 = x_1 - \mu$
$d_2 = x_2 - \mu$

⇓

Population SD

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + d_3^2 + \cdots d_n^2}{n-1}}$$

⇓

Sample S.D

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$d_1 = x_1 - \bar{x}$

$d_2 = x_2 - \bar{x}$

$\bar{x}$ = Estimating mean.

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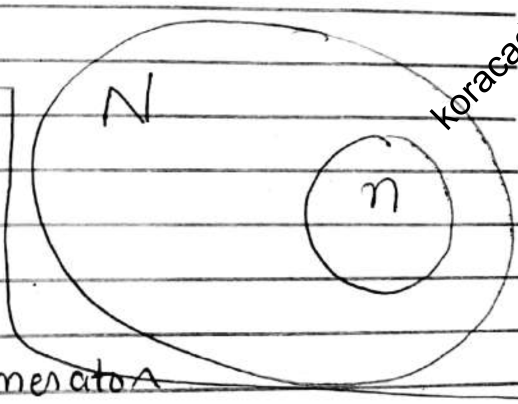
Parameter	Statistic
mean μ	$\bar{x}$
$\mu = \frac{\sum_{i=1}^{N} x_i}{N}$	$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$.

To measure height of Students of UET

→ To measure height of Each & everyone.

→ To measure heigh of 50 Students of every campus (sample)



① $(S) > (S)$

P.S.D numerator   S.SD numerator

therefore reduce denominator of one as $(S)_{P.SD} = (S)_{S.SD}$

② Degree of Freedom = n

Degree of Freedom = $n-1$

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$\mu = 7$

i	x_i	$d_i = x_i - \mu$
1	9	2
2	4	-3
3	?	?

$\bar{x} = 8$

i	x_i	$d_i = x_i - \bar{x}$
1	9	1
2	4	-4
3	? 11	? +3

→ Degree of freedom = n

We cannot insert any value.

$x_1, x_2, x_3, x_4, \ldots x_{1000}$

10.

It is not necessary mean of all population is 10.

→ Degree of freedom = n-1

02 Oct 2019.

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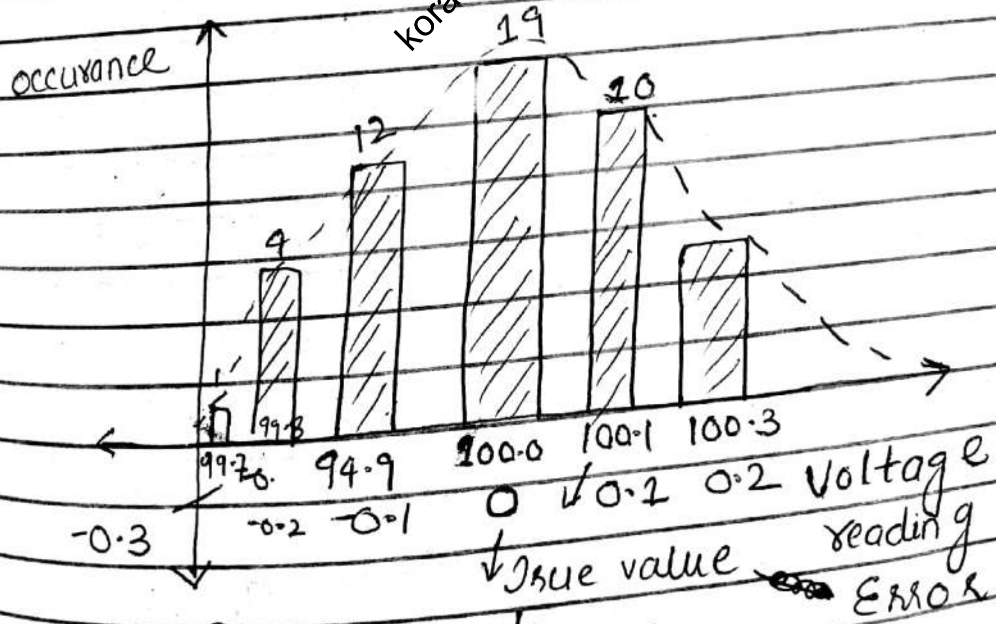
Probability of Error:

Normal Distribution of Error:-

Voltage Reading (V)	Number of Readings
99.7	1
99.8	4
99.9	12
100.0	19
100.1	10
100.2	3
100.3	1



Bar Graph
→ As it has spaces

When no spaces then called Histogram.

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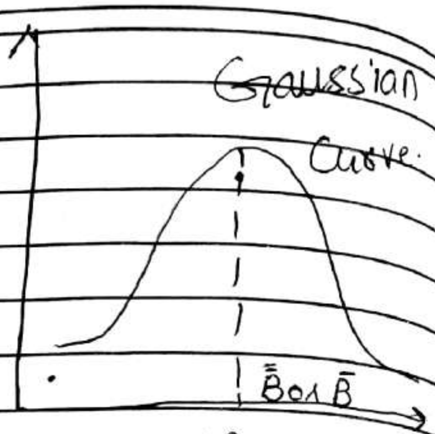

1) All observations include small disturbing Effect called random errors

2) Random Error can be +ve or -ve.

3) i There is an equal probability of +ve and -ve

Error Distributions:

i) Small Errors are more probable then large Errors

ii) Large Errors are very im-probable (probability is less)

iii) There is an equal probability of ~~+ve & -ve &~~ + and minus errors so that the probability of given error will be symmetrical about zero value.

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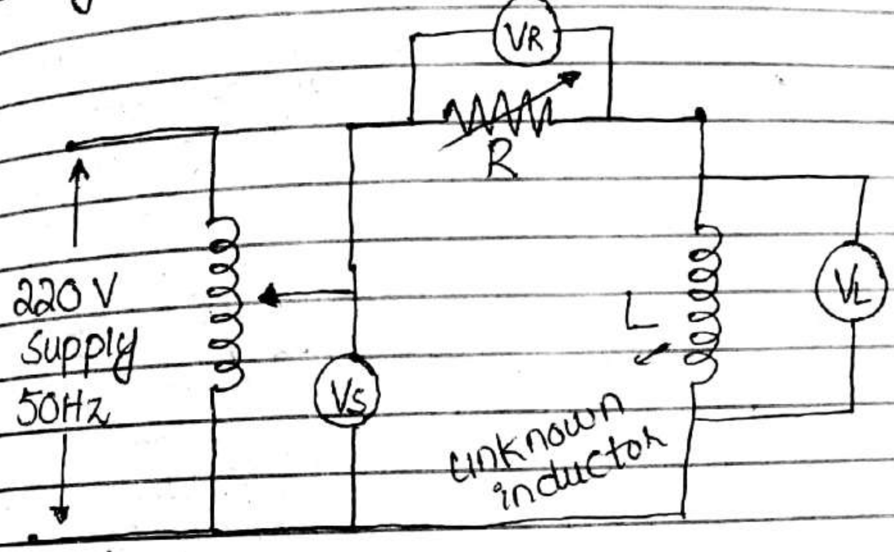
Experiment # 02 :-

To measure unknown inductance using three voltmeter method.



↓

Auto transformer (has only one winding)

In transformer frequency will not change. In transformer there will be phase shift of 180°. (at output)

$$E = -N\frac{d\phi}{dt}$$

The resistance of rheostat changes by

$$R = \frac{\rho L}{A} \Rightarrow \boxed{R \propto L}$$

$$\boxed{V_S = V_R + V_L} \rightarrow \text{phasor sum}$$

↓

Its magnitude will be

$$\boxed{V_S = \sqrt{V_R^2 + V_L^2}}$$

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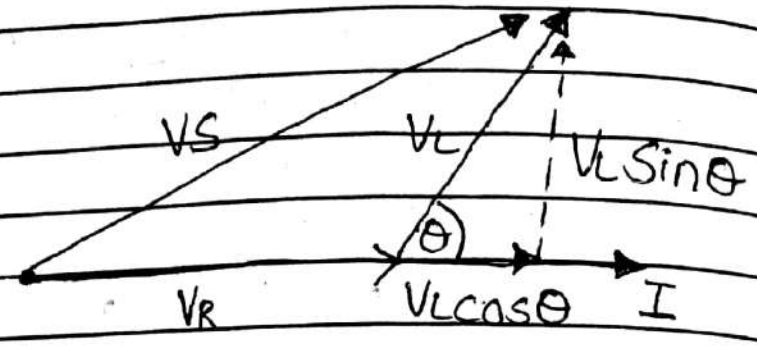
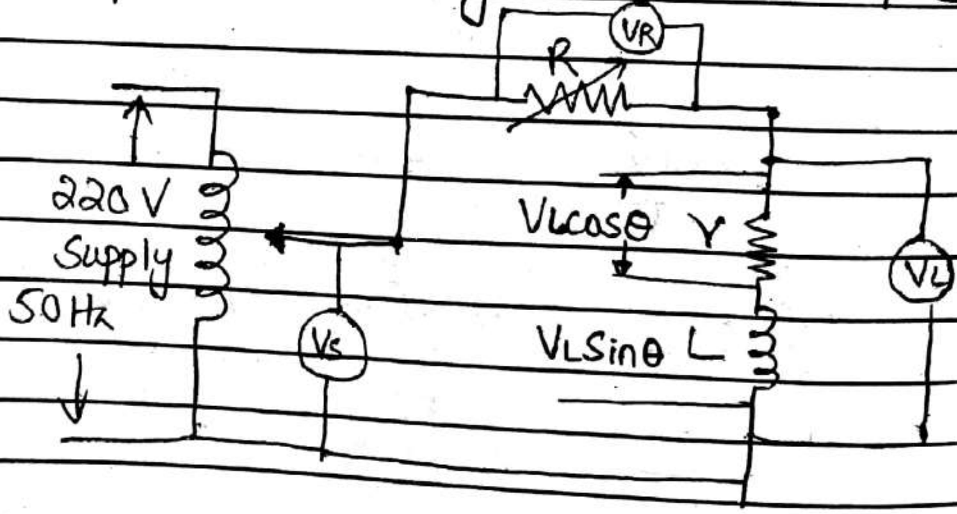


There will be some resistance of inductor so VL will lead behind the current by an angle of θ. In ideal case when we consider zero resistance of inductor so VL will lead behind current by an angle of 90°

Impedance only lie in 1st & 4th Quad



% Relative Static Error:-

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Inst A	Inst B
Error = 1A	10A

We cannot say which instrument is more accurate.

We can say which instrument is more accurate if we know relative Static Error.

$$\% RSE = \frac{Error}{True} \times 100$$

So true value is require to calculate % RSE.

A	B
True = 2A	True = 1000A
$\% RSE = \frac{1}{2} \times 100$	$\% RSE = \frac{10}{1000} \times 100$
$= 50\%$	$= 1\%$

Instrument B is more accurate.

$$V_L \sin\theta = I X_L$$

$$V_L \sin\theta = \frac{V_R}{R} \times 2\pi f L$$

$$L = \frac{V_L \sin\theta \cdot R}{2\pi f V_R}$$

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LAB # 03:- To learn some same useful ftns of calculator

Shift + 7

→ Then press number (no)

1 Constants

2) Table generation:-

3) Unit conversion:-

→ Shift + 8

$101F^\circ = 38.3^\circ c$

Table generation:-

$$f(x) = e^x + 2^x + 3x^2 + 5$$

$$x = 1 — 9$$

x	$f(x)$
1	12.718
2	28.389
3	
4	
5	
6	
7	
8	
9	

for $x \rightarrow$ alpha + $x \Rightarrow x$

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mode $\rightarrow$ 7 $\rightarrow$

Start = 1

End 9

Step size 1

→ Equation solving :-

$2x + 5y = 3$

$9x - 2y = -5$

$x = -0.387 \quad y = 0.755$

Mode → Eqn(5)

Quadratic Eqn:

Alpha calc

Mode 1 → $2^{2^x} = 1.2$

$x = ?$

] Mode 1

→ Shift + Calc] Solve command

Solve for x

~~0 and equal~~

$x = -2.9266.$

$e^{\frac{-\pi x}{\sqrt{1-x^2}}} = 0.8$

$x = ? \quad x = 0.070$

Newton Raphson give on solution & that solution to which our initial guess ~~in~~ is near.

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COMPLEX (Shift + 2)

$2\angle -45° = \sqrt{2} + \sqrt{2}\,i$

Shift(-)

MATRIX:

Shift + 4 to add data in B

$A = \begin{bmatrix} 2 & 3 \\ 2 & 5 \end{bmatrix}$, $B \begin{bmatrix} 1 & 2 \\ 2 & 3 \end{bmatrix}$

A+B =
AxB =
A^{-1} =

BASE-N

$(295)_{10} = (127)_{16}$

Mode 4 → Dec 295.

STAT: (Statistics)

Just we have to Enter data.

2, 3, 2, 5, 5, 4, 4.5, 2, 1, 3

Mode – 3

1. 1 – var
Then type ~~a~~ number
All clear (AC)

Sum

Date: __/__/__ $\Sigma x^2 =$ $\Sigma x =$

Variance - 4

$n \rightarrow$ no of entries

$\bar{x} \rightarrow$ mean

S.D [xS_n (population)] = 1.34257

[xS_{n-1} (Sample)] = 1.415915

x	f(x)
2	50
3	30
4.5	22
5	16
3.5	5

Shift → mode → State → freq ON

$\bar{x}$ = 3.047

S_n = 1.0958

S_{n-1} = 1.1005

We can find Eqn of line using calculator

If more than two points than calculator find Best fit line.

Mode → Stat

$(x, y) = (2, 5), (3, 7)$

$Y = A + Bx$

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$Y = 1 + 2x$

$R = 1$

~~R=1~~ mean best fit ~~0~~ curve.

$Y = 1$

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One meter is the lenght of path traveled by light in vaccum in time interval of $\frac{1}{299,792,458}$ sec.

299,792,458

2 hundred 99 million 7 hundred & 92 thousand 4 hundred & fifty eight.

Kilogram:

One kg of mass is the mass of ~~intert~~ international prototype of kg (platinium, Iridium cylinder kept at International Bureau of weights and measure near Paris.

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~~One Second~~

SECOND:-

One second is duration of

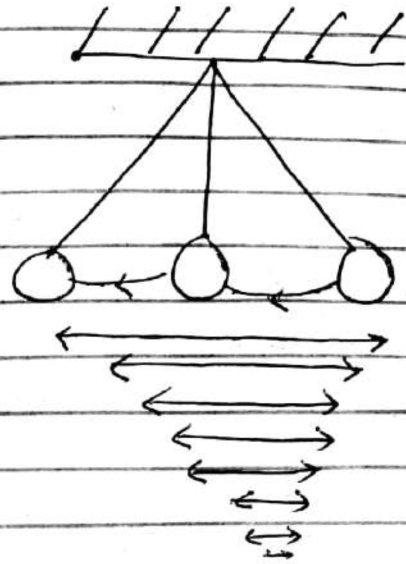
9,192,631,770

periods of radiations corresponding to transition between two hyperfine levels of ground state of Cs-133 atom!

Cesium clocks are the most accurate watches and clocks.

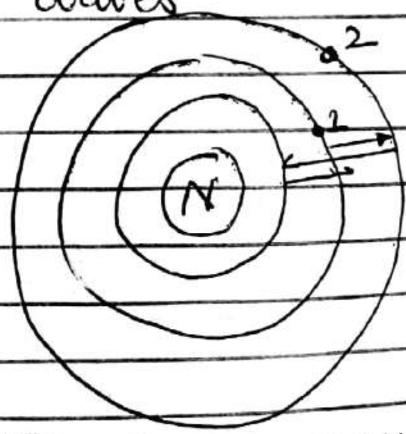
This definition was define in 1967.

-273.15°C is that temperature at which all the molecular motions in water ~~is~~ are ceased and this is equal to zero Kelvin.



Time period will remain same in each case because according speed will reduce.

Cesium will release energy in the form of Electromagnetic waves



we give energy to the electron of cesium atom & it vibrate about mean position

0.01°c is called as triple point

At this stage all three states of water exist

One Kelvin is deflection of thermodynamic temperature of triple point of water.

0.01°c ⟶ 273.16K

-273.15°c ⟶ 0K

Mole:

One mole is the amount of substance which contains as many elements particles as in 0.012kg of carbon.

Candela:

One candela is a luminious intensity of the source that emits monochromatic radiation of frequency

540×10^{12} Hz and that has radiant intensity in that direction of $\frac{1}{683}$ watts

540 × 10^{12} Hz → freq of red light

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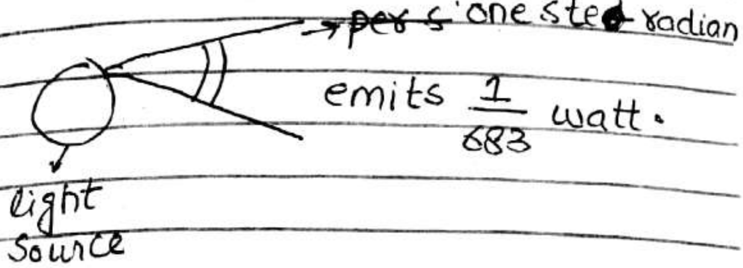
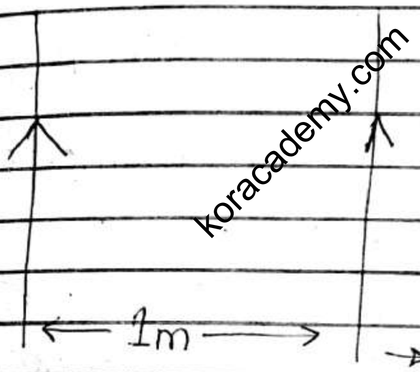
per ste-radian angle.



Ampere is the unit of electric current



→ Magnetic field will produce in Each wire

If current flows in same direction they will attract each other

Force b/w them is 2×10^{-7} N/m

Distance is 1m.

So the current is 1A

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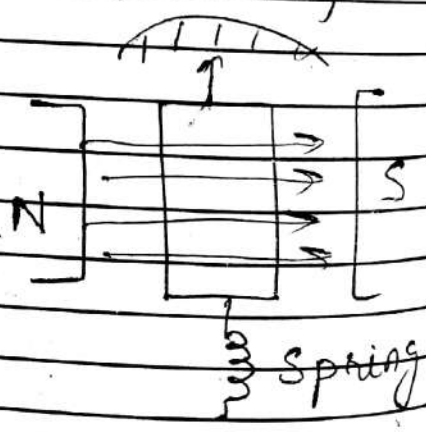
1A is that constant current which will maintained in two straight parallel conductors of infinite lenght, negligible cross-section and place one meter apart in vaccum would produce b/w them a force of $2\times10^{-7}\frac{N}{m}$ length

LECTURE NO 04

Oct 26, 2019

Moving coil Instruments

- Parmanent Magnet Moving coil (PMMC)
  - ↳ Deorsonoval measurment
  - Galwanometer principle
    - G
    - A
    - V
  - Suspension galwanometer
- Electric magnetic moving coil (EMMC)



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Two types of torques:

1) Deflection torque

2) Opposing torque (due to Spring)

Torque & Deflection of galvanometer:-

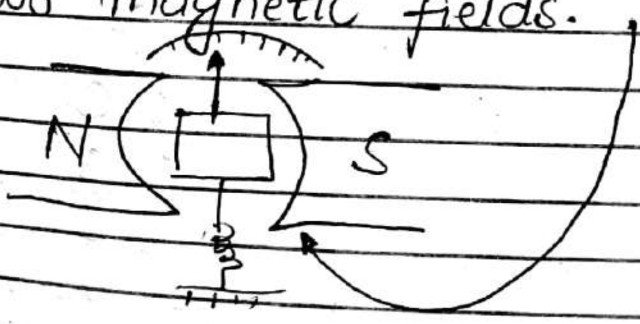
Steady State Deflection:-

The equation for the developed torque, derived from the basic laws for electromagnetic torque.

$T = B \times A \times I \times N$

$T = BINA\sin\theta$ → Angle b/w $\vec{B}$ & $\vec{I}$

We can to maximize the interaction of two magnetic fields.



We use concept of Radial magnetic field to maxime torque and make the angle b/w the A vector and the B 90 degree

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i-e making cylindrical magnet and cylindrical soft iron coil.

We use soft iron because it magnetizes easily.

Applied Torque = Restoring torque

or

$NAIB = C\phi$ for which $I \propto \phi$

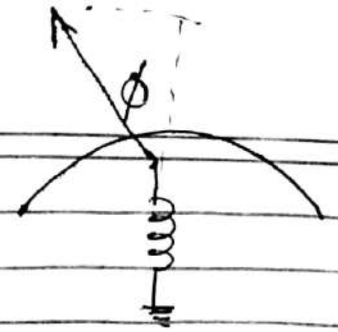
where C is torsional constant and is proportional to the angle of twist in spring ϕ (which is angle of twist in degree)

ϕ(deg)	C
1	1C
2	2C
3	3C

C → Depends on nature of spring.

Date: __/__/__

$I \propto \phi$



It depends on
B, N, A and C

Sensitivity of Galvanometer:-

$$\text{current sensitivity} = \frac{\phi}{I}$$

$$= \frac{\text{Deflection in Pointer}}{\text{change in current}}$$

So $NIAB = C\phi$

Which means
$$\boxed{\frac{\phi}{I} = \frac{NAB}{C}}$$

When we use it as a voltmeter

Voltage Sensitivity $\frac{\phi}{V}$ where $V = IR$

$$V = \frac{C\phi}{NABR}$$

So
$$\boxed{\frac{\phi}{V} = \frac{NAB}{CR}}$$

~~Hio~~ R → Resistance of high resistor connected in Series.

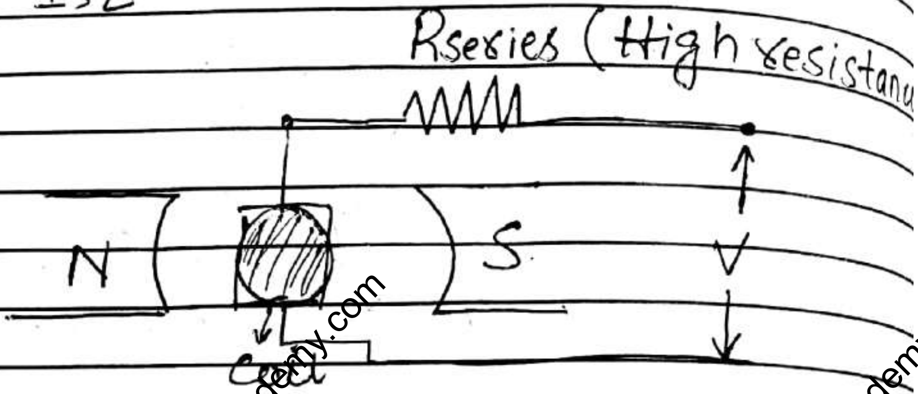
Bilal Register

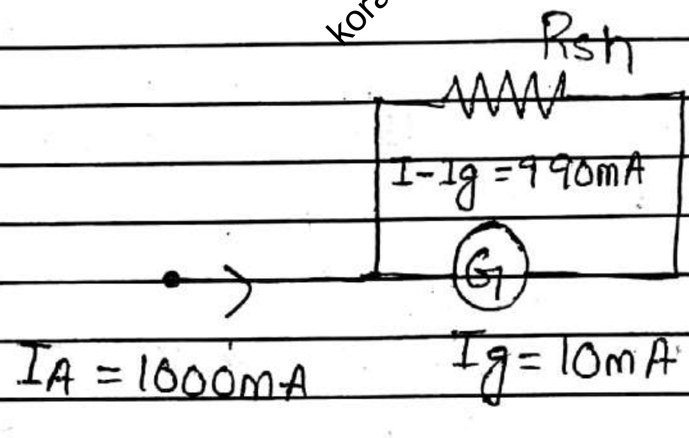
Date: __/__/__

Dynamic Behaviour :

damping constant (D) → affected by air / oil etc.

Resistance of winding is less the 1Ω

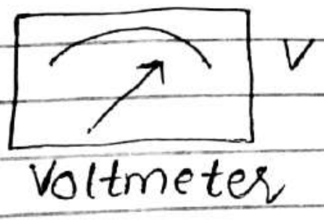




Date: __/__/__ Sir Farooq

1) Indicating type Instrument

Display



2) Recording type instrument

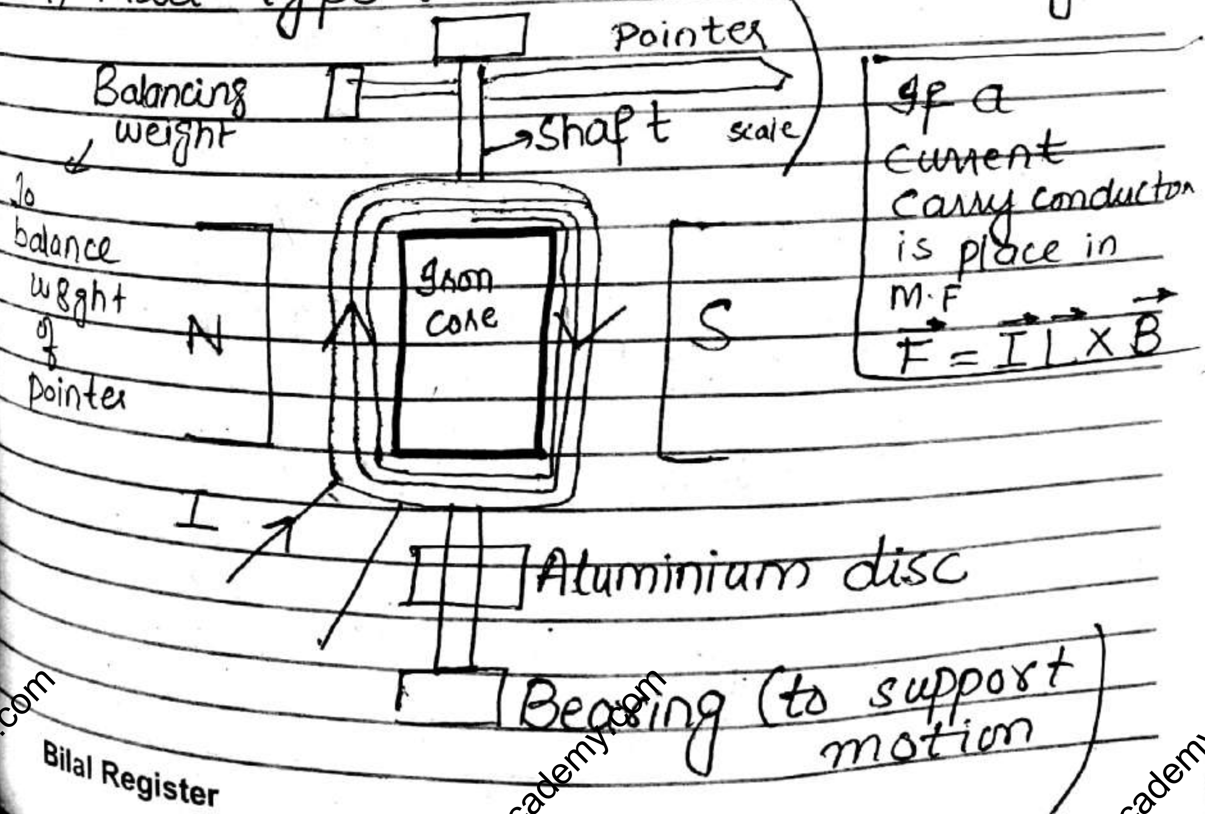
Display + Recording.

3) Integrating type instrument

Display + Recording + commulative addition

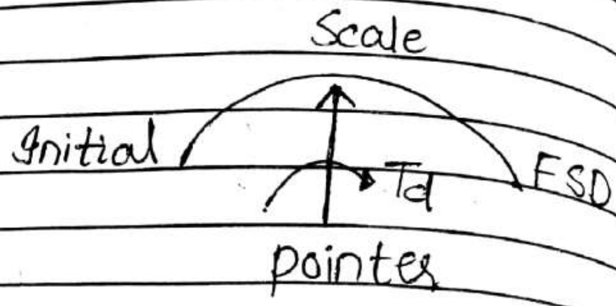
Eg: Energy meter. (964 → 965)

4) Null type : wheat stone bridge.



Date: __/__/__

Due to deflecting torque pointer start moving from initial point to full scale Deflection.



$T_d \propto I, \quad T_d \propto \phi \quad T_d \propto N$

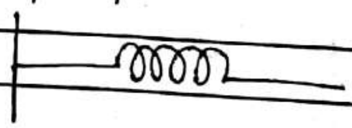
$T_d \propto NI\phi$

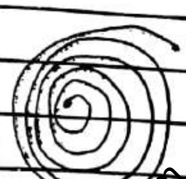
$T_d = BANI \Rightarrow \boxed{T_d \propto I}$

As current is continuously there so torque will be also there. To stop pointer at certain scale we need second torque i-e

2) Controling Torque (T_c)

We uses spiral spring for this purpose.

 $F = Kx$

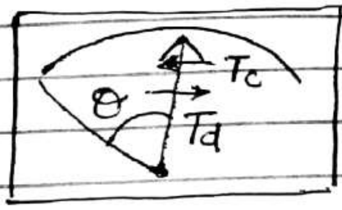
 $T = K\phi$.

Date: / /

The pointer will stop if both torques becomes equal.

$$T_c = K\theta$$

$$\boxed{T_d = T_c}$$

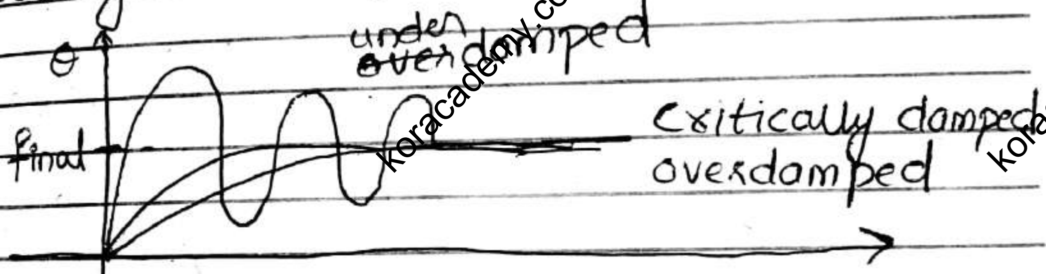


$$BANI = K\theta$$

$$\theta = \frac{BAN}{K} I$$

$$\theta = CI \Rightarrow \quad \boxed{\theta \propto I}$$

∴ Scaling is uniform



③ Damping Torque (T_{damp})

→ Aluminium disc
↓
Magnetic field linked due to vibration
↓
According to Lenz's law opposite its cause
↓
Eddy current will flow in Aluminium disc.

Date: __/__/__

Temperature Control:-

Two problems due to temperature

$$R_t = R_0 (1 + \alpha \Delta T)$$

α = +ve for metals

$R \propto T$

Metals have positive temperature Co-efficient

If $T \uparrow$

$R_t > R_0$

Semi-conductor has -ve temperature Co-efficient

If $T \uparrow$

$R_t < R_0$ $\boxed{\alpha = -ve}$

Mangenin (Mn) $\Rightarrow$ $\boxed{\alpha = 0}$

No effect of temperature on resistance.

As coil is of copper

If $T \uparrow$ $R \uparrow$

Value of current will reduce

Galvanometer will read low (due to temperature increase).

Bilal Register

Date: __/__/__

2) Due to T↑ softness of spring will increase.

Galvanometer will read high.

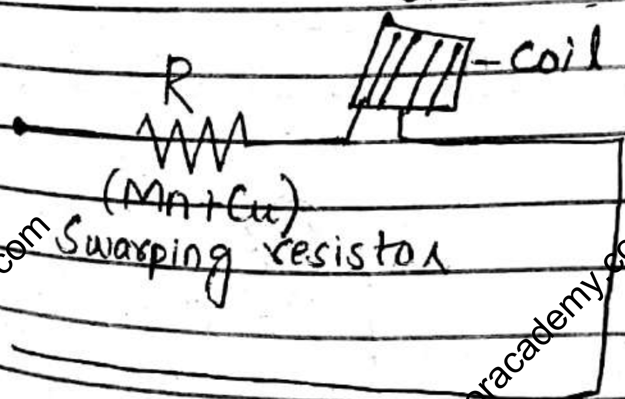
1st effect is more than 2nd one. Galvanometer will read low.

Temperature Compensating:-

If two effects becomes equal.

To overcome the first effect we connect a resistor in series with the coil, made up of (Mn + Cu). The resistor is called swarping resistor.

Mn — Cu
20 : 1 or 30 : 1



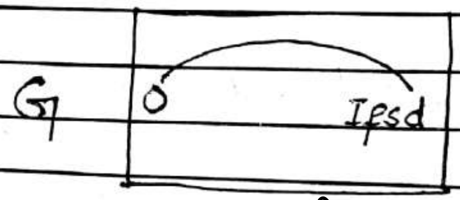
Date: __/__/__

DC AMMETERS:

Galvanometer are use for sensing current.

Conversion of galvanometer to ammeter:-

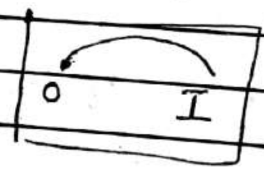
Galvanometer 0 to I_{fsd}

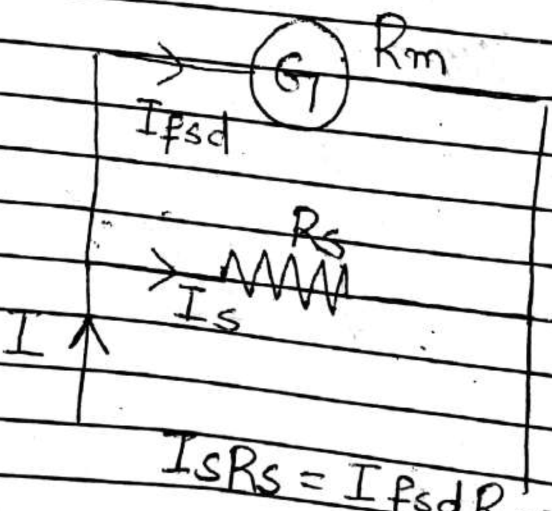


⇓

A) 0 to I

Ammeter





R_s

$R_s \propto \frac{1}{\text{Range of Ameter}}$

$I_s R_s = I_{fsd} R_m$

$$R_s = \frac{I_{fsd} R_m}{I - I_{fsd}}$$

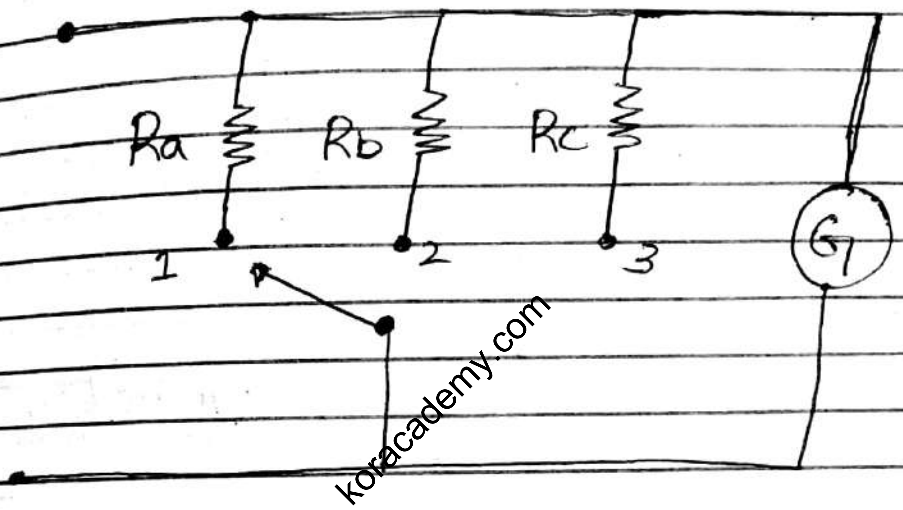
Bilal Register

Date: __/__/__ Example :-

I_{fsd} = 1mA
R_m = 100Ω
I = 100mA

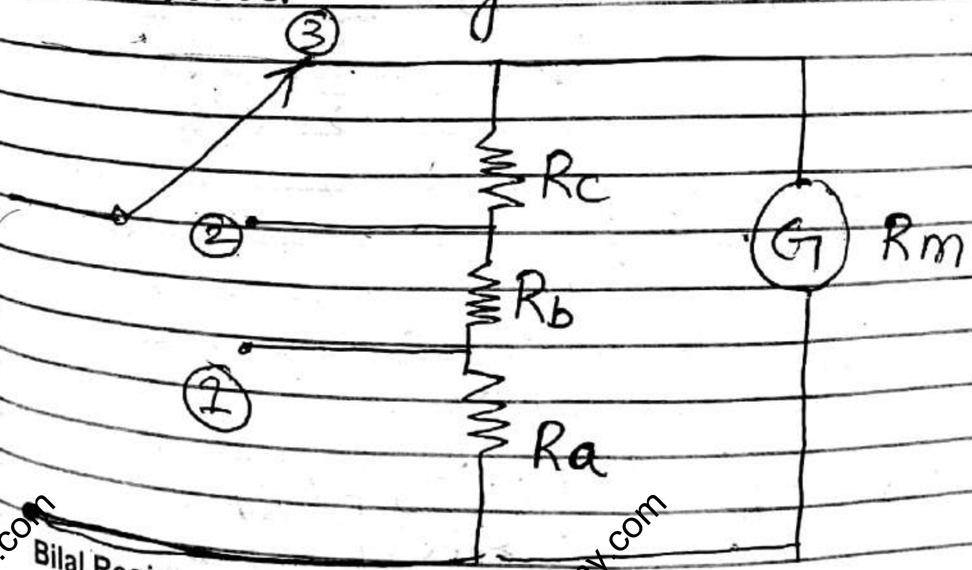
R_s = 1.01Ω

Multi-range Ameter :



Limitation: If switch is in between 1 & 2 alot of current can flow through galvanometer & it can damage galvanometer.

Universal on Ayrton Shunt :



Date: __/__/__

Exple 4.2

we need three ranges
1A, 5A and 10A

Internal resistance of galvanometer is 50Ω

$$I_{fsd} = 1mA$$

Find R_A R_B and R_C.

As $R_s \propto \frac{1}{\text{Range of Ammeter}}$

so At point 3:

$$I = 1A, \quad R_m = 50\Omega$$
$$R_s = R_a + R_b + R_c$$

$$R_a + R_b + R_c = \frac{1 \times 50}{1000 - 1}$$

$$R_a + R_b + R_c = 0.05005 \quad \text{--- (a)}$$

At point 2:

$$I = 5A$$
$$R_m = 50 + R_c$$
$$R_s = R_a + R_b$$

$$R_a + R_b = \frac{1 \times (50 + R_c)}{5000 - 1}$$

Bilal Register

Date: __/__/__

$Ra + Rb - 0.00220004\,Rc = 0.010002$ — (b)

At point-3

$I = 10A$

$Rm = 50 + Rb + Rc$

$Rs = Ra$

$$Ra = \frac{1 \times (50 + Rb + Rc)}{10{,}000 - 1}$$

~~$Ra = 0.00010001$~~

$Ra + Rb - 0.00020004\,Rc = 0.010002$

$Ra - 0.00010001\,Rb - 0.00010001\,Rc = 0.0050005$

Bilal Register

Date: __/__/__ Oct 22; 2019

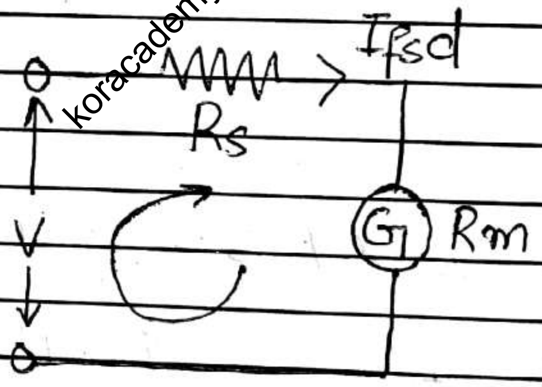
LECTURE

DC VOLTMETER:

(G) 0 to I_{fsd}

(V) 0 to V volts

Conversion of galvanometer to voltmeter



voltmeter

If we apply V volts then Galvanometer has to give full scale deflection & G give full scale deflection if I_{fsd} current pass through it

Applying KVL

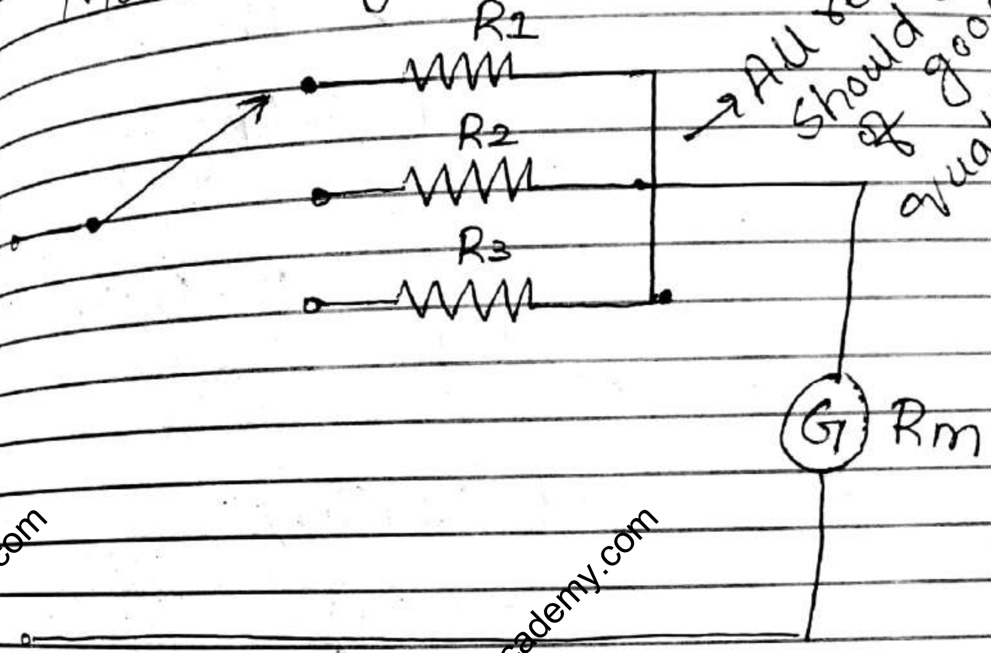
$$V = I_{fsd}(R_m + R_s)$$

$$\frac{V}{I_{fsd}} = R_m + R_s$$

Date: __/__/__

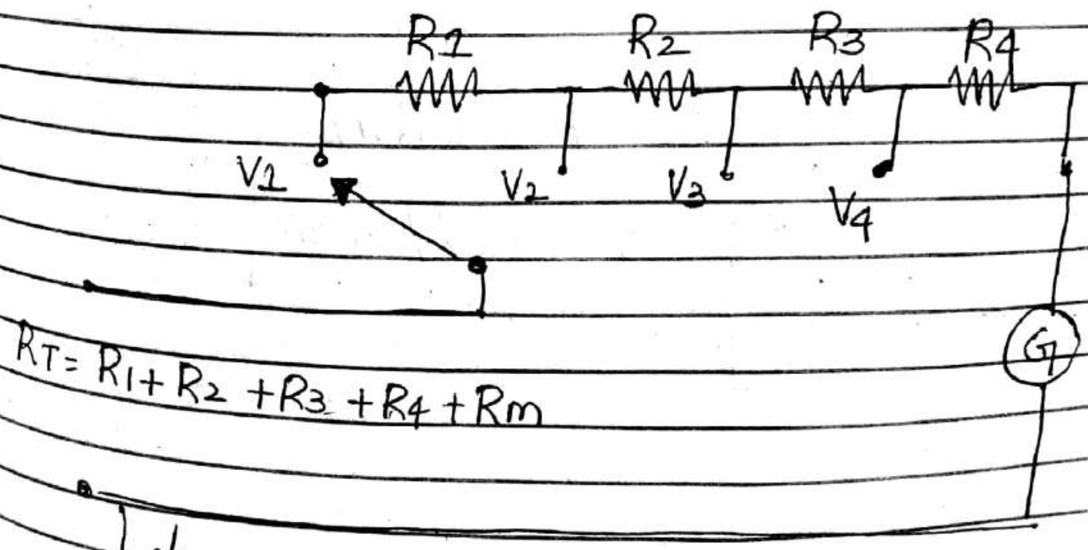
$$R_s = \frac{V}{I_{fsd}} - R_m$$

Multi-Range Voltmeter



All resistors should be good quality

More practical solution



$R_T = R_1 + R_2 + R_3 + R_4 + R_m$

→ R4 should be standard & of high quality.

→ less Expensive.

Date: __/__/__

Exple 4.3:

Voltmeter Sensitivity:-

It is define as "Ohms per volt rating of voltmeter."

$$\boxed{S = \frac{R_T}{V_{fsd}}}$$

$R_T = R_s + R_m$

$V_{fsd} = I_{fsd}(R_s + R_m)$

$V_{fsd} = I_{fsd}(R_T)$

$$S = \frac{R_T}{V_{fsd}} = \frac{1}{I_{fsd}}$$

$S \times V = R_s + R_m$

$$\boxed{R_s = (S \times V) - R_m}$$

Exple 4.4

Date: _/_/_

LOADING EFFECT:-

Current carrying capacity ~~load~~ is known as load.

Load ↑ I ↑ P ↑ R ↓

Higher load means low resistance.

Voltmeter has loading effect because we connect voltmeter in parallel. The equivalent resistance will decrease, the load will increase, ckt will then draw more current.

If two fans are connected in parallel the equivalent resistance will decrease

100W R↑

200W R↓

100W

200W

In parallel 200W will glow more

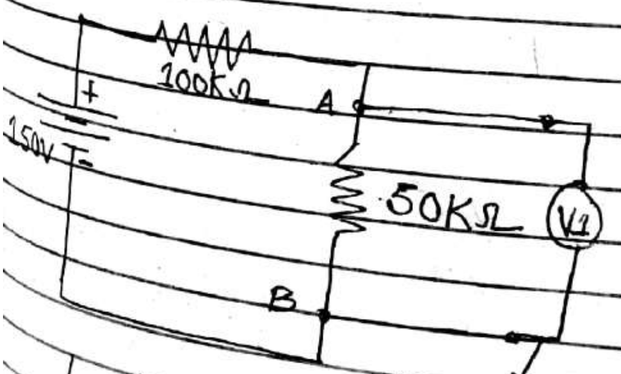
$P = \frac{V^2}{R}$ V = constant

In series 100W will glow more

$P = I^2 R$

I = constant

Example 4.5:-



Loading Effect ← Resistance will now decrease b/w A & B

Date: __/__/__

V_1 has full scale deflection = 50V

V_2 " " " " = 50V

$(V_1) \longrightarrow S_1 = 1000 \frac{\Omega}{V}$

$(V_2) \rightarrow S_2 = 20,000 \frac{\Omega}{V}$

$$V_T = \frac{50K\Omega}{100K+50K} \times 150$$

$$\boxed{V_T = 50 \text{ volts}}$$

If we connect voltmeter no 1:-

$$R_1 = S_1 \times V_{fsd}$$

$$R_1 = 1000 \times 50$$

$$\boxed{R_1 = 50K\Omega}$$

$$R_{AB} = 50K // 50K$$

$$\boxed{R_{AB} = 25K\Omega}$$

$$V_1 = 150 \times \frac{25}{100+25}$$

$$\boxed{V_1 = 30V}$$

Bilal Register

Date: _/_/_

Percentage Error = $\frac{50 - 30}{50} \times 100$

$= \frac{20}{50} \times 100$

$= 40\%$ Due to loading Effect.

If we connect Voltmeter no 2

$R_2 = S_2 \times V_{fsd}$

$= 20,000 \times 50$

$R_2 = 1,000,000$

$\boxed{R_2 = 1M\Omega}$

In ammeter no loading Effect

$R_{AB} = 1M\Omega // 50K\Omega$

$R_{AB} = 47.6K\Omega$

$V_2 = \frac{150 \times 47.6}{100 + 47.6}$

$\boxed{V_2 = 48.36V}$

Percentage Error = $\frac{50 - 48.36}{50} \times 100$

$= 3.28\%$ the Error has reduce significantly

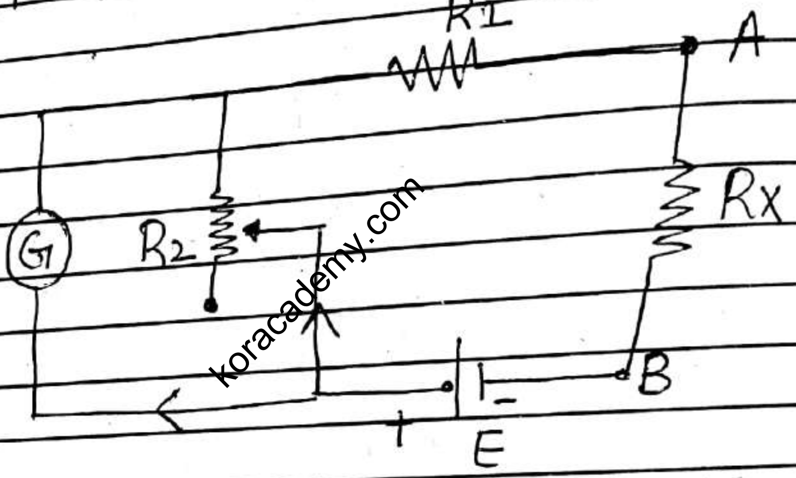
Date: __/__/__

If ckt contains lower resistances so then use V1

If ckt contains higher resistance so then use V2.

SERIES TYPE OHMMETER:-

→ SERIES TYPE OHMMETER
→ SHUNT TYPE OHMM



It can be made from galvanometer

E → voltage of internal battery

Rm → Internal resistance of galvanometer

R1 → Current limiting resistor

R2 → zero adjust resistor.

Rx → unknown resistor b/w point A & B.

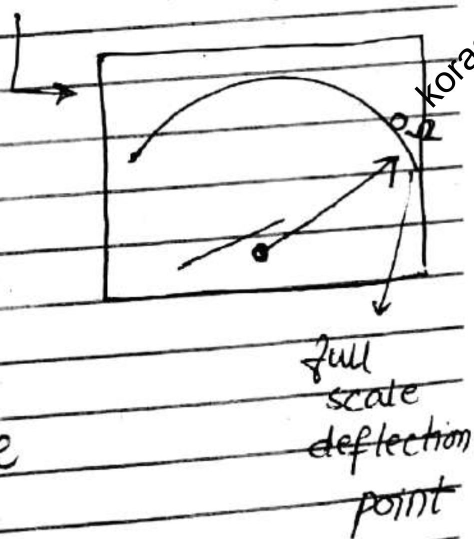
Date: __/__/__

we need to calibrate the galvanometer in terms of ohms. (to measure resistance of Rx)

CASES:-

1) $R_x = 0\Omega$ (Battery will provide maximum current)

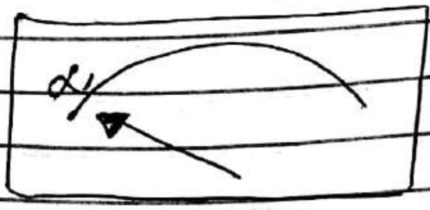
Adjust R_2 such that the galvanometer give full scale deflection. (I_{fsd})
Means we will increase R_2 till galvanometer give full scale deflection.



2) $R_x = \alpha$

From Pt A & B remove Rx

Galvanometer will give zero deflection as ckt is open.



Scale will be non-uniform.
→ linear (uniform)

uniform

non-uniform.

Date: __/__/__

The scale will be non uniform.

To calibrate the middle points there are different methods.

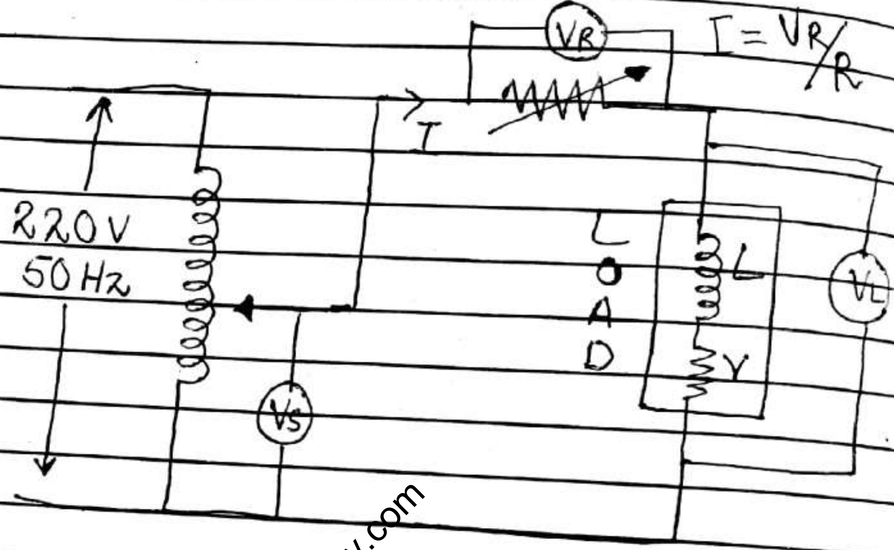
Take standard resistor whose R is known and see deflection of galvanometer & calibrate scale accordingly. (connecting them one by one)

Whenever we use series type ohm meter then first of all short A and B & adjust R_2 ~~to give~~ so that galvanometer give full scale deflection. (Becoz battery voltage will reduce w.r.t time)

Date: __/__/__

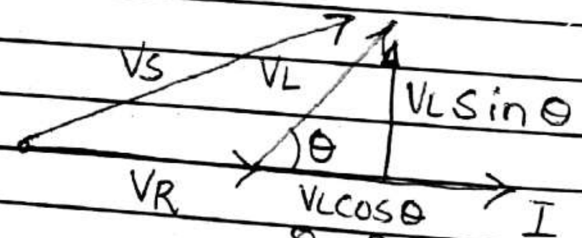
LAB #04:-

To measure the single phase power using three voltmeter method.



$$V_S = V_R + V_L$$

P.f = $\frac{P}{S}$



θ = Power factor angle.

$$V_S^2 = V_L^2\sin^2\theta + (V_R + V_L\cos\theta)^2$$

$$V_S^2 = V_L^2\sin^2\theta + V_R^2 + V_L^2\cos^2\theta + 2V_RV_L\cos\theta$$

$$V_S^2 = V_L^2(\sin^2\theta + \cos^2\theta) + V_R^2 + 2V_RV_L\cos\theta$$

$$V_S^2 - V_L^2 - V_R^2 = 2V_RV_L\cos\theta$$

Date: __/__/__

AC 3-ph → Rectifier → DC → Inverter → AC → Induction motor

$N_s = \frac{120f}{P}$

$$\cos\theta = \frac{V_s^2 - V_L^2 - V_R^2}{2 V_R V_L}$$ Power factor of the load

$$P = V_L I \cos\theta$$

$$P = V_L \left(\frac{V_R}{R}\right)\left[\frac{V_s^2 - V_L^2 - V_R^2}{2 V_R V_L}\right]$$

$$P = \frac{V_s^2 - V_L^2 - V_R^2}{2R}$$

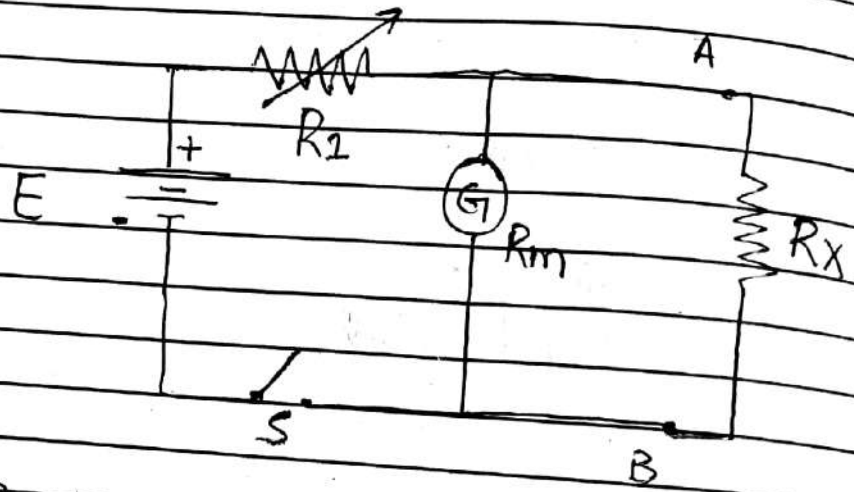
S.No	V_s	V_R	V_L	R	P
1	20.9	16.5	4.2	200 Ω	
	30	23.72	5.7		
	40	32.85	7.74		
	50.54	40.69	9.39	200	

P = 750 watt

Date: __/__/__

LECTURE

SHUNT TYPE OHMMETER:



$R_1 \Rightarrow$ Current limiting resistor

$R_m \Rightarrow$ Internal resistance of ameter

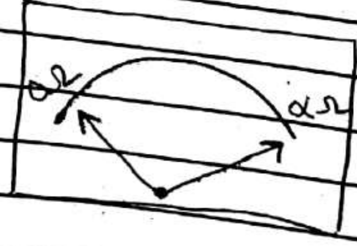
$R_x \Rightarrow$ unknown resistance

Cases:

1) $R_x = 0\Omega$ (Short circuit

No Deflection

$R_x = 0\Omega$

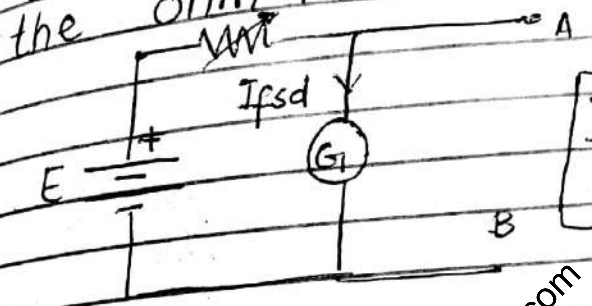


Date: _/_/_

$R_x = \infty\,\Omega$ (open ckt)

2) We will adjust $R_1 (\downarrow)$ such that galvanometer gives full scale deflection.

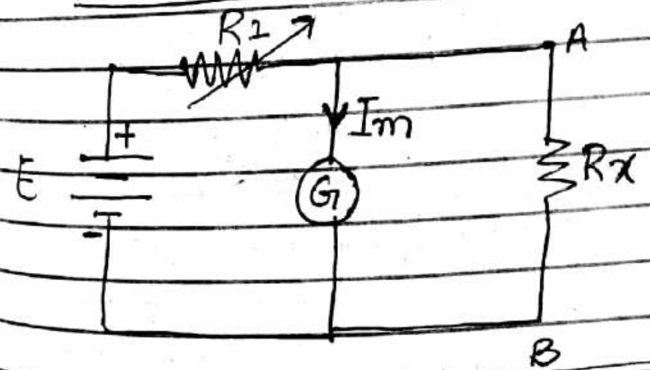
Then we will take known resistances and calibrate the ohm-meter



$$I_{fsd} = \frac{E}{R_1 + R_m} \quad \text{--- (1)}$$

$$I_{fsd} R_1 + I_{fsd} R_m = E$$

$$R_1 = \frac{E}{I_{fsd}} - R_m \quad \text{--- (2)}$$



$$I = \frac{E}{R_1 + R_m // R_x} \quad \text{--- (3)}$$

$$I_m = I \times \frac{R_x}{R_m + R_x}$$

Date: __/__/__

$$I_m = \frac{E}{R_2 + \frac{R_m R_x}{R_m + R_x}} \times \frac{R_x}{R_m + R_x}$$

$$I_m = \frac{E R_x}{R_1 R_m + R_2 R_x + R_m R_x} \quad \text{--- (4)}$$

÷ing eq (4) by eq (1)

$$\frac{I_m}{I_{fsd}} = \frac{E R_x}{R_1 R_m + R_1 R_x + R_m R_x} \times \frac{R_2 + R_m}{E}$$

$$\frac{I_m}{I_{fsd}} = \frac{R_x (R_2 + R_m)}{R_x (R_2 + R_m) + R_2 R_m}$$

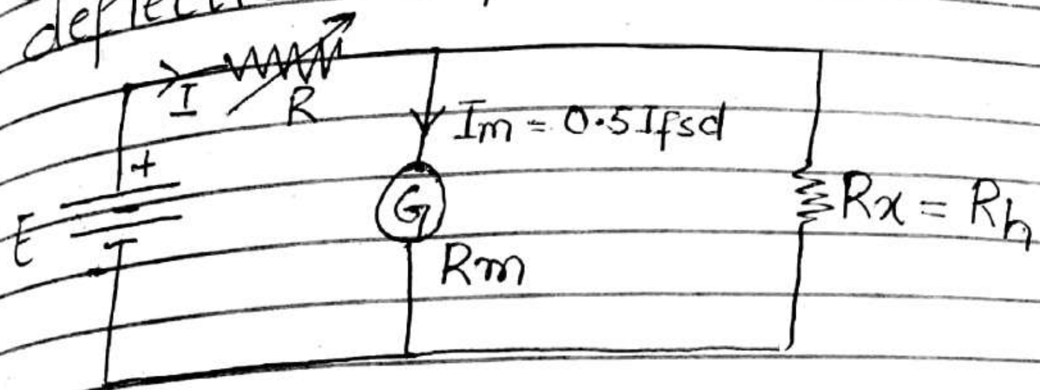
$$\frac{I_m}{I_{fsd}} = \frac{R_x}{R_x + \frac{R_1 R_m}{R_2 + R_m}}$$

$$\boxed{\frac{I_m}{I_{fsd}} = \frac{R_x}{R_x + R_p}} \quad \text{--- (5)}$$

The scale will be non uniform as relation b/w I_m & R_x is non linear.

Date: __/__/__

We can differentiate two ohm-meter by half scale deflection point.



$$R_x = R_h$$

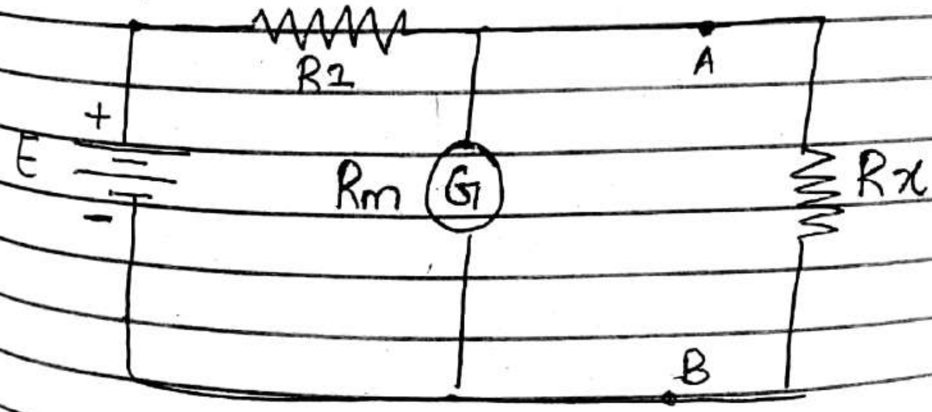
$$I_m = 0.5 I_{fsd}$$

$$\frac{0.5 I_{fsd}}{I_{fsd}} = \frac{R_h}{R_h + R_p}$$

$$R_h = R_p = \frac{R_m R_1}{R_m + R_1}$$

Rh is Equal to internal resistance of galvanometer

Example 4.8 (Imp)



$$I_{fsd} = 10mA$$

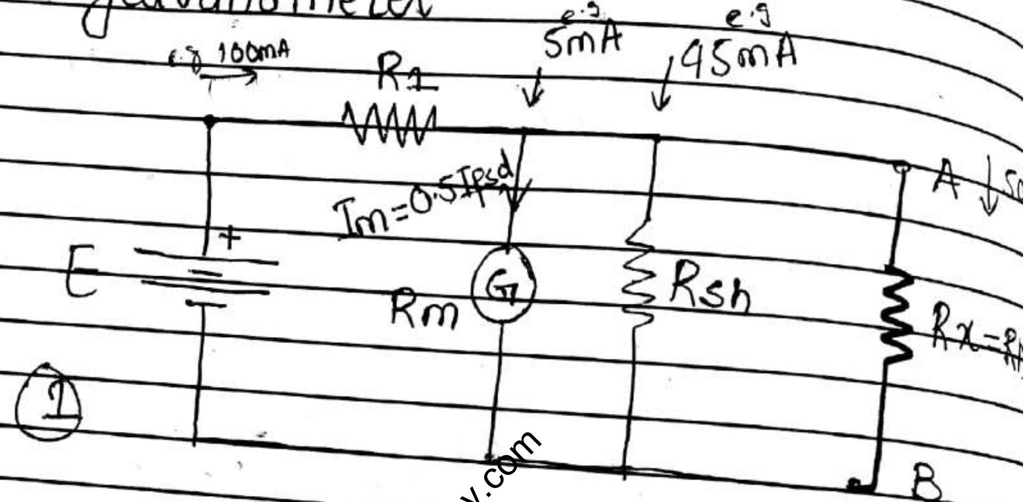
$$R_m = 5\Omega$$

$$E = 3V$$

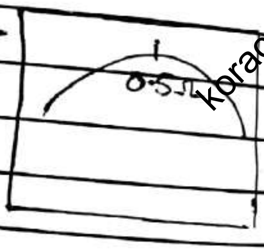
Date: __/__/__

$R_1 > R_m$

Q) want to modify ckt by connecting shunt resistance parallel to Galvanometer



$R_h = 0.5\Omega$ ←



Find

a) $R_{sh} = ?$ b) $R_1 = ?$

a) $R_{sh} = ?$

$R_x = R_h$

$I_m = 0.5 I_{fsd}$

$= 0.5 \times 10$

$I_m = 5mA$

$E_m = I_m R_m$

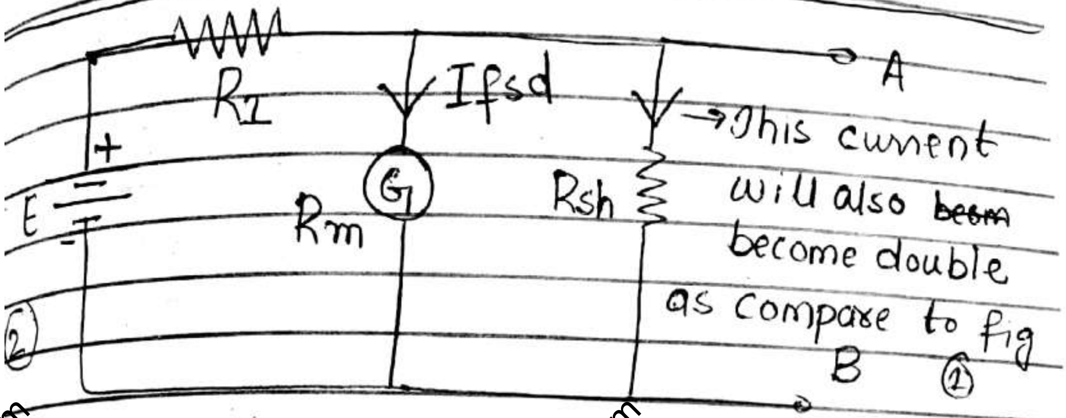
$= 5 \times 5$

$E = 25mv$

Bilal Register

$$I_x = \frac{E_m}{R_n} = \frac{25}{0.5}$$

$$\boxed{I_x = 50mA}$$



Current will be same in ① & ② (almost constant)
Battery is providing almost same current.

In fig ① due to Rn the meter current become half.

100mA	10mA	90mA

e.g

$$I_x = I_m + I_{sh}$$

$$I_{sh} = I_x - I_m$$

$$I_{sh} = 50 - 5$$

$$\boxed{I_{sh} = 45mA}$$

Date: __/__/__

$$R_{sh} = \frac{E_m}{I_{sh}} = \frac{25}{45}$$

$$\boxed{R_{sh} = \frac{5}{9}\,\Omega}$$

Part B)

Find R_1?

$$I = I_m + I_{sh} + I_x$$

$$I = 5 + 45 + 50$$

$$\boxed{I = 100\,mA}$$

$$E = E_1 + E_m$$

$$E_1 = E - E_m$$

$$= 3 - 25 \times 10^{-3}$$

$$E_1 = 2.975\,V$$

$$E_1 = I R_1$$

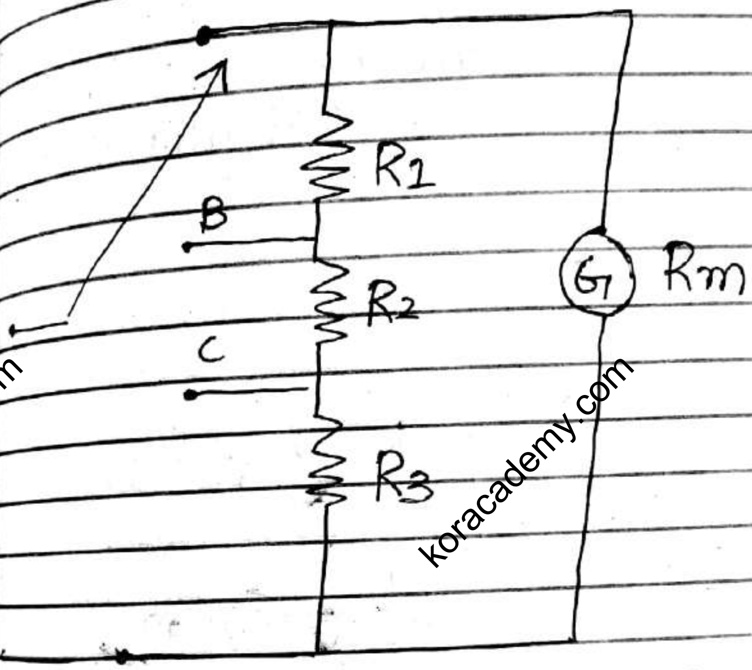
$$R_1 = \frac{E_1}{I_1} = \frac{2.975}{100 \times 10^{-3}}$$

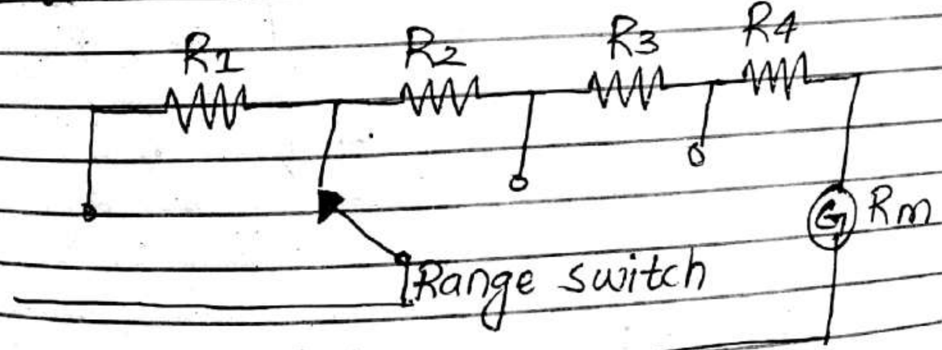
$$\boxed{R_1 = 29.75\,\Omega}$$

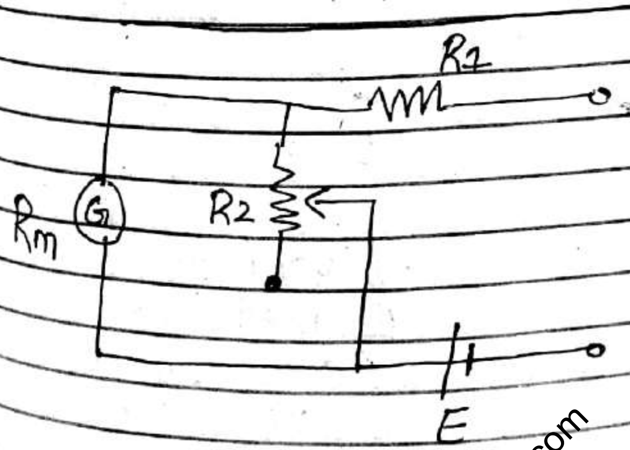
Date: __/__/__

Multimeter or VOM:

VOM (volt, ohm, milliamp)







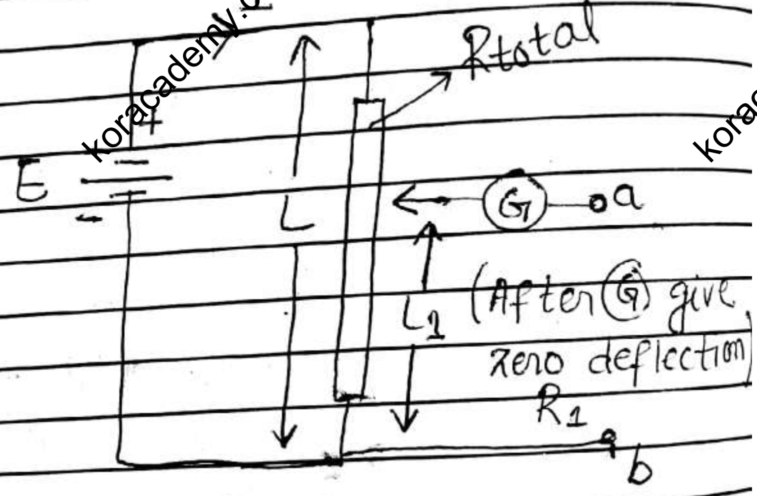
Date: __/__/__

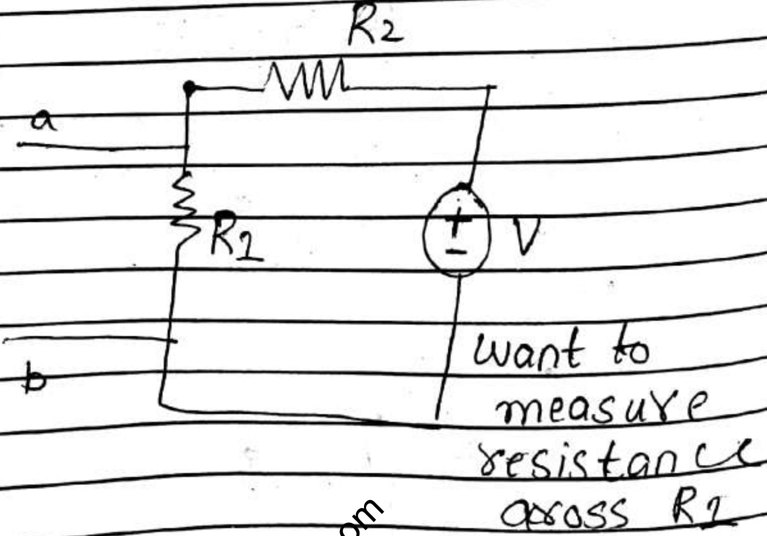
Calibration Of DC Instrument:-

If we want to calibrate ammeter.

One of the instrument use for calibration is potentiometer.

POTENTIOMETER:-





Date: __/__/__

We have to slide (G) across the resistive wire such that galvanometer give zero potential

⇒ voltage across galvanometer is zero

$R_{total} = \frac{SL}{A}$, $R_1 = \frac{SL_1}{A}$

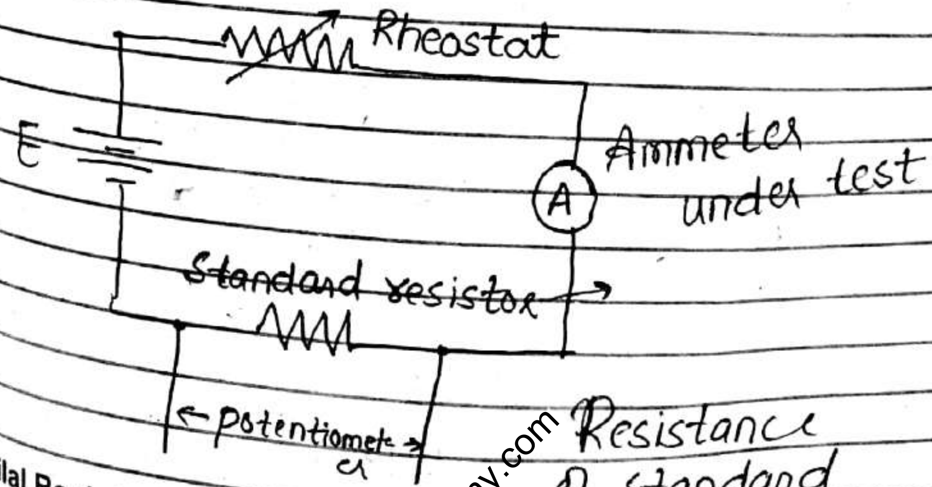
$E = IR_{total}$, $E_1 = IR_1$

$E = I\frac{SL}{A}$, $E_1 = I\frac{SL_1}{A}$

$$\frac{E_1}{E} = \frac{L_1}{L}$$

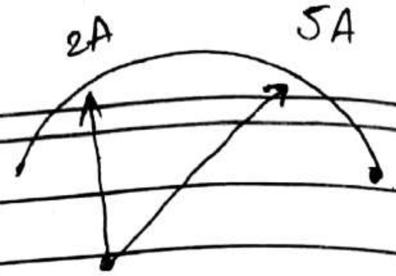
$$\boxed{E_1 = \frac{L_1}{L} \cdot E}$$

Calibration of DC Ammeter:-



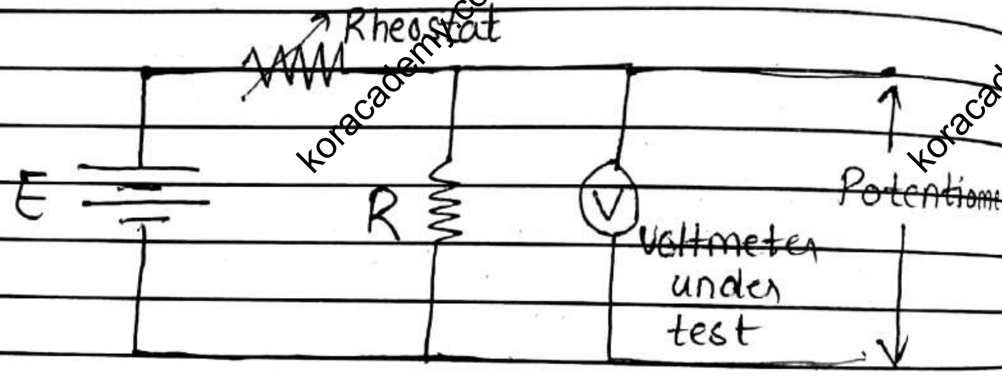
Resistance of standard resistor is known.

Date: __/__/__



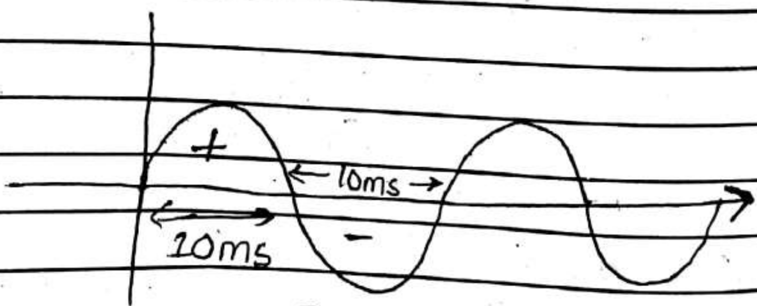
Potentiometer will give voltage across standard resistor. Resistance of standard resistor is known. We will divide $\frac{V}{R}$ ⇒ give current in the ckt (i-e ammeter)

Calibration of Voltmeter:-



Alternating Current indicating instrument:

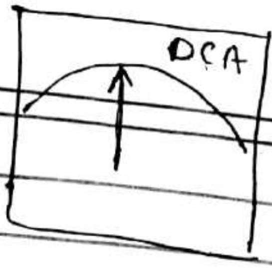
$\tau \propto I$



$f = 50Hz$

$T = 20ms$

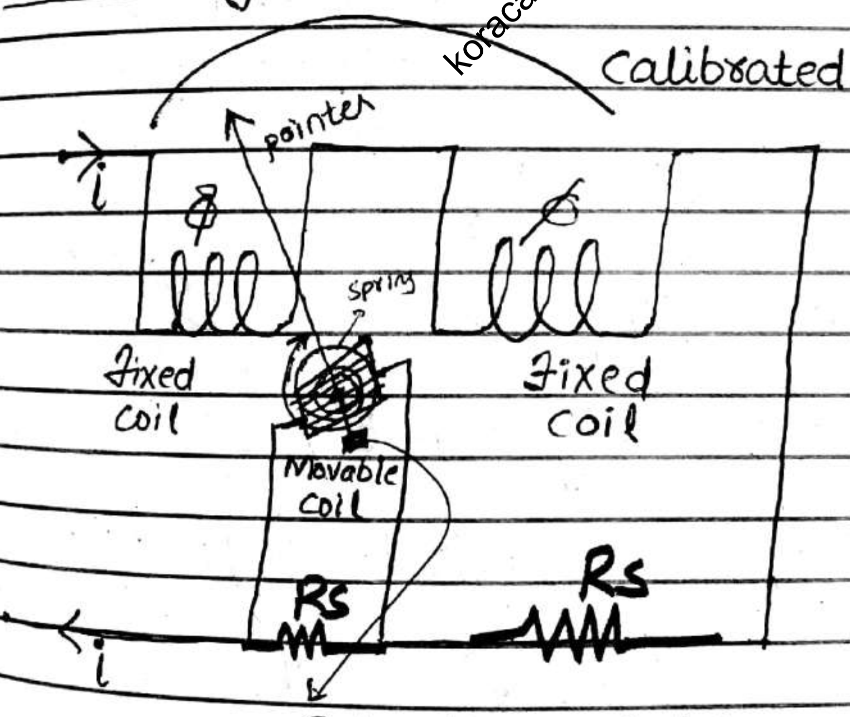
Date: __/__/__



Electrodynamometer:

Can measure AC voltage
can design instrument to
measure power and current.
(It can measure DC as well)X
Transfer Instrument:- (also Electrodynamometer called T.I.
Use only for power line
frequency (use for low
range frequency.

Electrodynamometer movement:-



When I flows fixed coil so flux
produce in fixed coil.
Flux is linked with movable
Coil

Date: _/_/_

Due to interaction of two magnetic field movable coil will rotate.

$$T \alpha \phi \cdot i N$$

N → number of turns of movable coil

$$T \alpha \phi i$$

$$\phi \alpha i$$

$$T_{ins} \alpha i^2_{ins}$$

If current instantaneous so Torque is also instantaneous.

$$T_{ins} = K_1 i^2_{inst}$$

~~$T_{avg} = avg(K_1$~~

$$T_{avg} = avg(T_{inst})$$

$$T_{avg} = avg(K_1 i^2_{inst})$$

$$T_{avg} = \frac{1}{T}\int_0^T K_1 i^2_{inst} \, dt$$

$$T_{avg} = K_1 \frac{1}{T}\int_0^T i^2_{inst} \, dt$$

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2_{inst} \, dt}$$

Bilal Register

Date: __/__/__

$$\tau_{avg} = K_1 I^2_{rms}$$

With pointer we attach a spiral spring (to provide controlling torque)

$$T_c = K_2 \theta$$

The pointer will stop when both the torques becomes Equal

$$\tau_{avg} = T_c$$

$$K_1 I^2_{rms} = K_2 \theta$$

$$\theta = \frac{K_1 I^2_{rms}}{K_2}$$

$$\theta = K I^2_{rms}$$

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

(Scale will be non uniform. The amount of Deflection depends on RMS value)

It is same As galvanometer for AC.

galvanometer → for DC

Bilal Register

T.I

If we measure DC current.

$$T \alpha I^2$$

$$T = K_1 I^2$$

$$K_2 \theta = K_1 I^2$$

$$\theta = K I^2$$

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

Disadvantage:

1) Scale is non uniform.
2) very low sensitivity. (no permanent magnet)
3) It has high power consumption.

Conversion to ammeter.

To increase the range add a shunt resistance across movable coil.

The conductors should be more thicker becoz

Range ↑

I ↑

Can withstand more current

Date: __/__/__

Conversion to voltmeter:-

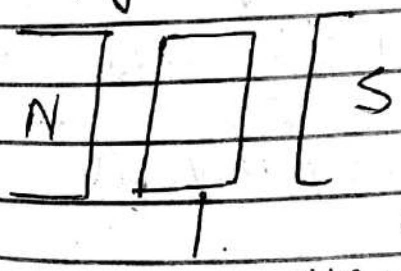
To convert it to a voltmeter add a shunt resistance in series with movable coil (—/\/\/\/—)

RECTIFIER TYPE INSTRUMENTS:

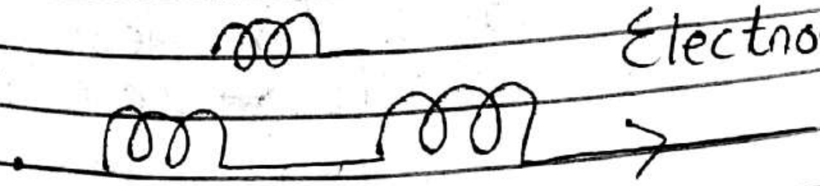
1) PMMC Instruments - D Arsonoval movement - (G) DC measurment

2) Electrodynometer EMMC (G) → AC measurment.

3) Moving Iron type



very sensitive
But cannot be use for AC measurment.



Electrodynometer

Use ~~us~~ for AC measurment but is less sensitive.

Date: __/__/__

We have problems in calculating small AC currents (communication signals(small))

Rectifier type used to enhance the capability to enhance the capability to measure small AC currents as in communication signals.

Using rectifier we ~~use~~ solve this problem and convert AC signal to DC and then use PMMC (which is of high sensitivity)

Signals —
- → Power signals - 220V EMMC
- → Communication signals (mV, μV)

Problem: (Rectifier Type Instrument)

You have to design RTT for each waveform i-e sinusoidal, rectangular, triangular

Becoz RMS value of each waveform will be different.

Date: / /

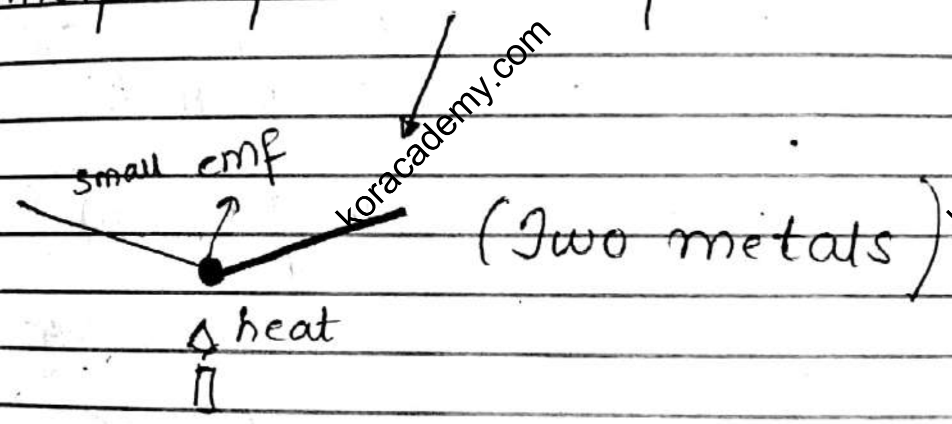
we will calculate form factor for all waveforms

Form factor =

~~Typical multimed~~

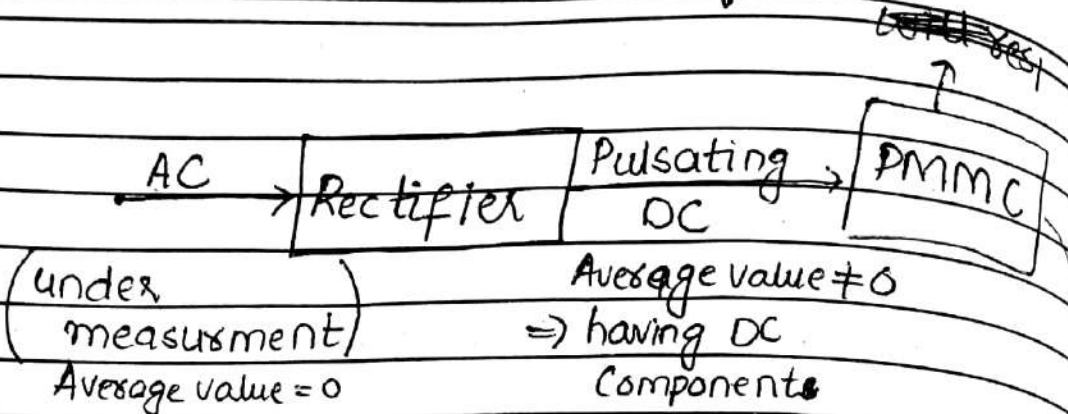
Typical measurment circuits

Thermo Instruments works on the principle of thermocouple.



Thermo-Instruments are use to measure small emf produce in thermocouple.

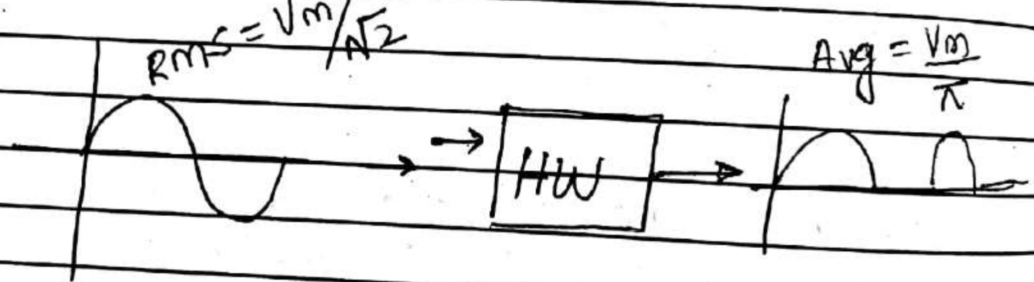
Date: _/_/_ Sir Farooq



Second solution for using AC quantities is to use a rectifier.

will responce to the average value. and we want RMS value.

For this reading x Form factor



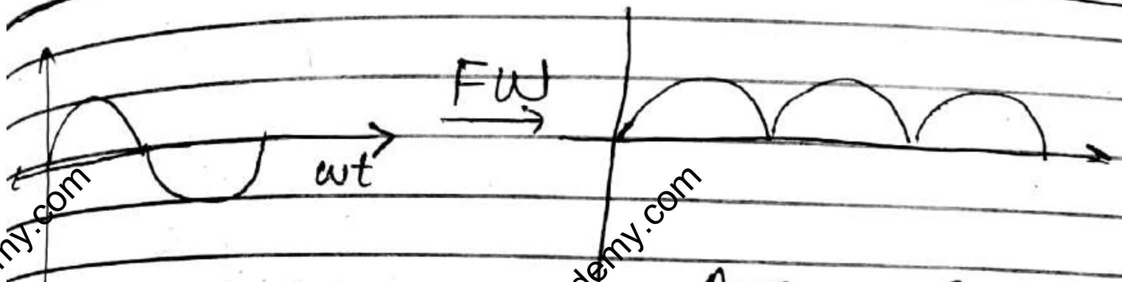
Form factor = RMS value of Input signal / Average value of signal at output of rectifier.

Date: __/__/__

Reading × FF

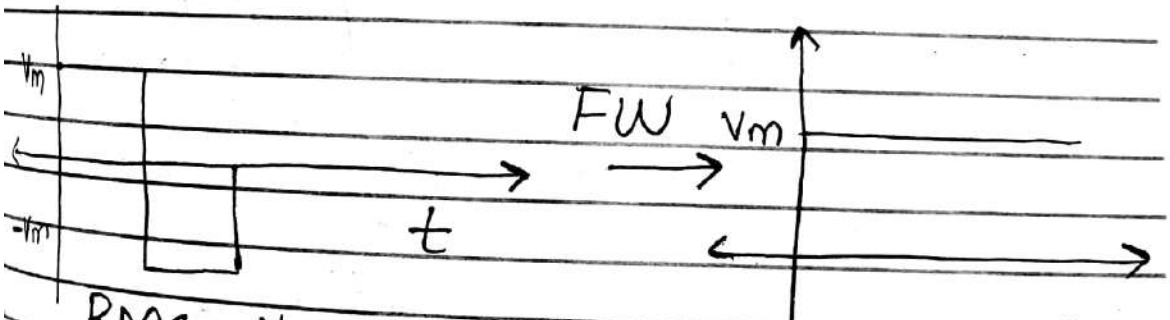
~~Avg val~~ × $\frac{\text{RMS value}}{\text{~~Avg value~~}}$ = RMS value

FF = 2.22 (Form Half Wave Rectifier)



$RMS = \frac{V_m}{\sqrt{2}}$

Avg = 1.11



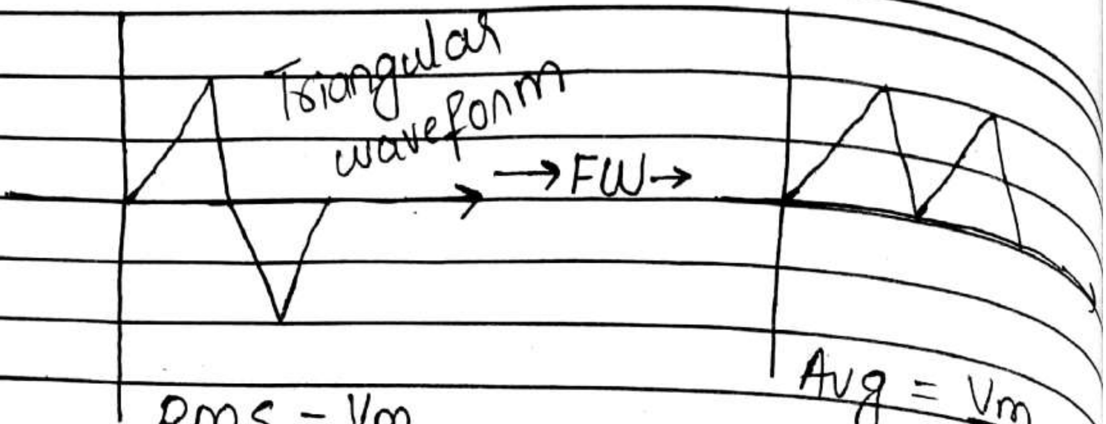
RMS = Vm

Avg = Vm

Form factor = 1

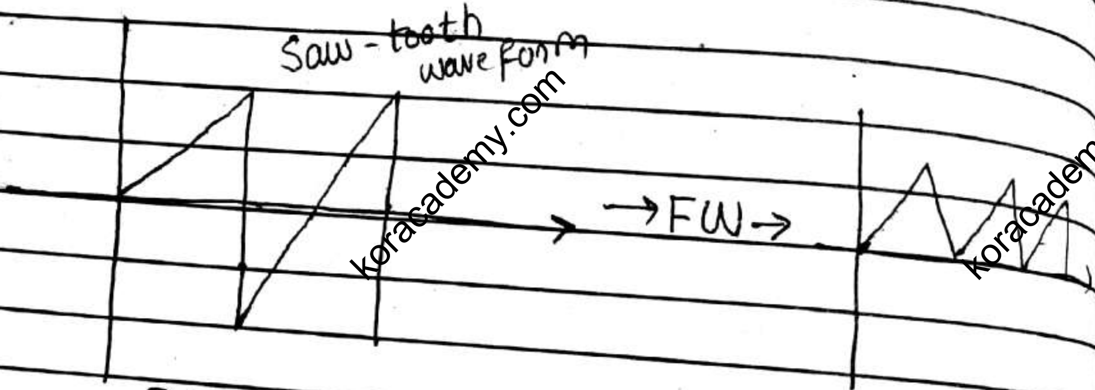
For square wave we don't need to change the scale.

Date: __/__/__



$RMS = \frac{V_m}{\sqrt{3}}$ $Avg = \frac{V_m}{2}$

Form factor = 1.154



$RMS = \frac{V_m}{\sqrt{3}}$ $Avg = \frac{V_m}{2}$

F.F = 1.154

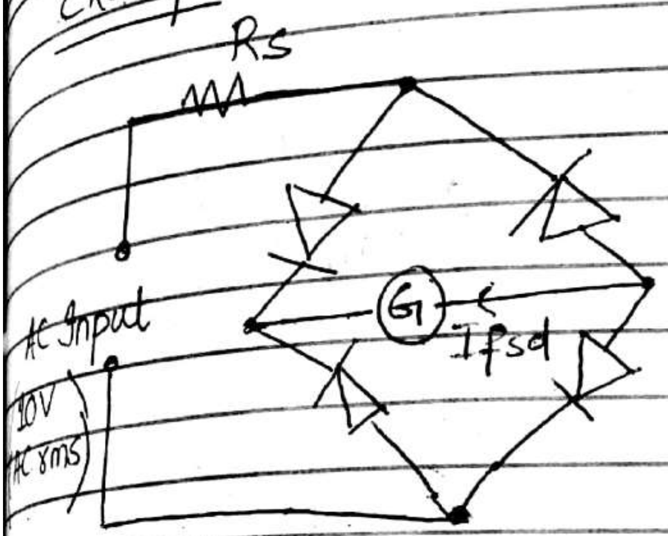
Disadvantage:- Different ~~wavef~~ Scale for different waveform.

Advantage: Scale is uniform

High sensitivity

Date: __/__/__

Example:



$R_m = 50\Omega$

$I_{fsd} = 2mA$

$R_s = ?$

10V(ac) → RMS → ~~9~~

↳ AC full scale deflection of 10V.

The waveform is sinusoidal.

Solution:-

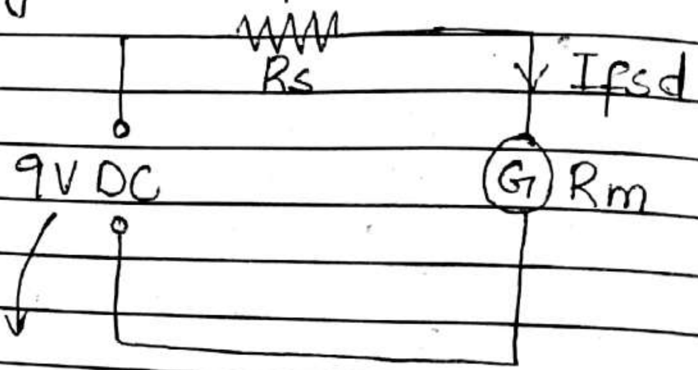
$$\text{Form factor} = \frac{E_{rms}}{E_{DC}}$$

$$\therefore E_{DC} = \frac{E_{rms}}{FF} = \frac{10}{1.11}$$

$E_{DC} = 9$ volts.

Date: __/__/__

The equivalent ckt of bridge rectifier is



For galvanometer when we apply 9V DC the ckt ~~will~~ is the same as bridge rectifier (when we apply 20V AC rms)

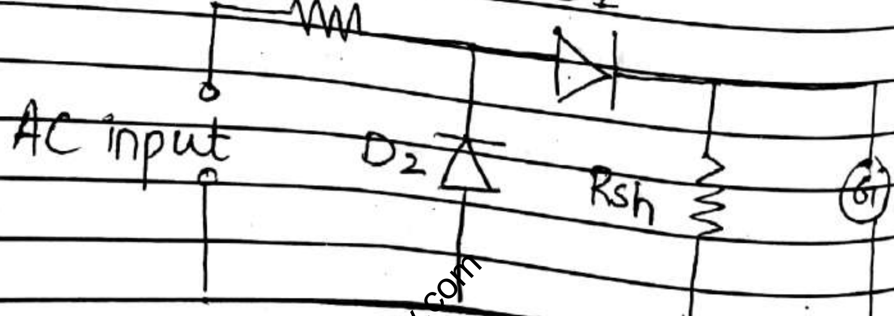
$$9 = I_{fsd}(R_s + R_m)$$

$$\frac{9}{1\times10^{-3}} = R_s + 50$$

$$9000 - 50 = R_s$$

$$\boxed{R_s = 8950\,\Omega}$$

Example 4-



Date: __/__/__ Solution:-

$R_m = 100\Omega$

$I_{fsd} = 1mA$

$R_s = 200\Omega$

$R_f = 400\Omega$

$R_r = \alpha\,\Omega$

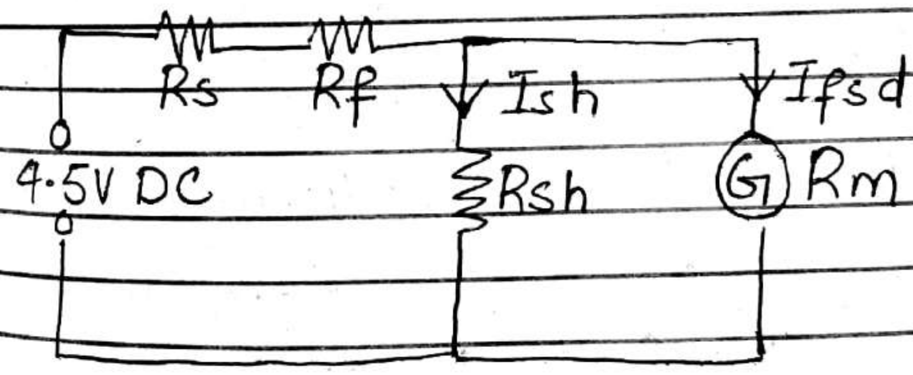
$E_{rms} = 10V$

a) $R_s = ?$ b) $S = ?$ (for AC range)

a) $F.F = 2.22 = \dfrac{E_{rms}}{E_{DC}}$

$E_{DC} = \dfrac{E_{rms}}{2.22} = \dfrac{10}{2.22}$

$E_{DC} = 4.5$ volts



$I_{sh} = 1mA$

$I_t = I_{fsd} + I_{sh} = 2mA$

$4.5 = I_t\,(R_s + R_f + R_m \parallel R_{sh})$

$R_s = 1800\Omega$

Date: __/__/__

b) $S = \frac{R_T}{V_{ac\ fsd}} = \frac{2,250}{10}$

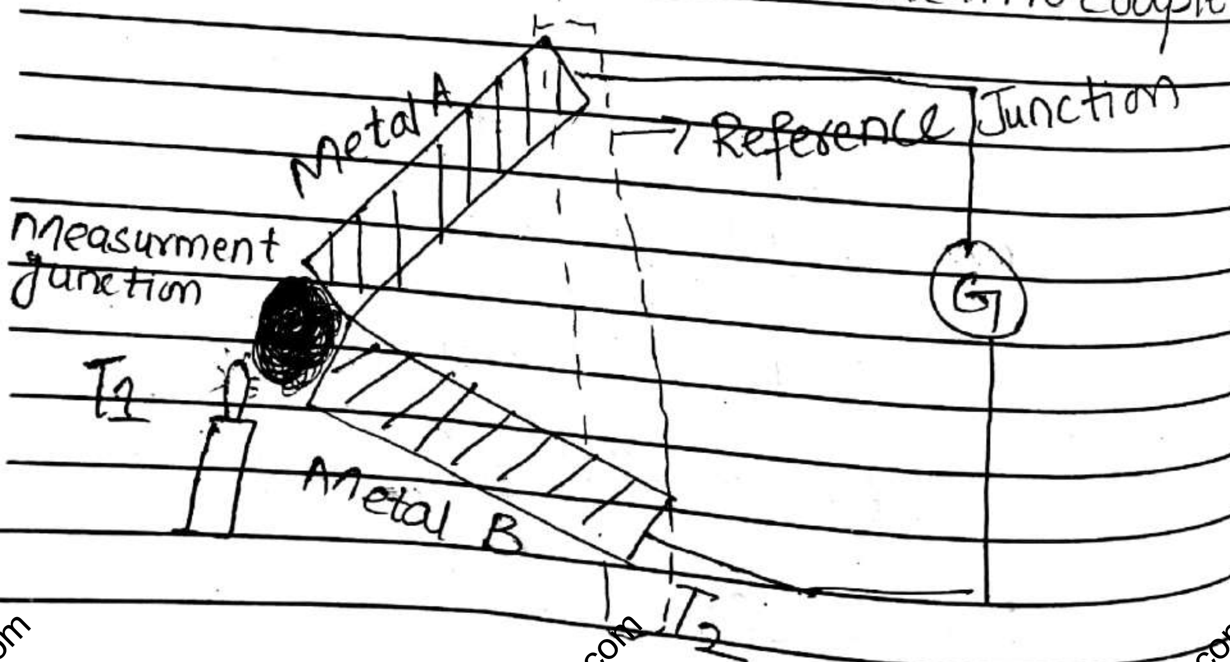
$$S = 225\ \Omega/V$$

per volt resistance of voltmeter is $225\ \Omega/V$

Thermoinstruments:-

We need different scale for different waveform in case of Rectifier type instrument therefore we uses thermoinstruments.

Thermoinstrument uses thermocouple



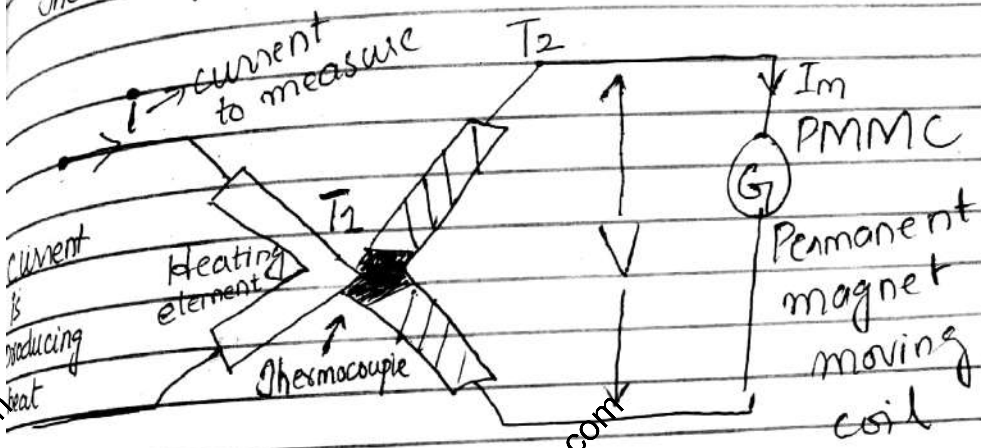
$T_1 - T_2 \propto$ potential difference

Thermocouple is the Jtn b/w two different metal

Date: __/__/__

This Effect is called Seebeck effect.

Thermocouple are temperature sensing device



$I_m \propto V$

$V \propto (T_2 - T_2)$

$V \propto \Delta T$

$V = a\Delta T$

$I_m \propto a\Delta T$

$I_m = ab\Delta T$

$\Delta T = c I^2_{rms} R$

$I_m = abc I^2_{rms} R$

$I_m = K I^2_{rms}$

$I_m \propto I^2_{rms}$

Date: / / Day

Watthour meter:

Energy meter:

Energy = Power × time

$$E = P \times t.$$

Two types of meters:
1) Analogue meter.
2) Digital meter.

1) Analogue Energy meter:-

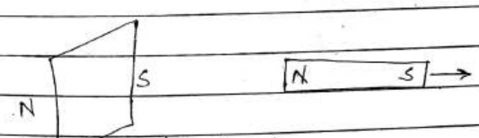
Single Phase Induction type Energy meter:-

→ It is Integrating type instrument
Display + Recording + addition

Date: / / Day

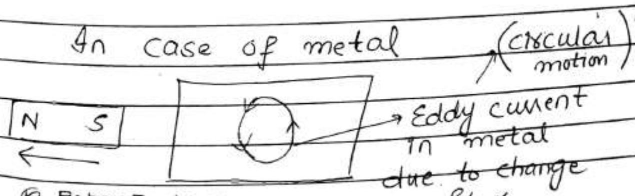
To count rotation we have registring system.
Disc is attached to shaft.

WORKING:-
It is induction type Energy meter
(Because phenomenon use is induction)



Lenz's law

In case of metal



Eddy current because it follow close path.

Date: / / Day

4 Main components in Energy meter.

1) Driving System:-
Consist of voltage coil, current coil and magnetic core. The function of driving system is to produce driving torque.

2) Moving System:-
Disc, shaft, bearing. Due to driving torque produce by driving system moving system will rotate.

3) Braking System:-
To control disc motion we need braking system which is U shaped parmanent magnet.

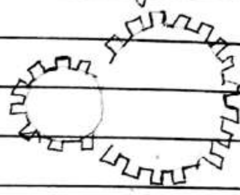
4) Registering/Counting System:-
Fourth system to count these rotati...

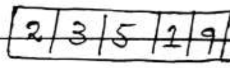
Date: / / Day

6

Registering system is made from gears.

Size of gears will be same but connected in such a way that speed of one will be greater than another.





Working Of Energy Meter:-

Voltage Coil (Highly inductor)

Current Coil

I

I_1

Voltage across voltage coil is V Volts.

$I_2 \rightarrow$ current flows in voltage coil

ϕ_2 (ϕ_1 in phase with I_1)

I_2 lags V by 90° (Highly inductive)

E_{e1}

I_{e2}

Flux produce due to I_2 is ϕ_2

$\phi_2 \propto I_2$

Induce Emf lags ϕ by 90° (always)

Date: / / Day

Due to alternating ϕ_2 Emf will produce in disc

$E = -N\frac{d\phi}{dt}$

E_{e2} lags ϕ_2 by 90°

E_{e_2}

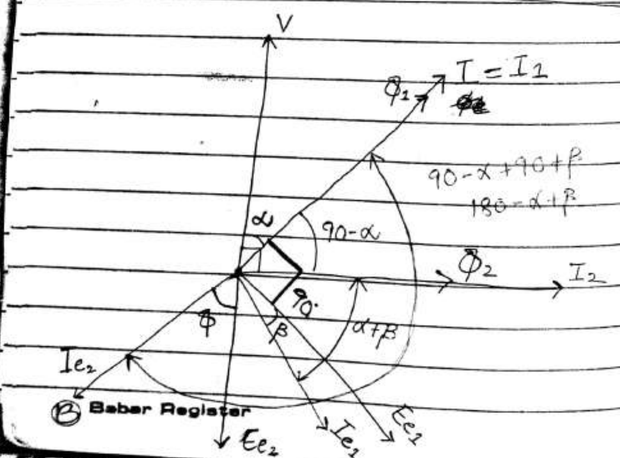
Power factor of disc

Disc → β

Load → α

Eddy current produce due to induce emf in disc: I_{e_2}

Current lags behinds E_{e2} and angle depends on impedance of disc or power factor.



Date: / / 6 Day

Current in disc is I_{e_2}

Due to interaction of I_{e_2} and ϕ_1 there will be a force on disc (Torque will produce).

Due to interaction of ϕ_2 and I_{e_1} torque will produce in disc.

These torques will be time varying.

$\tau_{1_{inst}} \propto i_{e_2}\phi_2$

$\tau_1 \propto I_{e_2}\phi_2 \cos(\alpha+\beta)$

$\tau_2 \propto I_{e_2}\phi_2 \cos(180-\alpha+\beta)$

$T_{inst} \propto iv$

$T_{avg} \propto P$

If voltage & current is sinusoid al so can write power

$T_{avg} \propto VI \cos\phi$ (RMS values of voltage & current)

Viva Question:

T_1 & T_2 are opposite in direction (T_1 & T_2) you need to verify this statement

so

Total torque = driving torque = $T_d = T_1 - T_2$

Date: / / Day

$\tau_d \propto I_{e1}\phi_2 \cos(\alpha+\beta) - I_{e2}\phi_1 \cos(180-\alpha+\beta)$

$\tau_d \propto IV\cos(\alpha+\beta) - VI\cos(180-\alpha+\beta)$

$\tau_d = K_1 VI[\cos(\alpha+\beta) - \cos(180-\alpha+\beta)]$

Home Assignment

$\tau_d = 2K_1 VI\cos\alpha \cdot \cos\beta$

$\tau_d \neq 2K_1\cos\beta = K_2$

$\tau_d = K_2 VI\cos\alpha$

$$\boxed{\tau_d = K_2 P}$$

Driving torque depends on power consumed by load.

⇒ *Another Eddy current will produce in disc due to Emf produce. (& its Cause

Ⓑ Babar Register

Date: / / Day

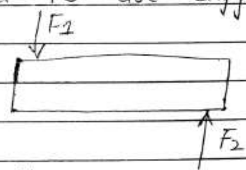
will oppose its cause) *

Due to cutting of magnetic field lines (of parmanent magnet) · Emf will produce in Disc. and Eddy current will produce in disc and direction of Eddy current will be such that to oppose its cause i-e motion of disc

$\tau_{braking} \propto n$ (Speed of disc)
rev/sec
rev/min
rev/hr.

$\tau_b = K_3 n$.

Point of action of these torques τ_d and τ_b are different



$\Sigma F = 0$
$a = 0$
uniform velocity

τ_d and τ_b are of same magnitude but their point of action is different. So disc will move

Ⓑ Babar Register

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Day

with uniform speed.

$$\tau_b = \tau_d$$

Disc will rotate with a uniform speed.

$$K_3 n = K_2 P$$

$$K_3 n t = K_2 P t$$

$$K_3 N = K_2 E$$

$$N = \frac{K_2 E}{K_3}$$

$$N = KE$$

$$N \propto E$$

$K = \frac{N}{E} \left(\frac{rev}{kwh}\right)$

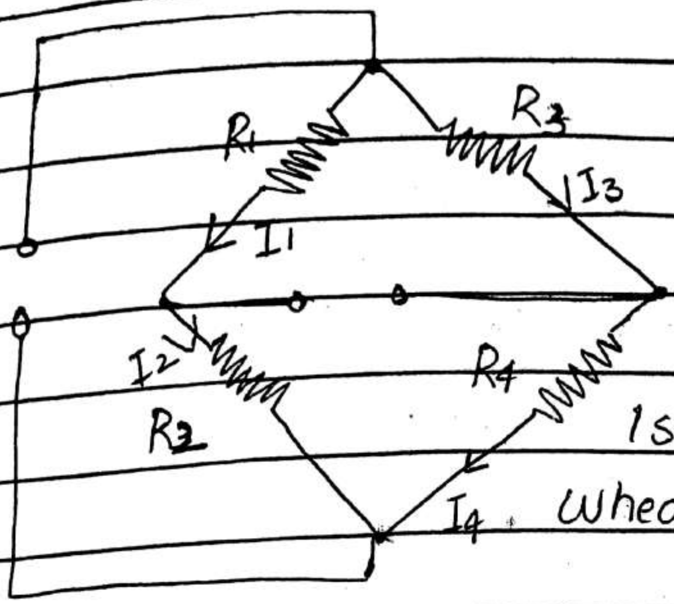
$K = 1500$

LECTURE #02

BRIDGE MEASURMENT:

Every bridge has

1) Input voltage source (ac, dc)
2) Output detector (G, buzzer, Electron eye etc)
3) Four sets of arms.
4) Checked for balance / unbalance conditions
5) Proper ~~arms~~ balancing of arms.
6) For solving we use KVL and KCL.



As if bridge consist of all resistors the bridge is called wheat stone bridge

R_4 is unknown resistance.

At two pts we apply source. (Rem two

At two pts we apply galvanometer. (connect).

At balance condition

$$I_1 = I_2 \text{ and } I_3 = I_4$$

$$I_3R_3 = I_1R_1 \text{ and } I_4R_4 = I_2R_2$$

unknown resistor will be the part of that arm which consist of variable resistor

Wheatstune stone bridge can be use for measuring

1) Inductance 2) Capacitance

2) Conductance 3) Admittance.

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If Galvanometer current is zero (In balance condition)

$$I_1 = I_3 = \frac{E}{R_2 + R_3}$$

$$I_2 = I_4 = \frac{E}{R_2 + R_4}$$

$$\boxed{R_1 R_4 = R_2 R_3}$$

we have limiting resistor it can withstand a certain amount of voltage & current. we should know power handling capability of bridge and should not go beyond that.

we make ~~galvano~~ bridge of same material to avoid thermal emf.

Errors may be reduced by using a Kelvin bridge.

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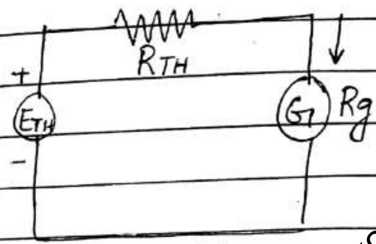
Thevenin Equivalent circuit:-

This helps to select the desired galvanometer (of particular sensitivity).



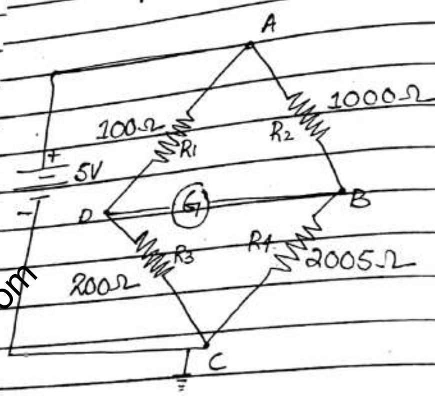
$$I_g = \frac{E_{TH}}{R_{TH} + R_g}$$

$$I_g = \frac{E_{TH}}{R_{TH} + R_g}$$ (so by knowing value of I_g we can select a particular galvanometer for our bridge)

$I_g \rightarrow$ Minimum current which is to be detected

(Farooq - Sir Lec)

Example 5-1



Bridge will be balance if

$R_1 R_4 = R_2 R_3$

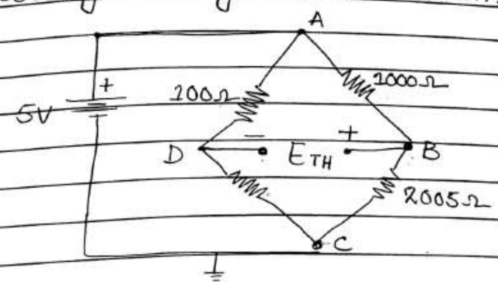
In this case bridge is not in balance condition.

$S = 10\,mm/\mu A \Rightarrow S = \frac{\Delta output}{\Delta input}$

$R_m = 100\Omega$

$D = ?$

Solving it by thevenin theorem:-



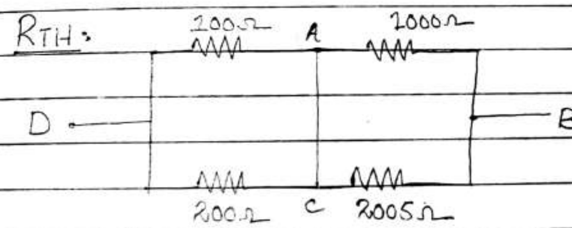
E_{TH} :-

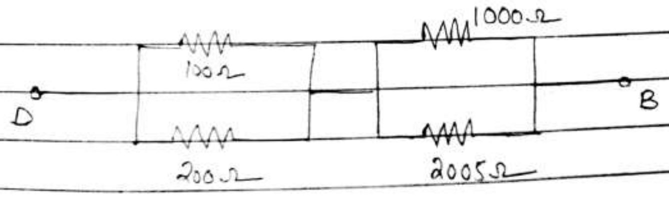
$E_{TH} = E_B - E_D$

$E_{TH} = \frac{5 \times 2005}{1000 + 2005} - \frac{5 \times 200}{100 + 200}$

$E_{TH} = 2.77\,mV$

R_{TH} :





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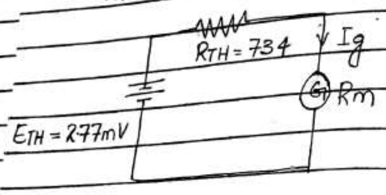
$R_{TH} = 100 // 200 + 1000 // 200.5$

$R_{TH} = 734\,\Omega$



NOTE:
We cannot use wheatstone for measuring resistance less than $1\,\Omega$ and greater than few Mega ohms.

$$I_g = \frac{E_{TH}}{R_{TH} + R_m}$$

$$I_g = \frac{2.77 \times 10^{-3}}{734 + 10.0}$$

$I_g = 3.32\,\mu A$

$D = I_g \times S$

$= 332 \times 10 = 332\,mm.$

$D = 332\,mm$

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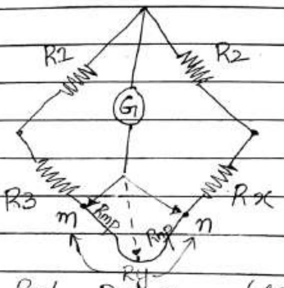
If resistance is less than $1\,\Omega$ we cannot neglect resistance of wires & leads.

Effect of connecting leads:
$R_x <<< 1\,\Omega$:



$R_1 R_x = R_2 R_3$

$R_x' = R_x + R_y$ (If lead is connected to m)

Then R_y is added R_x. Indication will be greater than R_x.

If Galvanometer is connected to pt n. The actual value of R_3 is $R_3 + R_y$ but we take R_3 so the Indication (value of R_x) will be less than R_x)

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If galvanometer is connected to point P.

Ballanced:-

$$R_1(R_x + R_{np}) = R_2(R_3 + R_{mp})$$

$$R_1 R_x + R_1 R_{np} = R_2 R_3 + R_2 R_{mp}$$

$$R_1 R_x = R_2 R_3 + R_2 R_{mp} - R_1 R_{np} \quad -(1)$$

We have to choose point P such as:-

$$\frac{R_{mp}}{R_{np}} = \frac{R_1}{R_2}$$

$$\boxed{R_2 R_{mp} = R_1 R_{np}}$$

If this condition is satisfy so we can use wheat stone bridge for low resistances. So eq (1) will become

$$R_1 R_x = R_2 R_3 .$$

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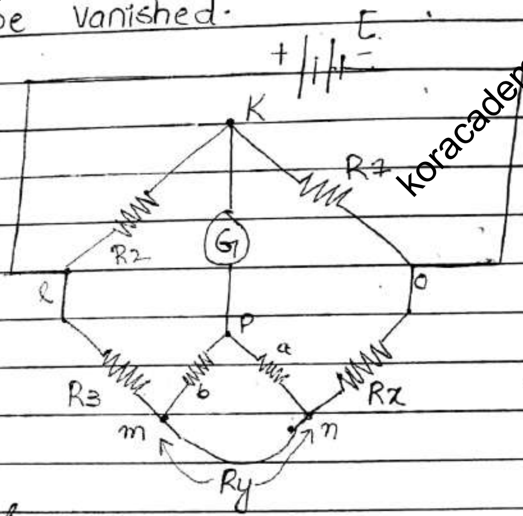
For selecting point P we have Kelvin Bridge:

We have to choose a and b resistors such that we get point P. and

$$\frac{a}{b} = \frac{R_1}{R_2}$$

Effect of lead resistance will be vanished.



Ballanced:

$$-E_K = -E_P$$

$$E_l - E_K = E_l - E_P$$

$$E_{lK} = E_{lP} \quad -(2)$$

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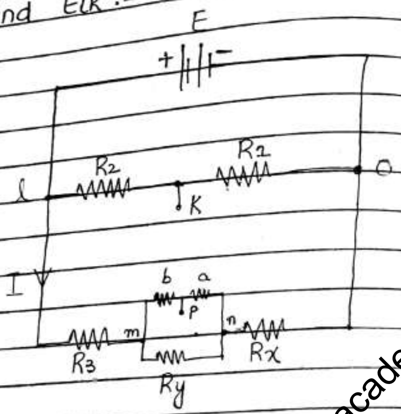
Find E_{lK} :-



$$E_{lK} = E \times \frac{R_2}{R_1+R_2} \quad -(3)$$

$$E = I \times \left(R_3 + (a+b)//R_y + R_x\right) \quad -(4)$$

$$E_{lK} = \frac{R_2}{R_1+R_2} \times I \times \left(R_3 + \frac{(a+b)R_y}{a+b+R_y} + R_x\right) \quad -(5)$$

E_{lp} :-

$$E_{lp} = IR_3 + E_{mp} \quad -(6)$$

$$E_{mp} = E_{mn} \times \frac{b}{a+b} \quad -(7)$$

$$E_{mn} = I \times \left((a+b)//R_y\right) \quad -(8)$$

$$E_{mp} = I \times \frac{(a+b)R_y}{a+b+R_y} \times \frac{b}{(a+b)}$$

$$E_{mp} = I \times \frac{bR_y}{a+b+R_y} \quad -(9)$$

Put eq (9) in eq (6)

$$E_{lp} = I\left(R_3 + \frac{bR_y}{a+b+R_y}\right) \quad -(10)$$

$E_{lK} = E_{lp}$

$$\frac{R_2}{R_1+R_2} \times I \times \left(R_3 + \frac{(a+b)R_y}{a+b+R_y} + R_x\right)$$

$$= I \times \left(R_3 + \frac{bR_y}{a+b+R_y}\right)$$

$$R_3 + \frac{aR_y}{a+b+R_y} + \frac{bR_y}{a+b+R_y} + R_x = \frac{R_1+R_2}{R_2}\left(R_3 + \frac{bR_y}{a+b+R_y}\right)$$

$$\frac{R_3 + aR_y}{a+b+R_y} + \frac{bR_y}{a+b+R_y} + R_x = \left(\frac{R_1}{R_2}+1\right)\left(\frac{R_3+bR_y}{a+b+R_y}\right)$$

$$\frac{R_3+aR_y}{a+b+R_y} + \frac{bR_y}{a+b+R_y} + R_x = \frac{R_1R_3}{R_2} + \frac{R_1}{R_2}\cdot\frac{bR_y}{a+b+R_y} + \frac{R_3+bR_y}{a+b+R_y}$$

$$R_x = \frac{R_1R_3}{R_2} + \frac{R_1}{R_2}\cdot\frac{bR_y}{a+b+R_y} - \frac{b\,aR_y}{b(a+b+R_y)}$$

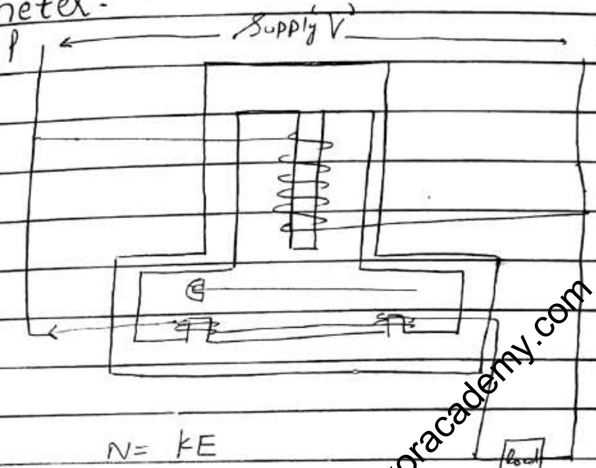
$$R_x = \frac{R_1R_3}{R_2} + \frac{bR_y}{a+b+R_y}\left(\frac{R_1}{R_2} - \frac{a}{b}\right)$$

If $\frac{a}{b} = \frac{R_1}{R_2}$

$$R_x = \frac{R_1R_3}{R_2}$$

Lab # 09:-

To find the meter constant of a single phase analog Energy meter.



$N = kE$

$k = \frac{N}{E} \quad \frac{rev}{kWh}$

Voltage coil is highly inductive its resistance is almost zero.

Disc is made from aluminium.

Registering system counts no. of rotations of disc.

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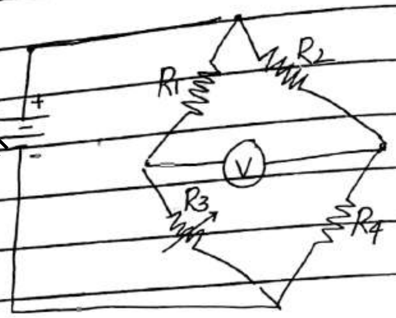
~~Clamp~~
Lab # 10:-
To measure unknown resistance using wheatstone bridge



$R_1R_4 = R_2R_3$

$R_4 = \frac{R_2R_3}{R_1}$

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LECTURE # 03

(When we uses inductor and capacitor)

1 Source → AC
  ↳ Power line frequency (50-60 Hz)
  ↳ Radiofrequency.

2) Detector:-
  ↳ Buzzer
  ↳ Headphone
  ↳ Electron gun/eye
  ↳ Amplifier

3) 4 Arms → Resistor
  ↳ Capacitor
  ↳ Inductor.

4) Basic principle for Balanced condition

~~Opposite~~

In bridge Capacitor - resistor & Inductor - resistor is possible

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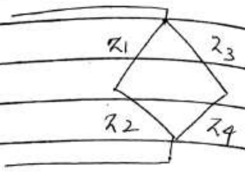
we will deal impedances as phasors.

$$\bar{Z}_1 = Z_1\angle\theta_1$$

$$I_1 = \frac{E}{Z_1 + Z_2}$$



$$I_2 = \frac{E}{Z_3 + Z_4}$$

Under balanced condition

$$Z_1 Z_4 = Z_2 Z_3$$

When using admittances

$$(Z_1\angle\theta_1)(Z_4\angle\theta_4) = (Z_2\angle\theta_2)(Z_3\angle\theta_3)$$

$$Z_1 Z_4 \angle\theta_1+\theta_4 = Z_2 Z_3 \angle\theta_2+\theta_3$$

$$\Rightarrow Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow \angle\theta_1 + \angle\theta_4 = \angle\theta_2 + \angle\theta_3$$

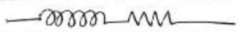
Exple 5.3:-

Exple 5.4:-

MAXWELL BRIDGE:

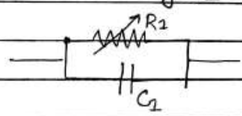
It is use to find out the value of unknown inductance.

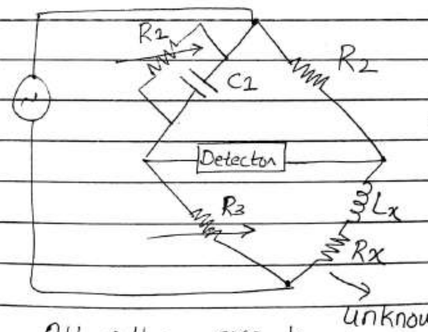
Maxwell Bridge
- Maxwell inductance bridge
- Maxwell inductance capacitance bridge



$$Z_1 = R_1 + \omega L_1$$

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





Maxwell bridge for inductance measurments.

All other are known.

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$$R_x = \frac{R_2 R_3}{R_1}$$

$$L_x = R_2 R_3 C_1$$

Findings / Conclusion:-

1) There is no role of frequency in the L_x and R_x.

2) We can calibrate inductance using resistances.

3) No inductive losses.

Limitations:-

To find out which coil is of better quality we deal with Q-factor (Quality factor)

$$\uparrow \text{Q-factor} = \frac{\text{Energy stored in coil}}{\text{Energy dissipated}} \uparrow \downarrow$$

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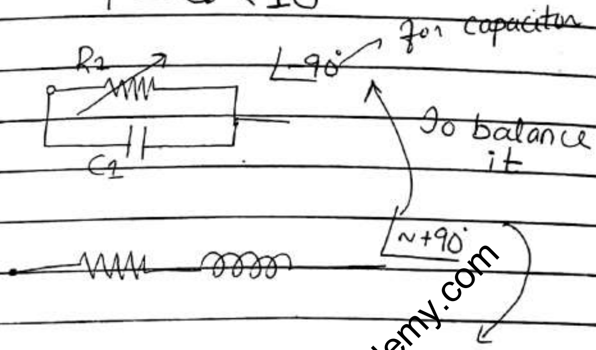
We can use maxwell bridge for finding L_x and R_x of low quality.

$$1 < Q < 10$$



One solution is to balance $+90°$ of inductor to $-90°$ of capacitor

1) To have a large resistance.

2) To vary capacitance of capacitor (variable capacitor). [We should be having a good capacitor which is very expensive)

We cannot use maxwell bridge for low Q.
We can use maxwell bridge for medium Q.

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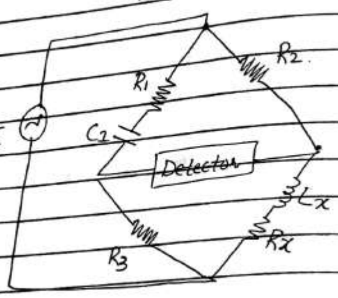
Variable capacitors are expensive

HAY BRIDGE



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

$$Z_1 = R_1 - \frac{j}{\omega C_1} \quad (H/\omega)$$

$$R_x = \frac{\omega^2 C_1^2 R_1 R_2 R_3}{1+\omega^2 C_1^2 R_1^2}$$

$$L_x = \frac{R_2 R_3 C_1}{1+\omega^2 C_1^2 R_1^2}$$

Frequency of the source must be accurately known.

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$$Q\text{-factor} = \frac{\text{Energy stored in coil}}{\text{Energy dissipated}}$$

$$= \frac{X_L}{R}$$

$$\tan\theta_L = \frac{X_L}{R} = \frac{\omega L_x}{R} = Q$$

$$\tan\theta_L = \tan\theta_C \text{ or } Q = \frac{1}{\omega C_1 R_1}$$

$$\tan\theta_L = \tan\theta_C \text{ or } Q = \frac{1}{\omega C_1 R_1}$$

$$\tan\theta_C = \frac{X_C}{R}$$

$$L_x = \frac{R_2 R_3 C_1}{1+(1/Q)^2}$$

For High Quality coil we uses hay bridge

$Q > 10$

e.g $Q = 100$

$$L_x = \frac{R_2 R_3 C_1}{1+\left(\frac{1}{100}\right)^2} \rightarrow \text{Neglecting } (1/100)^2$$

$$\boxed{L_x = R_2 R_3 C_1}$$

Babar Register

Sir Farooq

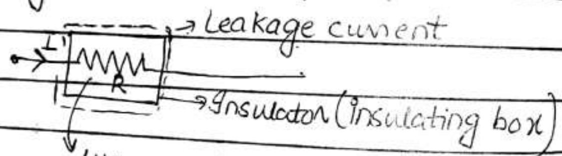
Guarded Wheatstone Bridge:

we can use wheatstone bridge upto few megaohms.

Problem if resistance is too much.

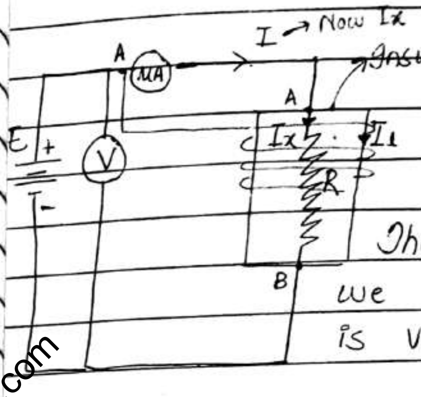
i) $I\downarrow$ (current will be too much less as galvanometer will show no ~~dect~~ detection) ~~[illegible]~~ Sensitivity of galvanometer is the problem. We have to increase sensitivity of galvanometer.

2) Leakage current problem:-



we want to measure the resistance of high resistor. Due to Temp, humidity leakage current will affect

Leakage current will cause measurement errors



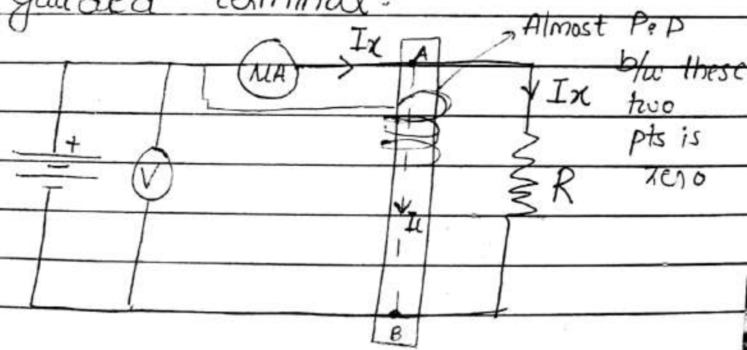
$$R = \frac{E}{I} = \frac{E}{I_x + I_L}$$

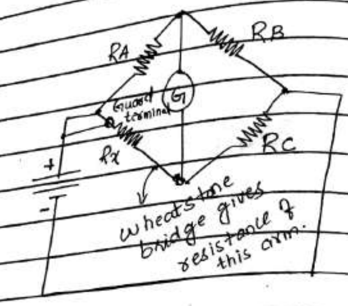
The resistance which we want to measure is very high.

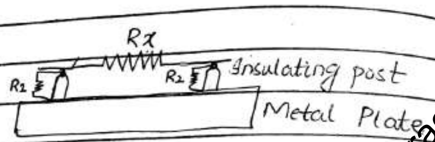
$$R_{actual} = \frac{E}{I_x}$$

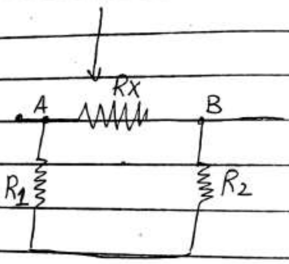
If increase R I_L will also increase and the error will increase.

A → This terminal is called as gaurded terminal.

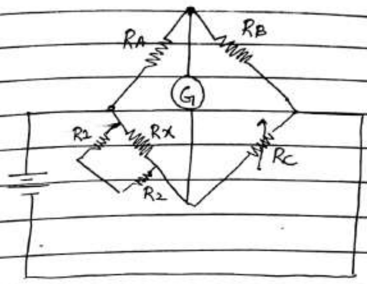




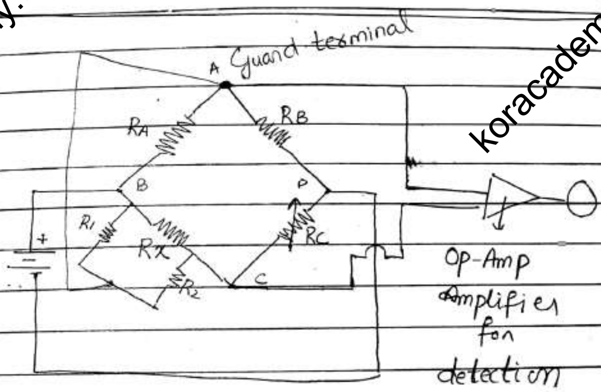




$R_x // (R_1 + R_2)$



$$R_x = \frac{R_A R_C}{R_B} = R_x // (R_1 + R_2)$$



(MΩ) R_1 is connected in parallel with R_A (kΩ)

$R_1 // R_A \cong R_A$

(MΩ) R_2 is connected in parallel with galvanometer (R_m)(ohms)

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$R_2 // R_m \cong R_m$.

Exple:-

$R_{x\,actual} = 100 M\Omega$

$R_1 = R_2 = 100 M\Omega$

So find % Error

Measured $R_x = R_x // (R_1 + R_2)$

$= 100 // 200$

$= 67 M\Omega$

% Error = $\frac{\text{Measured} - \text{Actual}}{\text{Actual}}$

$= 33\%$

We prefer Hay bridge for Quality factor > 10

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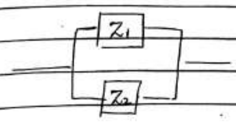
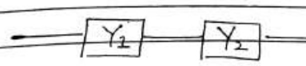
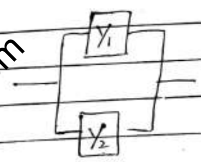
$Z_1 + Z_2$



$\frac{Z_1 Z_2}{Z_1 + Z_2}$



$\frac{Y_1 Y_2}{Y_1 + Y_2}$



$Y_1 + Y_2$

$Z = R + jX$

R = resistance

X → Reactance

$X_L = j\omega L$

$X_C = \frac{-j}{\omega L}$

$Y = G + jB$

G = Conductance → $G = 1/R$

B = susceptance → $B = 1/X$

LECTURE # 04

Instrument Transformers:

CT is a type of instrument transformer.

These are called instrument transformers because they are use with instruments (ammeter, voltmeter, wattmeter & energy meter.

We cannot measure 100's of ampere and large voltage with ammeter and voltmeter. To increase their range we uses instrument transformer.

Instrument transformer
- CT — Current measurment → Step down current
- PT — Voltage measurment → Step down voltage.

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Two important functions of instrument transformer:-

1) They extend the range of measuring instruments.

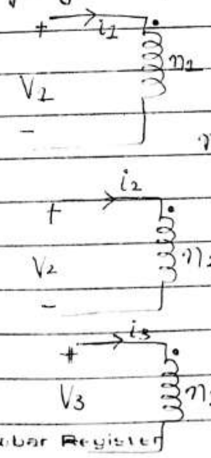
2) They provide isolation.

3) When we uses Instrument transformer to increase range so losses will be low (Low power consumption).

Transformers

IDEAL TRANSFORMER:

1) It provides isolation (It provides safety)



If all currents are moving towards dot

$$n_1 i_1 + n_2 i_2 + n_3 i_3 = 0 \quad (1)$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} = \frac{V_3}{n_3} \quad (2)$$

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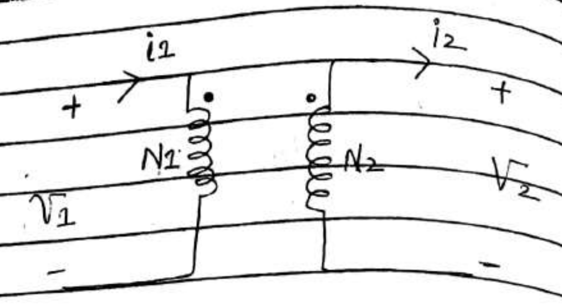

Using eq 1

$$N_1 i_1 + N_2(-i_2) = 0$$

$$N_1 i_1 = N_2 i_2$$

$$\boxed{\frac{N_1}{N_2} = \frac{i_2}{i_1}}$$

Using second relationship :-

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

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

Current transformer has to step down the current.

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CT:- It may be use with ammeter so we decreases I and ~~there~~ then measure it and then multiply it with the number of turns to get the actual current.

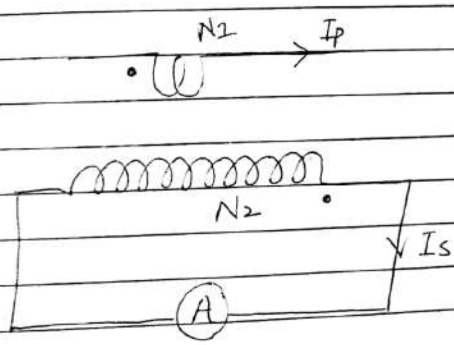
In current transformer

$I_2 < I_1$ ⇒ always

$N_2 > N_1$

If $N_1 = 1$ (Primary coil turn ratio $= 1$)

Bar Primary means number of turns at primary = 1



$0 \leq I_s \leq 5A$ (should be in this range)

~~Nr~~

$$N_1 I_1 = N_2 I_2$$

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

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Question:- We want to measure current from range of 0 – 500A but we have a ammeter whose range is 5 A so find turns ratio $\left(\frac{N_2}{N_1}\right)$ of C.T

$$\frac{N_2}{N_1} = 100$$

Viva Question

Why secondary winding of a C.T should never be open circuited?

Ans: It is basically a step up transformer

becoz $N_2 > N_1$

$V_2 > V_1$

It. A high voltage will damage the insulation (painting).

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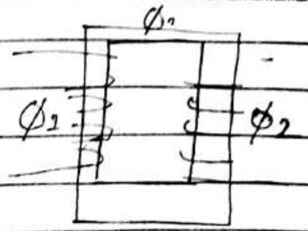
$$E_s = -N_2 \frac{d\phi}{dt}$$



Burden is that thing connected at output of transformer. It is mentioned in Volt - Ampere.

500A/1A   10VA (burden)   5P20 (Error which comes is 5%.)

20 means CT can carry 20 times more (higher) than ratted values.

Equivalent Ckt of CT:-

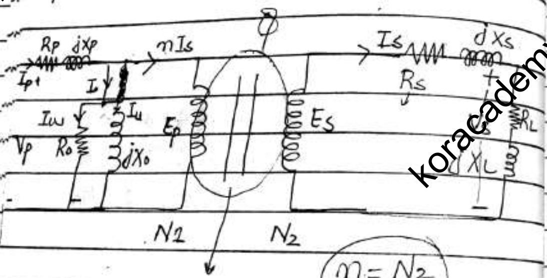
Ideal transformer is that in which losses is equal to zero

I/p power = O/p power

Losses in Practical T/F :-
→ leakage flux
→ Electrical losses in coil
→ Losses in core.

Equivalent Ckt of Practical CT :-

Ideal T/F is a part of practical T/F.



$n = \frac{N_2}{N_1}$

two lines || → Iron core
| → ferromagnetic core
no lines → Air core.

Rs → Electrical losses in secondary
Xs → Leakage flux in secondary.

jXo → To represent mutual inductance.

Vp = Input Primary voltage

Ip = Input " current

Rp = Primary winding resistance. and it represent the internal resistance of copper which is use in primary side

Xp = Primary winding leakage reactance. Also called parasitic reactance. It is responsible for leakage flux.

Ro is resistance of the core it is responsible for core losses or iron losses.

Xo ⇒ Magnetizing reactance of core. Magnetizing inductance of core. It is responsible for producing that working flux.

$I_s \Rightarrow$ Secondary winding current.

$R_s \Rightarrow$ Secondary winding resistance. Conduction losses in S. Side

$X_s \Rightarrow$ It is called secondary winding leakage reactance

$\ldots + jX_L$ (Inductive load or burden)

$E_p \Rightarrow$ Induced primary voltage.

$E_s \Rightarrow$ Induced secondary voltage. Also called no load secondary voltage.

V_s = Secondary voltage.

I_0 = No load primary current

$I_p = I_0$ As $I_s = 0$, $nI_s = 0$

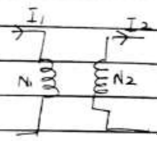
R_0 & I_w is core loss component

I_μ is magnetizing current

ϕ = Core flux or working flux of transformer.

$n = \frac{N_2}{N_1}$ = Nominal ratio

Ideally



$n = \frac{I_1}{I_2} = \frac{I_p}{I_s} = \frac{N_2}{N_1}$

It is only valid for Ideal T/F not for practical T/F.

δ = Angle b/w I_s and E_s

$\delta = \tan^{-1}\left(\frac{X_L + X_s}{R_L + R_s}\right)$

$I_p = I_0 + nI_s$

$\frac{I_p}{I_s} > n$

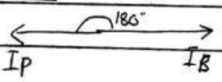
This error is called as ratio error

Ideally $I_p = nI_s$

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

This error is due to I_0.

Ideally	Practically
1) $\frac{I_p}{I_s} = n \Rightarrow$ $I_p = nI_s$	$I_p > nI_s$ $\frac{I_p}{I_s} > n$ (Ratio Error)
2) Angle b/w I_p & I_s is $180°$ (According to Lenz's law) $\angle I_p \& I_s = 180°$	$\angle I_p \& I_s < 180°$



This Error is also due to I_0 and is called Phase angle Error.

I_w is in-phase with E_p. As across E_p we have R_0 and current in R_0 is I_w.

I_s lags behind E_s by angle of δ (sigma)

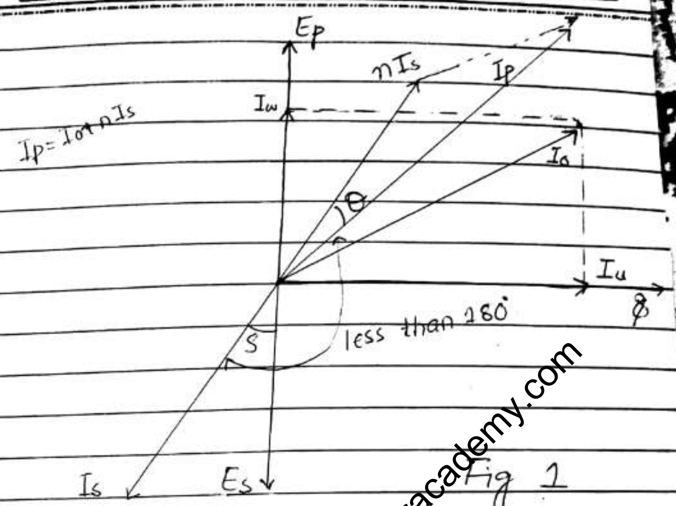


Fig 1

Formula to find Actual Ratio:-
Actual Ratio is represented by R.

$$R = n + \frac{I_w \cos\delta + I_u \sin\delta}{I_s}$$

$$\boxed{R = \frac{I_p}{I_s}}$$ Actual ratio.

$$\% \text{ Ratio Error} = \frac{n - R}{R} \times 100.$$

If Burden is resistive (load is resistive)
So δ is almost zero.

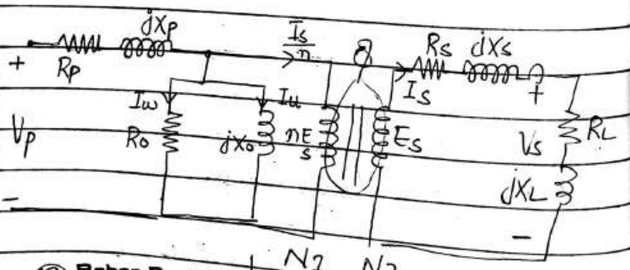
So $R = n + \frac{I_w}{I_s}$

Phang Phase angle Error (θ):-

$$\theta = \frac{I_u \cos\delta - I_w \sin\delta}{n I_s} \times \frac{180}{\pi}$$

POTENTIAL TRANSFORMER (PT):

Equivalent ckt of PT is same as CT. (as mentioned above)
We uses it to increase the range of voltmeter.



For all transformers

$n = \frac{N_1}{N_2}$ $n > 1$

$E_p = nE_s$
$\frac{E_p}{E_s} = n$] Ideally T/F

In Practical transformer
$\frac{V_p}{V_s} > n$ (Ratio Error).

$$R = n + \frac{\frac{I_s}{n}(R_p \cos\delta + X_p \sin\delta) + I_w R_p + I_u X_p}{V_s}$$

$$\theta = \frac{\frac{I_s}{n}(X_p \cos\delta - R_p \sin\delta) + I_w X_p - I_u R_p}{n V_s}$$

Actual phase $= 180 - \theta$.

$I_o = I_w + I_u$ (Phasor sum) (Fig 2)

$I_o = \sqrt{I_w^2 + I_u^2}$ (Magnitude form)

We cannot make $I_o = 0$ becoz by making $I_o = 0$ the working flux $= 0$ and T/F will not work

Magnetic Motive force

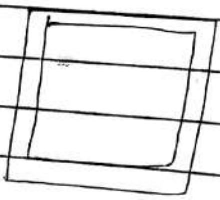
$$MMF = \phi R$$

R = Reluctance

$$NI_u = \phi R$$

$$\phi = \frac{NI_u}{R}$$

Use the core of low ~~reac~~ reluctance $R\downarrow$ $\phi\uparrow$
So then we can reduce I_u.
So that ϕ will remain same.



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

How to increase reluctance by decreasing area at ~~core~~ corners
Solution:

As $R > n$
so tell the ~~manufacturer~~ user more no. of turns

EXAMPLES:

1:

A ring core type CT has a ratio of 2000/20 when operating at a rated primary current with a secondary burden of non-inductive resistance whose value is 2Ω. $(Z_L = 2\Omega) \Rightarrow \delta = 0$. Takes a no load current (I_0) of 2A at power factor of 0.3 Calculate ratio error and phase angle error at full load.

$$nI_s = 2000$$
$$I_s = 10$$
$$n = \frac{2000}{10} = 200$$

2000/10A ↓ Maximum

$$\delta = 0$$

$$R = n + \frac{I_w \cos\delta + I_u \sin\delta}{I_s}$$

$$R = n + \frac{I_w}{I_s}$$

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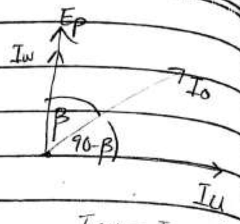
$P.f = 0.3$



$\cos\beta = 0.3$

$\beta = \cos^{-1} 0.3$

$\beta = 72.54°$

$I_w = I\cos\phi$
$= 2 \times 0.3$
$I_w = 0.6A$

$I_u = I_0 \cos(90-\beta) = 1.908A$

$I_w = I_0 \cos\beta =$

$R = 200 + \frac{2 \times 0.3}{10}$

$R = 200.06$

$\theta = \frac{I_u}{n I_s} \times \frac{180}{\pi}$ | $\theta = \frac{I_u \cos\delta - I_w \sin\delta}{n I_s} \times \frac{180}{\pi}$

$\phi = \cos^{-1}(0.3) =$

$I_u = I_0 \sin\phi \Rightarrow \theta = 0.05966°$ — If we are said to find actual phase angle so sub from 180

Q (If said half load so $I_s = \frac{10}{2} = 5A$)

$\%RE = \frac{n-R}{R} \times 100$
$= 0.03\%$ — Ratio Error

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Exple:
A bar type CT has 400 turns in secondary winding. The impedance of secondary ckt is $(2+j1.5)\Omega$ with the 4A flowing in the secondary, the magnetizing MMF is 80AT ~~Ampere turn~~ and iron loss is 1 watt. Determine the ratio error and phase angle error.

Solution:-

$N_1 = 1 \Rightarrow$ (Bar magnet)
$N_2 = 400$

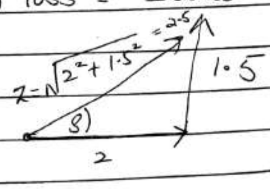
$n = N_2/N_1 = 400$

$Z_s = (2 + j1.5)\Omega = \sqrt{2^2 + (1.5)^2}$
$= 2.5\Omega$

$I_s = 4A$

$MMF = 80AT$

Iron loss $= 1$ watt



$\cos\delta = \frac{2}{2.5} = 0.8$

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$$\sin\delta = \frac{1.5}{2.5} = 0.6$$

$MMF = N_1 I_\mu = 80$

$\Rightarrow I_\mu = 80A$ (MMF is due to I_μ)

I_w is responsible for core losses (R_o represent core losses)

iron loss $= I_w^2 R_o = I_w \cdot I_w R_o$

$1 = I_w E_p$

$$\boxed{I_w = \frac{1}{E_p}}$$ (Now finding E_p)

For finding E_p finding E_s

$E_s = I_s \cdot Z_s = 4 \times 2.5$

$$\boxed{E_s = 10 \text{volts}}$$

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$$E_p = \frac{E_s}{n} = \frac{10}{400} = \frac{1}{40}$$

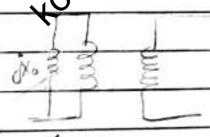
$$\boxed{E_p = \frac{1}{40} \text{ volts}}$$

$$I_w = \frac{1}{1/40} = 40A \Rightarrow \boxed{I_w = 40A}$$

$R = 420$ $n = 400$

% ratio error $= -4.76\%$

$\theta = 1.43°$



$R = \frac{400 + 40 \times 0.8 + 80 \times 0.6}{4}$ Xo 1: series = ?

What is jX_o = ?

R 420 Ω

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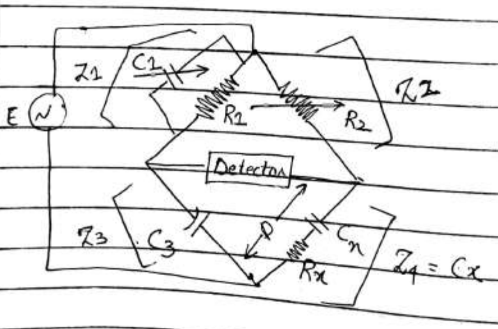
Lecture

Schering Bridge:-

The Schering bridge, one of the most important ac bridges used for measument of

- Capacitors
- Insulating properties i-e for phase angles very nearly 90°

ε_r = density of insulating material



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$Y_1 = \frac{1}{Z_1}$

$Z_1 = \frac{1}{R_1} = \frac{1}{1/j\omega C_1}$

$Z_1 = R_1 + j\omega C_1$

$= \frac{R_1 j\omega C_1 + 1}{R_1}$

$Z_2 = R_2$

$Z_3 = ? = \frac{-j}{\omega C_3}$

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

$$Z_x = Z_2 Z_3 Y_1$$

$$Z_1 Z_4 = Z_2 Z_3$$

$$R_x - \frac{j}{\omega C_x} = R_2 \left[\frac{-j}{\omega C_3}\right] \cdot \left[\frac{1}{R_1} + j\omega C_1\right]$$

$$R_x - \frac{j}{\omega C_x} = \frac{R_2 C_1}{C_3} - \frac{j R_2}{\omega C_3 R_1}$$

Equating real with real & imignary with imignary

$$\Rightarrow R_x = \frac{R_2 C_1}{C_3}$$

$$\Rightarrow C_x = \frac{C_3 R_1}{R_2}$$

Power factor: PF of a series RC combination is defined as the cosine of the phase angle of the circuit. Therefore PF of the unknown equals

$$PF = R_x / Z_x = \cos\theta$$

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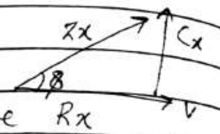

If $\theta = 90°$

Z_x = Purely capacitive

If $\theta = 0°$

Z_x = Purely resistive

$0° < \theta < 90°$ (In between behaviour)

Quality of capacitor depends on resistance of capacitor

$$Q = \frac{\text{Energy stored}}{\text{Dissipated}} = \frac{X_C}{R_x}$$

D = Dissipation factor

$$D = \frac{1}{Q} = \frac{X_L}{R_L} \frac{R_x}{X_x} = \omega C_x R_x$$

$D = \omega R_2 C_2 \qquad \omega = 2\pi f$

C_2 should impact quality of unknown capacitor C_x.

$D = 2\pi f R_2 C_2 \nearrow$ (f → const.)

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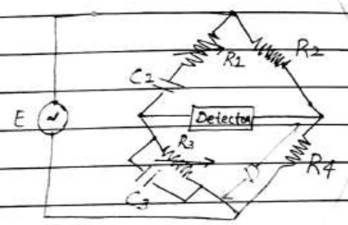
Unbalance conditions:- (Exple 5·5)

WIEN BRIDGE



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

$= R_1 - \frac{j}{\omega C_1}$

$Z_2 = R_2$

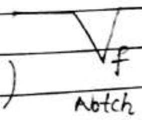
$Z_4 = R_4$

$\frac{1}{Z_3} = Y_3 = \frac{1}{R_3} + j\omega C_3$

$Z_1 Z_4 = Z_2 Z_3$

Wein bridge is used
- → for measuring freq in ac bridges
- → as a notch filter in harmonic distortion analyzer.
- as the frequency-determining element in audio and HF oscillators.

Notch filter (Passes a particular frequency through it)



Gang Capacitors (coupled)

$\frac{R_2}{R_4}$ (mechanically coupled)

$\frac{R_2}{R_4}$ = Fix ratio = 2

$R_2 = 2R_4$ (5-52)

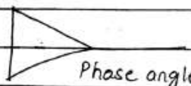
$R_1 = R_3 = R$

$C_1 = C_3 = R$

Shock in winter is due to stray capacitance

Wagner Ground Connection:

For oscillator gain should be 1.



Phase angle = 0°

$A = 1$

Google It:

Wein Bridge in Op-Amp

(Sir Farooq)

If unknown resistance is less than 1Ω wheatstone bridge is not good solution due to lead resistances (Solution is Kelvin bridge)

For high resistance measurement we cannot use wheatstone bridge

1) (becoz of sensitivity of detector)
R↑ V↓
→ For this problem we uses amplifier

2) Leakage current on surface of insulator & can be affected by humidity & temp.
→ For this we uses guard wheatstone bridge.

For Inductor (Maxwell Bridge)

$1 \le Q \le 10$

If $Q \le 1$

Desauthy bridge

WAGNER GROUND CONNECTION:

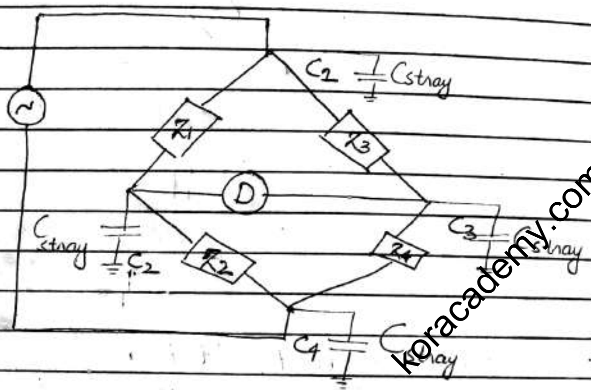
Stray capacitances exist in AC bridges. It exist between bridge element and ground. Do not exist physically but exist electrically

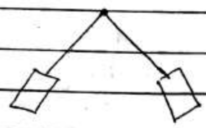
$$X = \frac{1}{2\pi f C} \quad \text{If } C\uparrow \; X_C\downarrow$$

x (If we increases f↑) (we take affect of stray capacitances when frequency is very high) ⇒ ? becoz $X_C\downarrow$ current will move to ground
we can reduce the affect of stray capacitances

1) Shield the arms of bridge and ground each of the shield. By doing this value of stray capacitance will get constant.

The best solution for solving this problem is Wagner ground connection.





Two conductors & In b/w di-electric is capacitor

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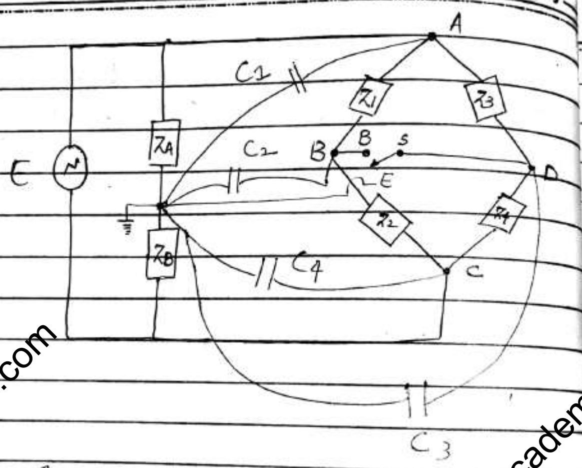

STEPS:-

1) Connect switch to Pt B and balance the bridge with the help of Z_1, Z_2, Z_3 and Z_4

2) Connect switch to pt E and balance the bridge with the help of Z_A, Z_B, Z_3, Z_4

⇓

It is possible that we change value of Z_3 and Z_4. To check it we have to repeat step 1 again.

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We have to do step 1 & 2 again & again unless the bridge is balance at both B and E for same values of impedances.

That it is my claim that there will be no effect of stray capacitances.

1 Step implies $V_D = V_B$

2nd Step implies $V_D = V_E = V_B = 0V$

C_4 is parallel to Z_B
C_1 is parallel to Z_A
} so neglect its effect

Disadvantage is balancing is time consuming & very difficult.

The best solution is shielding.

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Problem 5.5 :-

$f = 1KHz$

AB : $C_1 = 0.2\,uF$

BC : $R_2 = 500\Omega$

CD : unknown

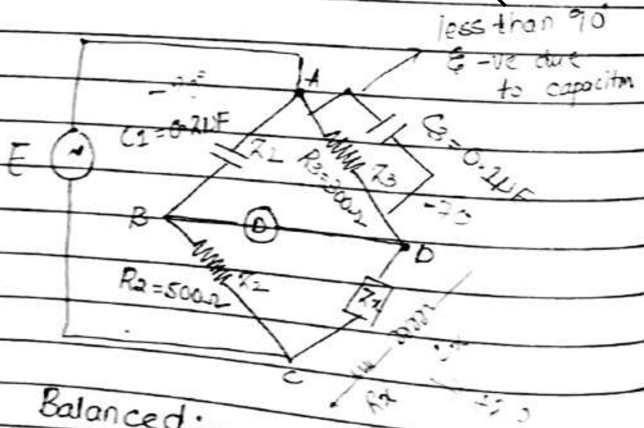
DA : $R_3 = 300\Omega \,//\, C_3 = 0.1\mu F$

CD: R and C or L

Series

Solution :

First step is to draw the circuit



Balanced:-

$$Z_1 Z_x = Z_2 Z_3 \quad \text{--- (1)}$$

~~In paralle~~ $Z_x = \dfrac{Z_2 Z_3}{Z_1}$

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In parallel we take admittance.

$$Y_3 = \frac{1}{Z_3}$$

$$Z_x = \frac{Z_2}{Z_1 Y_3}$$

$$Z_1 = \frac{-j}{2\pi f C_1} = \frac{-j}{2\pi(1000)(0.2\times10^{-6})}$$

$$Z_1 = -j795.8\Omega$$

$$Z_2 = R_2 = 500\Omega$$

$$Y_3 = \frac{1}{R_3} + j2\pi f C_3$$

$$Y_3 = \frac{1}{300} + j2\pi(1000)(0.1\times10^{-6})$$

$$Y_3 = (3.33\times10^{-3} + j628.32\times10^{-6})\,\mho$$

$$Z_x = \frac{500}{(-j795.8)(3.33\times10^{-3} + j628.32\times10^{-6})}$$

$+j \rightarrow$ Inductor

$-j \rightarrow$ capacitor

$$Z_x = (34.4 + j182.2)\,\Omega$$

$Zx = Rx + j2\pi f Lx$

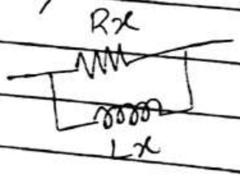
$Rx = 34.4 \Omega$

$2\pi f Lx = 182.2$

$Lx = 29mH.$

Question:

If in Question asked unknown arm is in parallel (Rest is same question)



$Yx = \frac{1}{Zx}$

$Yx = Gx - jBx$

$Yx = \frac{1}{Rx} - \frac{j}{2\pi f Lx}$

$Rx, Lx.$

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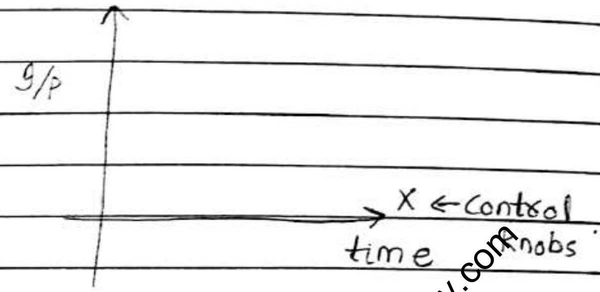
Lecture OSCILLOSCOPE

Oscilloscope give X-Y plot



Knob for magnification/attenuate.

Oscilloscope functions
- → Display
- → Analyze.
- → Measure

Cathode Ray Oscilloscope → Analogue / Digital storage Oscilloscope.

Oscilloscope parts:

Cathode Ray tube: It works on the principle of thermionic emission.

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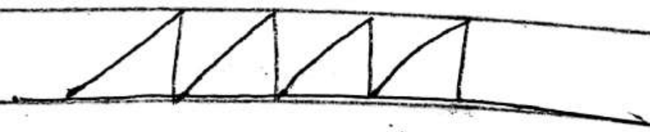
Barium oxide produces more $\bar{e}s$ when it is heated.

Astigmation:

Graticule (calibrate scale is graticule & ~~it~~ is pasted outside oscilloscope.

Time base generator produces saw-tooth waveform.



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LAST LECTURE

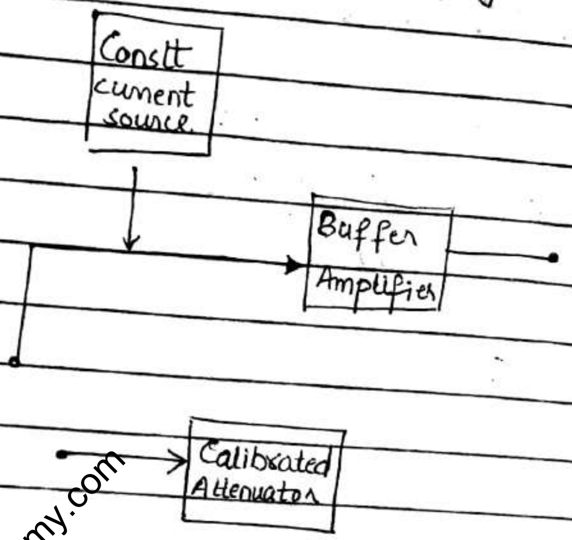
DIGITAL MULTIMETER:

We will study multimeter to measure 5 quantities:

Principle of operations is that AC voltage, current, resistance & DC current other than ~~AC~~ DC voltage. We will convert all these quantities to equivalent DC voltage. We will measure that DC voltage and by calibration we will find that unknown quantity. and then we will display it.

V~ AC voltage
V⎓ DC voltage
A~ AC current
A⎓ DC current
Ω → resistance.

Block diagram of digital multimeter:-



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DC VOLATGE MEASURMENT:

→ Keep Rotary switch to V⎓

Calibrated Attenuator will convert high voltage to low voltage as ADC, MC cannot withstand high voltage.

Calibrated attenuator can be consider as series resistance. Alot of voltage will appear across series resistance & less voltage will appear across MC.

Controller will know the table inside ADC.

ADC table

1mV	000001000
1.2m	

MC will search in this table and will find voltage at the input of ADC and MC also knows that calibrated attenuates how many times attenuates voltage and will multiply with the factor to get actual voltage.

→ by Noman

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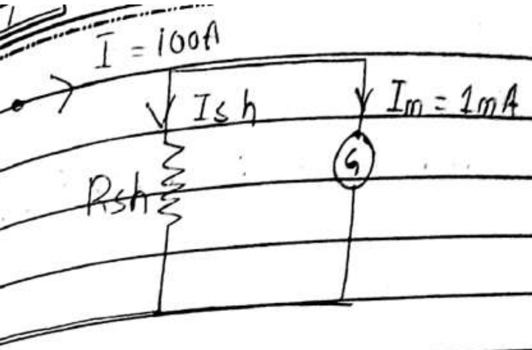
ADC converts to bits.
Other quantities we will convert to DC voltage and then we will find the known quantity.

If we want to measure small voltages so & then we will replace calibrated ~~an~~ attenuator by amplifier.

AC Voltage measurment
Move the rotary switch to V~.
→ first calibrated attenuator
→ Precision AC to DC converter (Rectifier)
→ ADC
→ Decoder on UC
→ LCD

DC Current Measurment:
first Convert Current to Equivalent DC voltage
→ Alot of Current will pass through Shunt & less current will pass through UC.



$I_{sh} \approx I$

$V_{shunt} = I_{sh} R_{sh}$

$V_{shunt} \cong I R_{sh}$

$V_{shunt} \propto I$ (It will produce voltage in ~~parall~~ proportional to current)

Shunt is very small resistance in mΩ.
If R_{sh} is less so Voltages V_{sh} ↓ less
so no need of attenuation of signal.

$I = \frac{V_{shunt}}{R_{shunt}}$

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Shunt bypass almost all current.
In Place of it we can use current to voltage converter.

RESISTANCE MEASURMENT:

Move switch to Ω position.

Constt Current source will provide DC current. That DC current will flow through unknown resistor and voltage will appear across it.

Difference b/w Current Source & Voltage Source:

Generators are voltage sources.

~~If we inc voltage~~ is

If voltage of source is independent of load then the source is voltage source.

If current provided by source is not changing by changing the load so it is a current source.

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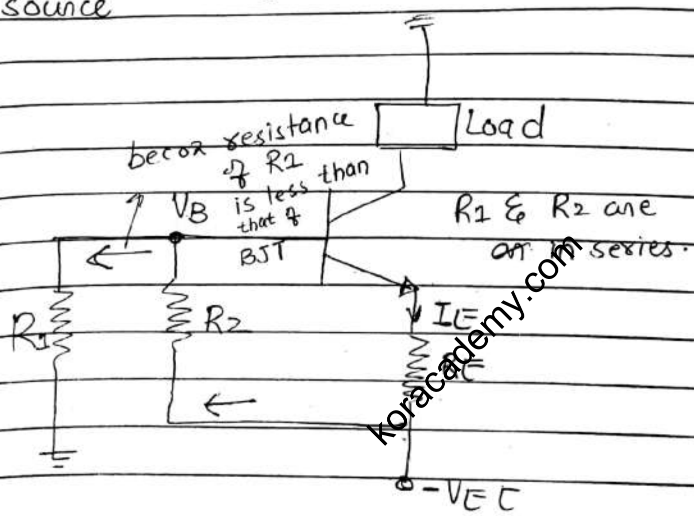
Unknown resistor will act as a load.

How we design a current source



Base I/P impedance of BJT is much larger than R_1 & R_2

$$V_B = \frac{R_1}{R_1 + R_2}(-V_{EE})$$

$$V_{BE} = V_B - V_E = 0.7V$$

$$V_E = V_B - 0.7$$

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V_{EE} = Constt (Constt Voltage source)
R_1 & R_2 = constt
V_B = constt
0.7 = constt

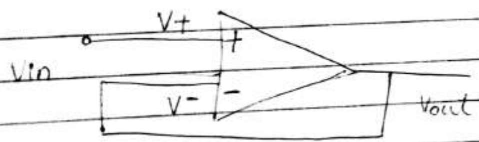
$\Rightarrow$ V_E = constt

$$I_E = \frac{V_E + V_{EE}}{R_E}$$

V_E = constt V_{EE} = constt
R_E = constt

$\Rightarrow$ I_E = constt
$I_E \propto I_C$, Acting as
so I_C = constt (Constt Current source)

Buffer Amplifier:



Gain = 1
Use for impedance matching

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-ve feedback property
$V^+ = V^-$ (Virtual ground concept)
-ve feedback will force op-Amp to have same potential at V^+ & V^-
i-e $V^+ = V^-$
-ve feedback will force op-Amp to have same potential at
$V^+ = V^-$

$V^+ = V_{in}$
$V^- = V_{out}$
$V_{out} = V_{in}$
$A_f = 1$

Buffer Amplifier provides two advantages.

1) They provide impedance matching.
2) Isolation (It isolate one part of ckt from another)

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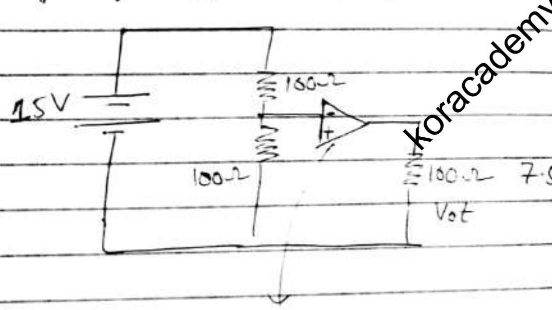
As Input impedance of Buffer Amplifier is $\propto$ (infinite) so current will pass through unknown resistance & minimum or no current will pass through Buffer Amplifier. & voltage drop across that unknown resistor. [$V_{drop} \propto I$]

Advantage of Buffer Amplifier:-



In presence of Buffer amplifier same voltage i.e 7.5 volt will appear i.e 7.5 V

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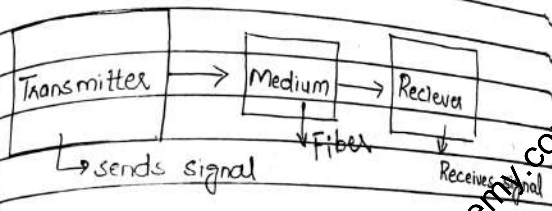
F1

FIBER OPTIC MEASURMENT:

Three main parts of communication system



Transmitter has to change the form of information so it can travel through the medium (fiber)

Medium → Fiber
signal ~~light can travel through~~

Fiber → light can travel through fiber.

LED converts the electrical signal to light signal.

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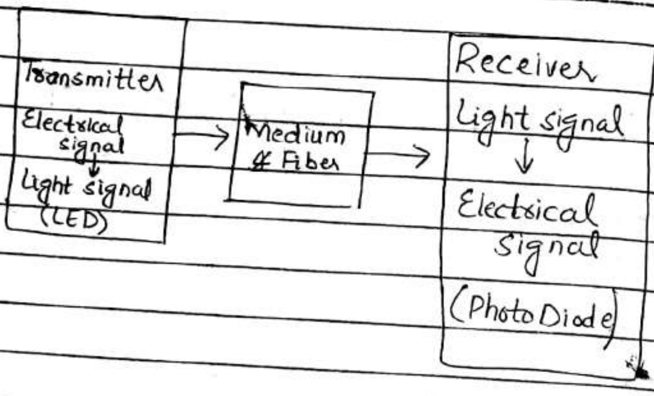
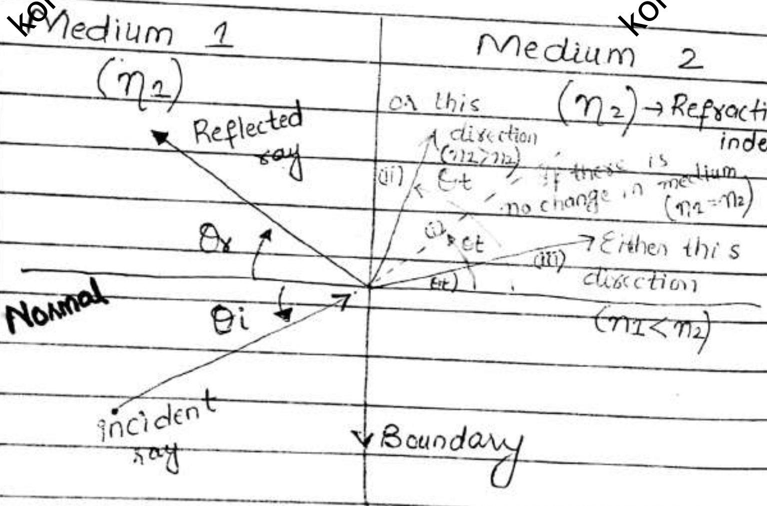


Fiber optic works on the principle of total internal reflection



η (Refractive index) of air is equal to one. & for other mediums $\eta > 1$.

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i) ~~$n_1 = n_2$~~

Snell's Law of Reflection:

$$\theta_i = \theta_r$$

Snell's Law of Refraction:-

$$n_1 \sin\theta_i = n_2 \sin\theta_t \quad \text{—(2)}$$

i) $n_1 = n_2$, $\theta_i = \theta_t$

ii) $n_1 > n_2$

According to Snell's law of refraction

$$\sin\theta_i < \sin\theta_t$$

$$\Rightarrow \theta_i < \theta_t$$

So the refracted ray (transmitted) will bend away from the normal.

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iii) $n_2 < n_2$

$\sin\theta_i > \sin\theta_t$

$\Rightarrow \theta_i > \theta_t$

When $n_1 > n_2$

$\theta_i \uparrow, \theta_t \uparrow$

when $\theta_t = 90^\circ$

$\theta_i = \theta_c$

Critical angle (θ_c):-

The incident angle at which θ_t become 90° is called Critical angle.

TOTAL INTERNAL REFLECTION:

When $\theta_i > \theta_c$

so the total ray will be reflected and no part of ray will be transmitted.

This phenomenon is use in ~~fibers~~ fiber. ~~on~~

For long range communication fiber is made up of glass

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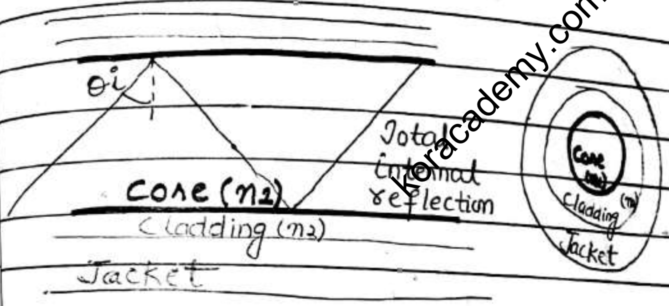
For short range we uses plastic.

For medium range mixture of glass & plastic is use.

OPTICAL FIBRE INTERNAL STRUCTURE:-



In medium at different points we use repeaters. (Shape of signal will be recover)

In fiber optic we need less number of repeaters.

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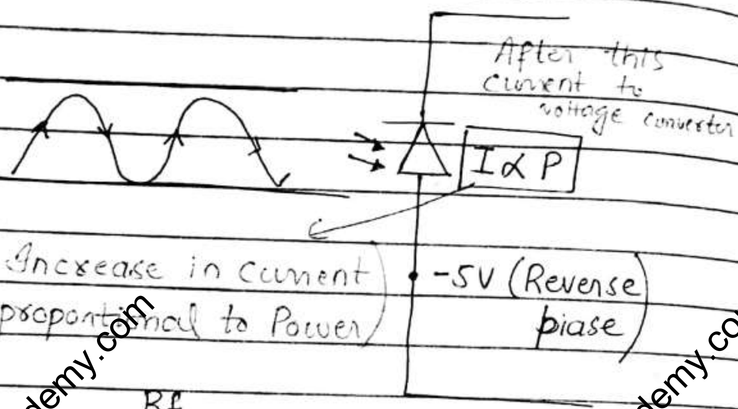
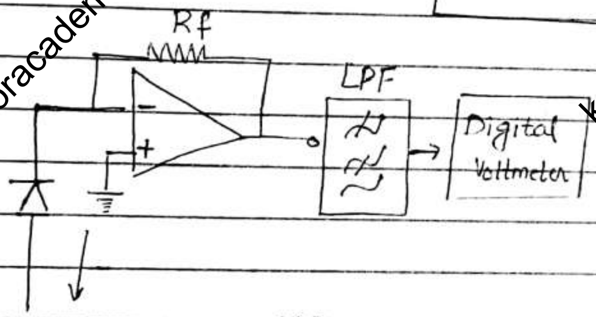
POWER OF THE SIGNAL:
(Light Signal)



(Increase in current is proportional to Power)



Trans-Impedance Amplifier (Convert current to voltage)

Current to voltage converter should have following two properties:-

i) $V_{out} = KI_i$ (resistor also give this property)

ii) Vout should be independent of load.

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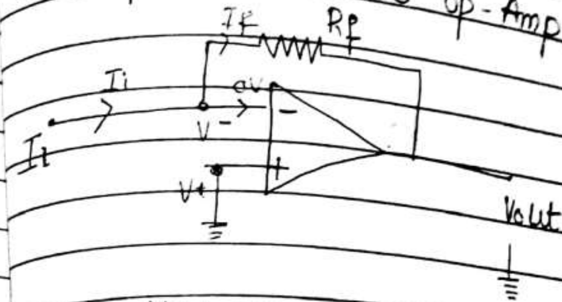
Property 2.

Resistor donot give this property.

Therefore we use op-Amp



~~VOLTAGE DIVIDER~~

VOLTAGE TO CURRENT CONVERTER

-Ve fb

$V^- = V^+$

$I_f = I_i$

$0 - V_{out} = I_f R_f$

$V_{out} = -I_i R_f$

$K = -R_f$

$V_{out} = K I_i$

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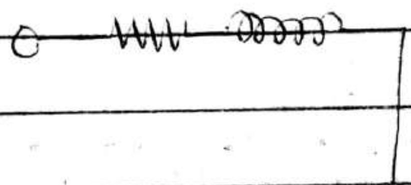
Due to known ~~rese~~ reasons there will be noise & noise is in χ high frequency component & therefore we uses LP filter.

CT :

$$n = \frac{I_P}{I_S} \Rightarrow \text{(Nominal ratio)}$$



Leakage flux & working flux.

EXAMPLE