ELECTRICAL
AND
ELECTRONICS
MEASURMENTS
2012

22/4/13
(6 to 8)

1. Error Analysis
2. Basic Instruments
   - M-C type
     - PMMC
     - EMMC
   - M-I type
     - Attraction
     - Repulsion
3. Extension Range of Basic Instruments
4. Electro static Voltmeters
5. Thermal Instruments
6. Rectifier Type Instruments
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   - Full Wave "
7. Measurement of 'R' 'L' & 'C'
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8. Q - meter
9. Potentio meter
10. Measurement of Power
11. Measurement of Energy
12. Measurement of Power Factor, Unknown Frequency
13. DVM'S
14. CRO
15. Instrument Transformers.

Venugopal, eee

Error Analysis :- Error (ϵ)

$$\boxed{\epsilon = A_m - A_t}$$

ϵ → +Ve ($A_m > A_t$), -Ve ($A_m < A_t$)

A_m → Measured

A_t → True Value

Static error — Independent of time

Dynamic error

the error which is independent of time → Static error

the error which changes w.r.t time → Dynamic error

Correction factor :- The Value which we are added / Subtracted from the "measured Quantity" inorder to get true Value.

$$\boxed{C.F = -(\epsilon)}$$

Relative Static error :-

$$* \ \% \text{ Relative Static Error} = \left(\frac{A_m - A_t}{A_t}\right) \times 100$$

* Determines Quality of the Instrument

23/4/12 (2 to 5:30)

Limiting Error :- * It is specified by the Manufacturer

* It give will the Range of operation (or) Range of Error

* the Limiting error is always wrt true Value

* the other names are Tolerance and Uncertainity

Range (0-10)A → Full scale Value	% LE
A	±2 %
B	±1 %
✓C	±0.5 %
D	±0.0 %

True Value 2A →

A:- $2 \times \frac{\pm 2}{100} = \pm 0.04$

2 ± 0.04 ↗ Measured Value

⇒ 1.96 - 2.04

B:- $2 \times \frac{\pm 1}{100} = \pm 0.02$

= 1.98 - 2.02

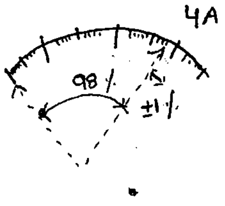
'C' is the best & We should not choose 'D'.

* In laboratories, experiments are performed repeatedly to cancel the Positive errors and Negative errors ~~case~~ So as to get the Accurate Value

* Basic Characteristics of Instruments :-

(Accuracy, Precision, Linearity, Sensitivity, Dead Time, Dead zone, Resolution).

Accuracy:- the Accuracy indicates the degree of Closeness of Measured Quantity to true Value.



Accuracy → Deviation (error)

A $\boxed{\pm 1\%}$ → High Accurate

B $\boxed{\pm 99\%}$ → 3rd "

C $\boxed{98\%}$ → 2nd high "

D $\boxed{1\%}$ → ~~4~~ 3rd "

→ Deflection

± Indicates DeViation from true Value

Normal Indicates Deflection from Initial

G.A.E - Guaranteed Accuracy Error

G.A.E:- (Guaranteed Accuracy Error)

It is Specified by Manufacturer. It is a Constant error seen by the Instrument. Because it is respect to Full Scale Value.

$(0-10)A \qquad \%\, GAE = \pm 1\%$

$$10 \times \frac{\pm 1}{100} = \pm 0.1$$

$\qquad$ G.A.E $\qquad\qquad$ % LE

$1A \quad \pm\ 0.1 \longrightarrow 1 \times \frac{x}{100} = 0.1 \Rightarrow 10\%$

$2A \quad \pm\ 0.1 \longrightarrow 2 \times \frac{x}{100} = 0.1 \Rightarrow 5\%$

$5A \quad \pm\ 0.1 \longrightarrow 5 \times \frac{x}{100} = 0.1 \Rightarrow 2\%$

$9A \quad \pm\ 0.1 \longrightarrow 9 \times \frac{x}{100} = 0.1 \Rightarrow 1.1\%$

As the pointer reaches to "Full Scale Value," the "Error % LE" decreases but the "Guaranteed Accuracy is Constant. Bcz the "% LE" is wrt "true Value" and "G.A.E" wrt "Full Scale Value"

1. A (0-10)A Ammeter with a GAE of ±1%. If we measure a true Value of 2.5 A. % LE is ——

$$2.5 A \quad \pm \quad 10 \times \frac{\pm 1}{100} = \pm 0.1$$

$$2.5 \pm 0.1 \longrightarrow 2.5 \times \frac{x}{100} = 0.1$$

$$\Rightarrow \quad x = \frac{0.1 \times 100}{2.5}$$

$$= 4\%$$

2. A (0-10) A Ammeter with G.A.E error of 98 %. If We measure a true Value of 2.5 Amp. Then % Limiting error is .

$$10 \times \frac{\overset{\pm 2}{\cancel{\pm 98}}}{100} = \cancel{9}. \pm 0.2$$

98 % → ±2 % 2.5 ± 0.2 → $2.5 \left(\frac{x}{100} \right) = 0.2$

(Deflection) (Deviation

$$x = \frac{0.2 \times 100}{2.5}$$

$$= \pm 8 \%$$

3. A (0-10) A Ammeter With GAE error of ±1 % of reading. If we measure a true value of 2.5 A. Then % LE is

$$\overset{GAE}{\cancel{10 \times \frac{\pm 1}{100} = \pm 0.1 V}}$$

$\overset{\pm 1 \%}{\boxed{\text{"Of reading"}}}$ → wrt true Value

$\cancel{2.5} \times \cancel{\%}$

→ $\boxed{\text{Limiting error}}$

Precision :- The Most repeatable Value (or) Reproducible Value out of Set of records is known as precision

'A' is Accurate & precise Instrument.

'B' is precise Instrument

$A_t = 2A$

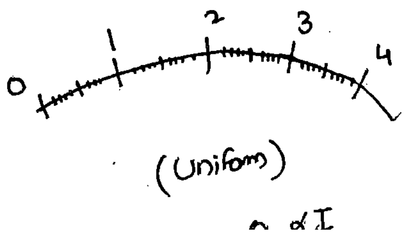
A	B
1.9	1.5
1.5	1.5
1.9	1.9
1.9	1.5
1.5	1.9
1.9	1.5
A & P	P

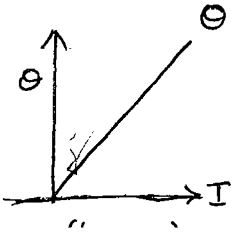
* "Accurate Instrument" may be "precise" but "precise" "Will not" Confirm "Any Accuracy". Be prefer Always Accurate as well as precise Instrument.

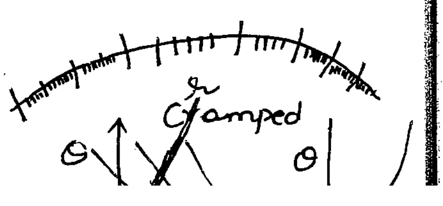
Linearity: the o/p follows the I/p with linear relation / equation is called Linearity .

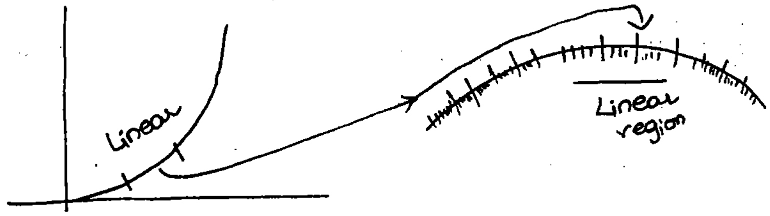
In most of the meters, the responsible quantity is Current. So, Current Causes a force on the Pointer to deflect. (Electrical to Force then Force to Angular deflection) θ ∝ I (Linear)

θ ∝ I² (Non-linear)









* We have to choose a meter so that it reads the pointer reading is in Linear region so that Accuracy is maintained.

To measure 17 A, we have to choose (0-20) A among (0-100)A, (0-20)A, (0-30)A meters

* Be prefer always the instrument in such a way that the pointer should enter "Linear region" so that we may not loose "Accuracy"

**
* Sensitivity :- (S):

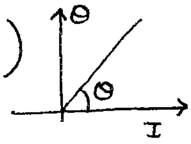
✓High Sensitive
Low "
Medium "

Be prefer always "high Sensitive" Instruments so that We may not lose "Accuracy"

$$\boxed{S = \frac{\text{Change in O/p}}{\text{Unit change in I/p}}}$$

$$\boxed{S = \frac{\Delta O/p}{\Delta I/p} = \text{Slope of the I/p-O/p chars} = \tan\theta}$$

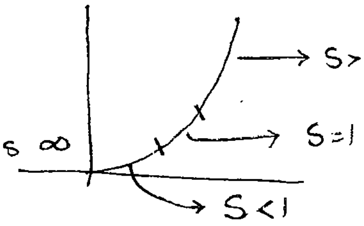
* For perfect linear Instruments, Sensitivity is Constant and is equal to '1' (as $\theta = 45^\circ$, $\tan\theta = 1$)



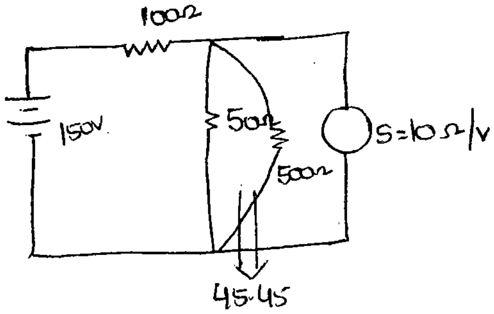
For PMMC, Sensitivity = 1

(Linear)

* For Non-linear Instruments, the Sensitivity will vary through out the scale.



Ideal voltmeter Int. Resist is ∞



$V_{AB} = 150 \times \frac{50}{150} = 50V$

$V_m = 150 \times \frac{45.45}{145.45}$

$= 46.87V$

Suppose 'S' is increased to 100kΩ then equivalent will become 49.99

* If Sensitivity is increased, then Accuracy will also be increased.

* We can manufacture Int. Resistance ∝ meter won't work as open Ckt exist & flows

* Be prefer "high Sensitivity" Instruments so increase "Accuracy"

24/4/12 (11 to 1)

1. A (0-10)V Volt meter the allowable c Reading.

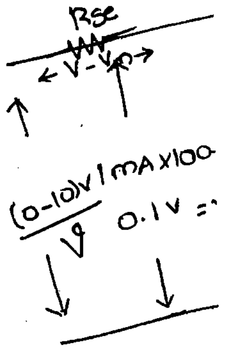
Units $S = \Omega/V$

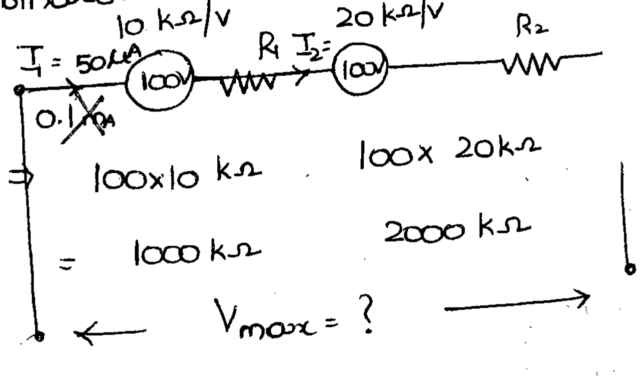
$$= \frac{1}{(V/\Omega)} = \frac{1}{I} \qquad \therefore \boxed{S = \frac{1}{I_{FSD}}}$$

" I_{FSD} is the max. allowable Current, that meter will damage".

Pb: Two 100V Voltmeters with sensitivities of 10 & 20 kΩ/V Respectively are connected in Serie. What is the max. Voltage that we can mea with this Series Combination.

2. A (0-1)m Resistance





$$I_{max_1} = \frac{1}{S_1} \Rightarrow$$

$$= \frac{1}{10\ k\Omega/V}$$

$$= 0.1\ mA$$

So,

$$I_{max_2} = \frac{1}{S_2} = \frac{1}{20\ k\Omega/V}$$

$$= 50\ \mu A$$

Among I_{max_1}, I_{max_2}, we have to allow 50 µA only otherwise 'V_2' will be damaged

So, I_1 = 50 µA

$$V_{max} = (50\ \mu A)(3000)\ k\Omega$$

$$= 150\ V$$

24|4|12 (11 to 1)

1. A (0-10)V Voltmeter with a Sensitivity of 10 kΩ/V. Find the allowable Current through Voltmeter at half full scale Reading.

$S = 10\ k\Omega/V$

$10 \times 10 \times 10^3 \cdot z$

$S = \frac{1}{I_{FSD}}$

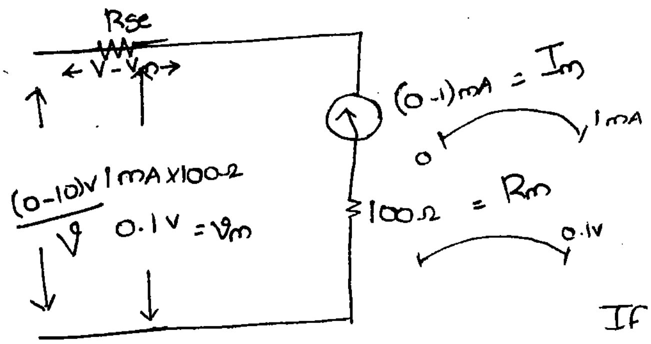
$I_{SD} = \frac{1}{10 \times 10^3}$

$= 10^{-4}\ A \quad 0.1\ mA$

∴ At half full Scale $= 5 \times 10^{-4}\ A$:

$\frac{0.1\ mA}{2}$ ~~0.50 mA~~ $= 0.05\ mA$

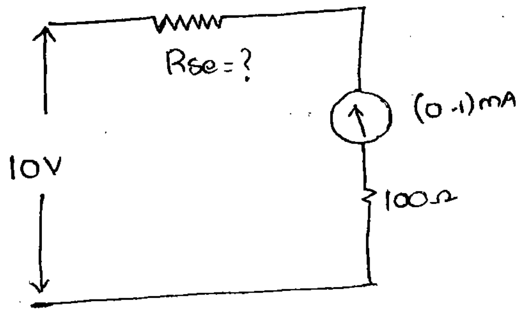
2. A (0-1) mA linear Instrument with an internal Resistance of 100 Ω is to be Converted into (0-10) V.



But if we have to design for (0-10)V

If we apply 10V, meter damages. as the allowable is 0.1V

So, a resistance in Series have to be added.



$I = \frac{V}{R}$

$1mA = \frac{10}{R_{se} + 100\Omega}$

$\Rightarrow (R_{se} + 100)\ 10^{-3} = 10$

$R_{se}\ 10^{-3} + 0.1 = 10$

$\Rightarrow R_{se} = \frac{9.99}{10^{-3}} = 9.9k\Omega$

* We can manufacture only Ammeters and it can be Converted into Voltmeter.

If we want to read for 20V, again Calculate Rse and change ~~th~~ it

As Current is Same

$$\Rightarrow \frac{V-V_m}{R_{se}} = \frac{V_m}{R_m} \quad \Rightarrow \quad \frac{R_{se}}{V-V_m} = \frac{R_m}{V_m}$$

Voltmeter → $\boxed{R_{se} = \left(\frac{V-V_m}{V_m}\right) R_m = \left(\frac{V}{V_m}-1\right) R_m}$

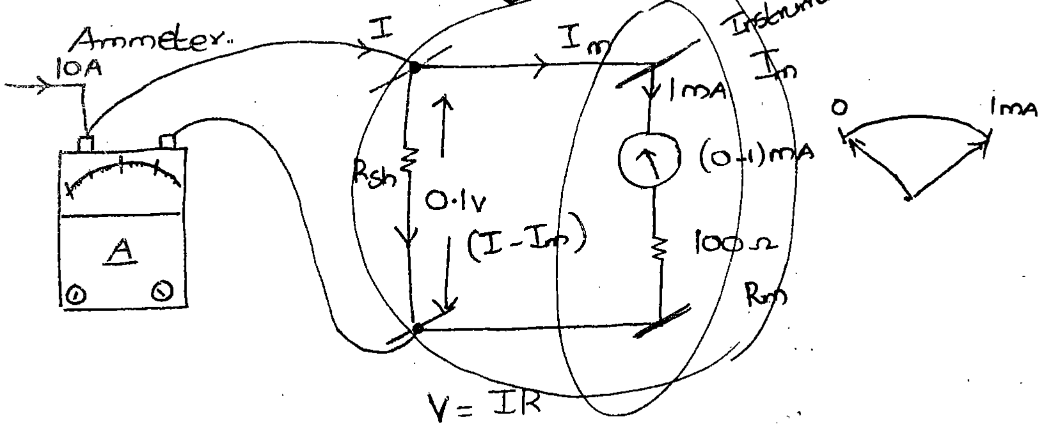
$$= (m-1)R_m \quad \left(m=\frac{V}{V_m}\right)$$

$\boxed{V\uparrow \leftrightarrow R_{se}\uparrow}$

Other Way: $R_{se} = \left(\frac{10}{0.1}-1\right)100$

$$= 9.9\,k\Omega$$

3. A (0-1) mA linear Instrument with an Internal Resistance of 100 Ω is ~~tov~~ be Converted into (0-10)A to Ammeter



$$V = IR$$

$$R = \frac{V}{I} = \frac{0.1V}{10A}$$

$$\Rightarrow \frac{R_{sh} \cdot 100}{R_{sh}+100} = \cancel{0.1\times 10^{3}}\ 0.01$$

$$= \cancel{100}$$

$\boxed{I\uparrow,\ R_{sh}\downarrow}$

$$R_{sh}(100) = 0.01 R_{sh} + 1$$

$$\Rightarrow R_{sh}(99.99) = 1 \Rightarrow R_{sh} = 0.01\Omega$$

* Voltage is Same

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

$$\Rightarrow R_{sh} = \left(\frac{I_m}{I-I_m}\right) R_m$$

Ideal Voltmeter,
Int. Res → ∞
Ideal Ammeter,
Int. Res → 0

$\boxed{R_{sh} = \frac{R_m}{\left(\frac{I}{I_m}-1\right)}}$ ~~Volt~~Ammeter

* We can manufacture them but they dont work

* In
alwa
* In
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Voltme
Note 1:
1. By
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Volt
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11.

-1) Rm

$\left(m = \frac{V}{V_m}\right)$

ool

(0-10)A

.01Ω

em but

* In Voltmeter, we have Series Ntwk inside. So, we always Connect in ||el (Voltage division)
* In Ammeter, we have parallel Ntwk inside. So, we always Connect in Series (Current division)
High Currents bypassed through Shunt Resistance

* Instrument is a part of meter. In Ammeter, Voltmeters Instruments are Same.

Note 1: (Summary)

1. By Connecting high Resistance in Series with an instrumen will become Voltmeter
2. By Connecting low Resistance across / parallel to the instrument will become Ammeter
3. In both the meters, the responsible Quantity is Current
4. The Value of $R_{se} = R_m\left(\frac{V}{V_m} - 1\right)$
5. The Value of $R_{sh} = \frac{R_m}{\left(\frac{I}{I_m} - 1\right)}$
6. As we are increasing the Voltage Range, Rse Value increases
7. As the Current Range increases, Rsh Value decreases
8. Voltmeters are to be always Connected in ||el Since Inside Voltmeter Series Ckt there
9. Ammeters are to be Connected in Series. Since, inside Ammeter parallel Ckt there
10. Ideal Voltmeters, Ammeters Can be manufactured but they ~~sh~~ should not be manufactured, as Current will not enter and it will not work
11. Instrument is a part Of Meter

24|4|12

Dead Time :-

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

Voltmeters $\theta \propto I \propto V$ $\boxed{\theta \propto V}$

In all electrical instruments, the responsible quantity is Current.

In Case of Current measurement $\boxed{\theta \propto I}$. In Case of Voltage measurement, $\theta \propto I \propto V \Rightarrow \boxed{\theta \propto V}$

We Cannot directly measure Voltage.

Note 1:. In all electronic Instruments, the responsible quantity is Voltage (Bcz pulse Counting is there, Pulse is nothing but Voltage pulse)

* All electrical ~~meters~~ Instruments are energy Converters which Converts electrical energy to Mech. energy

* All electronic ~~meters~~ Instruments are not energy Converters. So, these are fast response Instruments when Compared to electrical instruments Since there is no energy Conversion.

* If we use electrical instruments for low Values it will not deflect and if electronic instruments for high Values they damage

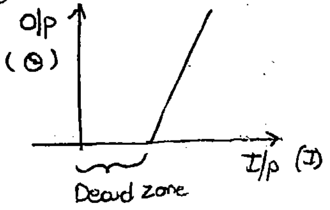
*The time taken by the instrument to move the pointer from its initial position is Called Dead time

* The Main reason for dead time is Inertia

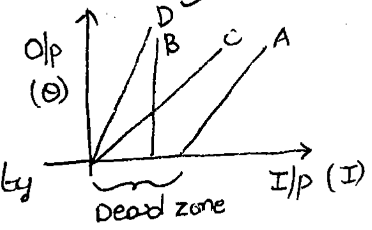
*All instruments will experience both transient as well as Steady State. Initially transient, finally reaches to steady State

Dead Zone:: the minimum Input beyond which the response will Come is Called Dead zone

other name is Thres hold



Among C, D.
D is best bcz
of high sensitivity



Resolution :- (R) :- The Smallest output that we Can detect with Certainity (or) Clarity is Called Resolution (or) The Smallest change in I/p that we Can detect with certainity Clarity. We prefer always High Resolution Instruments. As the Resolution increases, Clarity increases so that we may not loose Accuracy

$$R = \frac{\text{Full Scale Value}}{\text{Total No. of divisions}}$$

If No. of divisions increases, Resolution also increases

Types of Errors :-
1. Gross Error
2. Systematic Error — Instrumental, Environmental, observational
3. Random Error

* All Human Negligence errors Comes under Gross Error while taking errors (varies from one person to person)

* Instrumental errors — (Due to Manufacturing defects, ageing Loading error also come under this)
G. A. E, LE,
* Environmental errors — Due to temp. Changes in environment
* observational errors — parallax errors
→ Common for all

* Random errors — there is no particular reason for occuring of these errors. Suddenly, the error will Come and disappear.

d_{10}^2

* All the instruments will offer Random errors. The Random errors may be +ve (or) -ve. We Can solve these errors by using Mathematical tool Statistics

$$\boxed{S.D = \sigma = \sqrt{\frac{d_1^2 + d_2^2 + \cdots d_n^2}{n-1}}}$$

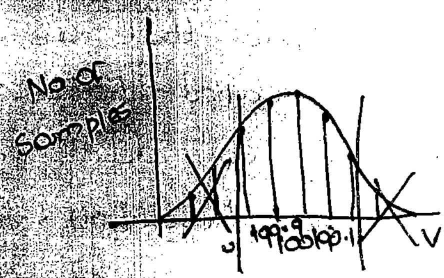
2135 * the Random errors Can be solved by using Mathematical tool statistics like Arithmetic mean, mode and standard deviation

25/4/12 (11 to 1)

9.30 2 Random Error Analysis :

Suppose (0 - 150) V, a Voltmeter taken and true Value A_t = 100 V. Measure 50 times

99.7 — 1
99.8 - 4
99.9 - 12
100 - 19
100.2 — 3
100.3 - 1



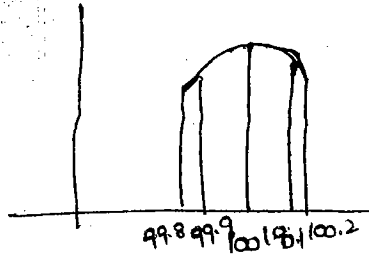
Probable error =

$\pm 0.6745\,\sigma$

$$S.D = \sqrt{\frac{d_1^2 + d_2^2 + \dots d_n^2}{(n-1)}} \quad (n)$$

$n \leq 20$

$n \geq 20$



Eliminate high deviations

True ↑ ↗ Absolute Error

Note: 1. Let $R_1 = (100 \pm 4)\Omega$, $R_2 = (50 \pm 2)\Omega$

$R_1 + R_2 = (150 \pm 6)\Omega$, $(R_1 - R_2) = (50 \pm 6)\Omega$

In case of Addition & Subtraction, the absolute errors will be added up

2. Let $R_1 = 50 \pm 6\%$, $R_2 = 10 \pm 3\%$

$R_1 \times R_2 = 500 \pm 9\%$, $\frac{R_1}{R_2} = 5 \pm 9\%$

In case of Multiplication & division, the % errors will be added up

$R_2^{②} R_1^{①} = 5000 \pm (2 \times 3\% + 1 \times 6\%) = 5000 \pm 12\%$

* Two Resistors R_1 & R_2 Connected in ||el, the Values of R_1 & R_2 are $(100 \pm 0.1)\Omega$, $R_2 = (50 \pm 0.05)\Omega$. Then calculate total uncertainity in the Combined Resistor.

$$\Rightarrow \frac{R_1 R_2}{R_1 + R_2} = \frac{(100 \pm 0.1)(150 \pm 0.05)}{(100 \pm 0.1) + (50 \pm 0.05)}$$

$100 \times \frac{x}{100} = 0.1$

$x = 0.1\%$

$$= \frac{(100 \pm 0.1\%)(50 \pm 0.1\%)}{(150 \pm 0.15)}$$

$50 \times \frac{x}{100} = 0.05$

$x = 0.1\%$

$$= \frac{(5000 \pm (0.2)\%)}{(150 \pm 0.15)}$$

$150 \times \frac{x}{100} = 0.15$

$\frac{15}{}$

$\left(5000 \pm (0.2)\%\right| = 33.333 \pm$

$\text{True} \times \frac{x}{100} = \text{tolerance}$ $\quad = (33.333 + 0.099)\,\Omega$

Method 2:- $\quad Req = \frac{R_1 + R_2}{R_1 + R_2}$

$$\boxed{\frac{\Delta Req}{Req} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_2}{R_2} + \frac{\Delta(R_1+R_2)}{(R_1+R_2)}}$$

$$\frac{\Delta Req}{33.33} = \frac{0.1}{100} + \frac{0.05}{50} + \frac{0.15}{150}$$

$$= 0.001 + 0.0001 + 0.001 = 0.003$$

$$\Delta Req = 33.33 \times 0.003 = 0.1\,\Omega$$

$$\therefore (33.33 + 0.1\,\Omega)$$

Method 3:- $\quad Req = \frac{R_1 R_2}{R_1 + R_2}$

$$Req = 33.33\,\Omega$$

extreme high

$$Req = \frac{(100+0.1) \times (50+0.05)}{(100-0.1) + (50-0.05)}$$

extreme low

$$= 33.43\,\Omega$$

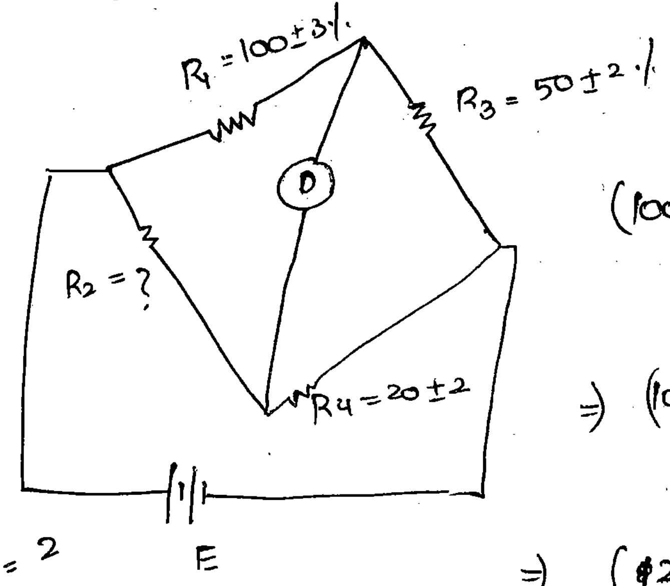
extreme low

$$Req = \frac{(100-0.1)(50-0.05)}{(100+0.1)+(50+0.05)} = 33.23$$

extreme high

On Careful examination of above two Answers, $(33.33 \pm 0.1)\,\Omega$ is the answer

2)



$(100 \pm 3\%)(20 \pm 2) =$

$(50 \pm 2\%)\,x$

$\Rightarrow (100 \pm 3\%)(20 \pm 10\%)$

$= (50 \pm 2\%)\,x$

$20 \times \frac{x}{100} = 2$

$\Rightarrow x = 10\%$

$$\Rightarrow \frac{(2000 \pm 13\%)}{(50 \pm 2\%)} = x$$

$x = 40 \pm 15\%$ $\quad \Rightarrow$ (~~24 ± 5.1%~~) = ?

3) The following ten readings were observed while measuring a voltage.

1 → 41.7
2 → 42
3 → 41.8
4 → 42
5 → 42.1
6 → 41.9
7 → 42.5
8 → 42
9 → 41.9
10 → 41.8

Find the probable error

Probable error = ± 0.6745 σ

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

Avg = 41.97

d_1 = 41.7 - 41.97 = -0.27
d_2 = 42 - 41.97 = 0.03
d_3 = 41.8 - 41.97 = -0.17
d_4 = 42 - 41.97 = 0.03
d_5 = 42.1 - 41.97 = 0.13
d_6 = 41.9 - 41.97 = -0.07
d_7 = 42.5 - 41.97 = -0.53
d_8 = 42 - 41.97 = 0.03
d_9 = 41.9 - 41.97 = -0.07
d_{10} = 41.8 - 41.97 = -0.17

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + - - d_{10}^2}{9}}$$

= 0.22135

Probable error =

± 0.6745 x 0.22135

= ± 0.14930

∴ 41.97 ± 0.14930

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4. The limiting errors of a 4 dial resistance box are

Units : ± 0.2 %

Tens : ± 0.1 %

Hundreds : ± 0.05 %

Thousands : ± 0.02 %

$$\boxed{④\ ③\ ②\ ⑤}$$

$\downarrow 4\times1000 \quad \downarrow 3\times100 \quad \downarrow 2\times10 \quad \downarrow 5$

The Value of Resistance set in the dial box is 4325 Ω. Find the total limiting error in the resistance

$$4000\times\frac{0.02}{100} + 300\times\frac{0.05}{100} + 20\times\frac{0.1}{100} + 5\times\frac{0.2}{100}$$

$$= \cancel{\pm 0.1043\%}\quad 0.8 + 0.15 + 0.02 + 0.01$$

$$\cancel{4325}\times\frac{\cancel{0.1043}}{\cancel{100}} \qquad 0.98$$

$$\Rightarrow (4325 \pm 0.98)$$

$$4325\times\frac{x}{100} = 0.98 \Rightarrow x = 0.0226\%$$

5. A 3ϕ Power is measured by using two Wattmeter method. one of the Wattmeter reading is 50 W with an Accuracy error of ± 0.5 %. And the Second Wattmeter reading is 125 W with an Accuracy error of ± 1.5 % of reading. Both the Wattmeters are having a full scale reading of 150 W. Then the total power in 3ϕ Ckt.

$(\cancel{50 \pm 0.5\%})$

$(\cancel{125 \pm 1.5\%})$

$$150\times\pm\frac{0.5}{100} = \pm 0.75$$

$$50\text{ W} \pm 0.75 \Rightarrow \frac{50\times x}{100} = 0.75 \Rightarrow x = \pm 1.5\%$$

is $\boxed{50 \pm 1.5\%}$ $\qquad \boxed{125 \pm 1.5\%}$ → given direct Error of reading → LE

$$\cancel{125}\times\pm\cancel{1.5} \qquad \cancel{150}\times\frac{\pm\cancel{1.5}}{100} = \cancel{2.25}$$

$$125 \pm 2.25 \Rightarrow$$

$$\Rightarrow \cancel{175\pm}$$

$$175 \pm 2.125$$

$$50\times\frac{0.5}{100} = 0.25$$

$$50 \pm 0.25$$

$$125\times\frac{1.5}{100} = 1.875$$

$$125 \pm 1.875$$

$150W \begin{cases} W_1 = \cancel{50} \\ W_2 = \cancel{125} \end{cases}$ $50 \times \frac{1.5}{100} = 0.75$

$\cancel{150} \times \frac{+\cancel{0.5}}{\cancel{100}}$ 50 ± 0.75

$125 \times \frac{1.5}{100} = 1.875$

125 ± 1.875

$\Rightarrow 175 \pm 2.625$

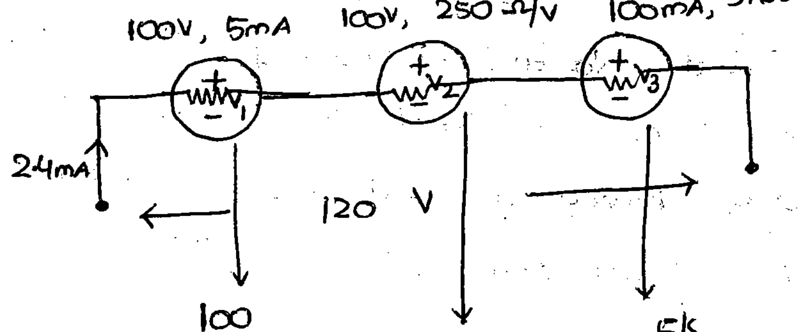
$\Rightarrow 175 \times \frac{\cancel{2.625}x}{100} = 2.625$

$x = 1.5\%$

$\therefore$ A: $175 \pm 1.5\%$

6) Three Voltmeters are Connected in Series across 120 V DC supply. They are 1) 100 V, and 5 mA
2) 100V and 250 Ω/V
3) 100mA and 5 kΩ

Then estimate the reading of each Voltmeter.



$\frac{100}{5mA} = 20k\Omega$

$\frac{100V \times 250\Omega}{V} = 25k$

5k

$\Rightarrow$ Eq. Resistance = 50k

$I = \frac{12\cancel{0}}{5\cancel{0}k} = 2.4\ mA$

I Voltmeter = $2.4\overset{mA}{} \times 20k = 48\ \Omega$

II Voltmeter = $2.4\ mA \times 25k = 60\ \Omega$

III " = $2.4mA \times 5k = 12\ \Omega$

7. A
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8. A
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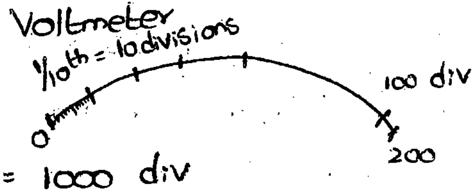
0.75

7. A Moving Coil Voltmeter has Uniform Scale with 100 divisions with a full Scale reading of 200V and 1/10th of the Scale division Can be measured Very Accurately. then Resolution Of the Voltmeter



⇒ Total divisions = 1000 div

⇒ Resolution = $\frac{200}{1000}$ $\left(= \frac{\text{Full Scale Value}}{\text{No. of divisions}} \right)$

= 0.2

5

8. A Variable 'W' is measured with three other Variables x, Y, z as $W = \frac{XY}{Z}$. the Variables are measured with three meters with an accuracies of ±0.5% of reading, ±0.1% of Full Scale and ±0.1^{5}% of reading. the Actual readings of three meters are 80, 20 & 50 with 100 being full Scale for 3' meters then find total uncertainity in measurement will be

across

$\Rightarrow \quad 80 \times \frac{\pm 0.5}{100} = \frac{4}{10} = \pm 0.4$

2/v

Ω

eter.

5kΩ

0.1 % of full Scale =

$20 \pm 0.1\%$

50 ± 0.05

$50 \times \frac{+0.1}{100} = 0.05$

$\Rightarrow W = \frac{(80 \pm 0.5\%)(20 \pm 0.1\%)}{(50 \pm 0.1\%)}$

$80 \times \frac{\cancel{0.4}x}{100} = 0.4$

$= \left(\frac{1600}{50} \right)$

$\Rightarrow x = \frac{4}{8}$

$= 0.5$

$50 \times \frac{\cancel{0.0}x}{100} = 0.05$

$x = \frac{0.5}{5}$

$= 0.1$

X = 80 ± 0.5%

Y = 20 $\Rightarrow 20 \times \frac{x}{100} = 1 \Rightarrow x = 5\%$

Z = 50 ± 1.5%

$= \left(\frac{80 \times 20}{50} \right) + \left(\frac{\pm 5.5}{\pm 1.5} \right)$

± 7%

26/4/12 (11 to 1)

9. The power factor is measured by using three meters, they are Ammeter, Voltmeter and Wattmeter. The Ammeter reads as 2.5A on 5A (Full Scale Reading). The Voltmeter reads as 115V on 250V (Full Scale Reading) and the power as 220W on 500W Wattmeter. The Ammeter and Voltmeter are having a GAE of ±0.5% of full scale deflection and the Wattmeter has GAE of ±1% of Full Scale deflection. then Calculate the uncertainity in Powerfactor will be —

Sol:

~~$I = 5 \times \frac{\pm 0.5}{100} = 0.025$~~

~~$V = 250 \times \frac{\pm 0.5}{100} = \cancel{12.5} = 1.25$~~

~~$W = 500 \times \frac{\pm 1}{100} = 5$~~

Sol: $P = VI\cos\phi$

$PF = \cos\phi = \frac{P}{VI}$

watt

Volt Ammeter

	FSV		At	% LE
±0.5%	5A ⟵	I ⟶	2.5	± 0.025
	250V ⟵	V ⟶	115V	± 1.25
±1%	500W ⟵	W ⟶	220W	± 5

$5 \times \frac{0.5}{100} = 0.025$

$2.5 \times \frac{x}{100} = 0.025 = \pm 1\%$

$115 \times \frac{x}{100} = 1.25 = \pm 1.086\%$

$220 \times \frac{x}{100} = 5 = \pm 2.272\%$

$\Rightarrow PF = \frac{220}{115 \times 2.5} = \pm 4.358\%$

$\Rightarrow$ A: 0.76 ± 4.358

$\text{Error} = \frac{\% GAE}{100} \times FSV = \text{True Value} \times \frac{\% LE}{100}$

10. 'A

eqx.

Vol

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as 220W
are
and
deflection.
will be —

$25 = \pm 1\%$

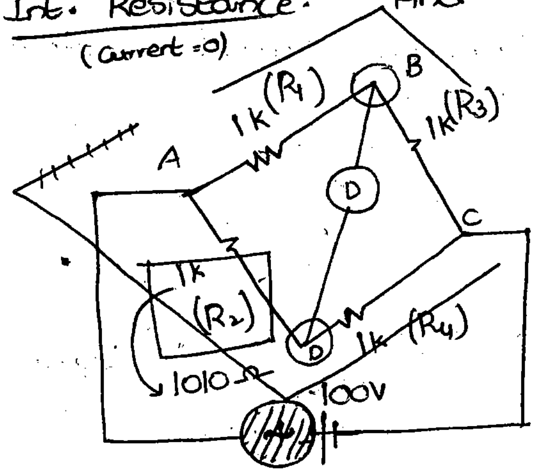
$5 = \pm 1.086\%$

$= \pm 2.272\%$

$\frac{\% LE}{100}$

---

10. A Wheatstone Bridge is balanced with all 4 resistance equal to $1^{k}\Omega$ each. The Bridge supply Voltage is 100V. The Value of one of the resistance is changed to 1010 Ω. (So, Voltage Division rule is applied) The o/p is measured with Voltage measuring device of '∞' Int. Resistance. Find the bridge Sensitivity
(Current = 0)



$$S = \frac{\text{change in o/p}}{\text{change in I/p}}$$

$$= \frac{e}{10}$$

change in o/p = e − 0 = e

$$e = V_B - V_D$$

$V_B \rightarrow$ It is nothing but total Voltage - Drop across AB
$= 100 - V_{AB}$

$$V_D = 100 - V_{AD}$$

$$e = \cancel{100} - V_{AB} - \cancel{100} + V_{AB}$$

$$= V_{AD} - V_{AB}$$

$$V_{AD} = 100 \times \frac{1010}{1010 + 1000} = 50.2487\,V$$

$$V_{AB} = 100 \times \frac{1000}{1000 + 1000} = 50\,V$$

$$e = 0.2487$$

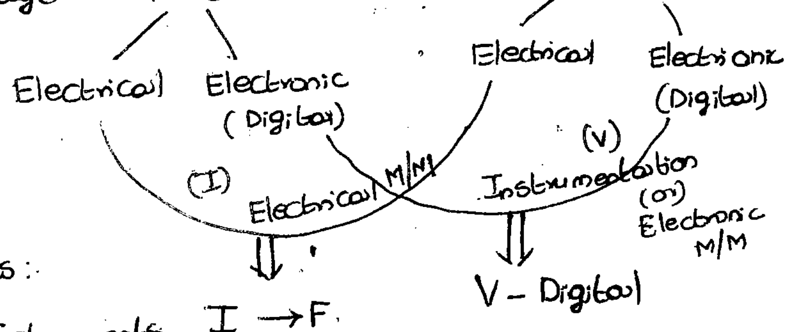
$$\Rightarrow \quad S = \frac{0.248}{10} = 0.0248 \simeq 25\,mV/\Omega$$

Unit - II

Basic Instruments:- the Instruments which are used for the measurement of basic quantities are called Basic Instruments

Voltage - Voltmeter, Current — Ammeter

~~Electronic~~ ~~Electrical~~

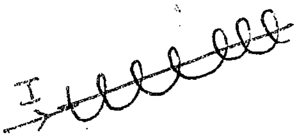


Electrical Measurements:-

In all electrical Instruments, the responsible Quantity is current and it is converted into force.

there are mainly 4 effects that convert current into force are:-

a) Magnetic Effect
b) Thermal effect
c) Electrostatic effect
d) Induction effect



$F = BIL \sin\theta$
↓
Lorentz's law

Any meter (i.e, almost all meters) come under the above four

* Basically there are three forces will develop in all electrical Instruments

a) Deflecting force / Torque (T_d)
b) Controlling force / Torque (T_c)
c) Damping force

a) this is the force reqd to move the pointer from its initial position by using any one of the effect. But because of this force, the pointer continuously rotate in the meter which is undesirable so that we need one more force which is opposite in direction

to the deflecting torque is called Control torque

b) Controlling Torque :- This is the force which is opposite in direction to the deflection torque. When $T_d = T_c$, pointer will come to steady state. But before coming to the steady state, the pointer will make so many oscillations which is undesirable so that we need one more force to reduce the no. of oscillations at steady state is called Damping Torque

c) Damping Torque :- It is the force reqd to reduce the no. of oscillations at steady state.

* Functions of Controlling Torque :-

→ It will provide a proportional output to the Input

→ When the I/p has been removed, the pointer should back to initial position.

Actually, the damping force will make to reduce the speed of the pointer so that the no. of oscillations will be reduced at steady state

* At steady state only two forces : deflection, Controlling

* When pointer comes to rest position from steady state only one force :- Controlling Torque

Ⓟ A PMMC instrument is spring controlled, the control spring stiffness decreased by 0.04 % /° rise in temp and strength of the magnet decreased by 0.02 % per degree raise in temp. The raise in temp of 10°c, the new deflection.

θ ↑ 0.4%

	1°C	10°C		
T_c Stiffness Op Spring	0.04 % ↓	0.4 %	T_c ↓ 0.4 %	T_d ↑ 0.4 %
Strength of Magnet	0.02 % ↓	0.2 %	0.2 % ↓	0.2 % ↓
			T_d	θ ↓

$\boxed{F = BIL \sin\theta}$

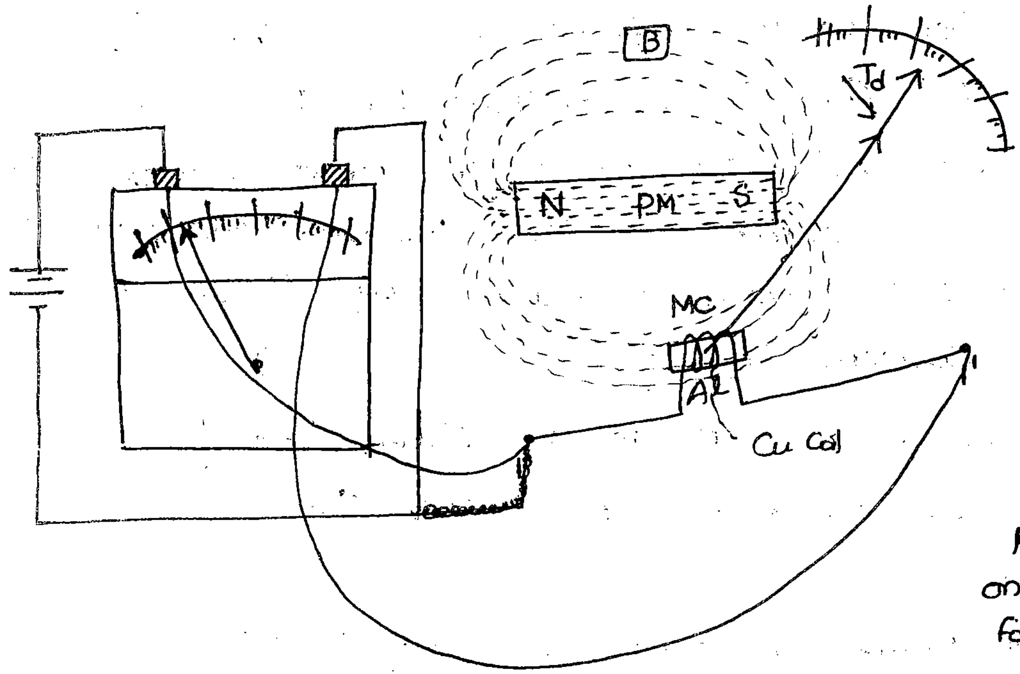
θ → 0.2 %

27/4/12 (11 to 1) Mechanism for Producing Td :- (Magnetic Effect)

1) Force b/w Permanent Magnet & Current Carrying Coil :

$$\overset{0.2\updownarrow}{\theta} = \frac{\overset{\downarrow 0.2\%}{BINA}}{\underset{0.4\%\downarrow}{k}}$$

0.4 % ↑

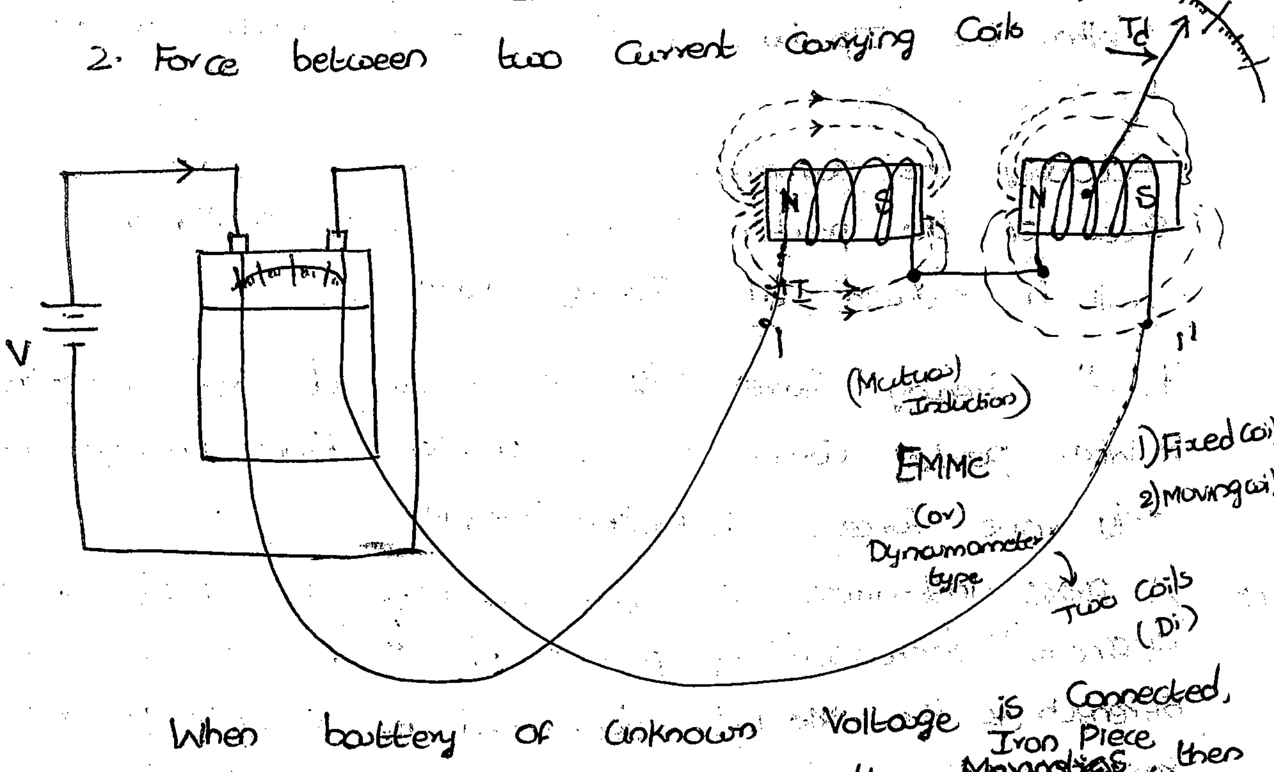


Dc < I, V

F = BIL Sinθ

PMMC works on Lorenzt's force equation

2. Force between two Current Carrying Coils



(Mutual Induction)

EMMC (or) Dynamometer type → Two Coils (Di)

1) Fixed coil
2) Moving coil

When battery of unknown Voltage is Connected,
It drives a current to enter the ~~Magnetises~~ Iron Piece then
Coil, apply ~~Flemings~~ Right hand thumb rule, to
find the direction of x Magnetic lines of force (Flux lines). Then
it become magnetised. Illy other also get
magnetised. Force of attraction exists btw magnets
and Td acts on pointer

AC/DC < V, I

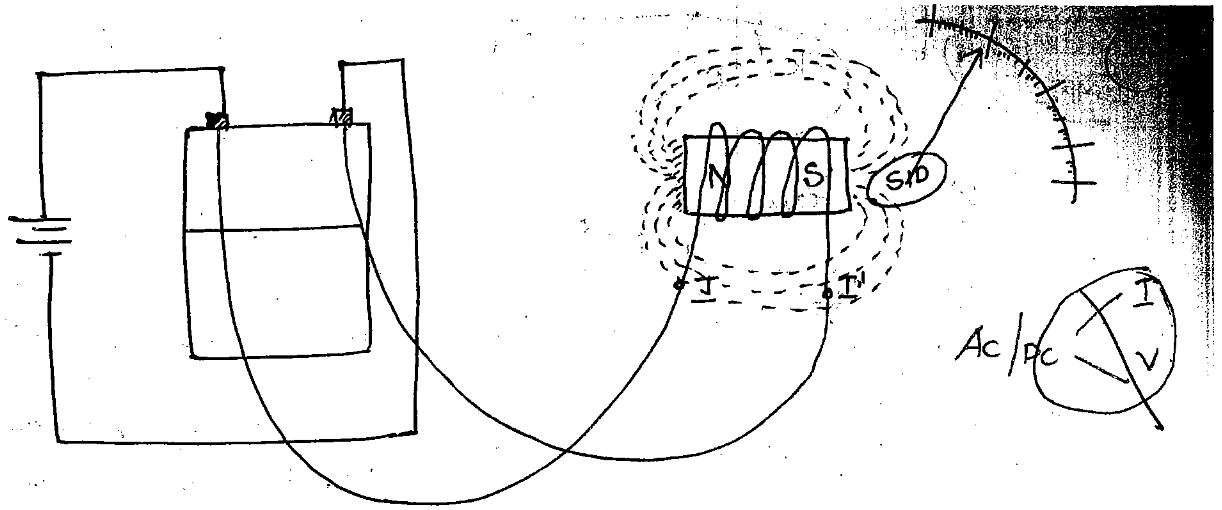
Power < AC, DC

PF

$pf = \frac{P}{VI}$

(three errors in P, V, I

3. Force between Current Carrying Coil & Iron Disc (SID)



Moving Iron Instruments

- SID attracted towards the Magnetised Iron Piece. In this, an [Iron Magnet piece] makes the pointer to move (in turn a deflection force) so, it is called Moving Fixed type Iron Instruments

* Purpose of fixed Coil is to provide magnetic field

* MC in Wattmeters have to be Short Circuited because in Dynamometers the four terminals, two terminals gets Short Circuited

* PMMC are Very accurate among all but the only disadvantage is it is suitable for DC. If Ac is Connected, the pointer won't show deflection exactly and deflects between Initial and final position

* MI Instruments Suitable for both Ac and Dc, but when used for DC it is less accurate, Sensitive Compared to PMMC

* ~~In MI meters, the basic principle is Law of Conservation of energy. A Coil on Iron piece is equivalent to Inductor. stores energy first and then~~

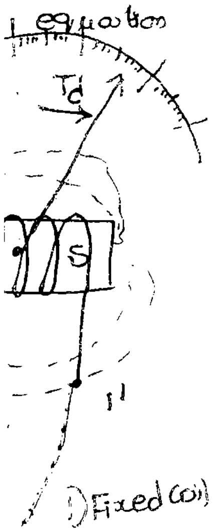
* Main Working principle of MI Instruments is <u>self Inductance of fixed Coil</u>

* By EMMC, we can measure Ac, Dc Power, Voltage, Current

DC I V

= BIL Sinθ

MC works Lorenzt's equation



1) Fixed coil
2) Moving coil

two Coils (Di)

connected, Piece ..s, then

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o magnets

c/DC V I

AC
Soft DC

P

DC = P / VI

(three errors in P, V, I

EMMC :- 1) Ac / Dc — I, V

2) Power — Ac, ~~Dc~~

3) ~~PF~~ ⟶ Error more bcz $\cos\phi = \frac{P}{VI}$

(three types of errors)

1*

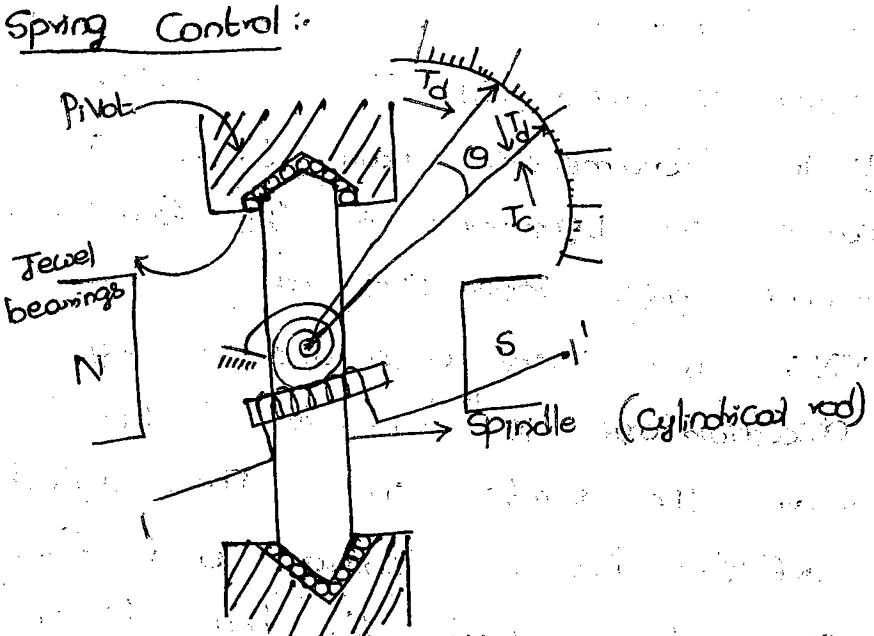
It is the worst meter still now, to measure Ac Power bcz for each & every thing there is no alternate to measure. But for Ac power measurement wattmeter is the one & only device used (available)

n

Mechanism for producing T_c :-

1) Spring Control :-

2)



Jewel bearings help to reduce friction between spindle & pivot. Again from one bearing to bearing, friction is reduced by using lubricant like oil, grease

During the action of deflecting torque due to rotation of spindle on pointer, the spring gets twisted. After the removal of Im I/p quantity ⊗ the spring gets released and controlling torque is generated to restore to its Initial position. phosphor-Bronze is used for the manufacture of spring.

28/4/12
(6 to 8:30)

$\theta \propto T_d \propto F \propto I$ $\quad \boxed{\theta \propto T_d}$

$T_c \propto \text{Spring} \propto \theta$ $\quad \boxed{T_c \propto \theta} \Rightarrow T_c = K_c\theta$

$$\boxed{K_c = \frac{T_c}{\theta} = \frac{N\text{-}m}{deg} \;(or)\; \frac{N\text{-}m}{rad}}$$

Advantage:-

1*) $T_c \propto \theta$ (Linear relation)

Scale is Uniform

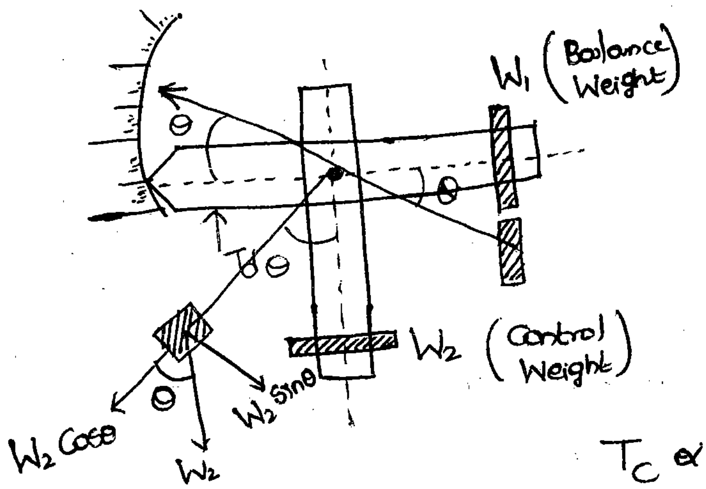
2) Both Vertically/ horizontally Can be used.

Draw backs:-

1) Ageing:- As the Age passes, the Springs may lose elasticity property

2) As the temp increases, stiffness decreases, Control Torque decreases, T_d increases, $\theta \uparrow$

2) Gravity Control:-



$T_c \propto W_2 \sin\theta$

$T_c \propto \sin\theta$

$\theta \propto T_d \propto F \propto I \propto V$

W_1 prevents unnecessary oscillations

Dis:-

1) Non-Uniform Scale

2) restricted to be Used in Vertical position

Adv:- 1) No Ageing

2) Temp. Independent

28/4/12 (6 to 8:30) Mechanism for producing Damping force:-

Based on speed Control We have 3 types of damping.

$\phi = \frac{P}{VI}$

es of errors)

AC

easurement

available)

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f Spindle removal

Controlling

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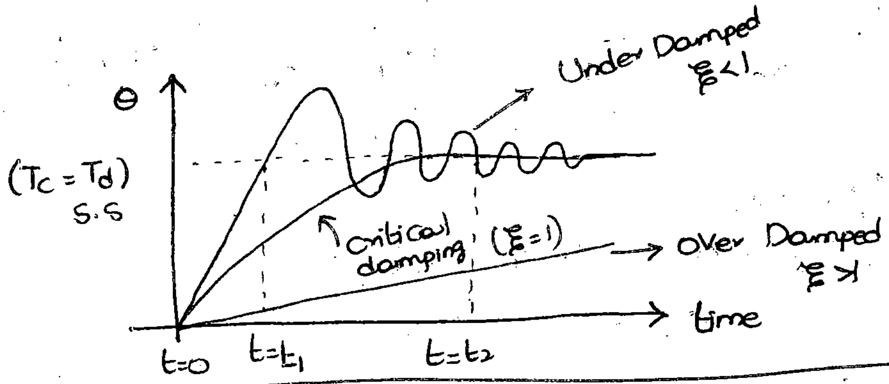
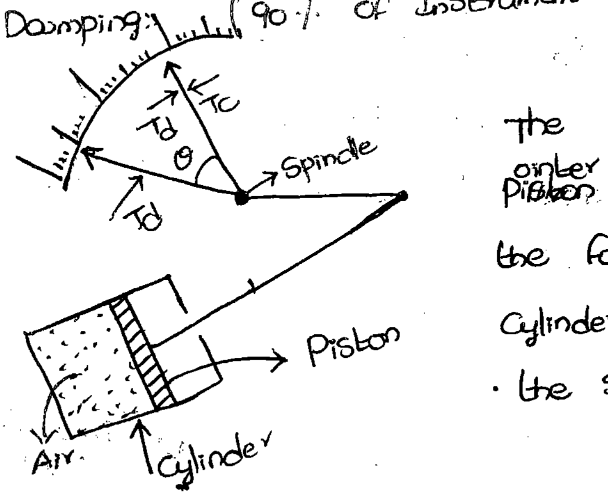
$\Rightarrow T_c = k_c\theta$



the best design is always "A little bit less than Under Damped System"

1) Air Friction Damping:- (90% of Instruments)



The Movement of the ~~Piston~~ pointer is opposed by the force of the air in Cylinder which reduces the Speed of pointer

2) Fluid Friction Damping:- * It is better than Air Friction damping because of Viscosity

Viscosity of Fluid > Viscosity of Air

* But We will use it Very rarely ~~less~~ Compared to Air friction Damping

<u>Drawbacks</u>:- ① Maintainence is difficult

3) Eddy Current Damping:- (powerful Compared to both)

Order of <u>effectiveness</u>: $\boxed{\text{Eddy} > \text{Fluid} > \text{Air}}$

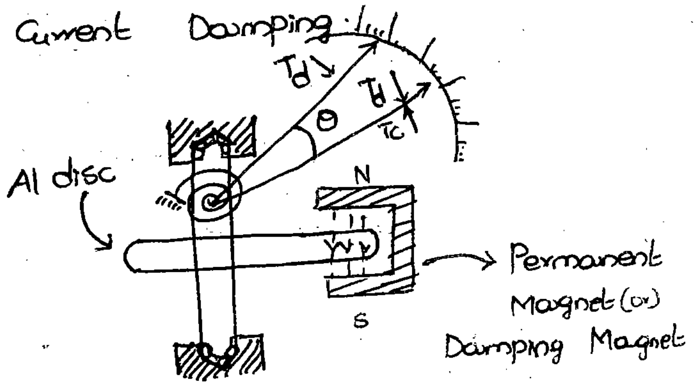
order of <u>priority</u>: $\boxed{\text{Eddy} > \text{Air} > \text{Fluid}}$

It is possible to use eddy Current Damping where we use permanent magnet

* <u>Eddy Current Damping</u> is <u>more effective</u> Compared to air, <u>fluid friction</u>. But it is not Suitable in all electrical ... the permanent magnet are available

PMMC - Eddy Current ; Dynamometer — Air Friction ; MI - Air

3) Eddy Current Damping

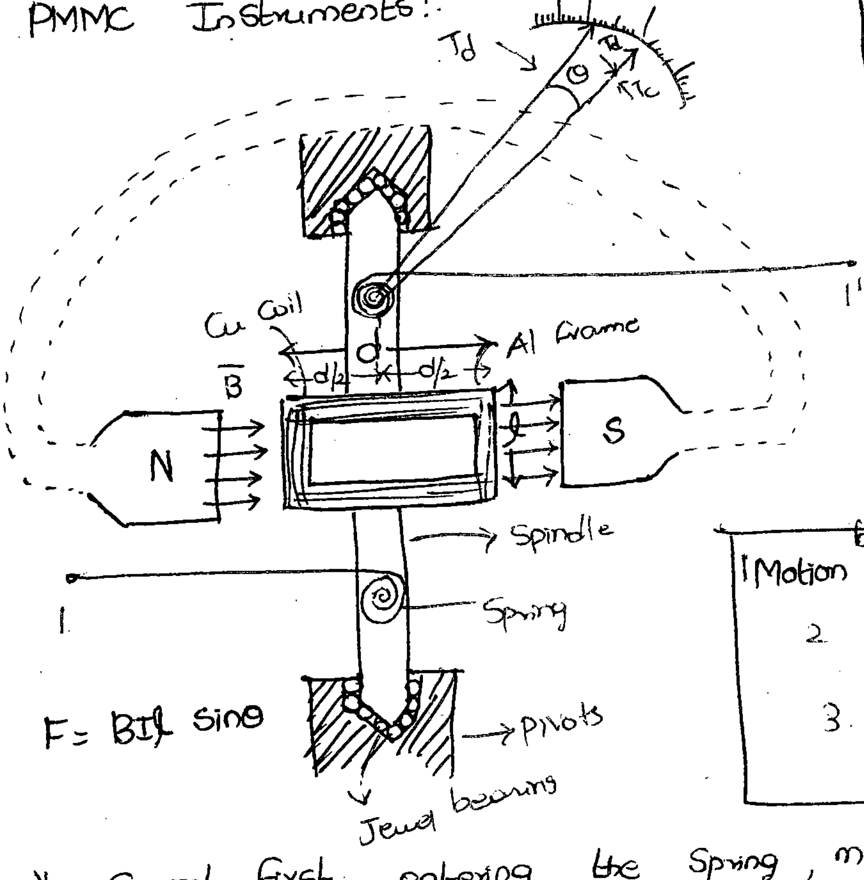


Eddy emf - we can't collect because it is in disc and it is dead emf

* Faraday's law, Lenz's law are involved in this.
As soon as the emf induces, as per Lenz's law effect opposes the causes ~~the~~. The eddy current in disc opposes the movement of spindle and comes to rest soon

* In case of PM, if we use E.M it gives variable magnetic field, then damping varies. But we need constant damping, so we prefer PM.

PMMC Instruments:



$F = BIl \sin\theta$

No load current is small in T/F bcz there will be induced emf due to coil on primary which reduces primary voltage there by no load current reduced, otherwise it will be very high

1 Motion btw PM & MC
2. Spring Control
3. Eddy Current damping

* Current first entering the spring, next coil
* There is continuity of conductor inside the spindle (not visible). Current carrying coil in PM, the coil will experience a force. Springs provides controlling torque. Eddy currents on Al frame produces

* When a Meter in Working Condition, we Send Current after that '1' spring fails then eff. Spring Const. $(= k/2)$, reading will double (i.e, deflection torque doubles) ⊗ and Comes to rest position

* Inside the meter two mechanical staffs are there to prevent the pointer go beyond '0' & Full Scale Value'

* While working (i.e, measuring) if two Springs are damaged, the pointer goes to full Scale Value and go back

* Before measuring, if one Spring fails, the pointer will not deflect (For PMMC only)

* Relation btw Input Current & output deflection Torque (T_d) the angle btw Magnetic field & Current Carrying Coil is 90°.

$$\boxed{F = BIl}$$

{ Two Cond - one turn
{ No. of turns - Coil

$$F/\text{Cond} = BIl$$

Torque = Force * lar distance

$$= \left(BIl \times d/2\right) + \left(BIl \times d/2\right)$$

$$T_d = BI\underbrace{\boxed{l[d]}}_{A}N$$

Deflection Torque, $\boxed{T_d = \underbrace{B\,\boxed{I}\,N\,A}_{\text{Constant}}} \longrightarrow Ⓐ$

$$\boxed{T_d \propto I}$$

i.e, ~~Relats~~ Deflection Torque is Linear

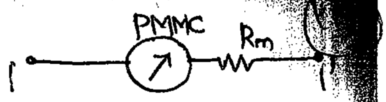
$$T_d \propto I$$
$$\propto V$$

$\boxed{T_d \propto V}$ change the scale it will be Voltmeter

$$T_c = K_c\theta \longrightarrow Ⓑ$$

At Steady State, $T_c = T_d$

* Eddy Current Damping is used to reduce no of Oscillations at Steady State Condition



Rm - Moving Coil Resistance

Advantages :-

1) Scale is (uniform) Linear ($\because \theta \propto I$)

2) High Accurate and high sensitive, Since powerful eddy current damping is used

Disadvantages :-

1) By using Basic PMMC, we cannot measure high current, Since Springs are carrying current

2) Maximum Allowable current through Basic PMMC is 50 mA

through spring only 50 mA enters and the remaining enters at the spring con which is at the end. if we are measuring more than 50 mA.

* Force direction can be identified by using Flemings left hand rule

Generator - Fleming's Right hand rule (Two R S, Twol4)
Motor - Fleming's left hand rule (one Ryone r)

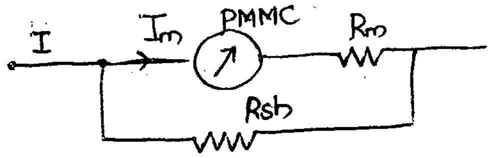
Fleming left hand rule :- Thumb - Force
Middle - Current
Index - Field

3) By using PMMC instrument we can't measure Ac When we allow Ac, the pointer will not deflect (we can't observe deflection, bcz that moves in very small fraction which cannot be detected by eye)

30/4/12
(8:30 - 1:00)

Extension Ranges Of PMMC :

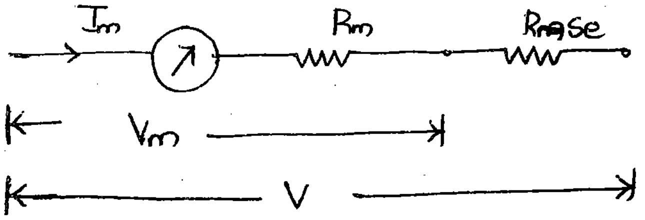
PMMC Instrument as Ammeter :-



Multiplier

$$\boxed{R_{sh} = \frac{R_m}{\left(\frac{I}{I_m} - 1\right)}}$$

PMMC as Voltmeter:



Multipliers

$$\boxed{R_{se} = R_m\left(\frac{V}{V_m} - 1\right)}$$

m

m → multiplication factor

* If R_{sh} & R_{se} is made up of Copper (which have a +ve temp coefficient) T ↑↓ → R ↑↓

So, We don't choose Copper.

We choose a Constant temp. Coefficient Material, Manganin & Constantanin. (as Multipliers)

1) All Multipliers are made up of

a) Manganin b) Al c) Constanin d) Any one

Among both Manganin is given 1st priority. Both are brittle Materials. ~~Const Manga~~ Constanin is not choosed
a) More brittle than Manganin
b) Cost is high
c) Availability is less Compared to Manganin

* Among Constanin, Manganin → the Constanin gives Accurate results and Same time Cost is high

But in practice, We don't use Manganin alone because brittleness Come into picture. So, to avoid the brittleness property We use a resistor (made up of mn & Cu). Cu helps in avoiding brittleness and increases strength of material

KDM Gold
↓
Cadmium
Mixing
with

30 : 1
mn + Cu

Swamping Resistance
↑
(Alloying)

(Reduces the errors due

Errors

1) Fri
2) Te
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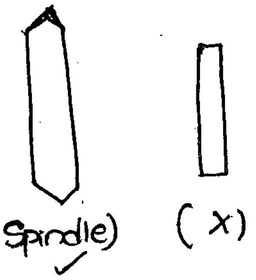
Errors in PMMC :

1) Frictional errors
2) Temp. errors
3) Freq. errors
4) Hysterisis errors
5) Stray Magnetic field errors

1) The errors due to friction Can be of low (or) high depending upon the Weight of Spindle.



Because to reduce the Area of Contact so as to reduce the friction

Torque ↑ ⇒ Friction ↓

Weight on Spindle ↑ ⇒ friction ↓

Friction depends on $\frac{\text{Torque}}{\text{Weight}}$ Ratio

$$* \quad \frac{\text{Torque} \uparrow}{\text{Weight} \uparrow} = \text{Moderate}$$

* Frictional errors are moderate in PMMC Instruments

To reduce the frictional errors by providing a sharp edges to Spindle and Jewel bearings in the Grooves

* In any electrical Instrument, the frictional error is more/ less can be decided depending upon $\frac{\text{Torque}}{\text{Weight}}$ Ratio.

* We prefer always high $\frac{\text{Torque}}{\text{Weight}}$ Instruments, as the $\frac{\text{torque}}{\text{weight}}$ is ~~[illegible]~~ more, frictional errors are less.

* Temperature errors: The temp. errors can be reduced by introducing Swamping Resistance

* Frequency errors is absent in ~~[illegible]~~ PMMC (meters. since) meters space DC measurement).

$$\boxed{T_d = BINA}$$

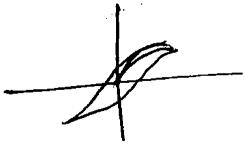
1) $\oiint_S \vec{E} \cdot d\vec{L} = \frac{1}{q}$

2) ~~D~~, ~~H~~ $\oiint_S B \cdot d\vec{L} = 0$

3) $\oint E \cdot d\vec{L} = 0 \Rightarrow KVL$

* The hysteresis error can be reduced by providing Aluminium frame in the moving system. Since Aluminium a thin ~~hysteresis~~ hysteresis loops so that the diff. btw two Magnetic fields can be neglected

* We cannot eliminate Hysteresis errors, but can reduce them



5) Stray Magnetic field ~~is~~ error :

The stray Magnetic field error is less ~~due~~ in the stray Magnetic field is available PMMC since, a strong Magnetic field is available inside the meter

* As all the errors can be minimised in PMMC instruments so that it is high accurate, high sensitive Instrument

Note:- 1) By using PMMC instrument, we can measure DC Current (or) Voltage but not AC Voltage, power

2) PMMC will always Average Value

1) The deflection ~~p~~ Torque of an Ammeter Varies as square of the Current passing through it. If a current of 5A produces a deflection of 90°. What the deflection occur for a current of 3A, if the instrument is controlled.

Sol:-

$$T_d \propto I^2$$

$$\Rightarrow \theta \propto I^2$$

$$\text{i.e,} \quad \frac{\theta_2}{\theta_1} = \left(\frac{I_2}{I_1}\right)^2$$

$$= \left(\frac{3}{5}\right)^2 = \frac{9}{25}$$

$$\theta_2 = 90 \times \frac{9}{25} = 32.4^\circ$$

If the instrument is ~~A~~ Gravity Controlled

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

$$\sin\theta_2 = \left(\frac{9}{25}\right) \Rightarrow \theta_2 = 21.1^\circ$$

2. A PMMC Instrument has dimensions has 15mm x12mm. The flux density in the Air gap is 1.8 μwb/m². The Spring Constant (kc) is 0.14 μNm / rad. Determine the no. of turns reqd to produce angular deflection of 90° when a Current of 5A flowing through Coil.

$$\theta = \frac{BINA}{k_c}$$

$$\Rightarrow N = \frac{k_c \cdot \theta}{BIA}$$

$$= \frac{(0.14\times10^{-6})\left(\overset{\frac{\pi}{2}}{90}\right)}{(1.8\times10^{-6})\ (5)\times(15\times12)\times10^{-6}}$$

$$= 135.74 \simeq 136$$

3. The pointer of MC Instrument gives a full scale deflection of 20 mA when the potential diff. is 400mV

1) The instrument is extended to 200 A. Then the Shunt resistance reqd. is

2) If the same instrument extended to 1000V. Series Resistance reqd. is

$$1)\ R_{sh} = \frac{R_m}{\left(\frac{I}{I_m}-1\right)} = \frac{\frac{400\times10^{-3}}{20\times10^{-3}}}{\left(\frac{200}{20\times10^{-3}}\right)-1}$$

$$= \frac{20}{10^4-1} = \frac{20}{9999} = 2\,m\Omega$$

$$2)\ R_{se} = R_m\left(\frac{V}{V_m}-1\right) = 20\left(\frac{1000}{400\times10^{-3}}-1\right)$$

$$= 49.98\ k\Omega$$

4. What is the Value of Rse reqd to extend (0-200)V Voltmeter having Sensity of 2000 Ω/V (5×10^{-4}) is to be extended to (0-2000) V

$R_m = 200 \times 2000$
$= 400\,k\Omega$

$$\Rightarrow R_{se} = R_m\left(\frac{V}{V_m} - 1\right)$$

$$= \frac{\overset{200}{\cancel{400\,k}}}{5\times10^{-4}}\left(\frac{2000}{200} - 1\right)$$

$$= 3600\ \Omega$$

(or) $400k\left(\frac{2000}{200} - 1\right) = 3.6\ k\Omega$

5. A Moving Coil Voltmeter with a resistance of 20Ω gives full Scale deflection of 120° when a potential difference of 100 mV is applied across it.

$(R_m = 20\,\Omega,\ \theta = 120^\circ,\ V_m = 100\,mV)$ and Moving Coil has dimensions of 30mm × 25 mm and is wound with 100 turns. the spring Constant is 0.375×10^{-6} N·m/degree. Find the Flux density in the air gap and find diameter of Cu Coil.

$\rho = 1.7\times10^{-8}\ \Omega\cdot m$, $N = 100$, $a = 750\times10^{-6}\ mm^2$

$k_c = 0.375\times10^{-6}$ N·m/°degree

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

$$\theta = \frac{BINA}{k_c} \Rightarrow B = \frac{\theta\ k_c}{INA}$$

$\cancel{\theta}$

$$= \frac{\frac{2\pi}{3}\times 0.375\times10^{-6}}{\left(\frac{100\times10^{-3}}{20}\right)\times100\times750\times10^{-6}}$$

⭐ $l = 2(l+d)\times 100$

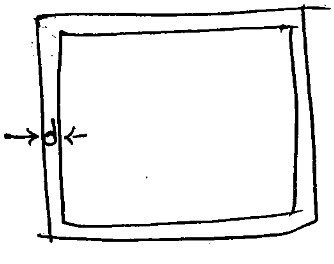
$\overset{4}{\cancel{120}} \times \frac{\pi}{\underset{6}{\cancel{180}}}$

$\Downarrow$

$$20 = \frac{(1.7\times10^{-8})(2)(30+25)\times10^{-3}\times100}{A}$$

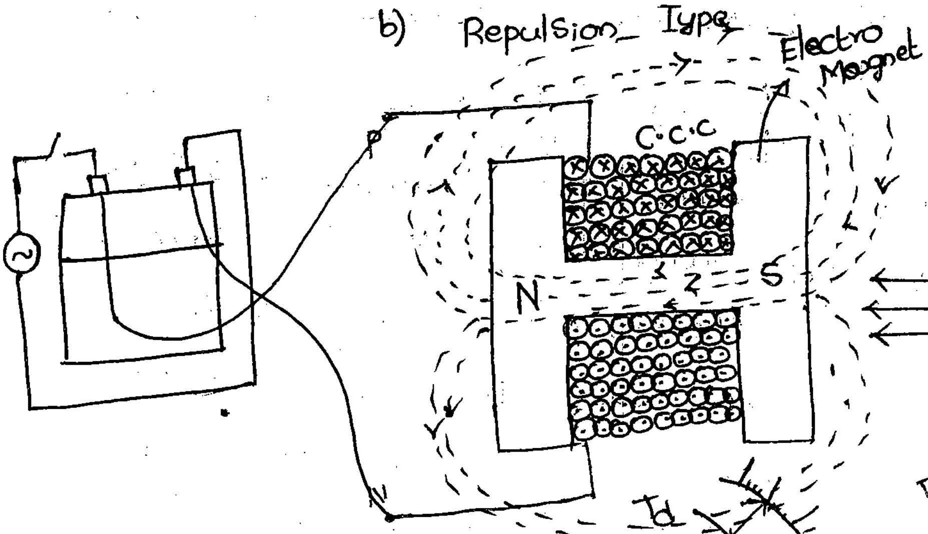
$$= \frac{(1.7\times10^{-8})\times11}{A}$$

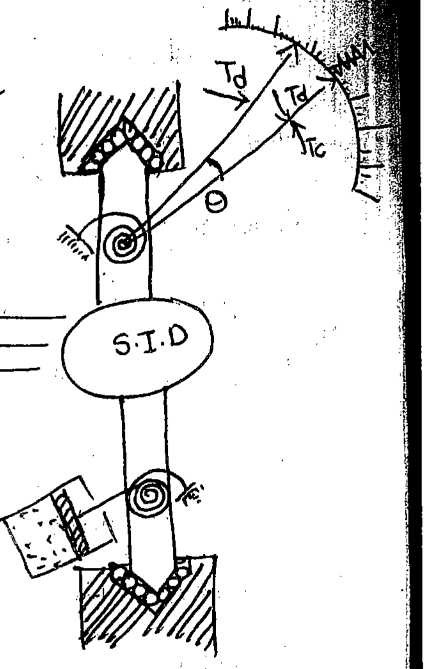
$$\Rightarrow A = 1.7\times10^{-8}\times11$$



MI Instruments (Moving Iron)

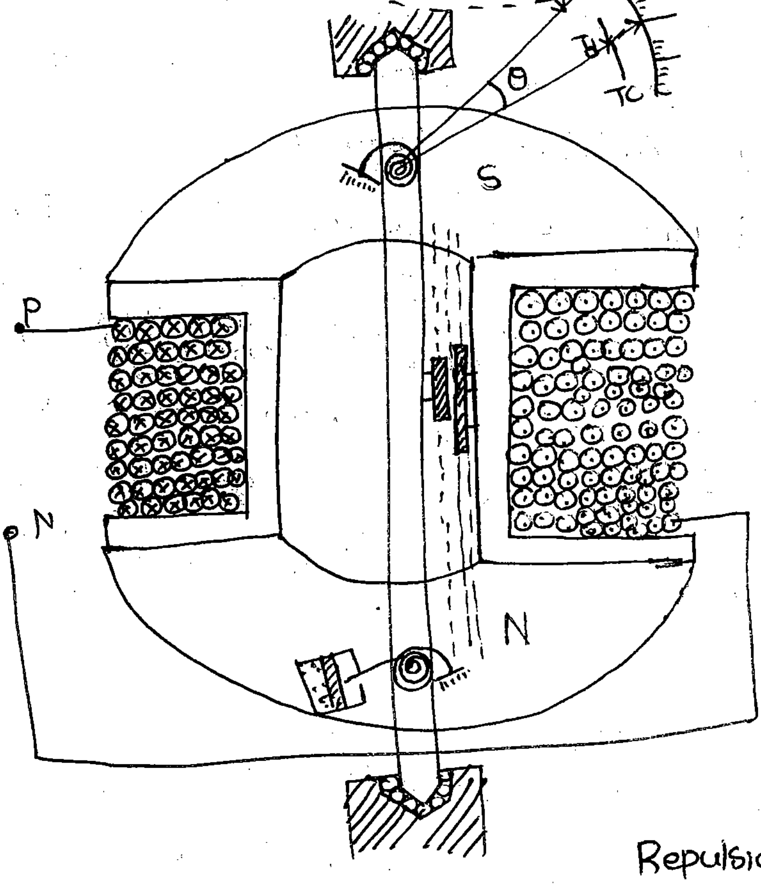
- a) Attraction Type
- b) Repulsion Type





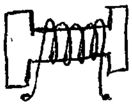
a) Attraction

thumb rule



Be

Repulsion type

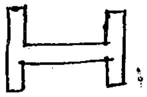
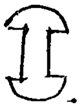


Iron piece gets magnetised due to the Winding which is carrying current. So, it is becomes like an <u>electro Magnet</u>. It <u>attracts the S.I.D</u> which produces <u>reqd deflection torque</u> then the pointer moves. Here, <u>Control torque</u> is produced by the <u>Spring Control</u>. <u>Damping torque is</u> produced by the <u>Air friction Damping</u>.

In measuring AC, if pol -ve half occurs, the polarities changes to (S to N). Thus, it

Repulsion type:

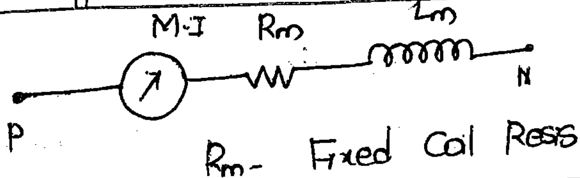
Deflection torque - Electro Magnet
Controlling torque - Spring Control
Damping " - Air friction

It's core is Similar to that type of Attraction type (Just rotate by 90° i.e,  ⇔ . When unknown quantity is passed through P, N terminals. it will get magnetised. By using Thumb rule, N, S are identified. Lines of Force of Attraction passes from South to North. In the path of them, two Iron rods (one fixed, other movable is present) a force of repulsion exists between them and deflects the pointer. Controlling Torque is provided with Spring Control. Damping torque is provided by Air friction Damping

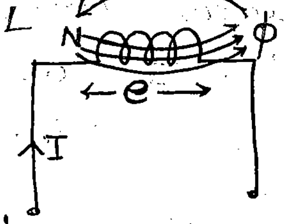
* In PMMC, Springs Carry Currents. In MI, Springs does not Carry Currents. If one of the Springs is damaged, deflection doubles (Control torque reduces to half) (pointer does not goes from final reading to zero). If both springs damaged Pointer reads Full scale and dont goes back to zero

* Self Inductance of fixed Coil is the working principle

* Relation b/w I/p Current & O/p deflection torque



Rm - Fixed Coil Resistance
Lm - Fixed Coil Self Inductance



2* ϕ links with its own no. of turns then 'e' is induced. By the time another current is waiting. [illegible]

Inductor coil not allow Sudden change of Current until flux linking is changed

* Time Varying Current produces time Varying flux

$\boxed{L = N\phi}$

So, $V_L \propto \frac{dI}{dt} \Rightarrow \boxed{V_L = L \cdot \frac{dI}{dt}} \rightarrow$ Transient

At Steady state, $V_L = 0$

So, it acts as Short Ckt (∵ bcz Current will not Vary wrt time) $dI/dt = 0$

* Never open the Inductor when it is Storing Energy, (leads to ∞ Voltage)

* Never Short the Capacitor when it is Storing Energy (leads to ∞ Current)

* [Inductor (Choke) in tube light helps to raise the Voltage from 230v to 2500v (approx). The Starter helps to open the Inductor, in turn leading to '∞' Voltage, then it will ~~st~~ glows]

* Inverter like a Capacitor

* Chopper → Inductor

$$L = \frac{N\phi}{I} \Rightarrow d(LI) = d(N\phi)$$

$$\Rightarrow I \times \left(L\frac{dI}{dt} + I\frac{dI}{dt} \right) = N\frac{d\phi}{dt} = e \times I$$

(dt - time taken for Switch closing, Multiply both sides by I)

$$\Rightarrow I \times \cancel{dt} \left(L\frac{dI}{\cancel{dt}} + I\frac{dI}{\cancel{dt}} \right) = e \times I \times \cancel{dt}\, dt$$

$$\Rightarrow \boxed{LI\,dI + I^2\,dI = d\omega} \rightarrow ①$$ (As Small time, $d\omega = eI\,dt$)

Where $d\omega$ = Total electrical energy Consumed by fixed Coil ~~form~~ / Inductor from the Source in 'dt' sec

This much electrical energy is Converted into Mech. energy So that it will do Some useful work done

∴ Mech. Work done in dt (sec) = $T_d \cdot d\theta \longrightarrow ②$

Energy stored in Inductor in 'dt' Seconds :-

= Energy Stored in (t+dt) − Energy Stored in 't' sec

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

$$= \frac{1}{2}(L+dL)(I^2 + \overset{0}{\cancel{dI^2}} + 2IdI) - \frac{1}{2}LI^2$$

$$= \frac{1}{2}(LI^2 + 2IL\,dI + dL\,I^2 + \overset{0}{\cancel{2IdIdL}}) - \frac{1}{2}LI^2$$

$$= IL\,dI + \frac{I^2}{2}dL \rightarrow ③$$

$$\boxed{\text{Electrical energy} = \text{Mech. Energy} + \text{change in Stored energy}}$$

(Law of Conservation of energy)

$$\Rightarrow \cancel{LIdI} + I^2dL = T_d.d\theta + \cancel{LIdI} + \frac{I^2}{2}dL$$

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

$$\Rightarrow \boxed{T_d = \frac{1}{2}I^2\left(\frac{dL}{d\theta}\right)}$$

$$T_d \propto I^2$$

So, MI got Scale as Non-Linear

$$I_1 - \theta_1 \rightarrow 15^\circ$$
$$2I_2 \rightarrow \theta_2 - ?60^\circ$$
$$\theta_2 = 15 \times \left(\frac{2}{1}\right)^2$$

Spring Control :- $\boxed{T_c = k_c\theta}$

$$\frac{1}{2}I^2\left(\frac{dL}{d\theta}\right) = K_c\theta \quad \left(\begin{array}{l}\text{At equilibrium,}\\ T_d = T_c\end{array}\right)$$

$$** \Rightarrow ** \boxed{\theta = \frac{1}{2}\frac{I^2}{K_c}\left(\frac{dL}{d\theta}\right)}$$

* Air Friction Damping is used to reduce no. of oscillations.

Advantages:

1. We Can measure both AC & DC
2. We Can avoid Current through the Springs.

Disadvantages:-

1. Non-Linear Scale
2. ⊛ It is Less Accurate, less Sensitive Since Air friction Damping Instrument is used.

* We Cannot measure high Currents using PMMC because Springs are damaged. In MI also we

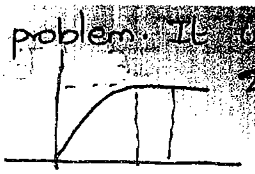
Magnetic Saturation

Magi
leads
(M/c
01/5/12 (8:30-1:00) 1.
as
Ra
Of

2. A
240
Find
Full

3. The
De
Find
Of

Magnetic Saturation Causes a Serious problem. It will leads the magnet to permanent Magnet (M/c will be not be under our Control



01/5/12 (3:30 - 1:00)

1. the Inductance of M.I Ammeter is assumed as $L = (10 + 10\theta - 3\theta^2)\ \mu H$. Where 'θ' is the deflection in Radians. Determine the deflection in degree for a current of 8A. $K_C = 10 \times 10^{-6}$ N.m/degree

$$L = (10 + 10\theta - 3\theta^2)\ \mu H$$

$$\frac{dL}{d\theta} = (10 - 6\theta) \times 10^{-6}$$

$$T_C = T_d$$

$$\boxed{K_C \theta = \frac{1}{2} I^2 \left(\frac{dL}{d\theta}\right)}$$

$$\Rightarrow 10 \times 10^{-6} \times \theta = \frac{1}{2}(8)^2 \times (10 - 6\theta) \times 10^{-6} \quad \Rightarrow \theta = 95.7^\circ$$

2. A Moving Iron Ammeter produces a full scale of 240 μN-m with deflection of 120° at a Current of 10 A. Find the Rate of Change of Self Inductance at Full Scale is ___

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

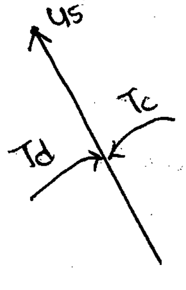
$$\frac{dL}{d\theta} = \frac{2 T_d}{I^2} = \frac{2 \times 240\ \mu N \cdot m}{(10)^2}$$

$$= 4.8\ \mu H / {}^\circ \text{degree}$$

3. the following figures gives the relation b/w deflection, Inductance

Deflection	20°	30°	40°	50°	60°	70°	80°	90°
L (μH)	335	345	355.5	366.5	376.5	385	391.3	396

Find the Current & Torque reqd to give a deflection of 45°. $K_C = 0.4 \times 10^{-6}$ N-m/degree



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

$$(0.4 \times 10^{-6}) \times 45^\circ = \frac{1}{2}(I^2)\left(\frac{110}{10}\right)$$

$$\Rightarrow I = 1.12\ mA$$

$$T_d = \frac{1}{2}(I^2)(1) =$$

If T_c is found, T_d is also same

$$T_c = k_c \times \theta$$

$$= (0.4 \times 10^{-6}) \times 45 = 18 \times 10^{-6}\ N.m$$

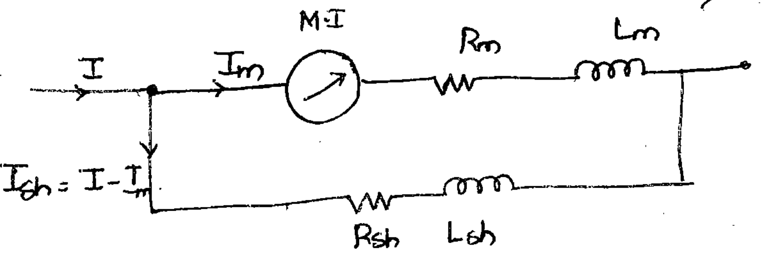
$$T_d = \frac{1}{2} (I^2) \frac{dL}{d\theta}$$

$$(18 \times 10^{-6}) = \frac{1}{2} (I^2) \quad (1.1 \times 10^{-6})$$

$$I = 5.7A$$

Extension of MI ~~sh~~ Instruments :-

$\rightarrow X_m = 2\pi f \uparrow L_m$



(Avoid Magnetic saturation)

(MI Instrument as Ammeter)

Inorder to bypass higher Currents, We keep a Resistor in Shunt 'Rsh' so as to bypass high Currents. But due to Lm, frequency Component exists. there by whenever there is a change in frequency, Rm changes and there by Im also changes. So, inorder to nullify this problem, We keep 'Lsh' in Series with 'Rsh'

$$I = \frac{V \nearrow Const.}{Z} \Rightarrow I \propto \frac{1}{Z}$$

$$\Rightarrow \frac{I_1}{I_2} = \frac{Z_2}{Z_1} \Rightarrow \frac{I_m}{I_{sh}} = \frac{\sqrt{R_{sh}^2 + (\omega L_{sh})^2}}{\sqrt{R_m^2 + (\omega L_m)^2}}$$

$$\frac{I_m}{I_{sh}} = \frac{R_{sh}}{R_m} \frac{\sqrt{1 + \left(\frac{\omega L_{sh}}{R_{sh}}\right)^2}}{\sqrt{1 + \left(\frac{\omega L_m}{R_m}\right)^2}}$$

$$\frac{\cancel{\omega} L_{sh}}{R_{sh}} = \frac{\cancel{\omega} L_m}{R_m} \Rightarrow \frac{L_{sh}}{R_{sh}} = \frac{L_m}{R_m}$$

$$\Rightarrow \tau_{shunt} = \tau_{meter}$$

Incase of basic M·I Ammeter We have to Connect a Shunt will across basic meter in Such a way that the time

Constant of the Shunt i.e, $\boxed{\frac{L_m}{R_m} = \frac{L_{sh}}{R_{sh}}}$. Then the mete

is independent of frequency

⊛ $T = L/R = H/\Omega$

$= RC = \Omega \cdot F$

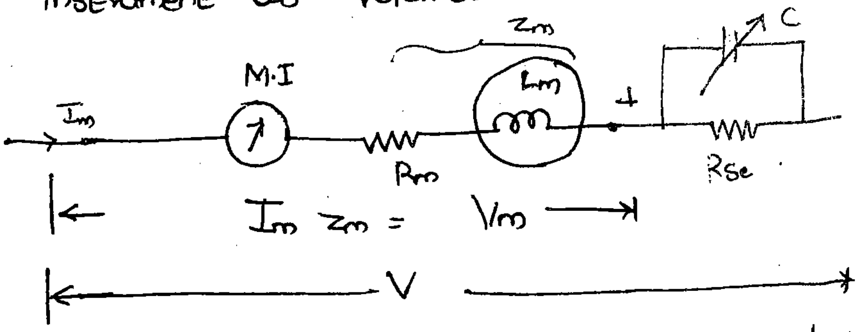
But We write units as seconds, how?

$$V_L = L\frac{dI}{dt} \Rightarrow L = \frac{V \times dt}{dI}$$

$$= \frac{\cancel{I}R \times sec}{\cancel{I}} = R\,sec$$

$$T = \frac{L}{R} = \frac{R\,sec}{R} = sec$$

M-I instrument as Voltmeter:



1) We have to choose a value of Capacitor So as to nullify the frequency of Lm

2) $$Z = (R_m + jX_{Lm}) + \left(R_{se} \parallel \frac{1}{j\omega C}\right)$$

$$= (R_m + jX_m) + \left(\frac{\frac{R_{se}}{j\omega C}}{R_{se} + \frac{1}{j\omega C}}\right)$$

$$= (R_m + jX_m) + \left(\frac{R_{se}}{R_{se}\,j\omega C + 1}\right)\left(\frac{1 - jR_{se}\,\omega C}{1 - jR_{se}\,\omega C}\right)$$

$$= (R_m + jX_m) + \left(\frac{R_{se} - jR_{se}^2\,\omega C}{1 + \omega^2 C^2 R_{se}^2}\right)$$

$$Z = (R_m + jX_m) + R_{se} - jR_{se}^2\,\omega C$$

$$= (R_m + R_{se}) + j\cancel{\omega}(X_m - R_{se}^2\omega C)$$

$$= (R_m + R_{se}) + j\omega(L_m - R_{se}^2 C) \quad L$$

$$L_m - R_{se}^2 C = 0$$

$$\Rightarrow \boxed{C = L_m / R_{se}^2}$$

In case of MI Voltmeter, we have to Connect a capacitor across Rse in Such a way that the Capacitive Reactance is Cancelled out by Inductive reactance of the meter. Then the meter is Independent of frequency

$$\boxed{C = \frac{0.41\ L_m}{R_{se}^2}}$$

Errors in MI instruments:-

1. Frictional error 2. Temp error 3. Freq Error
4. Hysteresis error 5. Stray Magnetic field error

MC PMMC		MI
↑	Torque	↓
↑	Weight	↓

1. Frictional error:- The frictional error is more in MI, compared to PMMC Since the torque/weight Ratio is Small / less

2. Temp error:- The temp. error is more in MI instrument Compared to PMMC by using Swamping Resistance in basic meter.

3. Freq. error:- The frequency error is more in MI Compared to PMMC Since Ac measurement. We Cannot eliminate ~~PMMC~~ freq. errors in M.I but we Can reduce by using above Arrangements.

4. Hysteresis error:- the hysteresis error is more in MI instrument Compared to PMMC. Since directly Iron disc by used in the Moving System

* We Cannot eliminate Hysteresis error in MI Instruments

5. Stray Magnetic field error:- The Stray Magnetic field is more Compared to PMMC Since, weak Magnet is available in meters

All the errors are more Compared to PMMC so that it is less Accurate, less Sensitive

can measure Ac/Dc

Current / Voltage but not power

2. In case of AC, the meter will read RMS Value. In case of DC, the meter will read Avg. Value

1. A 250V, MI Voltmeter has a Coil resistance of 500Ω and the Inductor of 1 Henry with a series Resistance of 2kΩ. What is the Value of Capacitance read to make independent of frequency.

$$C = 0.41 \frac{L_m}{R_{se}^2} = 0.41 \times \frac{1H}{(2 \times 1000)^2} = \frac{0.41}{4 \times 10^6}$$

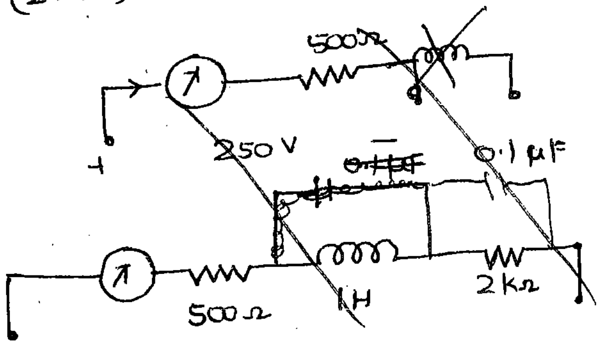
$$= 0.1\ \mu F$$

2. A Moving Iron Voltmeter reads Correctly on 250V DC if 250 V AC, 50 Hz Supply is applied. then what is the Scale reading. the instrument Coil has 500Ω. and Inductance of 1 H with Series Resistance of 2KΩ

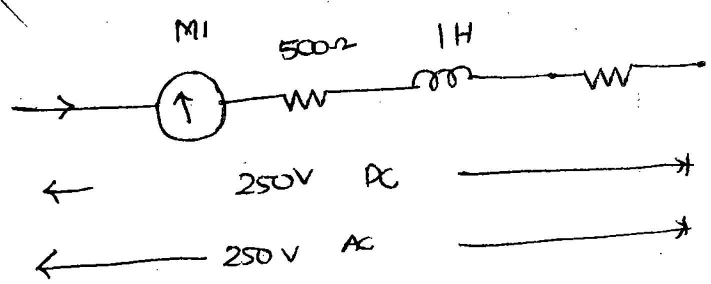
$$C = 0.41 \times \frac{1H}{(2 \times 10^3)^2} = 0.1\ \mu F$$

$$\cancel{I = \frac{250}{500} = 0.5A}$$

$$\cancel{\frac{250}{2x} = \frac{\sqrt{2500 + (j(50))}}{2500}}$$



$$\frac{\cancel{250}}{\cancel{x}} =$$



$$I_{dc} = \frac{250}{2500} = 0.1A$$

$$I_{ac} = \frac{250}{\sqrt{(2500)^2 + (2\pi \times 50 \times 1)^2}}$$

$$= 0.0992\ A$$

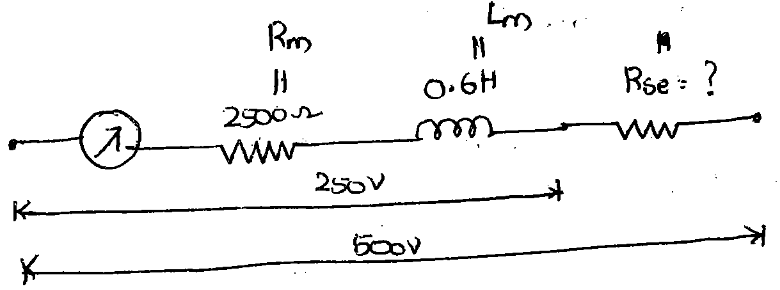
$(0.1)^2 \longrightarrow 250\ V$

$(0.992)^2 \longrightarrow ?$

~~250~~ × 246.11 V

In order to reduce this error, we go for Capacitor

3. A MI Voltmeter has an Inductance of 0.6 H with a Resistance of 2,500 Ω with a Full Scale deflection Corresponding to 250V. It is meant to operate at 50Hz. What is the 'Rse' to reqd increase the range to 500V



$$I = \frac{250}{\sqrt{(2500)^2 + (0.6 \times 2 \times \pi \times 50)^2}}$$

$$= 0.0997 \text{ A}$$

P

$$0.0997 = \frac{500}{\sqrt{(2500 + R_{se})^2 + (0.6 \times 2 \times \pi \times 50)^2}}$$

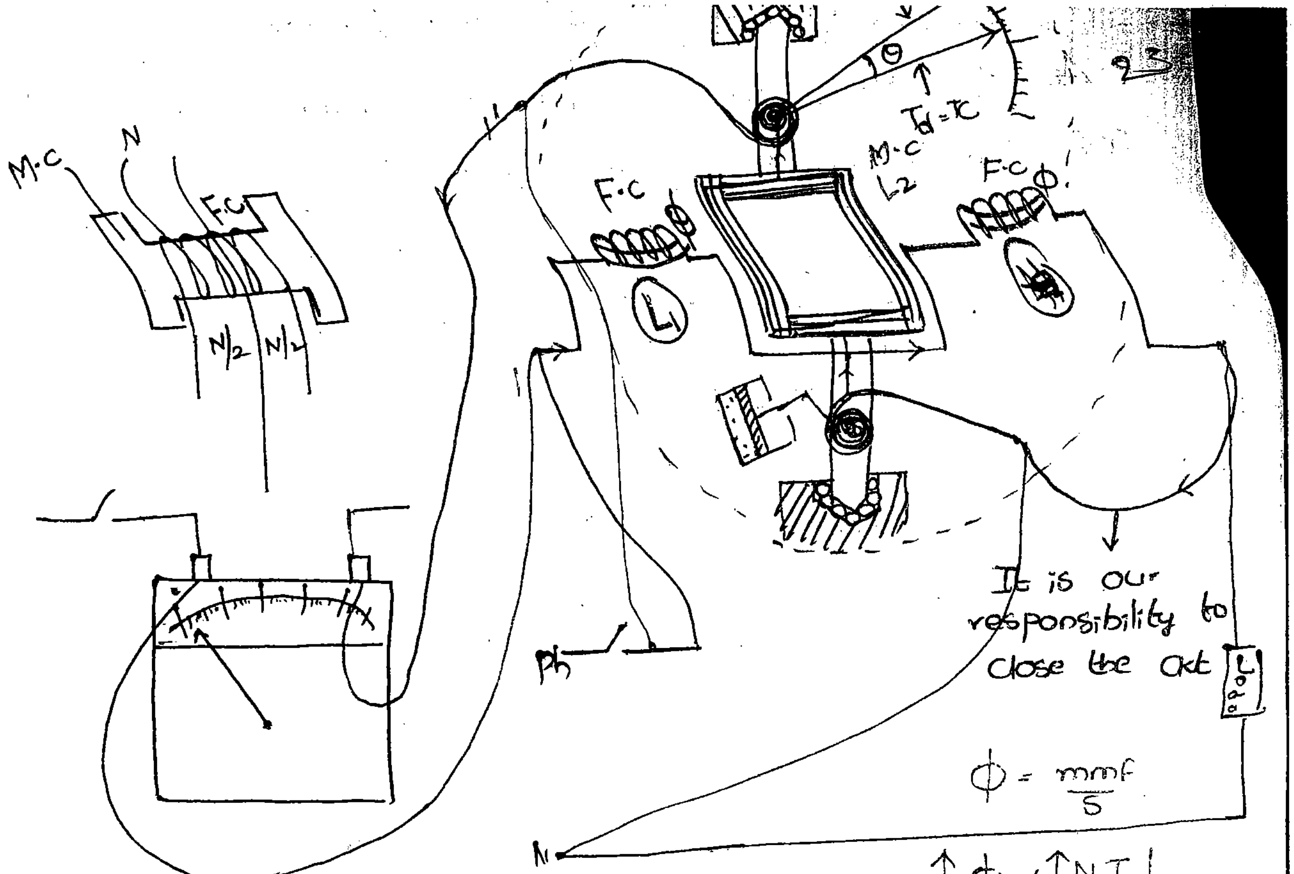
$$0.0997 = \frac{500}{\sqrt{(2500 + R_{se})^2 + (35530.5)}}$$

$$\Rightarrow \frac{500}{0.0997} = \sqrt{(2500 + R_{se})^2 + (35530.5)}$$

$$R_{se} = 2511.50\Omega$$

EMMC (Electro Magnet M.C)

* It is a Combination of PMMC & MI
* In this, the Moving Coil will be there and electromagnets are there.
* It Consists of two Coils i.e, Four terminals (M, L, C, V)
* The Working principle is "Mutual Induction"
* Among four terminals, two are to be short circuited



It is our responsibility to close the ckt

$\phi = \frac{mmf}{S}$

$\uparrow \phi \propto \uparrow NI \downarrow$

By increasing No. of turns

* Scale is Non-Linear.

* Springs carry current

* In PMMC, eddy current Damping is used as there are strong permanent Mag field. But here as electro magnets are there, we use Air friction damping

* Two Coils are Connected in series.

* If ~~in~~ 'I' increases, as Spring Carry Currents, they get damage. Inorder to increase 'I' and to keep springs safe we just go by increasing No. of turns.

* Current only responsible to produce deflecting Torque

Relation btw I/p Current & o/p deflecting Torque

Self Inductance of fixed Coil = L_1

Self Inductance of Moving Coil = L_2

Mutual Inductance = M

$$L_{eq} = L_1 + L_2 + 2M$$

$$\Rightarrow T_d = \frac{1}{2} I^2 \frac{dL_{eq}}{d\theta}$$

$$T_d = \frac{1}{2} I^2 \frac{d}{d\theta}\left(\cancelto{0}{L_1} + \cancelto{0}{L_2} + 2M\right)$$

As it Works on principle of Mutual Induction, the Self Inductances are ~~oo~~ negligible

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

$$\boxed{T_d = I^2 \frac{dM}{d\theta}} \rightarrow (A) \qquad T_d \propto I^2$$

So, it's Scale is ~~Un~~ Non-Linear

spring Control: $\boxed{T_c = k_c \theta} \rightarrow (B)$

At Steady State,

$$T_c = T_d \Rightarrow \quad k_c \theta = I^2 \frac{dM}{d\theta}$$

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

$$\Rightarrow \theta \propto I^2$$

$P = VI \cos\phi$

~~EMMC~~ $\rightarrow T_d = \overset{I.I}{I^2} \frac{dM}{d\theta}$ (there is a provision to separate) $\overset{\propto V^2}{\boxed{\theta \propto I^2}}$ Hence can EMMC used for the Power measurement

MI $\rightarrow T_d = \frac{1}{2} \underset{I.I}{\cancel{I^2}} \frac{dL}{d\theta}$

(No provision to split as there is only one coil)

* $T_d = I_1 I_2 \frac{dm}{d\theta}$

Let $I_1 = I_{m1} \sin\omega t$, $I_2 = I_{m2} \sin(\omega t - \phi)$

$$T_d = \frac{1}{2\pi} \int_0^{2\pi} I_1 I_2 \frac{dm}{d\theta} \, d(\omega t)$$

$$T_d = \frac{1}{2\pi} \int_0^{2\pi} I_{m1} \sin\omega t \cdot I_{m2} \sin(\omega t - \phi) \frac{dM}{d\theta} \, d(\omega t)$$

$$T_d = \frac{1}{2\pi} \left\{ \frac{I_{m1} I_{m2}}{2} \right\} \frac{dM}{d\theta} \int_0^{2\pi} 2 \sin\omega t \, \sin(\omega t - \phi) \, d\omega t$$

$$\downarrow$$

$$\boxed{T_d = \cancel{\frac{1}{2}} \, I_1 \cdot I_2 \cos\phi \frac{dM}{d\theta}}$$

$$I_1 = \frac{I_{m1}}{\sqrt{2}}, \quad I_2 = \frac{I_{m2}}{\sqrt{2}}$$

$$T_d = I_1 I_2 \cos\phi \, \cancel{\frac{dM}{d\theta}}$$

$$P = V I \cos\phi$$

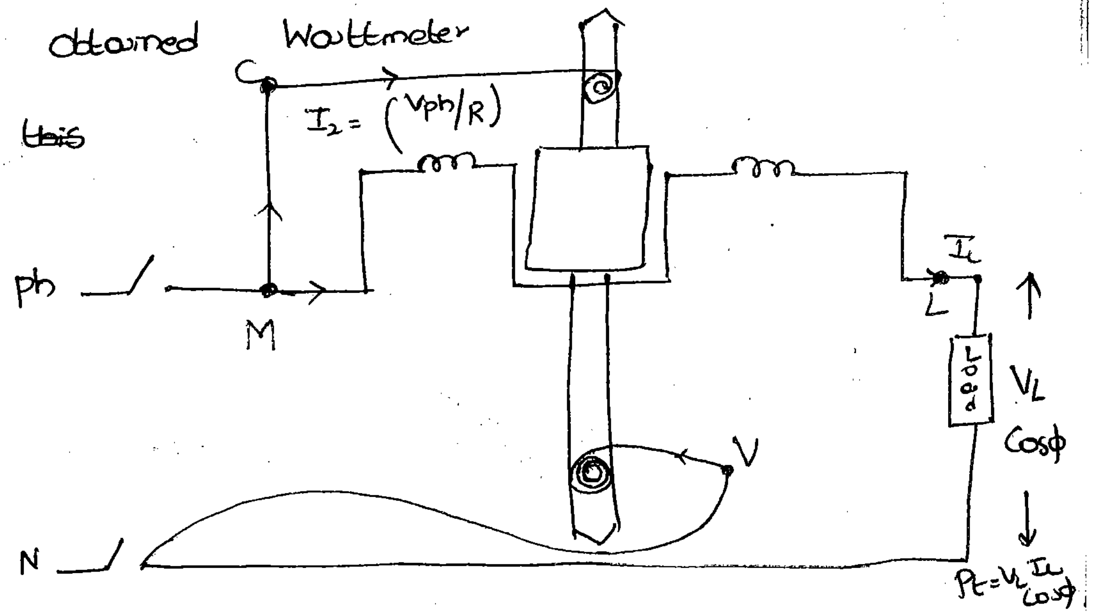
If two diff currents with some phase, $T_d = I_1 I_2 \cos\phi \frac{dM}{d\theta}$

If two diff currents with No phase, $T_d = I_1 I_2 \frac{dM}{d\theta}$

If two currents are same with no phase, $T_d = I^2 \frac{dM}{d\theta}$

If We ~~have~~ can make 'I_1' as I and I_2 as 'V' we obtained Wattmeter

~~For this~~



I_L will be equal to I_1 and $I_2 = \left(\frac{V_{ph}}{R}\right)$.

$$T_d = I_2 \cdot \frac{V_{ph}}{\cancel{R}} \cos\phi \, \cancel{\frac{dM}{d\theta}}$$

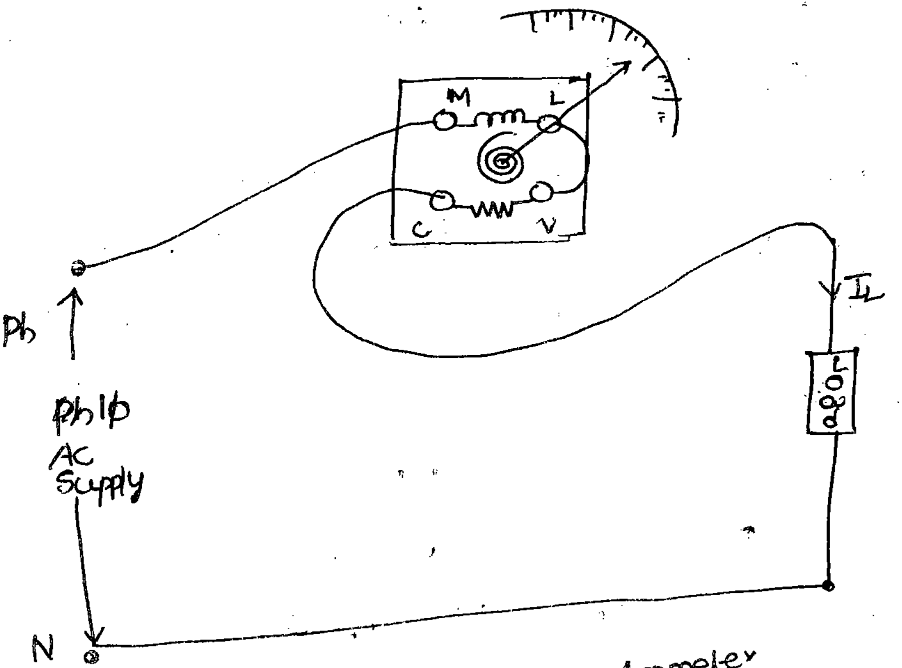
$$= I_2 \cdot V_{ph} \cos\phi \, .$$

M – Mains, L – Load, C – Common, V – Voltage

Make MC short always

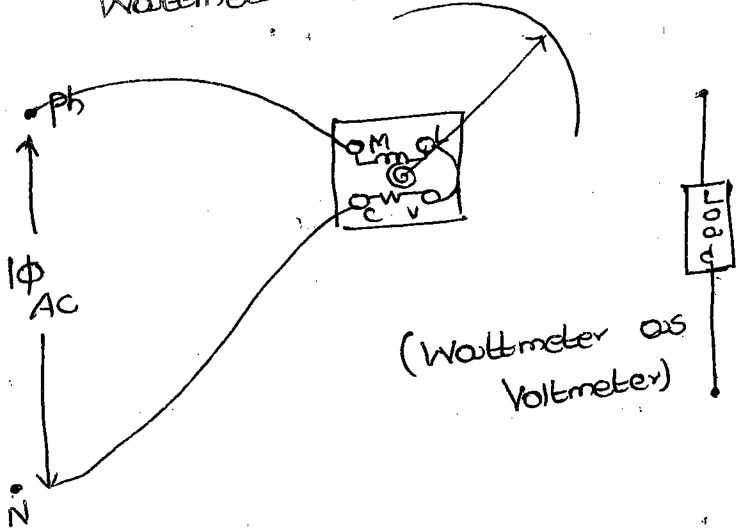
(because we have to split the current always.)

- * Moving Coil is Connected across Voltage. So, it is known as Voltage / pressure Coil
- * Fixed Coils are Connected in Series to load, they Carry load Current. So, they are Called Current Coil

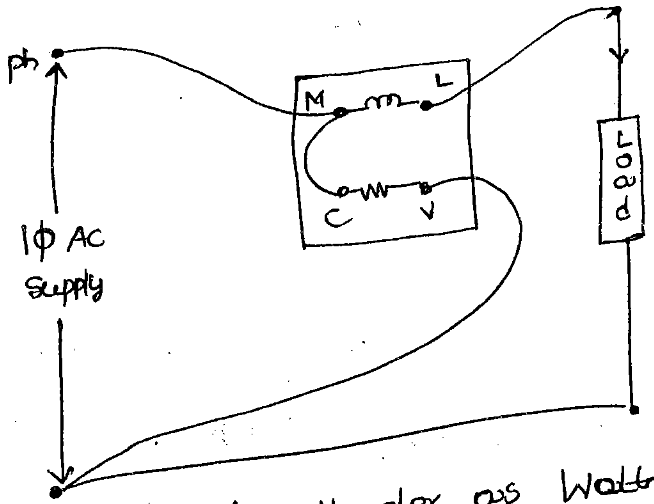


* We can measure current, but we are not supposed to do that because it does -not give Accurate results.

Wattmeter as Ammeter



(Wattmeter as Voltmeter)



Thus, Wattmeter can be used exclusively for A.c power

(Wattmeter as Wattmeter)

$$P = VI \cos\phi$$

$$\cos\phi = \frac{P}{VI}$$

Then, Wattmeter is also used in

ment

Note: In Case of Current and Voltage Measurement both the Coils Should be in Series

In Case of Power and power factor Measurement both the Coils Should be Connected in parallel

Errors in EMMC :- Order of Accuracy/ Sensitivity: $\boxed{PMMC > MI > EMM}$

1. Frictional error 2. Temp error 3. Frequency error
4. Hysterisis error 5. Stray Magnetic field error

Ve Can
reasure
urrent,
we are
supposed
o do that
ause it does
ive Accurate
results.

1. Frictional error :-

$$\boxed{EMMC > MI > PMMC}$$

The Frictional error is more in EMMC Compared to MI & PMMC. Since, a Very Very weak magnetic field is inside the meters

Torque to Weight Ratio :-

$$\boxed{PMMC > MI > EMMC}$$

2. Temp. Error: The temperature error is more compared to PMMC & MI. But it Can be reduced by employing Swamping Resistance

$$\boxed{EMMC > MI > EMMC}$$

Bcz No. of Coils more

ster

3. Frequency Error:

$$\boxed{EMMC > MI > PMMC}$$

Bcoz No. of Coils are more, Frequency Change → Impedance changes more

r

4. Hysterisis error:

$$\boxed{MI > PMMC > EMMC}$$

In this Instrument, hysterisis error is almost absent. Since there is no iron related materials in the Moving System

5. Stray Magnetic field error: Stray magnetic field error is more Compared to PMMC, MI. A Very Very weak [illegible] inside the meters $\boxed{EMMC > MI > PMMC}$

2|5|12 (9 to 1:00)

1. The Mutual Inductance of a 25A (EMMC) Dynamometer type Ammeter changes at 0.2 μH/°degree. Spring Constant is 10^{-6} N-m/degree. Find Angle of deflection

$$T_c = T_d$$

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

$$\Rightarrow 10^{-6} \times \theta = (25)^2 \times 0.2 \times 10^{-6}$$

$$\theta = 125$$

2. A Current of $i(t) = 80 - 60\sqrt{2} \cdot \sin(\omega t + 30)$ A is passed through three instruments PMMC, MI, Dynamometer type. Then the respective readings will be

PMMC = 80 (only DC Value)

MI = $\sqrt{80^2 + \left(\frac{60\sqrt{2}}{\sqrt{2}}\right)^2} = 100$ (RMS Value)

EMMC = $\underset{DC}{\downarrow}$ $\underset{RMS}{\downarrow}$

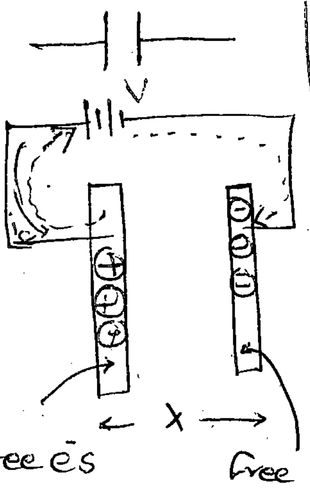
100

Electro Static Effect:

1) open Ckt, how Current flows

2) In $i = C\frac{dv}{dt}$ Where from $\frac{dv}{dt}$

3) How Current leads Voltage?



(Free of electrons)

i) Two Metal plates separated by ~~X~~ and dielectric Material placed b/w the plates

After the removal of charge, Potential difference occurs and Soon after the time progress, p.d increases. Slowly, it increases upto 'V'. Between these two plates, suddenly Voltage will not appear and takes certain time to develop 'V'

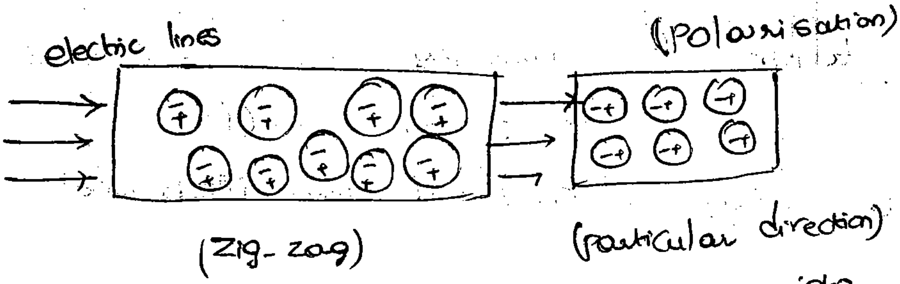
$$i_c \propto \left(\frac{dv}{dt}\right)$$

R → I ∝ V

I → V ∝ dI/dt

C → $i = C\frac{dv}{dt}$

Inductor will not allow Sudden



In the middle of the plates, dielectric material is placed which aligns the dipoles in zig-zag into particular direction so that the air is closed.

Electrostatic Voltmeters:-

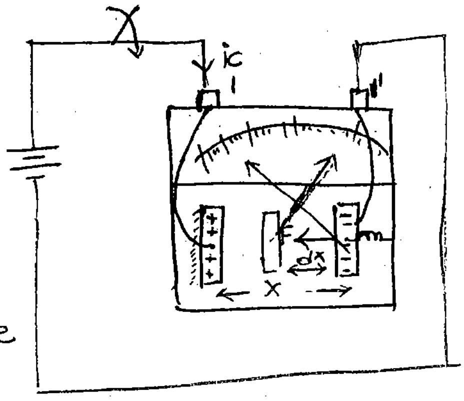
The responsible Quantity is Voltage

$\cancel{\boxed{Q \alpha I} \Rightarrow \boxed{Q \alpha \sqrt{I}}}$ Not Applicable to Capacitor

$\boxed{Q \alpha V} \Rightarrow Q = CV$

(Capacitor)

*once charging Current enters the plate becomes +Ve charged and force of attraction exists between these plates.



* Main Working principle of Electrostatic Voltmeter is

Capacitance

* In electrostatic Voltmeter, the responsible Quantity is Voltage.

Relation b/w I/p Voltage & O/p Force :-

$$i_c = \frac{dQ}{dt}$$

$$= \frac{d}{dt}(CV)$$

Variable

(x, C, V, F, Q)

$$\cancel{C} = \frac{\epsilon A}{\cancel{d}} \text{(Variable)}$$

$$i_c = \left(C\frac{dv}{dt} + V\frac{dc}{dt}\right)$$

$$\text{Power} \Rightarrow V \times i_c = \left(C\frac{dv}{dt} + V\frac{dc}{dt}\right) \times V$$

$$\text{Energy} \Rightarrow V \times i_c \times (dt) = dt\left(C\frac{dv}{dt} + V\frac{dc}{dt}\right) V$$

$$= CV\,dv + V^2 dC$$

dt - time taken for Switching

$$\boxed{CV\ dv + V^2 dc = dw} \rightarrow ①$$

This electrical energy is Converted into Mechanical Work done

∴ Mechanical Work done in 'dt' sec $= F \times dx$ → ②

According to law of Conservation of energy

Energy stored in Capacitor in 'dt' sec

$$= (\text{Energy Stored in } t+dt) - (\text{Energy stored in } dt)$$

$$= \frac{1}{2}(C+dc)(V+dv)^2 - \frac{1}{2}CV^2$$

$$= \frac{1}{2}(C+dc)(V^2 + \overset{\nearrow 0}{\cancel{dv^2}} + 2V\,dv) - \frac{1}{2}CV^2$$

$$= \frac{1}{2}(CV^2 + 2V\,dvC + V^2dc + 2V\,\overset{\nearrow 0}{\cancel{dv}}\,dc) - \frac{1}{2}CV^2$$

$$= \frac{2V}{2}\,dvC + \frac{V^2}{2}dc$$

$$= VC\ dv + \frac{V^2}{2}dc \rightarrow ③$$

Electrical energy = Mech. Energy + Energy stored

$$\cancel{CV\,dv} + V^2dc = F\cdot dx + \cancel{VC\,dv} + \frac{V^2}{2}dc$$

$$\Rightarrow \boxed{F\cdot dx = \frac{1}{2}(V^2)\,dc}$$

$$F = \left(\frac{1}{2}\right)V^2\left(\frac{dc}{dx}\right)$$

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

So, the Scale is Non-Linear

* Both are storing If use Inductor as storing element, slowly Inductor charges. Inductor can reverse the polarities It acts as source then; it gives back the energy whatever stored. Capacitor won't reverses after fully charged also.

	Steady State	Transient
capacitor	open	shorted
Inductor	Short Ckt	open

* In place of Capacitors, if we use Inductors ~~the~~ Size of device is high

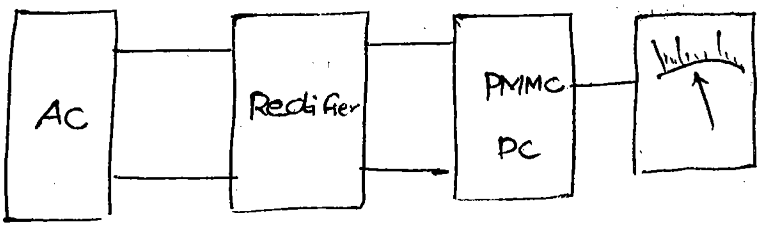
* In Capacitor, Noise will be less (almost zero) whereas in Inductor Noise (will be high) (Generator)

Eg: Inverter

Electro Static Voltmeters are ~~not~~ best Suitable for measurement for Very high Voltages [(Min. 1KV) - Max 500 KV]

* These Instruments are Suitable for the measurement of both Ac & Dc. Ac is not measured directly, first Converted to Dc and then it measures.

To Measure the AC With PMMC, use a Rectifier in the middle



$FF = \frac{RMS}{Avg}$

For change of Scale, multiply the Value by 1.1 to get RMS Value.

$\Rightarrow RMS = 1.1 \times Avg$

Ⓟ An Absolute Electro Static Voltmeter has a Movable Circular plate of 8cm in diameter. If the dist. btw two Plates during Measurement 4 mm. Find the potential diff. for a force of Attraction is 0.002 N

$X = 4\,mm$

$F = 0.002\,N$

$$\boxed{F = \frac{V^2}{2} \times \frac{dC}{dx}}$$

$$0.002 = \left(\frac{V^2}{2}\right) \times \left(\frac{1.39 \times 10^{-11}}{4 \times 10^{-3}}\right)$$

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

$$= \frac{8.854 \times 10^{-12} \times \frac{\pi}{4}(8^2 \times 10^{-4})}{4 \times 10^{-3}}$$

$$= 1.39 \times 10^{-11}$$

$V = 12\,KV$

$$C = \frac{\epsilon A}{x}$$

$$\left|\frac{dc}{dx}\right| = \frac{\epsilon A}{x^2}$$

$$= \frac{(8.85 \times 10^{-12}) \times \left(\frac{\pi}{4} \times 8^2 \times 10^{-4}\right)}{(4 \times 10^{-3})^2}$$

$$= \underline{2.8 \times 10^{-9}}$$

$$F = \frac{1}{2} V^2 \left(\frac{dc}{dx}\right)$$

$$0.02 = \frac{1}{2} V^2 \left(\frac{dc}{dx}\right)$$

$$\frac{0.04 \times 1}{2.8 \times 10^{-9}} = V^2$$

Ⓟ The Spring Constant of 3000 V E.S.V.M is 7.206 $\times 10^{-6}$ N-m/rad. The FSD of instrument is 80°. Assume the rate of change of Capacitance is Constant over an operating Range. Find the total change in ~~deflectio~~ capacitance from zero to F.S.D

$$K_c = 7.206 \times 10^{-6} \text{ N-m/rad}$$

$$T = \frac{1}{2}(V^2)\left(\frac{dc}{dx}\right)$$

[As 'θ' are given]

$$T = \frac{1}{2}(V^2)\left(\frac{dc}{d\theta}\right)$$

$$K_c \cdot \theta = \frac{1}{2}(V^2)\frac{dc}{d\theta}$$

$$\Rightarrow (7.206 \times 10^{-6}) \times 80 \times \frac{\pi}{180} = \left(\frac{1}{2}\right)(3000)^2 \left(\frac{dc}{d\theta}\right)$$

$$2 \times \frac{1.006 \times 10^{-5}}{(3000)^2} = \left(\frac{dc}{d\theta}\right)$$

$$\Rightarrow \frac{dc}{d\theta} = (2.23 \times 10^{-12})$$

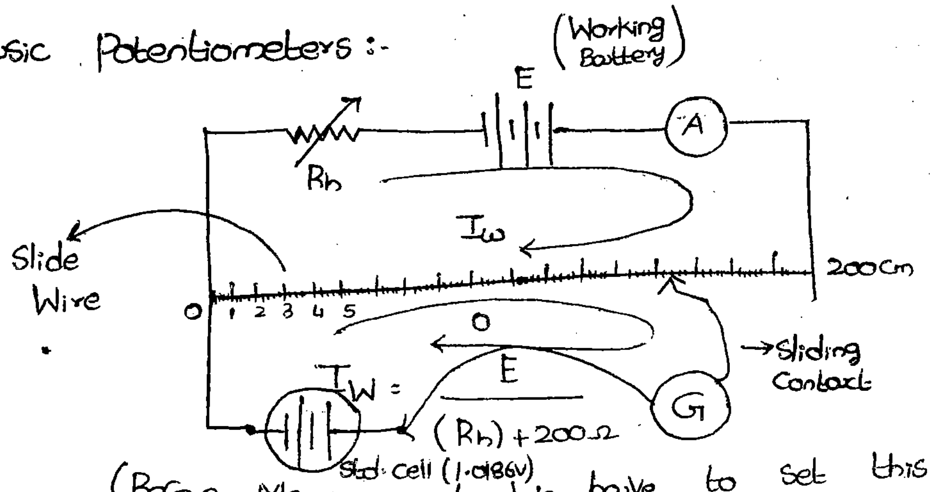
$$dc = (2.23 \times 10^{-12})(80) \times \frac{\pi}{180}$$

4/5/12
(8:30-1:00)

PotentioMeter :-

By using Potentio Meters, We Can measure a <u>Very low</u> <u>Voltages</u> With an <u>Accuracy</u>

Basic Potentiometers :-



$I_W = \dfrac{E}{(R_h)+200\Omega}$

(Nothing but 200 Cm scale)
1Cm = 1Ω
(Design is like this)
i.e, equivalent to 200Ω

(Before Measurement, We have to set this I_W (Eg: 10mA) this can be done by Varying Rheostat)

* Really it is Circulating 10 mA / not we don't depend on Ammeter, to <u>Cross Check</u> this take a <u>Standard cell</u> (available in labs as 1.0186 V) & <u>Galvanometer</u>. once, Checking is over, We can Remove the Standard cell Whenever We have to make the Contact of Sliding Contact, Whenever it is in Contact, the Galvanometer reads zero deflection It reads Zero, Whenever the drop across the Slide Wire equals the Standard cell, Current in that loop is 'O'A

Now record the Value of 'R'

$$10\,mA \times R = 1.0186$$

$$R = \frac{1.0186}{10\,mA} = 101.86\,\Omega$$

$$= 101.86\text{ Cm}$$ at this distance

(If Galvanometer is not Showing zero, the Ammeter Shows is not Correct).

This Can be known as Standardization. (For 10 mA)

* To measure the Unknown battery Voltage, remove the Standard cell, Connect unknown battery in its place

* Galvanometer reading will not be zero, then Vary the Slide Wire Contact until reading is zero (Suppose occurs at 140 Cm)

Unknown = $140\,\Omega \times 10\,mA = 1.4\,V$

$$R = \frac{V}{Cm} \quad [\text{Resolution}]$$

$$= \frac{IR}{Cm} = \frac{10\,mA \times 200\Omega}{200\,Cm}$$

$$\boxed{R = 0.01\ V/Cm}$$

Why it is Accurate?

In PMMC, when we working with low Voltages, due to drop in Connecting Wires, resistance in meters, the meter Won't deflect

But in Potentiometers, the Current is zero (Current zero method) even though due to the presence of resistance of Connecting Wires, Slide Wire & Contact (due to Current absent) No drop will be there and it is more Accurate

* The Suitable material for Slide Wire is

Platinum - Gold - Silver

Drawbacks:

1) Lengthy Meter (bcz of 2m)

2) Resolution is not so high (R = 0.01 V/cm)

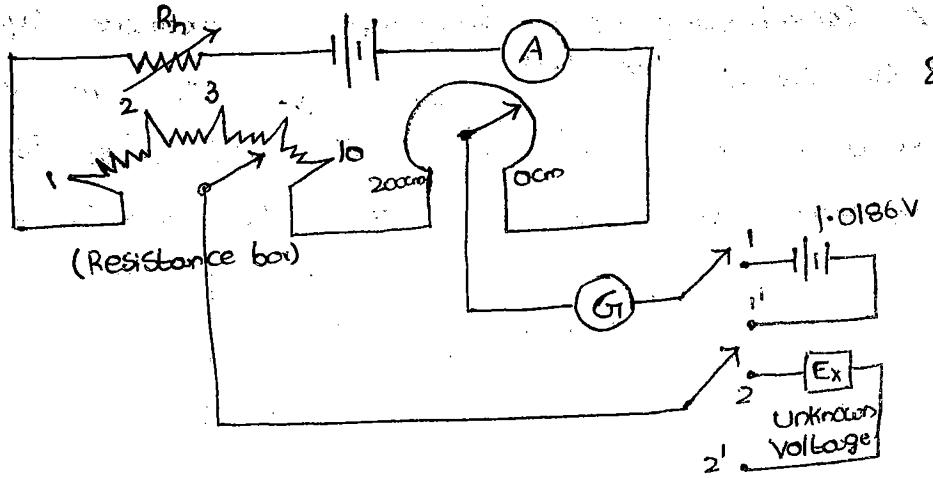
Crompton's Potentiometer:

(To overcome the drawbacks of basic Potentiometer i.e, to reduce the length and to improve the Resolution of the instrument)

We go for Crompton's Potentiometer

* Slide Wire is made to reduce by moulding it as Circular in shape, there by it is Compact in Size.

* In Basic P.M, at 10 mA, the Resistance 101.86Ω is Completely Contributed by Slide Wire. Now here it is divided into two parts (one by Slide Wire,



* Resistance box has 10 steps, each step is designed for 10 Ω (Total 10 x 10 = 100 Ω). Remaining 1.86 Ω is Contributed by Sli$\overset{de}{\text{ght}}$ Wire. Another thing is 200 cm Slide Wire is designed for 10 Ω (unlike 200 Ω in basic Potentiometer).

[For Eg:: To obtain 88 Ω
Take 80 Ω on resistance box i.e, on 8th step
and remaining 8 Ω on Slide Wire]

* After Standardisation is over, Change the Switch from 1-1' to 2-2'. Then the Galvanometer reads Some Value. Now, we have to adjust by using Resistance box (For Major deflection) & Slide Wire (For Minor deflection) Resistance.

200 cm = 10 Ω
? = 1.86 Ω
$$\Rightarrow 1.86 \times \frac{200}{10} = \underline{37.2 \text{ cm}}$$

Now, if We obtain as 30 on box & 2 on Wire

$$\Rightarrow (30 \text{ cm} \Leftrightarrow (30 + 0.01)\Omega \times 10 \text{ mA} = \text{Unknown Voltage}$$

$$\text{Resolution} = \frac{V}{cm} = \frac{IR}{cm} = \frac{(10 \text{ mA})(10\Omega)}{200} = 0.0005 \text{ V/cm}$$

Ⓟ A Potentiometer is designed is measure upto ~~2Ω~~ 2V, Slide of 800 mm. (1mm = 1Ω). A Standard Cell emf of 1.18 V is balance at 600 mm. At test cell is seen to obtain balance at 680 mm. Then the emf of test cell

Sol: $I_\omega' \times 600\text{ mm} = 1.18$

$I_\omega = 1.96\text{ mA}$

Unknown = $I_\omega \times 680\text{ mm}$

$= 1.96 \times 680 = 1.337\text{ V}$

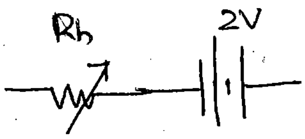
$600\ \Omega = 1.18\text{ V}$

$680\ \Omega = ?$

$\Rightarrow 680 \times \frac{1.18}{600}$

$= 1.337\text{ V}$

Ⓟ A wire potentiometer of length 11m and resistance 1Ω/m balances a std cell Voltage of 1.018 V at a length of 10.18 m. If the Voltage of the battery supplying current through potentiometer is 2V. then the series resistance corresponding connect through P.M ?



$I_\omega \times 10.18 = 1.018$

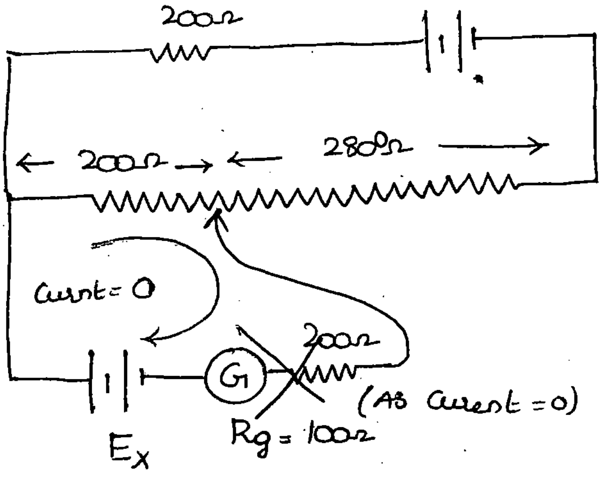
$I_\omega = 0.1\text{ A}$

$$I_\omega = \frac{2}{R_h + ~~\text{rotes}~~ 11\Omega}$$

$\Rightarrow (R_h + 11)(0.1) = 2$

$\Rightarrow R_h = 20 - 11 = 9\Omega$

Ⓟ the potentiometer is balanced then find the Value of E_x.



$$I_\omega = \frac{3.2}{200 + 200 + \overset{2}{\cancel{4}}800}$$

$= 1\text{ mA}$

$I_\omega \times 200 = E_x$

Measurement of Resistance.

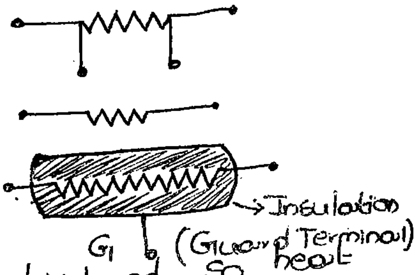
1. Low Resistance $(R < 1\Omega)$ → Armature Winding Resistance, Diode F-B resistance, Series field Wdg
2. Medium Resistance $(1\Omega - 100k\Omega)$ → Shunt field Resistance, Potentiometer Slide Wire
3. High Resistance $(R > 100k\Omega)$ → Diode R-B Resistance, OP-Amp I/p Impedance, Insulation Resistance

* By Seeing the terminals, We can identify the Resistances

Low Resistance – 4 terminals

Medium Resistance – 2 terminals

High Resistance – 3 terminals



Purpose of Guard terminal: (More heat developed, So heat dissipation is must. So Insulation is there, outside High Insulation Required)

Inside High resistance Resistance. When we connect the Multimeter, Req will be ||lel Combination of both and We won't get exact Value So, Guard terminal is grounded to avoid leakage Current (Makes Insulation Resistance is zero)

Low Resistance	Medium Resistance	High Resistance
1) Kelvin's Double Bridge	Accurate 1) Wheat stone Bridge 2) V-A / A-V } method 3) Substitution Method Worst 4) Ohm-meter Method	1) Megger Accurate 2) Loss of Charge method 3) Direct Deflection Worst 4) Mega ohm Bridge Method

Measurement of Low Resistance:

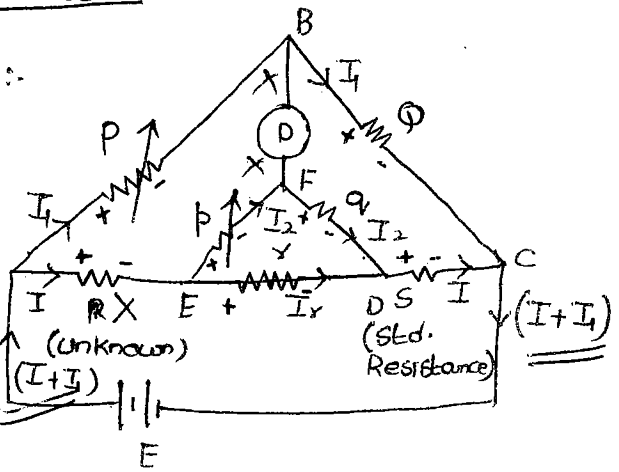
Kelvin's Double Bridge:-

P, Q, p, q

Bridge Resistances A

'r' – Contact leads Resistance.

D – Detector



Under balanced condition, 'D' is Short circuited

Three KVL Equations,

$$\boxed{X = \frac{P}{Q} S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]}$$

kelvin's Double Bridge is useful to measure the low & Medium Resistances

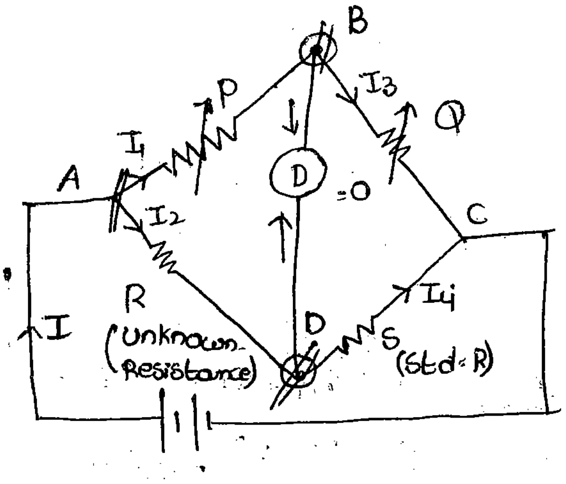
If We want to measure Medium Resistance,

make $\boxed{\frac{P}{Q} = \frac{p}{q}}$

Then $\boxed{X = \frac{P}{Q} S}$

Measurement of Medium Resistance:

1) Wheat stone Bridge



Voltage Drop across AB = Voltage Drop across AD

$$I_1 P = I_2 R$$

$$\boxed{\frac{I_1}{I_2} = \frac{R}{P}} \rightarrow (1)$$

Voltage Drop across BC = Voltage drop across DC

$$I_3 Q = I_4 S$$

$$\Rightarrow \boxed{\frac{I_3}{I_4} = \frac{S}{Q}} \rightarrow ②$$

$$\frac{R}{P} = \frac{S}{Q} \Rightarrow \boxed{R = \frac{P}{Q} S}$$

Sensitivity :- (Change in o/p to Change in I/P)

1. Detector Sensitivity (S_D)

2. Bridge Sensitivity (S_B)

In Between B, D. Detector reads zero bcz of B, D at same potential. To know the Detector Sensitivity, make the Bridge intentionally unbalance. To achieve this change the Resistance 'R' to ($R + \Delta R$). 'e' is change in P.D; '$\Delta\theta$' is the deflection occurs

$\therefore$ Detector Sensitivity = $\frac{\text{Change in Deflection}}{\text{change in P.D}}$

$$= \frac{\Delta\theta}{e}$$

$$\boxed{S_D = \frac{\Delta\theta}{e}} \Rightarrow \boxed{\Delta\theta = S_D \cdot e}$$

Bridge sensitivity = $\frac{\text{change in Deflection}}{\text{Unit change in Resistance}}$

$$\boxed{S_B = \frac{\Delta\theta}{(\Delta R/R)}}$$

$$\therefore \boxed{S_B = \frac{S_D \cdot e}{\Delta R/R}}$$

We always prefer Bridge high sensitivity; Which in turn depends on detector sensitivity

$$e = V_B - V_D$$

$$= (E - V_{AB}) - (E - V_{AD})$$

$$\Rightarrow \boxed{e = V_{AD} - V_{AB}}$$

$$= E\left[\frac{R + \Delta R}{(R + \Delta R) + S}\right] - E\left[\frac{P}{P + Q}\right]$$

$$e = E\left(\frac{R + \Delta R}{R + \Delta R + S} - \frac{P}{P + Q}\right) \longrightarrow ①$$

We know $\frac{P}{Q} = \frac{R}{S}$

$$\Rightarrow \frac{Q}{P} = \frac{S}{R}$$

Add '1' on both Sides

$$\Rightarrow \frac{Q}{P}+1 = \frac{S}{R}+1 \quad \Rightarrow \frac{Q+P}{P} = \frac{S+R}{R}$$

$$\Rightarrow \frac{P}{Q+P} = \frac{R}{S+R}$$

Now Substitute the above in ①

$$\Rightarrow \quad e = E\left(\frac{R+\Delta R}{R+\Delta R+S} - \frac{R}{R+S} \right)$$

$$= E\left(\frac{(R+\Delta R)(R\cancel{+\Delta R}) + (R(\cancel{\Delta}+\Delta \cancel{R})S}{(R+\Delta R+S)(R+S)} - R(R) - R\Delta R - SR \right)$$

2)

$$= E\left(\frac{\cancel{R^2} + R\cancel{\Delta}R + \cancel{RS} + \Delta RS - \cancel{R^2} + R\cancel{\Delta}R - \cancel{SR}}{(R+\Delta R+S)(R+S)} \right)$$

$$= E\left(\frac{S\Delta R}{(R+S)^2 + \Delta R(\cancel{R}+S)} \right)$$

(Neglect) as Very Small)

$$\boxed{e = \frac{ES\Delta R}{(R+S)^2}}$$

$$\therefore \text{Bridge Sensitivity} = \frac{S_D\, e}{(\Delta R/R)}$$

$$= \frac{\dfrac{S_D \cdot ES\cancel{\Delta}R}{(R+S)^2}}{\left(\dfrac{\cancel{\Delta R}}{R}\right)}$$

$$\therefore \boxed{S_B = \frac{S_D \cdot ESR}{(R+S)^2}}$$

$$= \frac{S_D \cdot ERS}{R^2+S^2+2RS}$$

*

Divide by RS

$$\Rightarrow \quad S_B = \frac{\dfrac{S_D \cdot ERS}{RS}}{}$$

$$\Rightarrow \boxed{S_B = \frac{S_D \cdot E}{\left(\frac{R}{S} + \frac{S}{R} + 2\right)}}$$

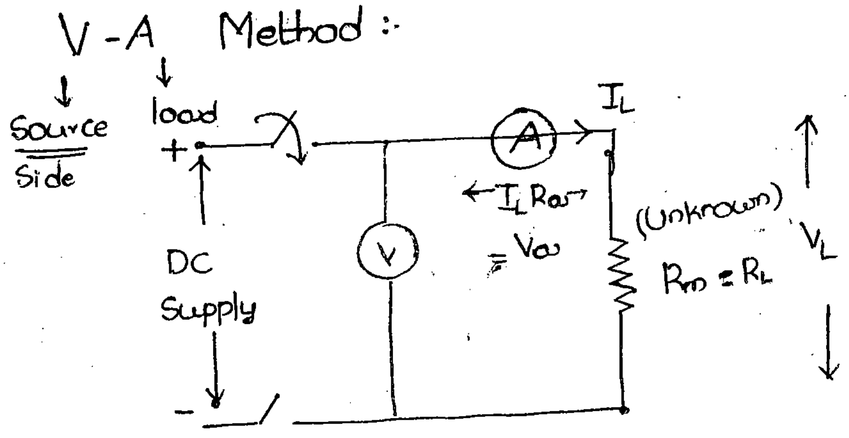
To get Bridge Sensitivity as Maximum;

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

$$\therefore S_B = \frac{S_D \cdot E}{1+1+2} = \frac{S_D \cdot E}{4}$$

$$\therefore \boxed{S_{B_{max}} = \frac{S_D \cdot E}{4}}$$

2) V-A Method :-



$$\text{True Value} = (R_m)_t = \frac{V_L}{I_L}$$

$$\text{But } \underset{(\text{Measured Value})}{(R_m)_m} = \frac{\text{Voltmeter Reading}}{\text{Ammeter Reading}} \quad (\text{Apply KVL})$$

$$= \frac{V_L + V_a}{I_L} = \frac{V_L}{I_L} + \frac{I_L R_a}{I_L}$$

$$= \frac{V_L}{I_L} + R_a$$

$$\therefore \boxed{(R_m)_m = (R_m)_t + R_a}$$

i) $(R_m)_m > (R_m)_t$

* In V-A method, for the measurement of Medium Resistance, error is because of only Ammeter

$$\% \text{ Error} = \left(\frac{A_m - A_t}{A_t}\right) \times 100$$

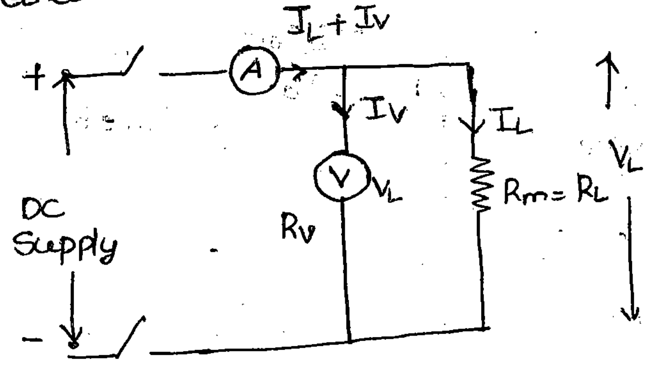
$$\boxed{\% \text{ Error} = \frac{R_a}{} \times 100}$$

* Error is always to be less. It occurs When R_a is low (Which is not in our hand). / R_m is high (So, Better to measure high Value in Medium Range) to reduce errors.

Conclusions:

1. In Voltmeter-Ammeter method, $R_m > R_t$
2. In V-A method, error because of always due to Ammeter
3. this method is useful for measurement of high Resistance in Medium Range so that % error is minimum

A-V Method:



$$(R_m)_t = \frac{V_L}{I_L}$$

$$(R_m)_m = \frac{\text{Voltmeter Reading}}{\text{Ammeter Reading}}$$

$$= \frac{V_L}{I_L + I_V}$$

$$\text{So, } (R_m)_m < (R_m)_t$$

$$(R_m)_m = \frac{\cancel{V_L}}{\left(\frac{\cancel{V_L}}{R_L}\right) + \left(\frac{\cancel{V_L}}{R_V}\right)}$$

$$\Rightarrow (R_m)_m = \frac{1}{\frac{1}{R_L}\left(1 + \frac{R_L}{R_V}\right)}$$

$$(R_m)_m = \frac{R_L}{1 + \frac{R_L}{}}$$

$$\Rightarrow (R_m)_m \left(1+\frac{R_L}{R_V}\right) = R_L$$

$$\Rightarrow (R_m)_m - R_L = \frac{-(R_m)_m R_L}{R_V}$$

$$\Rightarrow \left(\frac{(R_m)_m - R_L}{R_L}\right) = \frac{-(R_m)_m}{R_V}$$

$$\boxed{\% \text{ Error} = \left(\frac{(R_m)_m - R_L}{R_L}\right) \times 100 = \frac{-(R_m)_m}{R_V} \times 100}$$

Conclusions:

1. $R_m < R_L$
2. Error due to Voltmeter
3. Useful for Measurement of low Resistance in Medium Range

Note:

1. In any Method, error is due to the instrument (thing) which is connected nearer to load side
2. Inorder to get the Same error while measuring in both the methods, it occurs only when the Unknown Medium Resistance is $\boxed{R_L = \sqrt{R_a R_V}}$

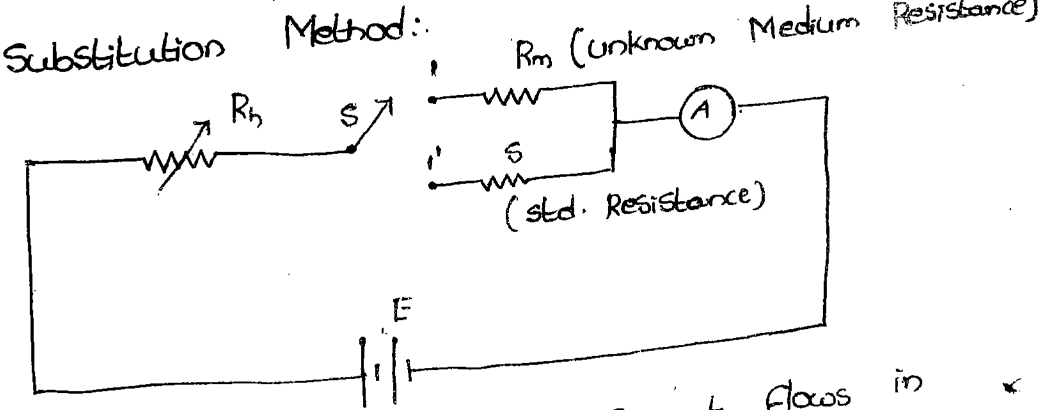
[error in V-A = error in A-V

$$\Rightarrow \frac{R_a}{R_L} = \frac{R_L}{R_V} \Rightarrow R_L = \sqrt{R_a R_V}$$]

Where 'R_a' is Ammeter Internal Resistance

'R_V' is Voltmeter Internal Resistance

3) Substitution Method:



1. Connect Switch S to '1', Current flows in Ammeter. Note down it as $\boxed{I_1 = \frac{E}{R_m + R_h}}$

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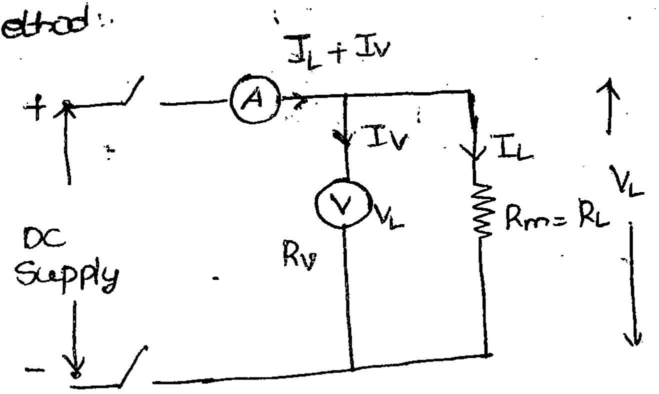

$$(R_m)_t = \frac{V_L}{I_L}$$

$$(R_m)_m = \frac{\text{Voltmeter Reading}}{\text{Ammeter Reading}}$$

$$= \frac{V_L}{I_L + I_V}$$

$$\text{So, } (R_m)_m < (R_m)_t$$

$$(R_m)_m = \frac{\cancel{V_L}}{\left(\frac{\cancel{V_L}}{R_L}\right) + \left(\frac{\cancel{V_L}}{R_V}\right)}$$

$$\Rightarrow (R_m)_m = \frac{1}{\frac{1}{R_L}\left(1 + \frac{R_L}{R_V}\right)}$$

$$(R_m)_m = \frac{R_L}{1 + \frac{R_L}{}}$$

occurs

hand).

value in

due to

igh

minimum

$)_t = \frac{V_L}{I_L}$

$$\Rightarrow (R_m)_m \left(1+\frac{R_L}{R_V}\right) = R_L$$

$$\Rightarrow (R_m)_m - R_L = \frac{-(R_m)_m R_L}{R_V}$$

$$\Rightarrow \left(\frac{(R_m)_m - R_L}{R_L}\right) = \frac{-(R_m)_m}{R_V}$$

$$\boxed{\% \text{ Error} = \left(\frac{(R_m)_m - R_L}{R_L}\right) \times 100 = \frac{-(R_m)_m}{R_V} \times 100}$$

Conclusions:

1. $R_m < R_L$
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Note:

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$\Rightarrow \frac{R_a}{R_L} = \frac{R_L}{R_V} \Rightarrow R_L = \sqrt{R_a R_V}$]

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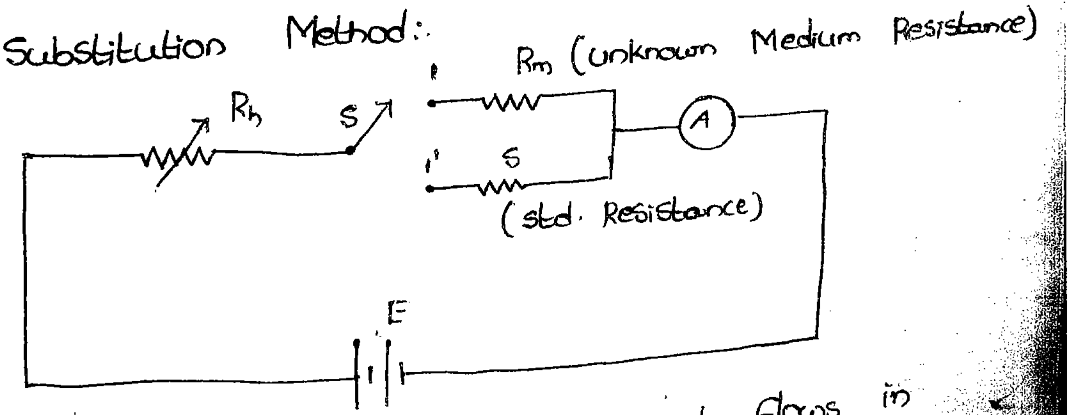


1. Connect Switch S to '1', Current flows in Ammeter. Note down it as $\boxed{I_1 = \frac{E}{R_m + R_h}}$

Now Connect to '1'', Note it as I_2

$$I_2 = \frac{E}{R_h + S}$$

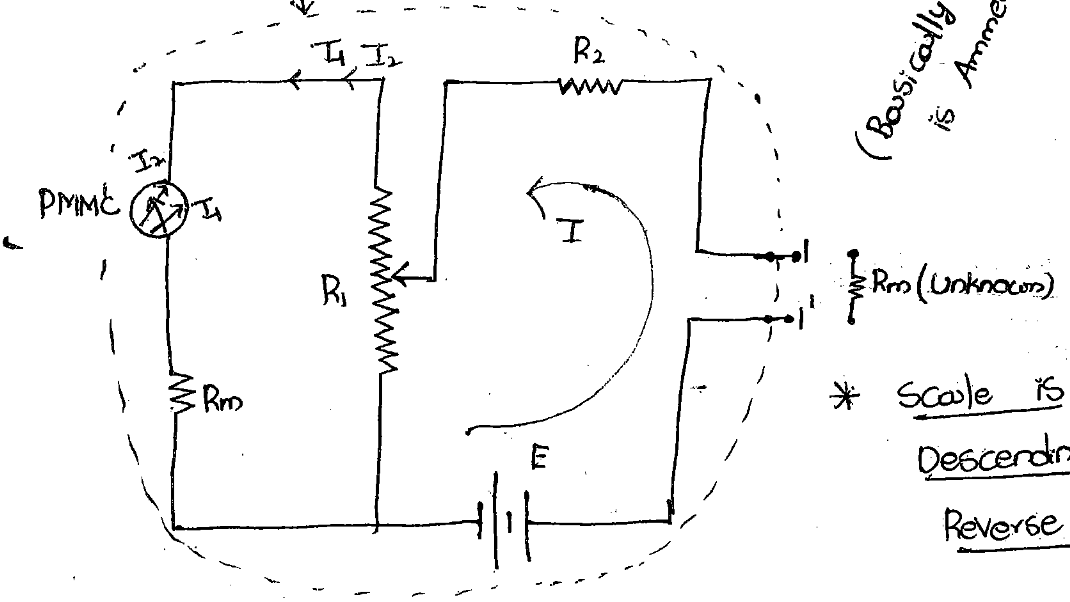
Make "I_2" as equal to I_1

To achieve this Vary resistance in Standard decade box, until it is equal to I_1 $[\because (I_2)]$

then the Std. Resistance is the required Medium (Unknown) Resistance

4) Ohm - Meter Method:-

(Basically it is Ammeter)



* Scale is Descending i.e, Reverse Scale

R_m - Internal Resistance of PMMC

* Before Connecting R_m, Short Ckt 1 & 1'. Then 'I' Flows, I_1 flows through PMMC. Note I_1.

* Connect Now R_m, 'I' decreases because of more Resistance Compared to previous.

* Now I_2 flows through PMMC, I_2 will be less Compared to I_1

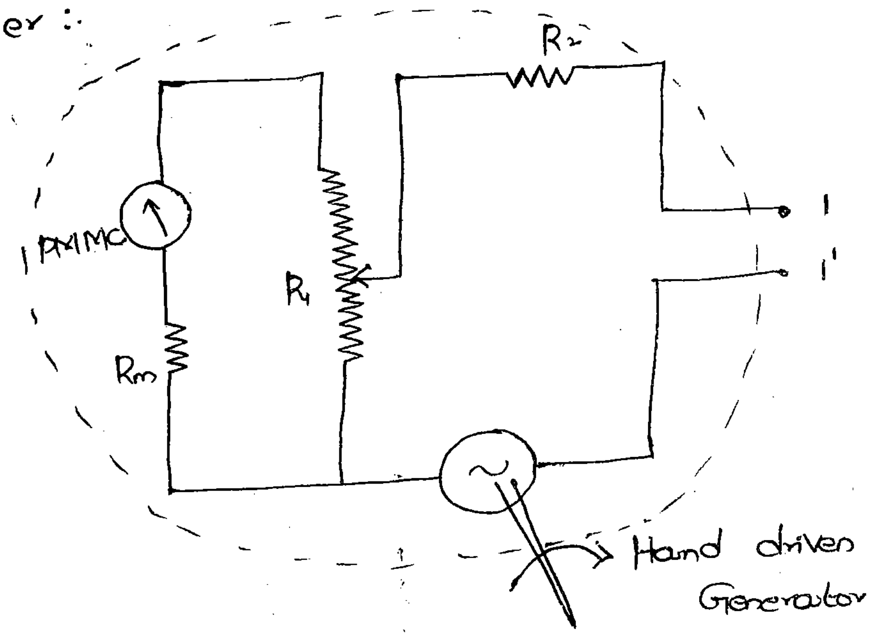
* Decrease in this Current is equal to the increased Resistance

* Change the Scale of PMMC Ammeter to Resistance Scale

* Ohm-meter Method is

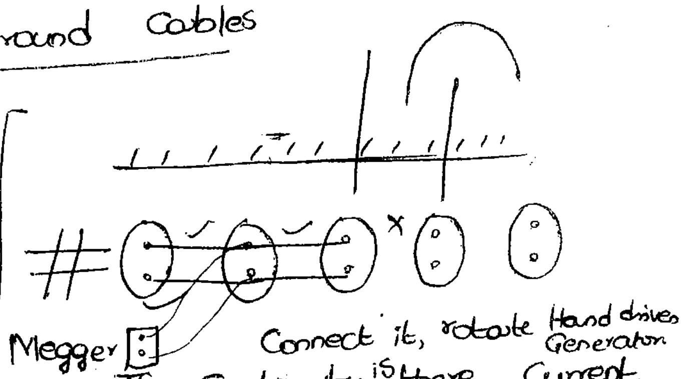
of Resistance beyond 100 KΩ bcz 'E' is not sufficient. But, to increase the measurement of (high) Resistance range, replace "E" with Hand driven generator (Bcz it produces more Voltage compared to Battery) Which is known as Megger

Megger :-



* By Replacing the Battery with Hand driven Generator, we can measure high Resistance. Since, it produces more Voltage compared to battery So that it is sufficient to drive Current in the Circuit

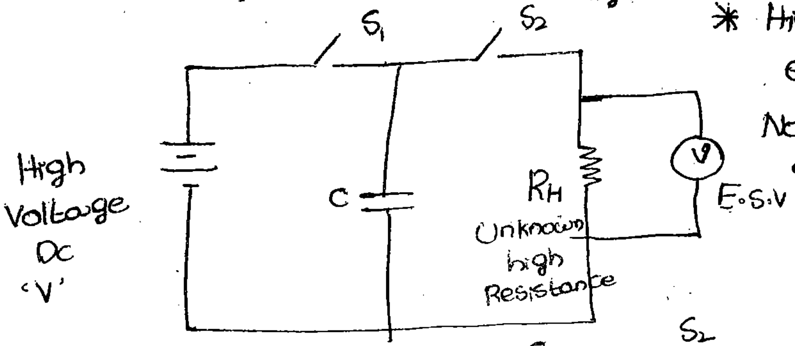
* The Megger is best suitable to check the Continuity in Underground Cables



Connect it, rotate Hand driven Generator
If Continuity is there, Current flows
If damage is there, infinite Resistance occurs no Current flows

3/5/12 (11 to 1)

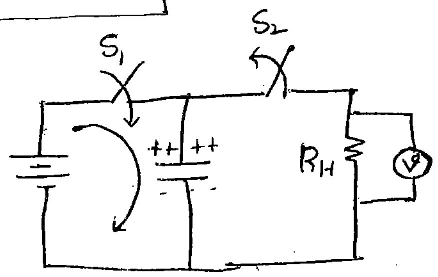
Loss of Charge Method:- (By using Charge, high Resistance is measured)



* Highly economical

Not preferable generally

Close S_1 and open S_2 then Capacitor V will charge.

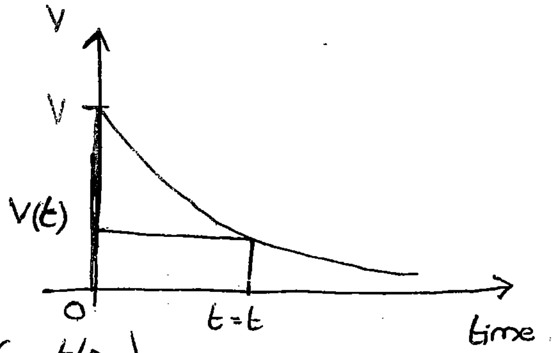


After $t = t(\text{sec})$

open S_1 and close S_2 then the Capacitor starts discharging in exponential manner (decaying)

* High Voltage $\simeq 66$ kV

So, it is of high Cost.



$$v(t) = V e^{-t/RC}$$

$$\Rightarrow \ln\left(\frac{v}{V}\right) = \ln\left(e^{-t/RC}\right)$$

$$\ln\left(\frac{v}{V}\right) = -t/RC$$

$$\ln\left(\frac{V}{v}\right) = \frac{t}{RC}$$

$$\Rightarrow \boxed{R = \frac{t}{C \ln\left(\frac{V}{v}\right)}}$$

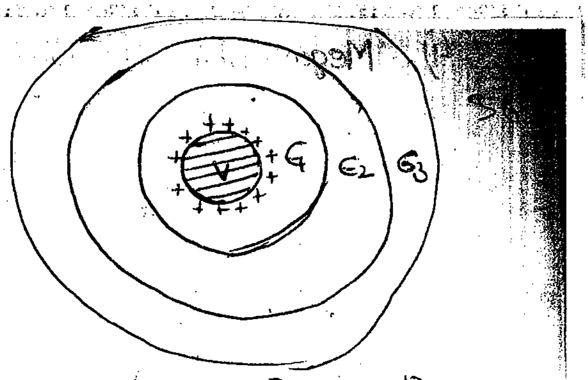
$$\boxed{R = \frac{0.434\, t}{C \log\left(\frac{V}{v}\right)}}$$

* Capacitor of high rating reqd bcz of 66 kV which is economical

* Loss of charge method is best suitable for measurement of Insulation Resistance in case of Cables

Charge deposited on outside of Core because of Voltage

* Electric field lines inside the Conductor is 'O'



Locomotives
AC
1φ
25 kV

$R_1 > R_2 > R_3$ ----
$\epsilon_1 > \epsilon_2 > \epsilon_3$ ----

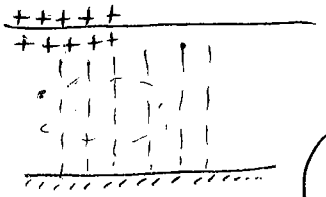
Gauss law

$$\oint\!\!\oint_S \vec{E}\cdot\vec{ds} = \frac{1}{\epsilon_0}(Q)$$

$$\bar{E}\cdot 2\pi r = \frac{1}{\epsilon_0} Q$$

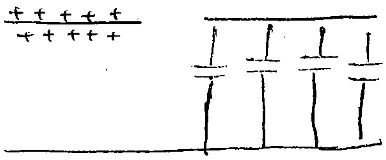
$$\Rightarrow \bar{E} = \frac{Q}{2\pi r \epsilon_0}$$

$$E \propto \frac{1}{r}$$



(Equivalent to parallel plate cap)

In the middle of the line if it is open. even though if it is open We can't touch the wire because



Ceq increases & Current bypasses through our body

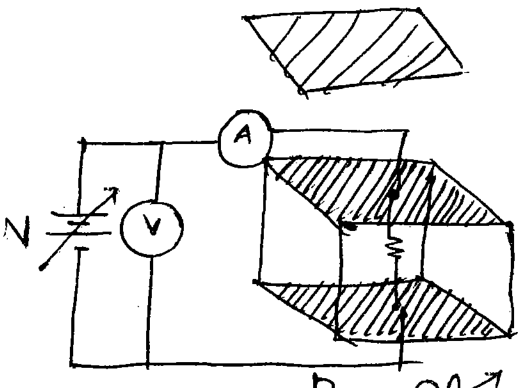
3) Direct Deflection Method

* The direct deflection Method is best suitable for the measurement of Resistivity

$\rho_{Cu} = 1.7\times 10^{-8}$ Ω-m

Take 1 unit cube of material from the thing for which resistivity to be found

Measure resistance b/w any two b as surfaces

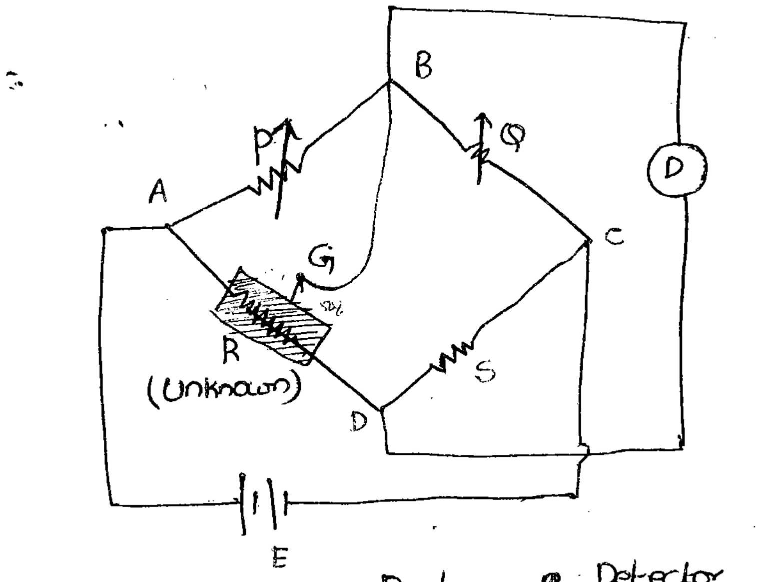


$$R = \frac{\rho \cancel{l} \nearrow 1}{\cancel{A} \nearrow 1}$$

$$R = \frac{V}{A}$$

sub in adjacent method

4) Mega - ohm Bridge:



* |||r to Wheatstone Bridge, Detector Connected btw B, D outside

* Connect high Resistance in place of 'R'

* Vary P, Q such that deflection is zero

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

We get Unknown Resistance (Including Insulation Resistance)

* Connect the Guard terminal of resistance to 'B'.

So, we connected the Detector outside

* P, Half of the Insulation Guard Resistance in Parallel

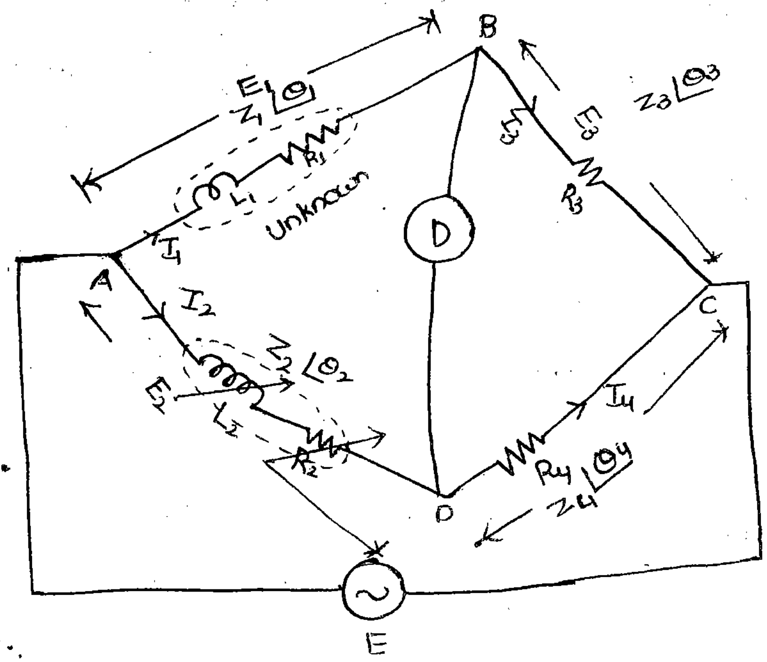
So that Insulation Resistance donot Actual Resistance

M/M Of Inductance: (L) (MaxWell)

(AC Bridges)

1) MaxWell's Inductance Bridge
2) MaxWell's Inductance - Capacitance Bridge
3) Hay's Bridge
4) Owen's Bridge
5) Anderson's Bridge (Accurate)

10) Maxwell's Inductance Bridge:



***

$$\boxed{\begin{array}{l} Z_1 Z_4 = Z_2 Z_3 \\ \angle\theta_1 + \angle\theta_4 = \angle\theta_2 + \angle\theta_3 \end{array}}$$

B, D

Step 1:

1) $I_1 = I_3$, as no current in Detector

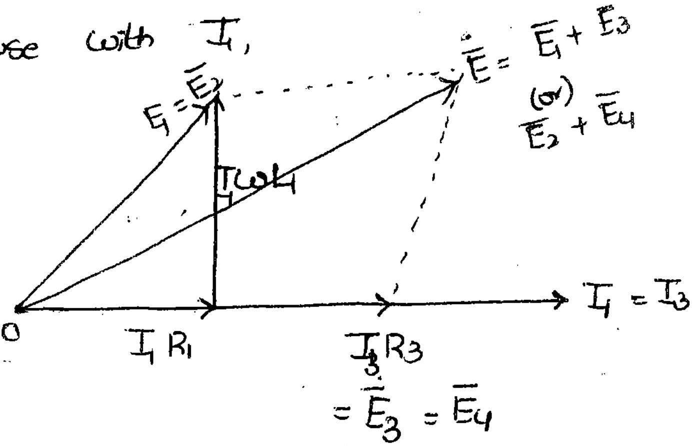
2) Draw $I_1 R_1$ in phase with I_1, and next draw $I_1 X L_1$ (Current lags Voltage by 90°)

3) $\bar{E}_1 = \bar{E}_2$

4) Draw $I_3 R_3$ in phase with 'I_3'

5) $\bar{E}_3 = \bar{E}_4$

6) Draw Resultant of $\bar{E}_1$ and $\bar{E}_3$ (or) $\bar{E}_2$ and $\bar{E}_4$ to get $\bar{E}$



$$\therefore\ Z_1 Z_4 = Z_2 Z_3 \Rightarrow (R_1 + j\omega L_1)(R_4) = (R_2 + j\omega L_2)(R_3)$$

$$\Rightarrow R_1 R_{24} + j\omega L_1 R_4 = R_2 R_3 + j\omega L_2 R_3$$

Real: $R_1 R_4 = R_2 R_3$; $L_1 R_4 = L_2 R_3$

$$\boxed{R_1 = \frac{R_2 R_3}{R_4}}, \quad \boxed{L_1 = \frac{R_3 L_2}{R_4}}$$

Quality factor of Inductor, L_1

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

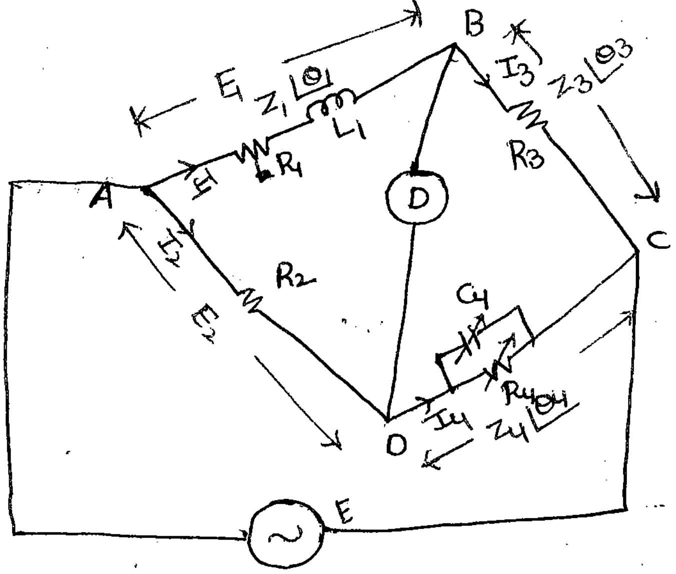
$$\Rightarrow \cancel{Q = \frac{\omega L_2}{R_2}}$$

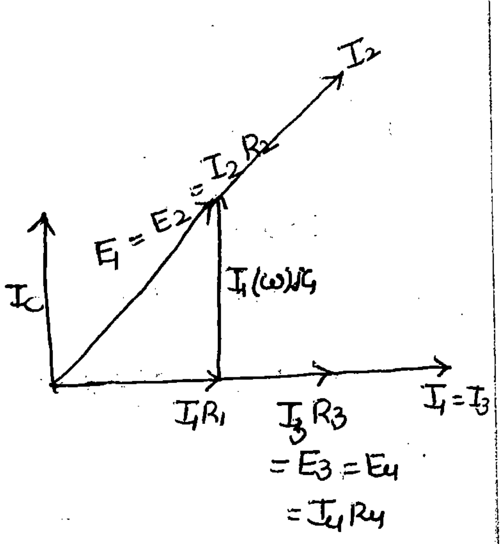
* As no capacitor, We can't get ~~Q~~ Resonance Condition And the Quality factor formula Valid for RLC

→ By using Maxwell's Inductance Bridge, we cannot quality factor ~~we~~ ~~Q~~ since the bridge cannot be brought to Resonance Condition

* Identification of Variable quantities can be obtained by cancellation of common terms from the obtained results

Maxwell's Inductance-Capacitance Bridge:





$$Z_1 Z_4 = Z_2 Z_3$$

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

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

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

Real:-

$$R_1 R_4 = R_2 R_3$$

$$R_1 = \left(\frac{R_2 R_3}{R_4}\right)$$

$$L_1 R_4 = R_2 R_3 R_4 C_4$$

$$\Rightarrow L_1 = R_2 R_3 C_4$$

$$Q = \frac{\omega L_1}{R_1} = \frac{\omega(R_2 \cancel{R_3} C_4)}{R_2 \cancel{R_3}} = \omega C_4 R_4$$

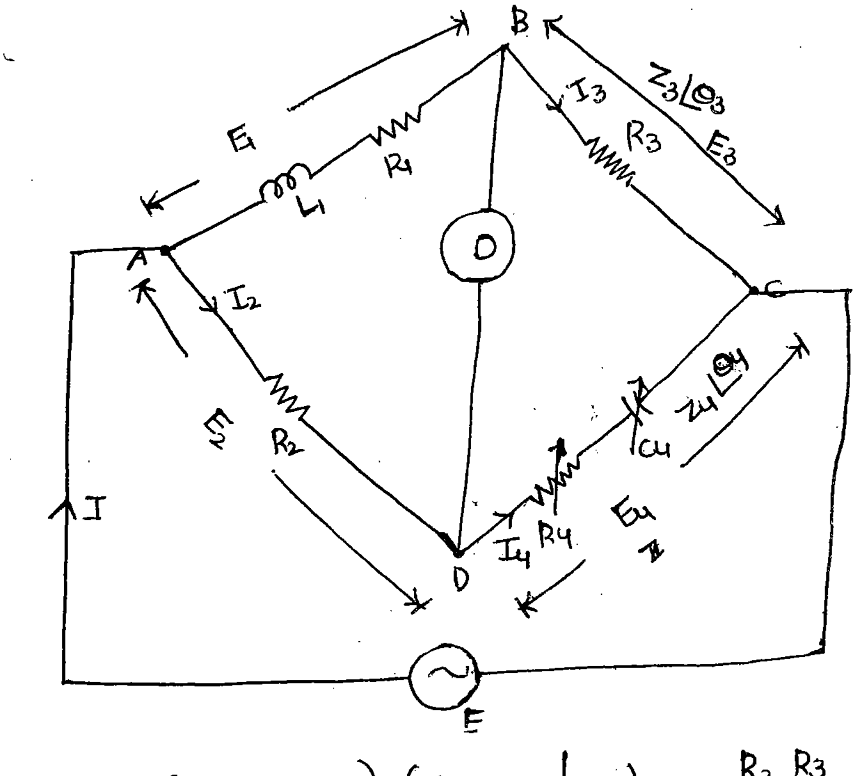
* It is not easy to ~~difficul~~ manufacture variable Capacitor $\left(C = \frac{\epsilon_0 A}{d} \right)$ we have to Vary either A (or) d Where as manufacturing 1 fixed Resistor is difficult. Inductor (both Cases) are difficult to Manufacture (Since Inductance Values changes even from one person to Other person because no.of turns easily changes due to force & Inductor changes

$L = \frac{N^2}{S}$; (reluctance changes) & even if it is moved in air, ϕ changes)

$L = \frac{N\phi}{i}$,

* So, High Quality factor $(Q \propto C_4)$. High Values Capacitor not possible. So, only Low Values Can be measured $(Q < 10)$

Hay's Bridge:-



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

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

Real:- $\frac{L_1}{C_4} + R_1 R_4 = R_2 R_3 \longrightarrow ①$

Im:- $\omega L_1 R_4 - \frac{R_1}{\omega C_4} = 0 \Rightarrow L_1 = \frac{R_1}{C_4 R_4}$

$\Rightarrow \omega L_1 R_4 = \frac{R_1}{} \Rightarrow R_1 = \omega^2 L_1 C_4 R_4 \longrightarrow ②$

② in ① ⇒

$$\frac{L_1}{C_4} = R_2R_3 - R_4R_1$$

$$\Rightarrow \frac{L_1}{\frac{R_4C_4}{C_4}} = R_2R_3 - R_4R_1$$

$$L_1 = R_2R_3C_4 - R_1R_4C_4$$

$$\Rightarrow \quad = R_2R_3C_4 - \omega^2 L_1 C_4 R_4 R_4 C_4$$

$$L_1\left(1+\omega^2 R_4^2 C_4^2\right) = R_2R_3C_4$$

$$\Rightarrow \boxed{L_1 = \frac{R_2R_3C_4}{1+\omega^2R_4^2C_4^2}}$$

Again substitute L_1 in ②

$$R_1 = \omega^2 L_1 C_4 R_4$$

$$\boxed{R_1 = R_4 \frac{\omega^2 R_2 R_3 C_4^2}{1+\omega^2R_4^2C_4^2}}$$

Quality factor, $Q = \frac{\omega L_1}{R_1}$

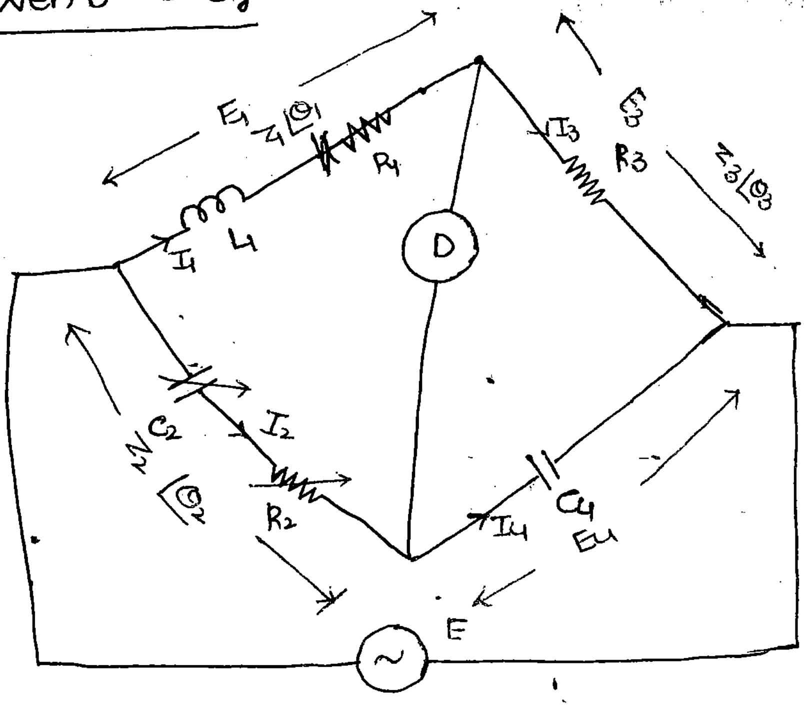
$$= \frac{\frac{\omega\left(R_2R_3C_4\right)}{1+\omega^2R_4^2C_4^2}}{\frac{\omega^2 R_2R_3C_4^2R_4}{1+\omega^2R_4^2C_4^2}}$$

$$= \frac{1}{\omega C_4 R_4}$$

$$\boxed{Q \propto \frac{1}{C_4}}$$

∴ $Q > 10$ can easily obtained as low capacitances are available.

Owen's Bridge :-



$$\Rightarrow (j\omega L_1 + R_1)\left(\frac{1}{j\omega C_4}\right) = R_3\left(R_2 + \frac{1}{j\omega C_2}\right)$$

$$\Rightarrow \frac{L_1}{C_4} + \frac{R_1}{j\omega C_4} = R_3 R_2 + \frac{R_3}{j\omega C_2}$$

Real :- $\frac{L_1}{C_4} = R_3 R_2 \Rightarrow \boxed{L_1 = R_3 R_2 C_4}$

Im :- $\frac{R_1}{C_4} = \frac{R_3}{C_2}$

$$\Rightarrow \boxed{R_1 = \frac{R_3 C_4}{C_2}}$$

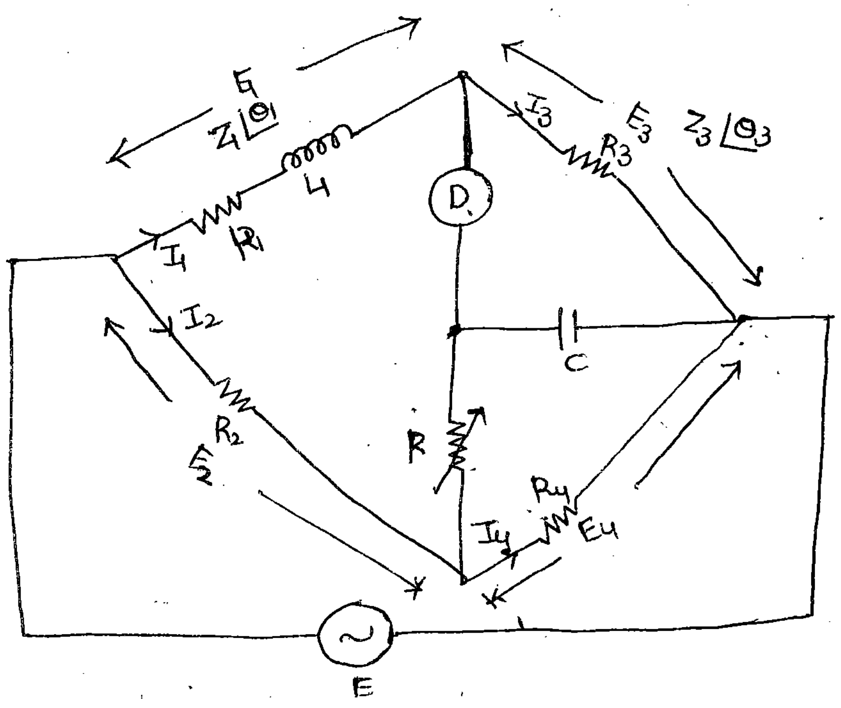
$$Q = \frac{\omega(\cancel{R_3} R_2 \cancel{C_4})}{\frac{\cancel{R_3 C_4}}{C_2}} = \omega C_2 R_2$$

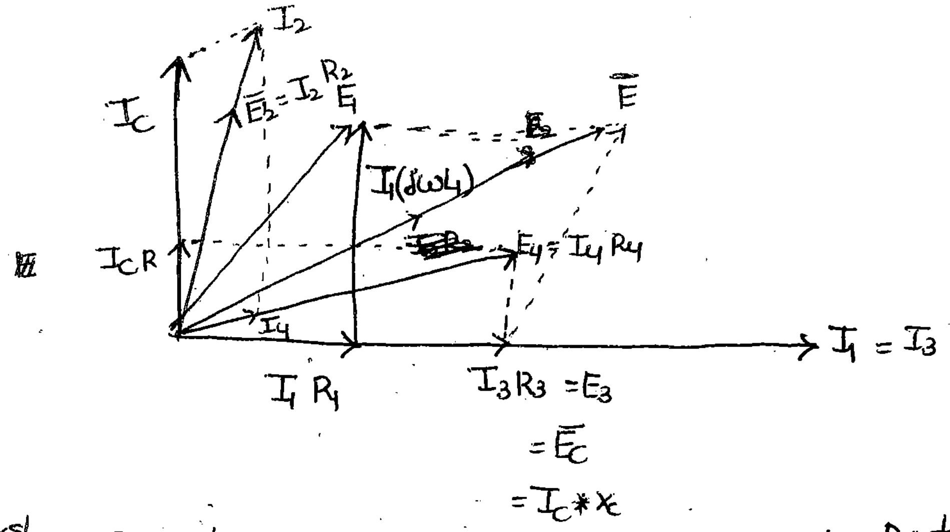
$$\boxed{Q \propto C_2}$$

only Low Quality factor is achieved $(Q < 10)$

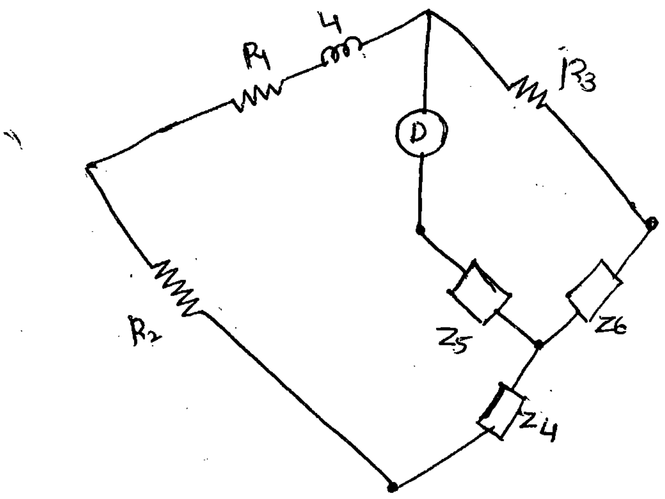
High Q.F →
Inductive React ↑
Low Resist ↓
Low Q.F →
Inductive React ↓
High Resist ↑

5) Anderson's Bridge :-





First Convert '5' point Bridge to 4-point Bridge



$$Z_4 = \frac{(R)(R_4)}{R(R_4) + R\left(\frac{1}{j\omega c}\right) + R_4\left(\frac{1}{j\omega c}\right)}$$

~~Z5~~

~~Z6~~ =

$$Z_4 = \frac{R(R_4)}{R + R_4 + \frac{1}{}}$$

Z5 :

* Accu

* Accu

Meas

*

D-

Q

* Pun

$$Z_5 = \frac{\left(\frac{1}{j\omega C}\right)(R)}{R_1 + R_4 + \frac{1}{j\omega C}}$$

on balancing equations,

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

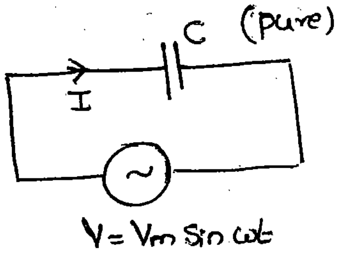
$$\boxed{L_4 = \frac{C R_3}{R_4}\left(R_2 R + R R_4 + R_2 R_4\right)}$$

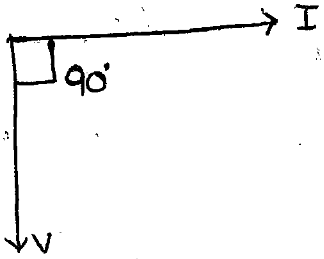
$$Q = \cancel{\frac{\omega L_4}{R_1}} =$$ ~~ω~~ ≠ (Wrong) [Q factor is measured when only at resonance which cannot be obtained here due to invariable capacitor)

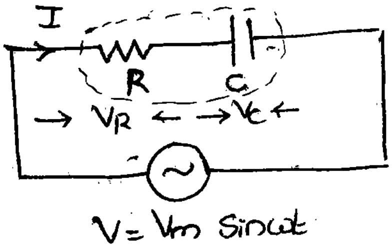
* Accurate Bridge for Inductance – Anderson's Bridge

* Accurate Bridge for Quality factor – Hay's Bridge

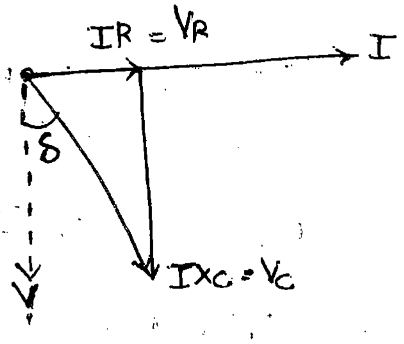
Measurement Of Capacitance (C):-







$$V = \vec{V_R} + \vec{V_C}$$



δ → Loss Angle

*In pure Capacitor, the loss Angle is '0'

* In

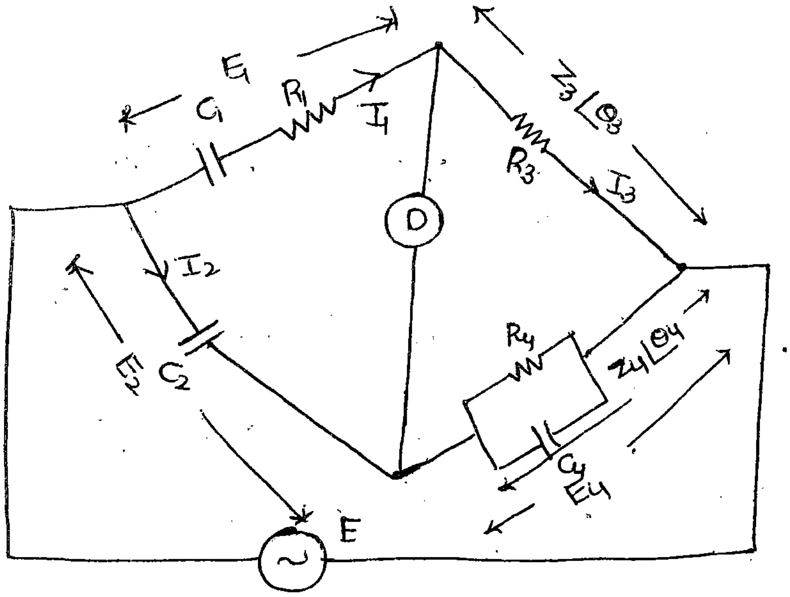
$$\boxed{\tan\delta = \frac{V_R}{V_C}} = \frac{IR}{IX_C}$$

D- Factor (Quantity of ↓ determines Capacitance) $= \frac{R}{X_C} = \frac{R}{1/\omega C}$

Quality of capacitor $= \omega CR$

* Pure capacitor, D-factor is '0' ⇒ $\boxed{\tan\delta = \omega CR}$

(1) ~~Desauty's~~ Bridge
(2) Modified ~~Desauty's~~ Bridge } Not Required
✓(3) Schering Bridge (Accurate)



At Balance,

$$Z_1 Z_4 = Z_2 Z_3$$

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

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

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

$$(R_1 j\omega C_1 + 1)(R_4)(j\omega C_2) = (R_3 j\omega C_1)(R_4 j\omega C_4 + 1)$$

$$\Rightarrow R_1 R_4 (-1)\omega^2 C_1 C_2 + R_4(j\omega C_2) = R_3 R_4 (-1)\omega^2 C_1 C_4 + R_3 j\omega C_1$$

$\Rightarrow$ Im:- $R_4 C_2 = R_3 C_1$

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

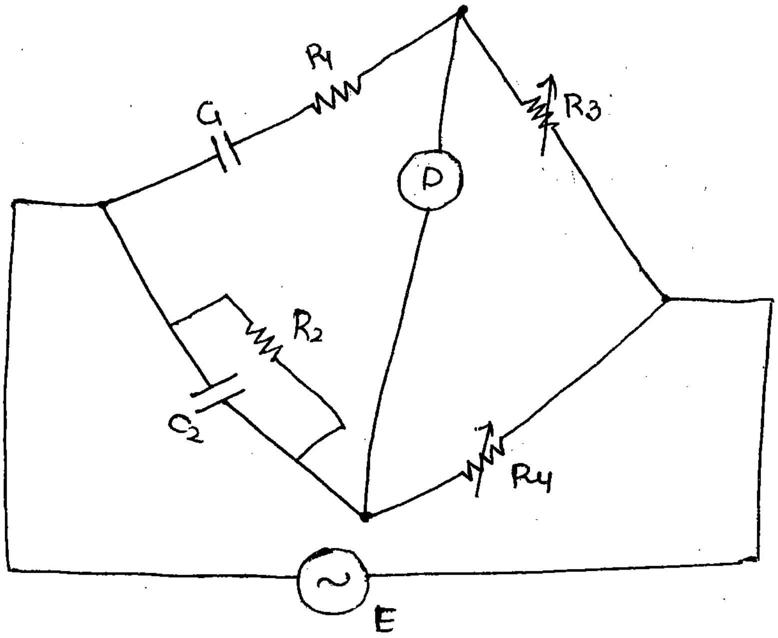
Real:- $R_1 R_4 C_1 C_2 = R_3 R_4 C_1 C_4$

$$\Rightarrow R_1 C_2 = R_3 C_4$$

$$\text{D- Factor} = \omega C_1 R_1 = \omega \left(\frac{\cancel{C_2} R_4}{\cancel{R_3}} \right) \left(\frac{\cancel{R_3} C_4}{\cancel{C_2}} \right)$$

$$= \omega R_4 C_4$$

Measurement of frequency (Wein's Bridge)



$$\Rightarrow \left(R_1 + \frac{1}{j\omega C_1} \right) (R_4) = R_3 \left(R_2 \parallel \frac{1}{j\omega C_2} \right)$$

$$R_1 R_4 + \frac{R_4}{j\omega C_1} = R_3 \left(\frac{\frac{R_2}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}} \right)$$

$$R_1 R_4 + \frac{R_4}{j\omega C_1} = \frac{R_3 R_2}{R_2 j\omega C_2 + 1}$$

$$\Rightarrow \left(\frac{R_1 R_4 j\omega C_1 + R_4}{j\omega C_1} \right) = \left(\frac{R_3 R_2}{R_2 j\omega C_2 + 1} \right)$$

$$\Rightarrow R_2 R_1 R_4 (-1) \omega^2 C_1 C_2 + R_4 R_2 (j) \omega C_2 + R_1 R_4 j\omega C_1 + R_4 = R_3 R_2 j\omega C_1$$

Equate Real parts

$$R_4 = R_2 R_1 R_4 (-\omega^2) C_1 C_2$$

$$\Rightarrow \omega^2 C_1 C_2 R_1 R_{\cancel{4}2} = 1$$

$$\omega^2 = \frac{1}{R_1 R_2 C_1 C_2} \Rightarrow \boxed{F = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}}$$

Ⓟ

Venugopal Sir

86 86 211233
86 86 211200

1) Identify the Bridge

Sol: Owen's Bridge

$R_3 = 10\Omega$, $R_2 = 842\Omega$, $C_2 = 0.135\ \mu F$, $C_4 = 1\mu F$

$$R_1 = \frac{R_3 C_4}{C_2} = \frac{(10)(1\times10^{-6})}{0.135\times10^{-6}} = 74.07\Omega$$

$$L_1 = R_3 R_2 C_4 = (10)(842)(1\times10^{-6}) = 8.42\,mH$$

2) $C_2 = 500\ \mu\mu F = 500\ pF$

$R_3 = 300\Omega$, $R_4 = 72.6\Omega$

$C_4 = 0.148\ \mu F$

$C_1 = ?$, $\delta = ?$

$$\boxed{C_1 = \frac{C_2 R_4}{R_3}} = \frac{(500)(72.6)\times10^{-12}}{300}$$

$$= 121\ PF$$

$$\tan\delta = \cancel{\tan}^{-1}\ \omega R_4 C_4$$

$$= 2\pi(50)(72.6)(0.148\times10^{-6})$$

$$\boxed{\delta = 0.193}$$

3) $R_4 = 5.1k$, $C_4 = 2\mu F$, $R_3 = 7.9k$, $R_2 = 790\Omega$

$$L_1 = \frac{R_2 R_3 C_4}{1+\omega^2 R_4^2 C_4^2} = \frac{(790)(7.9\times10^3)(2\times10^{-6})}{1+(1000)^2(5.1\times10^3)^2(2\times10^{-6})^2} = 0.118\ H$$

$$= 118\ mH$$

$$R_1 = \frac{R_4\ \omega^2 R_2 R_3 C_4^2}{1+\omega^2 R_4^2 C_4^2} = \frac{(5.1\times10^3)(1000)^2(790)(7.9\times10^3)\times(2)^2\times10^{-12}}{1+(1000)^2(5.1\times10^3)^2(2\times10^{-6})^2}$$

$$= 1.2\ K\Omega$$

$\omega = 1000$ rad/sec

4) $R_3 = 1000\Omega$

$C_2 = 50\ PF$

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

$$= \frac{8.85\times10^{-12}\times 2.3\times(314\times10^{-4})}{0.3\times10^{-2}}$$

$\tan\delta = \omega C_1 R_1$

4D

$\tan 9^\circ = (2\pi \times 50)(213.14 \times 10^{-12}) R_1$

$\Rightarrow R_1 = 2.36\ M\Omega$

$R_4 = \dfrac{C_1 R_3}{C_2}$; $C_4 = \dfrac{C_2 R_1}{R_3}$

$= 4.26\ k\Omega$

$= \dfrac{(50 \times 10^{-12})(2.36) \times 10^6}{1000} = 0.118\ \mu F$

F

)

2

$= 0.118\ H$

$= 118\ mH$

$\dfrac{790)(7.9 \times 10^3) \times (2)^2 \times 10^{-12}}{3)^2 (2 \times 10^{-6})^2}$

2 $k\Omega$

$\times 10^{-4})$

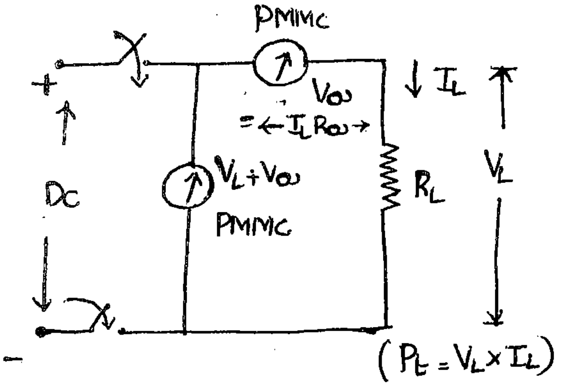
Measurement Of POWER

1) Dc power → R-Load ⇒ $P = \underset{DC}{V}\underset{DC\,(PMMC)}{I}$

2) Ac power ⇒ $P = \underset{MI}{V} \times \underset{MI}{I} \times \underset{PF}{\cancel{\cos\phi}}$ → Not Accurate Value

Measurement of Dc power:

V-A method



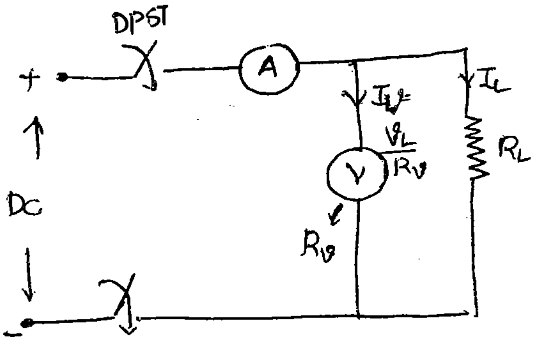
$$P_m = \text{Volt} \times \text{Am}$$
$$= (V_L + V_a) * I_L$$
$$= V_L I_L + \underset{\hookrightarrow I_L R_a}{V_a I_L}$$
$$\boxed{P_m = P_t + I_L^2 R_a}$$

⇒ 1) $P_m > P_t$

2) Error is due to Ammeter (Instrument nearer to load)

3) Error is min., When I_L is less which happens for high Resistive load

A-V method



$$P_m = V_L \times (I_L + I_V)$$
$$= V_L I_L + V_L I_V$$
$$= V_L I_L + V_L \left(\frac{V_L}{R_V}\right)$$
$$= P_t + \frac{V_L^2}{R_V}$$
$$\boxed{P_m = P_t + \frac{V_L^2}{R_V}}$$

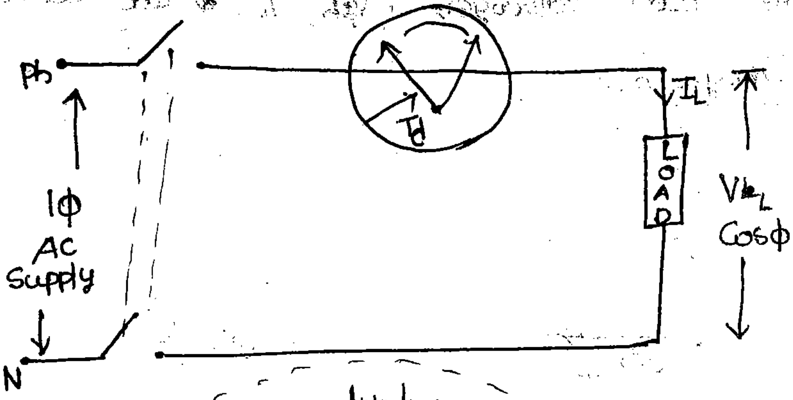
1) $P_m > P_t$

2) Error is due to Voltmeter (Instrument nearer to load)

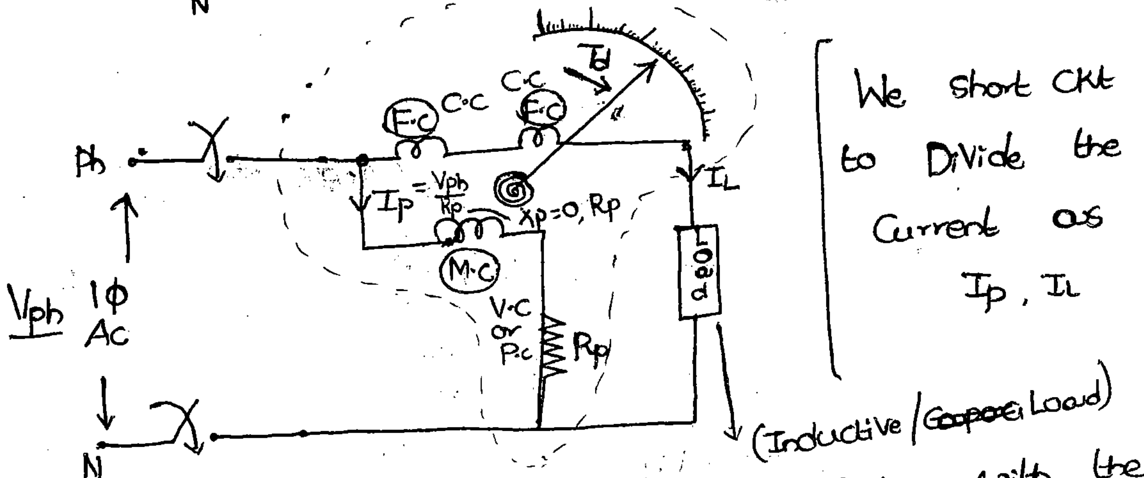
3) Error is min when I_V is less, it occurs when I_L is more which happens for Light Resistive loads.

★★★ Measurement of Ac power :-

CS



$P_t = V_L I_L \cos\phi$



[We short Ckt M,C to Divide the Current as I_p, I_L]

- ✱ the coils which are connected in Series with the load are called Current Coils (Same as fixed Coil) which will carry a full load current (I_L) as shown in the fig.
- ✱ the Coil which is connected across the Supply is called Pressure Coil (Voltage Coil) [Same as moving Coil] which will carry proportional Current of Supply Voltage (I_p) as shown in fig.
- ✱ Both the Coils are connected in llel so that two diff. Currents flow through the Coils (I_L, I_p respectively)
- ✱ Let us consider the load is lagging load (Inductive load) i.e, I_L lags V_L by angle 'φ'
- ✱ Inorder to measure the Ac power by using this meter We have to consider two Assumptions inside the meter

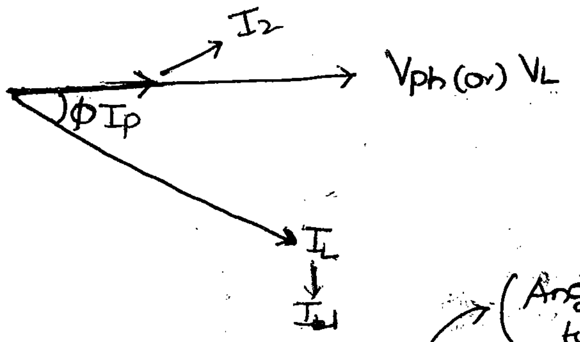
Assumption 1 :- the Supply Voltage is equal to load Voltage i.e, drops in Current Coil Neglected.

Assumption 2 :- The pressure Coil is assumed to be purely and highly Resistive in nature

$V_L \quad V_L \quad X_p = 0$

* there are two Voltages (V_{ph}, V_L) & two Currents (I_p, I_L)

Phasor Diagram :-



(Angle b/w two currents)

$$T_d = I_1 \, I_2 \cos(\phi) \frac{dM}{d\theta} \rightarrow P_L$$

$$= I_L \, I_p \cos\phi \frac{dM}{d\theta}$$

$$= I_L \left(\frac{V_{ph}}{R_p}\right) \cos\phi \frac{dM}{d\theta}$$

$$\Rightarrow \boxed{T_d = I_L \left(\frac{V_L}{R_p}\right) \cos\phi \frac{dM}{d\theta}} \Rightarrow P_L$$

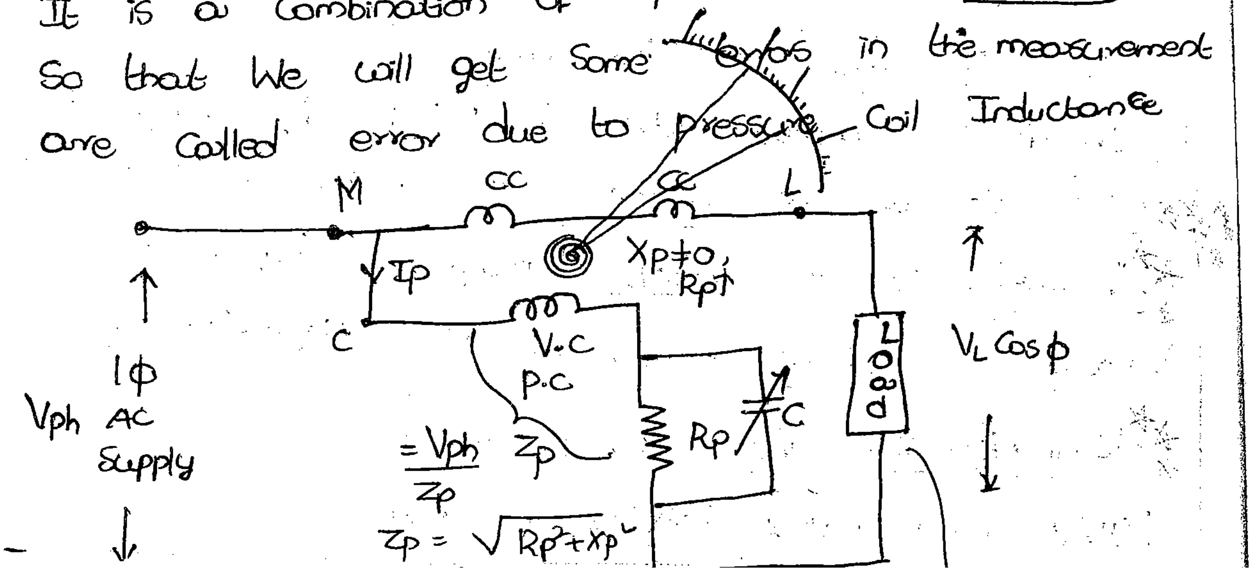
(True power eqn)

$$T_d \propto V_L I_L \cos\phi$$

(AC power)

13/5/12 (6 to 8:30) Error due to Pressure Coil Inductance:

* Earlier We assumed pressure Coil is purely Resistive in nature. But in practice, it Cannot be purely resistive. It is a Combination of X_p & R_p, i.e, $\boxed{X_p \neq 0}$ So that We will get Some errors in the measurement are called error due to pressure Coil Inductance

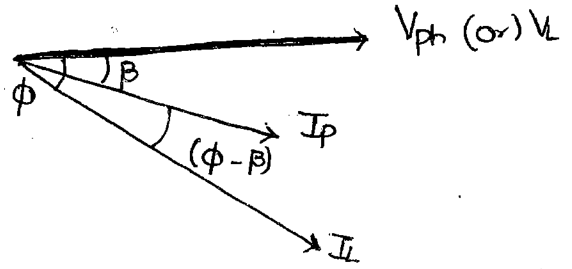


Where $Z_p = \sqrt{R_p^2 + X_p^2}$

Where Z_p is pressure Coil Impedance,

β is pressure Coil Impedance Angle.

Phasor Diagram :-



$$T_d = I_1 \; I_2 \; \cos\underset{\uparrow}{(\phi-\beta)} \; \frac{dM}{d\theta} \Rightarrow P_M$$

$$= I_L^{\uparrow} \left(\frac{V_L}{Z_p}\right)^{\uparrow} \boxed{\cos(\phi-\beta)}\!\downarrow \frac{dM}{d\theta}$$

$$\star \; \boxed{P_M > P_t}$$

$$T_d = I_L \left(\frac{V_L}{R_p} \cos\beta\right) \cos(\phi-\beta) \frac{dM}{d\theta} \Rightarrow P_M - (2)$$

$$P_m \times CF = P_t$$

$$\star \; \boxed{CF = \frac{P_t}{P_m} = \frac{\cos\phi}{\cos\beta \cos(\phi-\beta)}}$$

$$\star \; \boxed{P_m \times \frac{\cos\phi}{\cos\beta \; \cos(\phi-\beta)} = P_t}$$

$$\star \; \boxed{C.F < 1}$$

$$\star \; \boxed{\% \text{ error} = \left(\frac{P_m - P_t}{P_t}\right) \times 100}$$

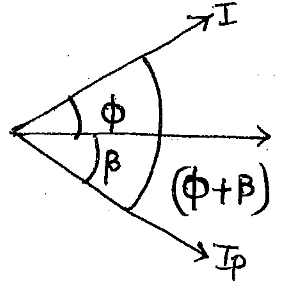
$$= \left(\frac{P_m}{P_t} - 1\right) \times 100$$

$$\star \; \boxed{\% \text{ error} = + \left(\frac{1}{C.F} - 1\right) \times 100}$$

$$\star \; \boxed{\% \text{ error} = + \left(\tan\phi \tan\beta\right) \times 100}$$

These formulae will be valid only when it is lagging loads.

In Case of leading loads:-



$$T_d = I_L \left(\frac{V_L}{R_p}\right) \cos\phi \frac{dM}{d\theta} \rightarrow P_t$$

$$T_d = \downarrow I_L \left(\frac{V_L}{Z_P}\right)\downarrow \cos(\phi+\beta)\downarrow \frac{dM}{d\theta} \rightarrow P_m$$

$$\boxed{P_m < P_t}$$

$$T_d = I_L \left(\frac{V_L}{R_p}\right) \cos\beta \cos(\phi-\beta) \frac{dM}{d\theta} = P_m \rightarrow (2)$$

$$\boxed{P_m \times C{\cdot}F = P_t}$$

$$\boxed{CF = \frac{P_t}{P_m} = \frac{\cos\phi}{\cos\beta \cos(\phi+\beta)}}$$

$$P_m \times \frac{\cos\phi}{\cos\beta \cos(\phi+\beta)} = P_t$$

$$\boxed{C{\cdot}F > 1}$$

$$\%\ \text{Error} = \left(\frac{P_m - P_t}{P_t}\right) \times 100$$

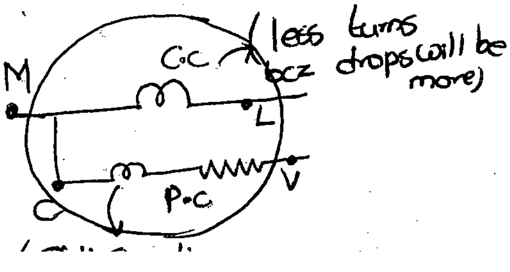
$$\%\ \text{error} = -\left(\frac{1}{C{\cdot}F} - 1\right) \times 100$$

$$\boxed{\%\ \text{error} = -\left(\tan\phi \tan\beta\right) \times 100}$$

(To Minimise all these errors, it is ample to make the $X_p = 0$, to do that)

* The error due to pressure Coil Inductance Can be reduced by Connecting a Capacitor across 'Rp' in Such a way that the Capacitive reactance is Cancelled out by Inductive reactance of pressure Coil. then the pressure Coil is purely resistive. The Value of $\boxed{C = 0.41 \frac{L_p}{R_p^2}}$

* If the manufacturer Shorts M, C it Cannot be used as Ammeter, Voltmeter



(less turns bcz drops will be more)

* Based on Connections, We have two ~~types~~ types of machines us

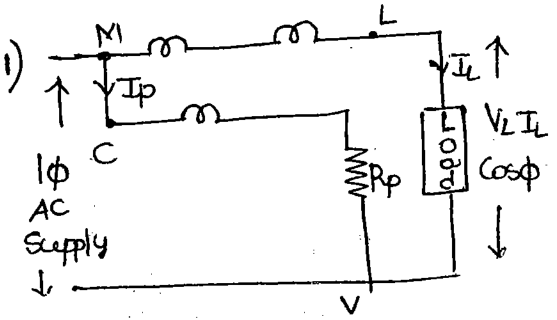
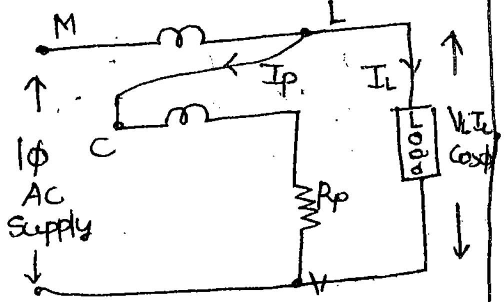
a) M-C Short Wattmeter ↓ (|||r to Voltmeter - Ammeter method) (Error due to Current Coil)

b) LC Short Wattmeter ↓ (|||r to Ammeter - Voltmeter method) (Error due to pressure Coil)

Error due to Coil Connections :-

→ Based on Coil Connections, we have two types of Wattmeter

a) MC short wattmeter b) Lc short Wattmeter

· MC Short	Lc Short
1) 	
2) Pressure Coil Connected before the Current Coil	2) Pressure Coil Connected after the Current Coil
3) Error due to Current Coil	3) Error due to pressure Coil
4) $\boxed{P_m = P_L + I_L^2 R_{CC}}$	4) $\boxed{P_m = P_L + \frac{V_L^2}{R_{PC}}}$
5) $P_m > P_L$	5) $P_m > P_L$

* Mc Short is used more frequently because ——

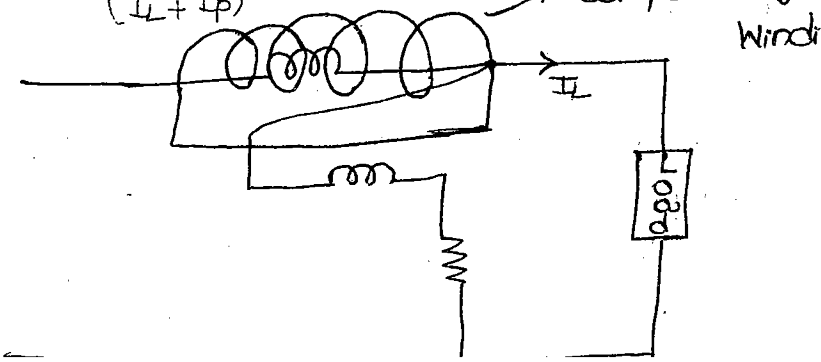
$p = I_{cc} \cdot I_{pc} \cos(\ ) \, dM/d\theta$

$MC, P = I_L \cdot I_p \cos(\ ) \frac{dM}{d\theta}$

$LC, P = (I_L + I_p) I_p \cos(\ ) \frac{dM}{d\theta}$

↓

Here Current Coil Carries extra Current Compared to MC short Connection; Which increases the error



be

p' in

e is

ssure Coil.

be

ums
ops (will be
more)

Current through $\overset{\text{Current}}{\text{Coil}}$ = $I_L + I_P$

Flux = $\phi_L + \phi_P$

⇒ To reduce ϕ_P, flow a reverse current I_P in current coil by using a <u>Compensating Winding</u>

→ Compensating Winding is wound on current coil from 'L' and brought again to 'L'

→ In general, we use MC short and don't need Compensating Wdg (Necessary in case of LC short wattmeter)

LPF UPF

↳ For Low PF, Cosϕ↓

$T_d \propto \cos\phi$

T_d ↓

. Deflection is not obtained

For that purpose

$$T_d = I_L\left(\frac{V_L}{R_P\uparrow}\right)\overset{\downarrow}{\cos\phi}\left(\frac{dM}{d\theta}\right)$$

R_P is increased for that

↳ Unity power factor

Resistance (↓)

Compared to LPF

* Here, Pressure Coil Resistance is increased for that

Measurement of poly phase power :-

↓

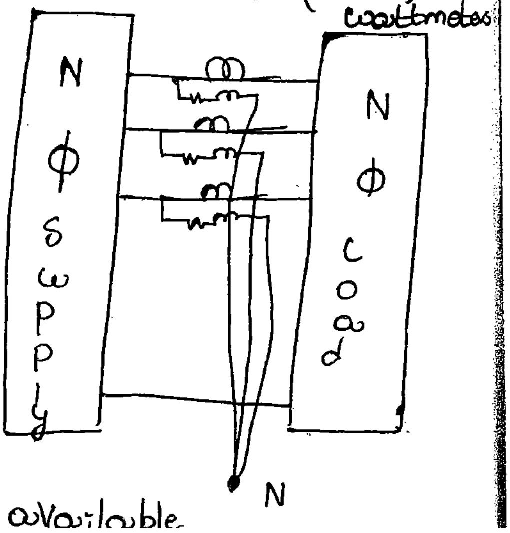
N - phase

Blondel's

N or (N-1) wattmeters

* According to Blondel's theorem, the no. of wattmeters req'd to measure the total power in N-phase system is N (or) N-1 depends upon coil connections.

* When separate neutral point is available in system, No. of wattmeters = N



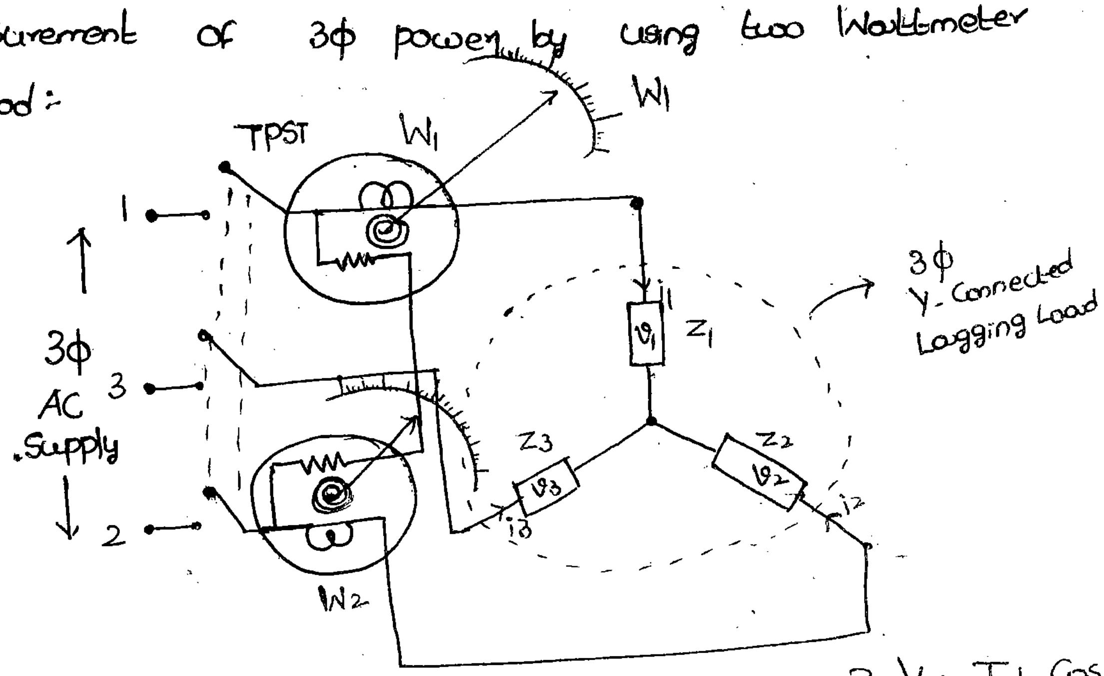
* When the neutral point not available

Measurement of 3-ϕ power

N=3 < ② Wattmeters, ③ wattmeters

4.b)

Measurement of 3ϕ power by using two Wattmeter method :-



$P_m = W_1 + W_2$; $P_t = \sqrt{3}\, V_L\, I_L \cos\phi$ (or) $3\, V_{ph}\, I_{ph} \cos\phi$

$I_{ph} = I_L$

$V_{ph} = \frac{V_L}{\sqrt{3}}$

$W_1 = i_1\, v_{13} \cos(i_1, v_{13})$

$= I_{ph}\, \sqrt{3}\, V_{ph} \cos(30-\phi)$

$W_1 = \sqrt{3}\, V_{ph}\, I_{ph} \cos(30-\phi)$

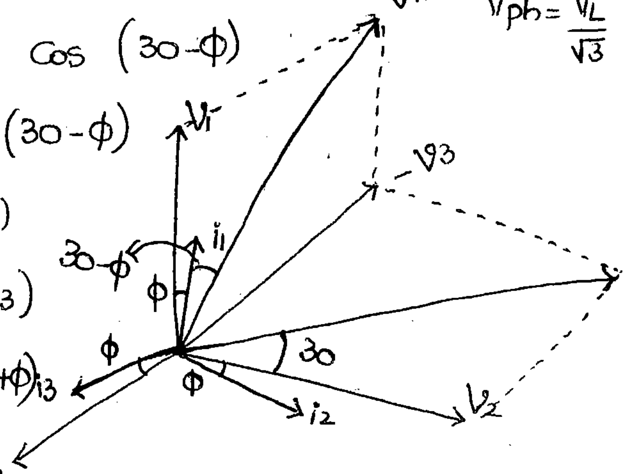
$= V_L\, I_L \cos(30-\phi)$

$W_2 = i_2\, v_{23} \cos(i_2, v_{23})$

$= I_{ph}(\sqrt{3}\, V_{ph}) \cos(30+\phi)$

$W_2 = \sqrt{3}\, V_{ph}\, I_{ph} \cos(30+\phi)$

$= V_L\, I_L \cos(30+\phi)$



$P_m = W_1 + W_2 = V_L\, I_L \cos(30-\phi) + V_L\, I_L \cos(30+\phi)$

$= \sqrt{3}\, V_{ph}\, I_{ph} [\cos(30-\phi) + \cos(30+\phi)]$

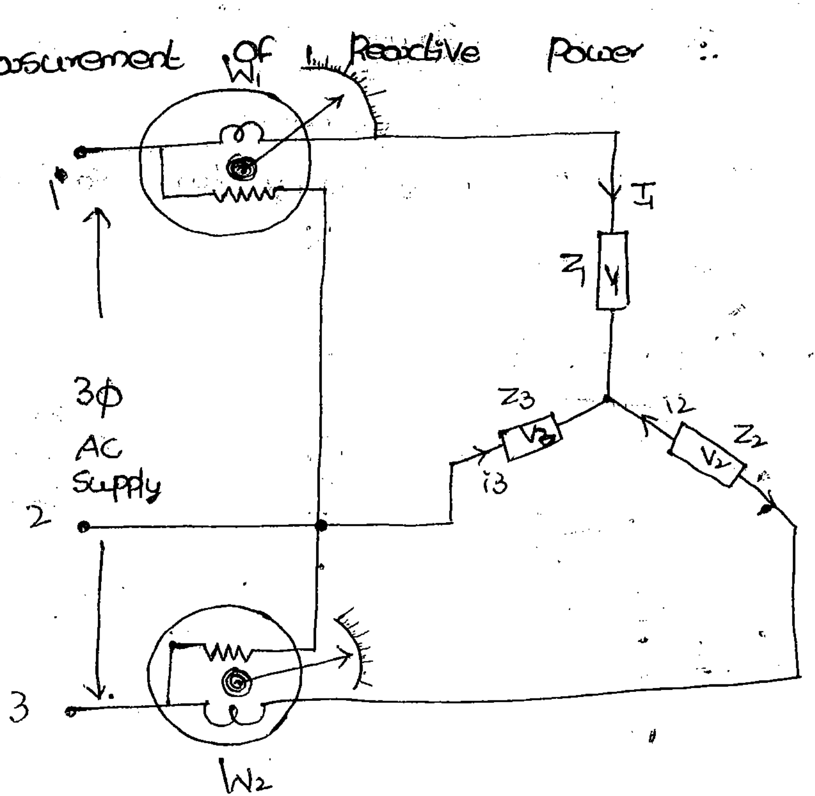
$= \sqrt{3}\, V_{ph}\, I_{ph} (2 \underbrace{\cos 30}_{\sqrt{3}/2} \cos\phi)$

$\Rightarrow P_m = 3\, V_{ph}\, I_{ph} \cos\phi$

$= W_1 + W_2$

17/5/12
(6 to 8:30P)

Measurement of Reactive Power :-



$$\boxed{W_1 = \sqrt{3}\ V_{ph}\ I_{ph}\ \cos(30-\phi) = V_L\ I_L\ \cos(30 \mp \phi)}$$ → Log / → Lead

$$\boxed{W_2 = \sqrt{3}\ V_{ph}\ I_{ph}\ \cos(30+\phi) = V_L\ I_L\ \cos(30 \pm \phi)}$$ → Log / → Lead

$$\boxed{P = W_1 + W_2 = \sqrt{3} V_L I_L \cos\phi = 3 V_{ph} I_{ph} \cos\phi} \rightarrow (1)$$

$$W_1 - W_2 = \sqrt{3}\ V_{ph}\ I_{ph} \left(\cos(30-\phi) - \cos(30+\phi) \right)$$

$$= \sqrt{3}\ V_{ph}\ I_{ph} \left(2 \underbrace{\sin 30}_{1/2} \sin\phi \right)$$

$$W_1 - W_2 = \left(\sqrt{3}\ V_{ph}\ I_{ph}\ \sin\phi \right)$$

$$\Rightarrow \boxed{\begin{aligned} \sqrt{3}(W_1 - W_2) &= \sqrt{3}\left(\sqrt{3}\ V_{ph}\ I_{ph}\ \sin\phi\right) \\ &= 3\ V_{ph}\ I_{ph}\ \sin\phi \\ &\phi \longrightarrow (2) \end{aligned}}$$

Measurement of phase Angle

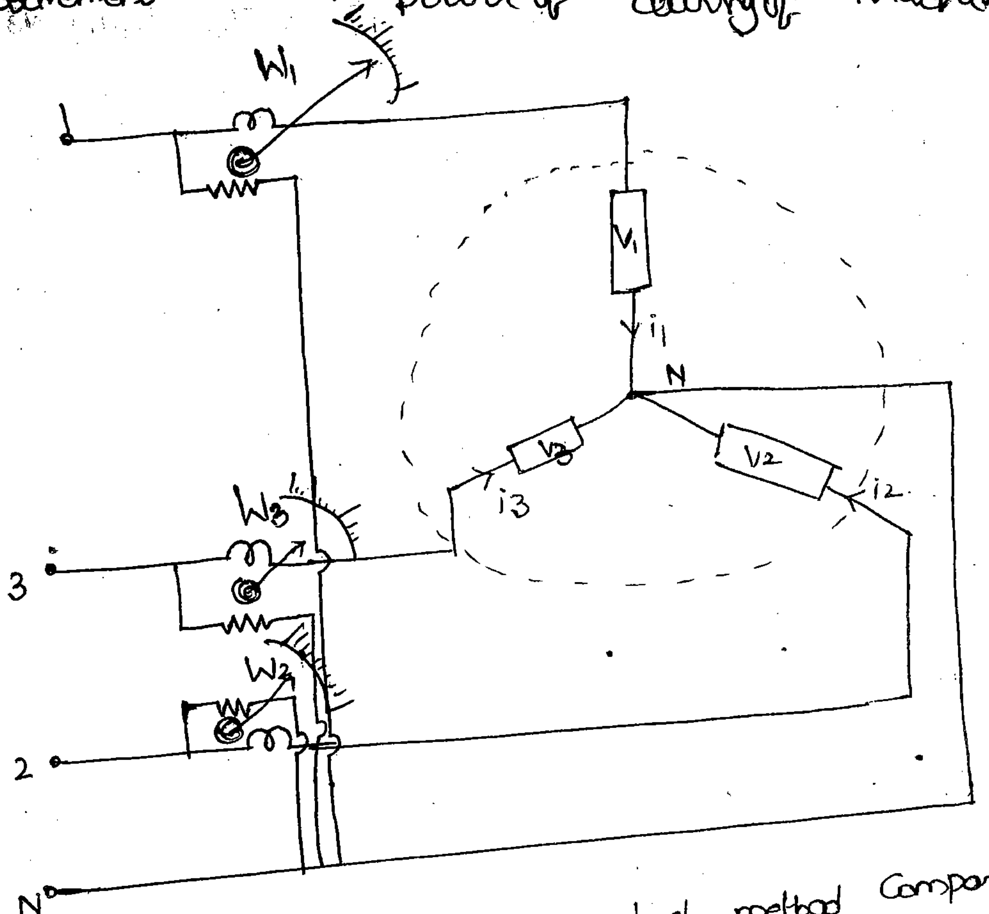
$$\frac{P}{\phi} \quad \frac{(2)}{(1)} =$$

$$\tan\phi = \frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}$$

$$\boxed{\phi = \tan^{-1}\left(\sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2} \right) \right)}$$

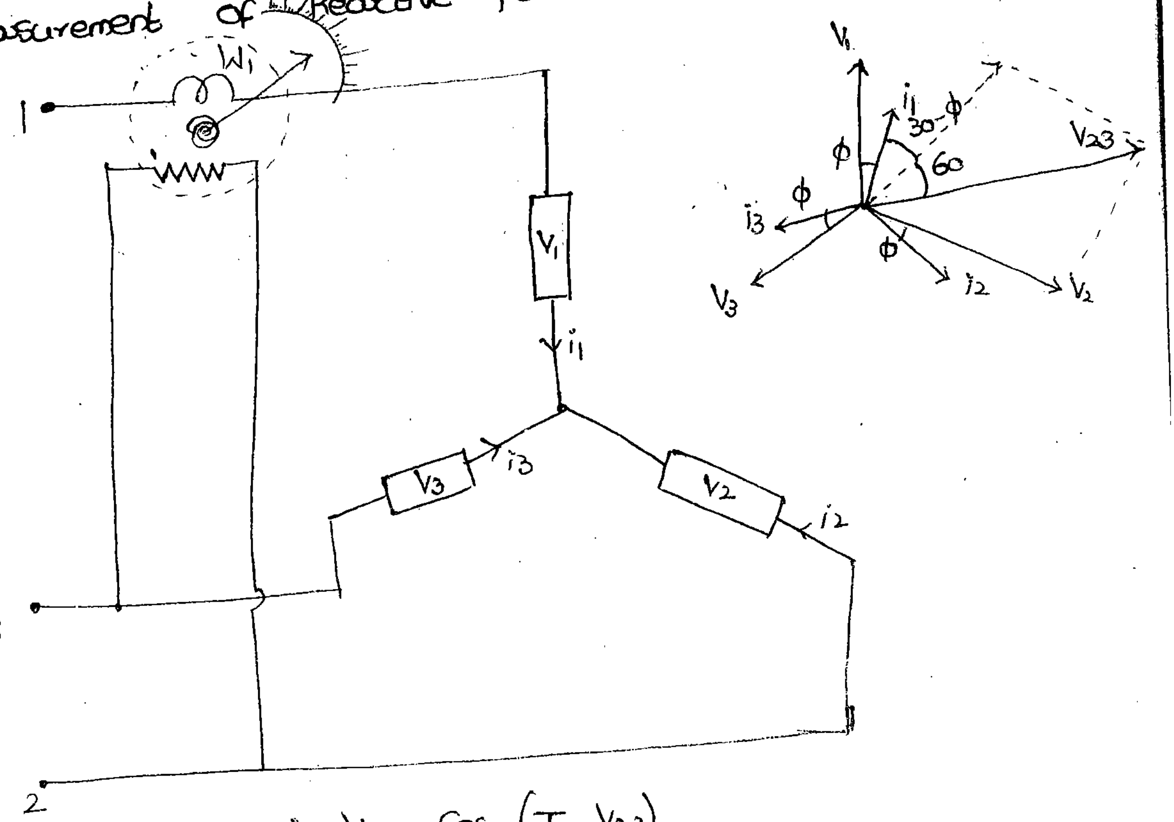
M/m of power factor

Measurement of 3φ power of during machines



* Two Wattmeter method is a best method Compared with three Wattmeter method since error can be minimised.

Measurement of Reactive power by 1φ Wattmeter:



$W = i_1 \; V_{23} \; \cos(I_1, V_{23})$

$= I_{ph} (\sqrt{3}\; V_{ph}) \; \cos(I_1 \,\&\, V_{23}) \longrightarrow V_2$

$= \sqrt{3} \; V_{ph} \; I_{ph} \; \cos(90-\phi)$

$= \sqrt{3} \; V_{ph} \; I_{ph} \; \sin\phi$

$$\Rightarrow \boxed{\sqrt{3} \times (W) = (\sqrt{3}\, V_{ph}\, I_{ph} \sin\phi)\sqrt{3} = 3\, V_{ph}\, I_{ph} \sin\phi = Q}$$

* Single Wattmeter method is best method Suitable for the measurement of 3φ reactive power compared to 2-Wattmeter method because errors are reduced

* Manufacturer does not Make M-C short because

a) It cannot be used as Voltmeter, Ammeter

b) It cannot be used as L-C short

c) We cannot to use it for reactive power Measurement

★★★★★

φ	p.f	Relation b/w W_1 & W_2
0°	unity	$W_1 = W_2$
30°	0.866 lag	$W_1 = 2W_2$
60°	0.5 lag	$W_2 = 0$, W_1 = Total power
90°	zero	$W_1 = -W_2$

$W_1 = V_L I_L \cos(30-\phi)$

$W_2 = V_L I_L \cos(30+\phi)$

* When Wattmeter reads -Ve Value, We interchange M, L terminals.

★★★★★★	Balanced Load	Unbalanced load
3-φ 4-Wire	1	3
3-φ 3-Wire	2	2

√3

uitable for

to 2

because

Measurement

$I_L \cos(30-\phi)$

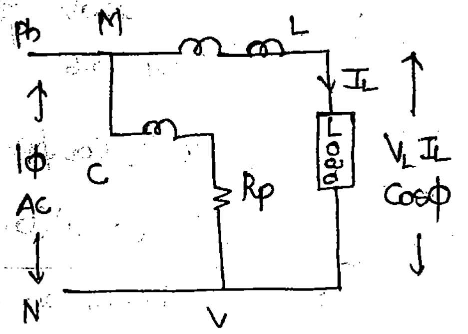
$I_L \cos(30+\phi)$

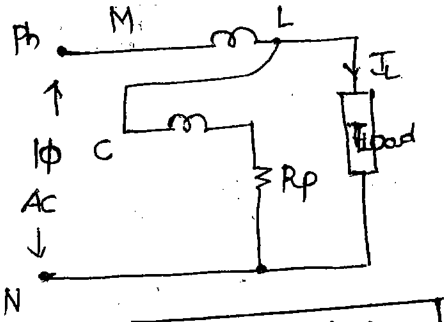
erchange

balanced

ad

4. Measurement of power (Problems)





$$P_t = V_L I_L \cos\phi$$

$$= 250 \times 4 \times 1 = 1000W$$

$$\boxed{P_m = P + I_L^2 R_{c.c}}$$

$$= 1000 + (4)^2 \times (0.5)$$

$$= 1008$$

$$\Rightarrow \% Error = \frac{1008-1000}{1000} \times 100$$

$$= \frac{\cancel{0}.8}{10} = 0.08\ \%$$

$$\boxed{P_m = P + \frac{V_L^2}{R_{pc}}}$$

$$= 1000 + \left(\frac{(250)^2}{12.5k}\right)$$

$$= 1005$$

$$\% error = \left(\frac{1005-1000}{1000}\right) \times 100$$

$$= 5\ \%$$

2

$$X_p = 1\ \%\ R_p$$

$$\cos\phi = 0.5$$

lagging

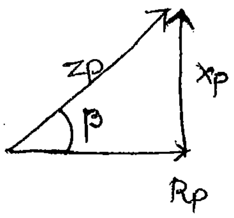
Load lag → +ve % error

Load lead → -ve % error

$$\boxed{\% error = \pm (\tan\phi \tan\beta) \times 100}$$

$$= \pm(\sqrt{3} \times 0.01) \times 100$$

$$= \sqrt{3}\ \%$$



$$\tan\beta = \frac{X_p}{R_p}$$

$$= \frac{0.01 R_p}{R_p}$$

3.

$$\boxed{\cos\phi = \cos\left(\tan^{-1}\left(\sqrt{3}\left(\frac{W_1-W_2}{W_1+W_2}\right)\right)\right)}$$

$$W_1 = 2000\ W; \quad W_2 = 500W$$

$$= \cos\left(\tan^{-1}\left(\sqrt{3}\left(\frac{\overset{3}{\cancel{1500}}}{\underset{5}{\cancel{2500}}}\right)\right)\right)$$

$$= 0.69 \text{ lagging}$$

4. $R_{c \cdot c} = 0.03\Omega$, $R_{pc} = 6000\Omega$, $I_L = 20A$

$V_L = 220V$

$\cos\phi = 0.6$

$$\boxed{P_m = P_L + I_L^2 R_{c \cdot c}}$$

$= 2640 + (20)^2(0.03)$

$P_L = V_L I_L \cos\phi$

$= (220)(\cancel{0.}20)(0.6)$ W $= 2640$

$= 2640 + (40\cancel{0})\left(\frac{3}{1\cancel{00}}\right)$

$= 2652$

$$\boxed{\text{Current Coil is on Load Side - MC short}}$$

$\% \text{ error} = \left(\frac{2652 - 2640}{2640}\right) \times 100 = 0.4545$

5. After modifying the connections, it will measure reactive power

Before modification

$V_{ph} I_{ph} \cos\phi = 400$

$V_{ph} I_{ph} (0.8) = 400$

$V_{ph} I_{ph} = 500$

$\cancel{\phi =}$

$$\boxed{W \; \cancel{\phi} = \sqrt{3} V_{ph} I_{ph} \; \cancel{\cos}\sin\phi}$$

$= (500)(\sqrt{3})(0.6)$

$= 519.6$ VAR

6. At Angle 60°, one of Wattmeter Reads '0' (All are $5\angle 60°$)

$W_1 = V_L I_L \cos(30-\phi) = 100 \times 11.54 \cos 30$

$= 1000k$

$W_2 = V_L I_L \cos(30+\phi)$

$= 100 \times 11.54 \; \cancel{= 0} \cos(30+60)$

$= 0$

$I_L = I_{ph} = \frac{V_{ph}}{Z}$

$= \frac{100\sqrt{3}}{5}$

$= 11.54$

7. $P_L = (20)(200) = 4000$

$P_m = 4000 + (20)^2(0.02)$

$= 40008$

$\% \text{ error} = \left(\frac{4008 - 4000}{4000}\right) \times 100$

$= 0.2\%$

$C.F = \frac{\cos\phi}{\cos\beta \cos(\phi - \beta)}$ lagging

$C.F = \frac{\cos\phi}{\cos\beta \cos(\phi + \beta)}$ leading

$X_p = 0.5\% R$ $= \frac{0.8}{\cos 26.56 \cos(36.56 - \cos 36.86)}$

$\frac{X_p}{R_p} = 0.5$

$\Rightarrow$ ~~$\tan\beta = 0.5$~~

$\tan\beta = 0.5$

$\beta = 26.56$

Measurement of Power factor

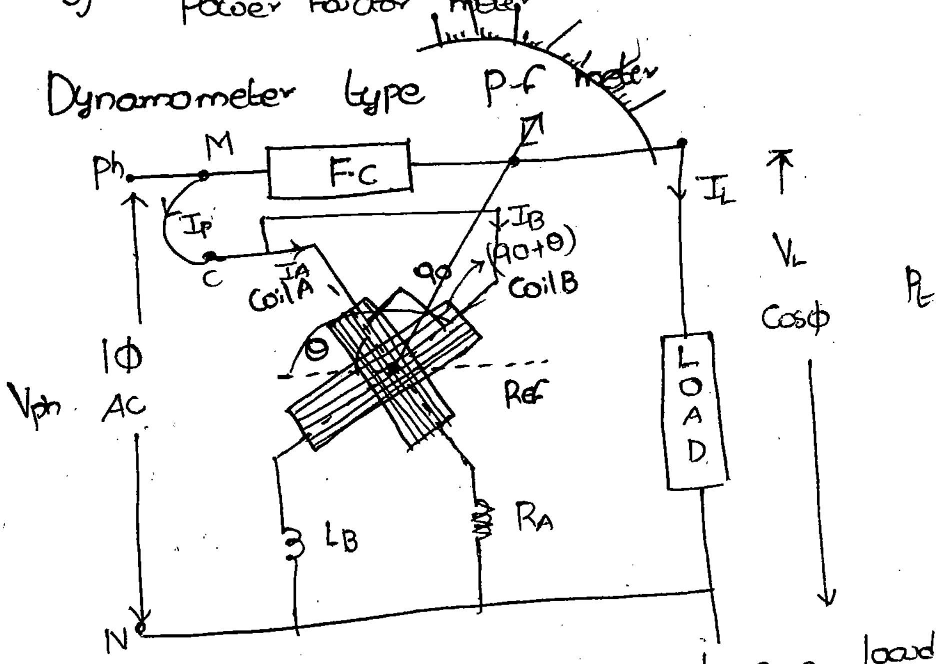
1) $P = VI \cos\phi$

$\Rightarrow \cos\phi = \frac{P}{VI}$ (3 ~~meters~~)

2) $\cos\phi = \cos\left(\frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}\right)$ (2 ~~meters~~)

3) Power factor meter

Dynamometer type P.f meter



one fixed coil

Two Movable Coils

(i.e, two pressure coils)

$P_L = V_L I_L \cos\phi$

3 - Currents

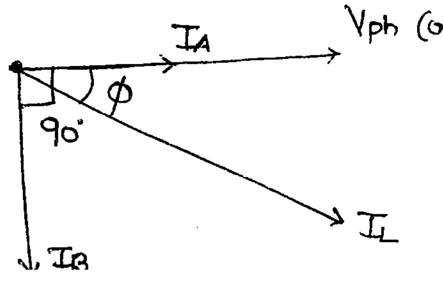
two Voltages

* Let us consider the load is lagging load.

* Coil - A is assumed to be purely resistive

* Coil - B is assumed to purely Inductive

I_a is in phase with V_{ph} because of 'R_A'



18/5/12
(6 to 8:30
10)

$$T_d = I_1 I_2 \cos(\quad) \frac{dM}{d\theta}$$

$$T_{dA} = I_L I_A \cos\phi \frac{dM}{d\theta}$$

$$T_{dB} = I_L I_B \cos(90-\phi) \frac{dM}{d\theta}$$

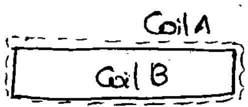
Two torques developed due to two moving Coils

[$\frac{dM}{d\theta}$ = Change of Mutual Inductance ~~Wrt to~~]

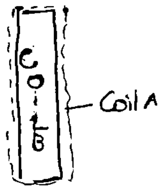
$$M = {}^{M}M_{ax} \cos\theta$$

$$\frac{dM}{d\theta} = -M_{max} \sin\theta$$

Max. flux when $\theta = 0$



Min flux when $\theta = 90°$



$$T_{dA} = I_L I_A \cos\phi \times -M_{max} \sin\theta$$

$$\Rightarrow T_{dB} = I_L I_B \cos(90-\phi) \times -M_{max} \sin(90+\theta)$$

Inorder to measure the p.f by using this meter, We have to design both the moving Coils in such a way that the resistance of the moving Coil A is equal to the inductive reactance of the moving Coil B

$$R_A = \omega L_B$$

$$\boxed{R_A = X_B}$$

$$\begin{tikzcd} I_A \arrow[d] & = & I_B \arrow[d] \\ T_{dA} & = & T_{dB} \end{tikzcd}$$

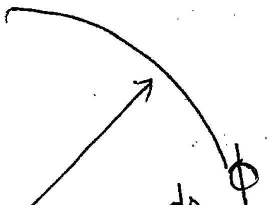
$$\Rightarrow$$

$$\cancel{I_L} \cancel{I_A} \cos\phi (-\cancel{M}_{max}) \sin\theta = \cancel{I_L} \cancel{I_B} \cos(90-\phi) (-\cancel{M}_{max}) \sin(90+\theta)$$

$$\Rightarrow \cos\phi \sin\theta = \sin\phi \cos\theta$$

$$\Rightarrow \boxed{\tan\phi = \tan\theta}$$

$$\Rightarrow \boxed{\phi = \theta}$$



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Sin(90+θ)

18/5/12
(6 to 8:30P)

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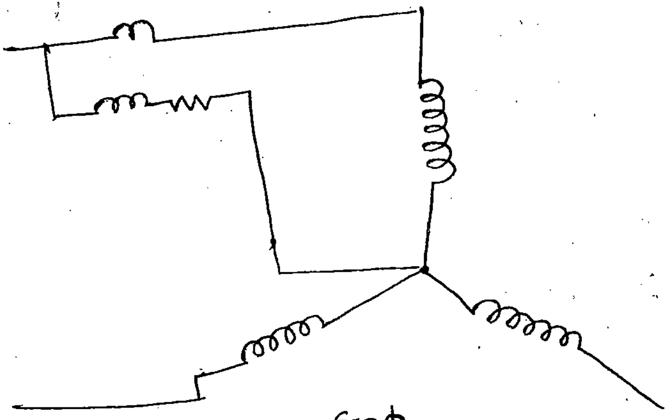


$P = V_{ph} I_{ph} \cos\phi$

$5.54 \times 10^3 = \frac{400}{\sqrt{3}} \times 30 \times \cos\phi$

$\Rightarrow \cos\phi = 08$

$\sin\phi = 0.6$

a) $W = \sqrt{3}\, V_{ph}\, I_{ph} \sin\phi$

$= (\sqrt{3}) \left(\frac{400}{\sqrt{3}}\right)(30)(0.6)$

$= 7.2$ KVAR

b) Total Reactive power $= \sqrt{3} \times 7.2$ KVAR

$= 12.47$ KVAR

M/M of Energy:

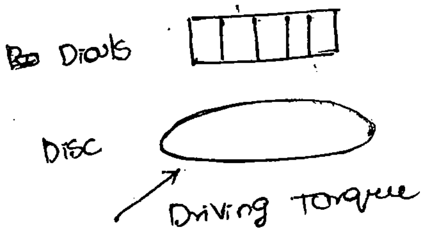
Energy = power × time

$\Rightarrow \boxed{E = \int (\text{power})\, dt}$

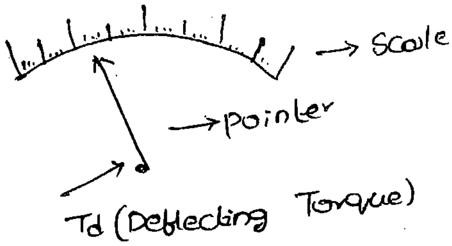
⇓

Integrated type Instrument

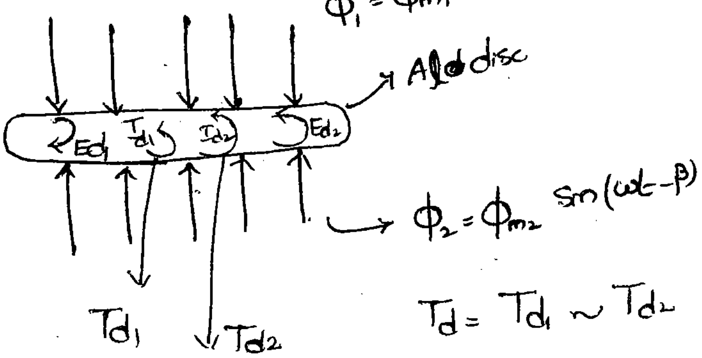
Energy Meter



Watt meter

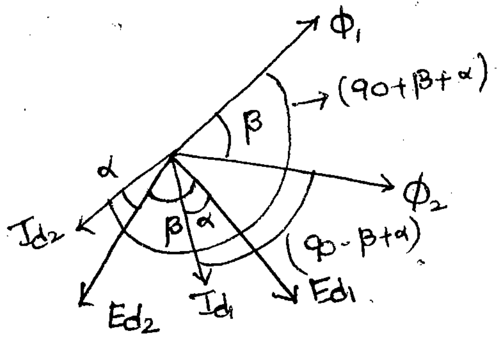


Induction effect



$T_d = T_{d1} \sim T_{d2}$

Due to fluxes, Two eddy currents (Ed1 & Ed2) developed in the disc in turn two currents Id1, Id2 These produce Td1 & Td2. The net driving torque is $T_d = (T_{d1} \sim T_{d2})$



Al → 98%
resistive
(remaining
Inductor)

ϕ_1 does not interlink with I_{d_1} because angle almost 90°

$\cos 90^\circ = 0$

ϕ_2 does not interlink with I_{d_2}

ϕ_1 interlink with I_{d_2} to produce T_{d_1} & ϕ_2 interlink with I_d to produce T_{d_2}.

$$\Rightarrow \quad T_d = T_{d_1} \sim T_{d_2}$$

$$T_{d_1} = \phi_1 \; I_{d_2} \cos(\phi_1, I_{d_2})$$

$$T_{d_2} = \phi_2 \; I_{d_1} \cos(\phi_2, I_{d_1})$$

$$I_{d_1} = \frac{E_{d_1}}{Z}$$

$$I_{d_2} = \frac{E_{d_2}}{Z}$$

$$E_{d_1} = -N\frac{d\phi_1}{dt} \quad (\text{Acc. Faraday's law})$$

$$|E_{d_1}| = \cancel{N}^{11}\frac{d\phi_1}{dt} \qquad |E_{d_2}| = \cancel{N}\frac{d\phi_2}{dt}$$

$$= \frac{d}{dt}(\phi_{m_1}\sin\omega t) \qquad = \frac{d}{dt}(\phi_{m_2}\sin(\omega t-\beta))$$

$$I_{d_1} = \frac{\boxed{\phi_{m_1}\cos\omega t}(\omega)}{z} \qquad I_{d_2} = \frac{\phi_{m_2}\cos(\omega t-\beta)\omega}{z}$$

$$I_d = \frac{\Phi_1 \cdot \omega}{z} \qquad I_{d_2} = \frac{\Phi_2 \cdot \omega}{z}$$

$$T_{d_1} = \phi_1 \cdot \frac{\Phi_2\,\omega}{z}\left[\cos(90+(\beta+\alpha))\right]$$

$$T_{d_2} = \phi_2 \cdot \frac{\Phi_1\,\omega}{z}\left[\cos(90-(\beta-\alpha))\right]$$

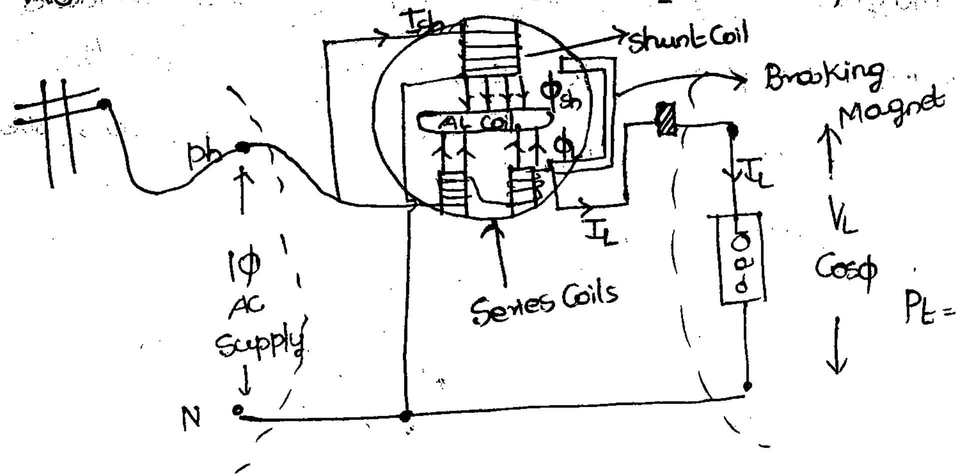
$$T_d = T_{d_1} - T_{d_2}$$

$$= k\,\phi_1 \cdot \phi_2\left[\sin(\beta-\alpha) - \sin(\beta+\alpha)\right]$$

$$T_d = k\,\phi_1\,\phi_2\,\sin\beta\cos\alpha$$

$$\boxed{T_d \propto \phi_1\phi_2 \sin\beta\cos\alpha} \qquad \alpha = 0$$

We have to make $T_d \propto V_L I_L \cos\phi$



$P_L = V_L I_L \cos\phi$

* The Coil Which are Connected in Series with a load Which will Carry a full load I_L, So that it will produce a flux as shown in fig. These magnets are called Series Magnets

* The Coil which is Connected across the Supply is Called Shunt Coil (same as pressure coil) which will Carry a Current I_{sh} so that it produces a flux ϕ_{sh} as shown in fig. These magnets are called as shunt magnets

* Both Coils are Connected in parallel

* Let us consider the load to be lagging to load

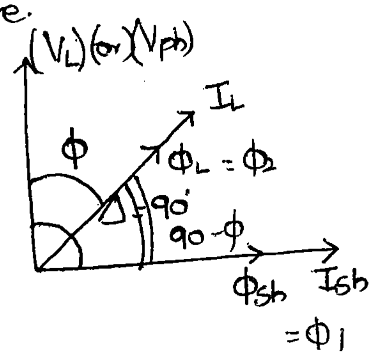
Inorder to measure the energy by this meter, we have to consider two Assumptions inside the meter

Assumption : 1

1) $V_{ph} = V_L$ i.e, the Supply Voltage is equal to the load Voltage i.e, drops in Series Coil neglected

Assumption : 2

2) The Shunt Coil is assumed to be purely Inductive in Nature.



~~$V_L = V_{ph}$~~

$T_d \propto \phi_1 \phi_2 \sin\beta$

$T_d \propto \phi_{sh} \phi_{L} \sin(90-\phi)$

$T_d \propto V_L I_L \cos\phi$

$\boxed{T_d \propto \text{AC Power}}$

Braking Magnet:- the Braking Magnet Will produce Some braking torque (T_b) which will ~~se~~ see the disc to rotate at Constant speed as long as the load is Constant

$$T_d \propto \text{Ac power}$$

$$T_B \propto \text{Speed of the disc } (N)$$

At steady state 1.

$$T_d \propto T_B$$

$$\Downarrow$$

$$\int (\text{Ac power})\, dt \propto \int \left(\begin{matrix}\text{Speed of the} \\ \text{disc}\end{matrix}\right)$$

$$\text{Energy} \propto \text{No. of revolutions}$$

Meter Constant:- The no. of revolutions Should be made by the disc inorder to indicate the exactly 1 kwhr Consumption is Called Meter Constant

$$\text{Meter Const} = \frac{\text{No. of Rev}}{\text{kWhr}}$$

② 5. Measurement of Energy

$V_L = 230\text{V}$, $I_L = 10\text{A}$

$\text{M.C} = 1800 \text{ rev}/\text{kwh}$

Half Load

$A_m =$ 80 revolutions

time = 138 sec

~~M~~ ~~80~~ Energy Consumed = kwh

= Power x time

$$= \frac{V_L I_L \cos\phi}{1000} \times hr$$ 7.

$10/_2 = I_L$

(As it is at half load)

$$= \frac{(230)\left(\frac{10}{2}\right) \times 1}{1000} \times \frac{138}{3600}$$

Meter Const = $\dfrac{\text{No. of revolutions}}{\text{kwh}}$

$\Rightarrow (\text{kwh})_m = \dfrac{\text{No. of revolutions}}{\text{M.c}}$

$= \dfrac{80}{1800} = 0.04444$ kw/hr

% error = 0.82

1. $V_L = 240V$, M.C = 600 rev | kwh

$I_L = 10A$, $\cos\phi = 0.8$ lag

$\Delta = 86^\circ$

E_c = kwh

= Power x time

$= \dfrac{V_L I_L \cos\phi}{1000} \times hr = \dfrac{240 \times 10 \times 0.8}{1000} \times 1 = 1.92$ kwh

$\text{M.C} = \dfrac{\text{No. of rev}}{\text{kwhr}} \Rightarrow$ No. of rev = M C x kwhr

= 600 x 1.92

= 1152

Speed rps = $\dfrac{1152}{3600}$

= 0.32 Rps

% Error = $\dfrac{A_m - A_t}{A_t} \times 100$

$= \cancel{\dfrac{V_L I_L \cos\phi - V_L I_L \sin(86-\phi)}{}}$

$= \dfrac{\cancel{V_L} \cancel{I_L} \sin(86-\phi) - \cancel{V_L} I_L \cos\phi}{V_L \cancel{I_L} \cos\phi} \times 100$

$= \dfrac{\sin(86 - 0^\circ) - 1}{1} \times 100$

= −0.24

7. $\Delta = 90^\circ$ (Actually)

But 3° departure $\Delta = 87^\circ$

$N_{FL} = 40$

$N_{FL/4} = ?$

$\left[N \propto \text{AC power} \right]$

$$N \propto V_L I_L \sin(\Delta - \phi)$$

$$\frac{N_{FL}}{N_{\frac{FL}{4}}} \propto \frac{\cancel{V_L}\cancel{I_L} \sin(\Delta-\phi)}{\cancel{V_L}\left(\frac{\cancel{I_L}}{4}\right) \sin(\Delta-\phi)}$$

$$\Rightarrow \frac{40}{N_{\frac{FL}{4}}} = \frac{\sin(87-0^\circ)}{\sin(87-60^\circ)}$$

$\cos^{-1}(0{\cdot}5)$
$= 60$

$$\Rightarrow N_{\frac{FL}{4}} = 40 \times \frac{\sin 27}{\sin 87} = 4{\cdot}54$$

Date 8/07/2011

Electronics Measurement

Review of DC voltmeter

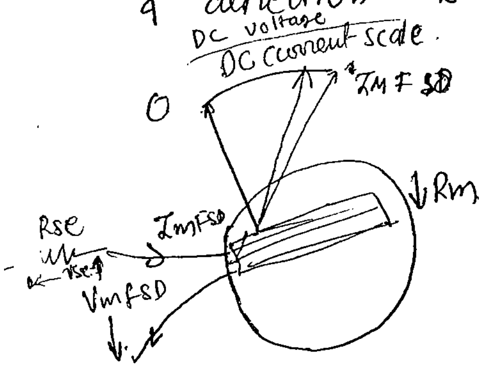
Electoronic Voltmeter
- ↳ Amplifier Type
- ↳ Rectifier Type
- ↳ Peak Type
- ↳ TC Type (Thermocouple)

Q - meter

Digital measurement
voltage, $\underbrace{\text{timeperiod of frequency, magnitude}}_{ET/C}$
DVMA

Cathode ray oscilloscope

* Any analog measureing unit is a current measuring unit since current is the only analog quantity that is measureable & deflection is always produce due to current effect only



Ep :- $0 - \underbrace{\overset{Im}{1mA}, \overset{Rm}{100\Omega}}$

0.1V ← VMFSD
↓
1V ← VFSD

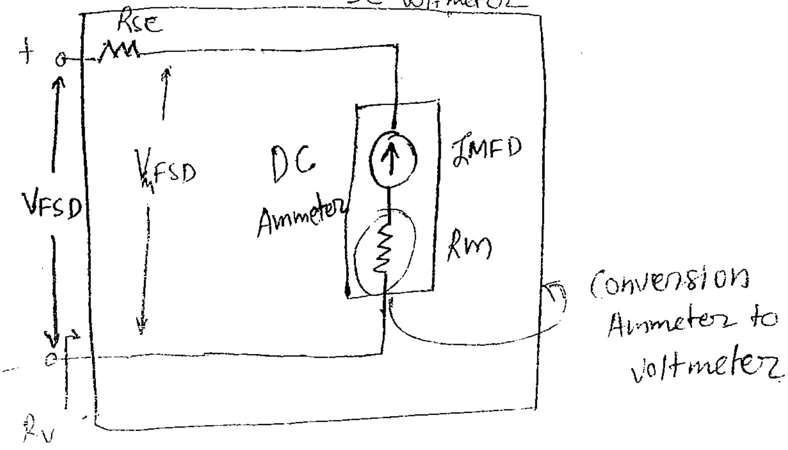
DC volt~~meter~~

DC voltmeter (Design) - A DC voltmeter consist of a dc ammeter i.e PMMC instrument with a high value multiplier resistance (rse) in series with the ammeter & the scale properly calibrated to read dc volts. Multipleor is high value resistance
DC current can be calibrated in DC scale

$$\boxed{V_{MFSD} = I_{MFSD} \times R}$$

the ~~to~~ Rv = resistance to voltage rating
Rse = series resistance

* Electronic Circuit representation



Conversion Ammeter to voltmeter

① Voltmeter resistance (R_v) :-

* → $\boxed{R_v = \frac{V_{FSD}}{I_{mFSD}}}$ → required Full scale DC voltage range
→ Available Full scale current range

* $\boxed{R_v = R_{se} + R_m}$

* $R_v = R_m[M-1] + R_m$,
$R_v = MR_m - \cancel{R_m} + \cancel{R_M}$
$\boxed{R_v = MR_m}$

* $\boxed{R_v = \text{sensitivity} \times \text{voltage range}}$

② Series Multiplier resistance (R_{se})

* Series current limiting resistance

* $\boxed{R_{se} = R_v - R_m}$

= i/p resistance of voltmeter − Internal resistance of meter

$= \frac{V_{FSD}}{I_{MFSD}} - R_m$

$= R_m\left[\frac{V_{FSD}}{I_{MFSD} \times R_m} - 1\right]$

$= R_m\left[\frac{V_{FSD}}{V_{MFSD}} - 1\right] \Rightarrow \boxed{R_{se} = R_m[M-1]}$

where M= Multiplying factor

$$\boxed{M = \frac{V_{FSD}}{V_{MFSD}}}$$

oor $$\boxed{M = \frac{R_{se}}{R_m} + 1}$$

③ sensitivity of voltmeter (S_v)

$$\boxed{S_v = \text{resistance / volt rating}}$$

$$= \frac{\text{resistance}}{\text{Voltmeter}} = \frac{\Omega}{V} \text{ oor } \frac{k\Omega}{kV}$$

* DC voltmeter have DC sensitivity

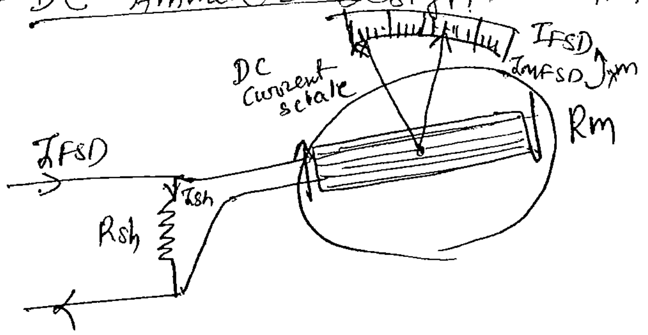
$$\therefore \boxed{S_{dc} = \frac{R_V}{V_{FSD}}} = \frac{V_{FSD}/I_{MFSD}}{V_{FSD}}$$

$$\boxed{S_{vdc} = \frac{1}{I_{mFSD}}}$$

senseitivity is also known as "Figure of merit"

~~Note~~ DC Ammeter Design :-

* A practical DC Ammeter consist of a PMMC instrument with a low valued shunt resistance place accross the coil & scale properly calculated



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

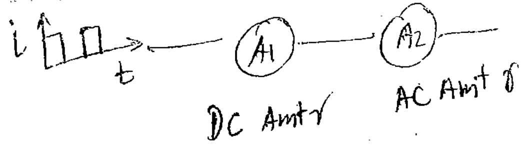
where m = multiplying factor

$$= \frac{I_{FSD}}{I_{MFSD}}$$

* PMMC is scale is linear.

* DC Meter :- A DC meter is an avg measuring (oor responding) avg indicating (reading) meter linear scale & works for only DC i/p. Eg. → PMMC

Soln



→ DC amtor reading $= I_{dc} = \frac{1}{2}\int_0^t 100\,mA\,dt = \frac{100\,mA}{2}$

$= 50\,mA$ (Moving coil ammeter)

Note:- When square wave is given may be symmetrical or unsymmerical

$I_{dC} = I_m \alpha$

where α is duty cycle $= \frac{t_{ON}}{t_{ON}+t_{OFF}}$

$\therefore I_{dc} = 100\,mA \times \frac{1}{1+1} = \frac{100}{2} = 50\,mA$

→ AC ammetor reading $= I_{rms}$

$= \sqrt{\frac{1}{2}\int_0^1 (100\,mA)^2\,dt}$

$= \frac{100}{\sqrt{2}} = 70.7\,mA$

Note - $I_{rms} = I_m\sqrt{\alpha}$

$= 100 \times \sqrt{\frac{1}{1+1}} = \frac{100}{\sqrt{2}} = 70.7\,mA$

Gate

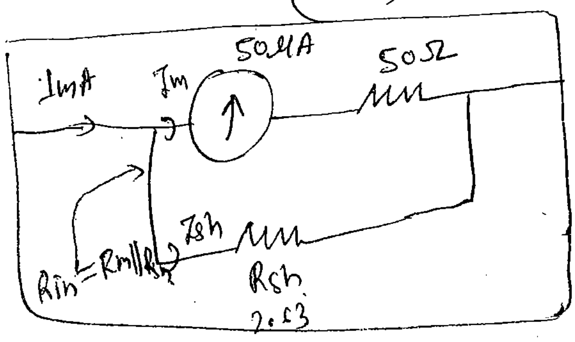
Que:- An ammeter with internal resistance of 50Ω give full scale deflection for 50 μA current. The i/p resistance of a 0-1 Ammeter obtained by connecting a shunt accross the 50μA ammeter will be ----.

(a) 50 Ω (b) 2.63 Ω (c) 5Ω (d) 2.5Ω

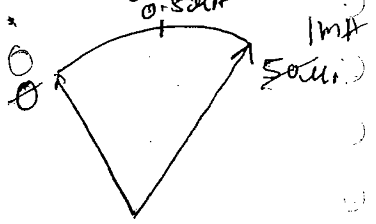
Soln $R_{in} = 50\,\Omega$, $I = 50\,\mu A$, $R_{sh} = ?$ ⟶ 1mA

$R_{sh} \simeq \cancel{0}$ $m = \frac{1\,mA}{50\,\Omega} = 20$

$R_{sh} = \frac{50}{(20-1)} = \frac{50}{19}\,\Omega = 2.63\,\Omega$

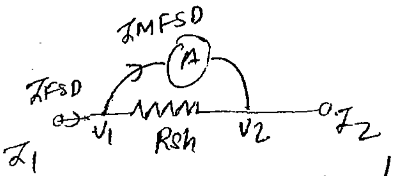


DC Ammeter (0-1mA)



$R_{in} = R_m || R_{sh} = 50\Omega || 2.63\Omega$

$\boxed{R_{in} = 2.5\Omega}$



Note:- $R_{sh} < 1\Omega$

Que:- A (0-200) μA DC ammeter is to be used in 50 volt dc range. the internal resistance of the ammeter is 100Ω. Then the value of Rse is ---

Soln:-

$$200\mu A = \frac{V}{R_{se} + R_i + 100}$$

Given $I_{MFSD} = 200\mu A$

$R_m = 100\Omega$

$V_{FSD} = 50V$

$$200\times10^{-6} = \frac{50}{100 + R_{se}}$$

$$100 + R_{se} = \frac{50}{200\times10^{-6}} \Rightarrow R_{se} = 0.25\times10^{6} - 100 = 249.9\ k\Omega$$

$$R_{se} = R_V - R_m$$

$$= \frac{50V}{250k\mu A} - 100\Omega$$

$$= 250k\Omega - 100\Omega$$

$$= 249.9k\Omega$$

Que:- The sensitivity of a 200 μA meter movement when it is used as a dc voltmeter is given by ---

(a) 500 Ω/mV (b) 5 Ω/V (c) 0.5 Ω/mV [✓ (d)] 5 Ω/mV

Soln:-

$$\frac{1}{I_{FSD}} = \frac{1}{200\mu A} = 0.5\times10^{4}\ \frac{\Omega}{V}$$

$$= 5\frac{k\Omega}{V} = \frac{5\Omega}{mV}$$

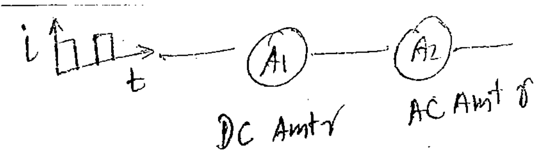
Que:- (0-50)V dc voltmeter having sensitivity of 5kΩ/V is constructed employing a dc ammeter if Rin of ammeter is 100Ω then the value of Rse = ---

$S = R/V$

$V_{FSD} = 50\ V$, $S_{dc} = 5k\Omega$, $R_m = 100\Omega$

$\therefore R_{se} = R_V - R_m = S_{dc} \times V_{FSD} - R_m$

Soln



→ DC amtor reading $= I_{dc} = \frac{1}{2}\int_0^1 100\,mA\,dt = \frac{100\,mA}{2}$

$= 50\,mA$ (Moving coil ammeter)

Note:- When square wave is given may be symmetrical or unsymmerical

$I_{dc} = I_m \alpha$

where α is duty cycle $= \frac{t_{ON}}{t_{ON} + t_{off}}$

$\therefore I_{dc} = 100\,mA \times \frac{1}{1+1} = \frac{100}{2} = 50\,mA$

→ AC ammeter reading $= I_{rms}$

$= \sqrt{\frac{1}{2}\int_0^1 (100\,mA)^2 dt}$

$= \frac{100}{\sqrt{2}} = 70.7\,mA$

Note -

$I_{rms} = I_m\sqrt{\alpha}$

$= 100\,A\sqrt{\frac{1}{1+1}} = \frac{100}{\sqrt{2}} = 70.7\,mA$

Gate

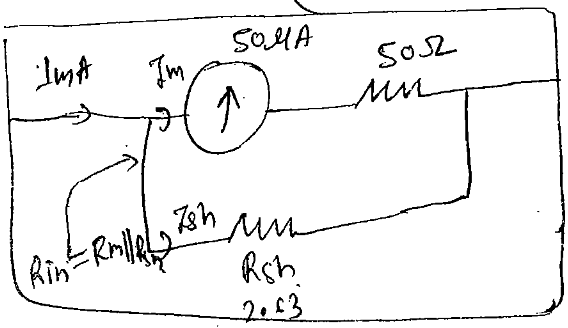
Que:- An ammeter with internal resistance of 50Ω give full scale deflection for 50 μA current. The i/p resistance of a 0-1 Ammeter obtained by connecting a shunt across the above ammeter will be ----.

(a) 50 Ω (b) 2.63 Ω (c) 5 Ω (d) 2.5 Ω

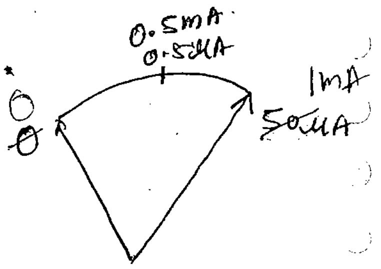
Soln $R_{in} = 50\,\Omega$, $I = 50\,\mu A$, $R_{sh} = ?$ → 1mA

$R_{sh} \approx$ ~~0~~ $\quad m = \frac{1\,mA}{50\,\mu A} = 20$

$R_{sh} = \frac{50}{(20-1)} = \frac{50}{19}\,\Omega = 2.63\,\Omega$



DC Ammeter (0-1mA)

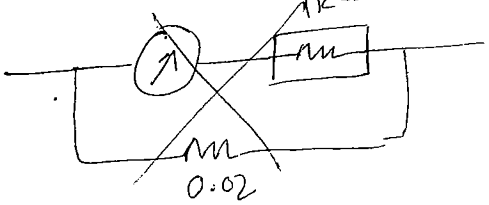


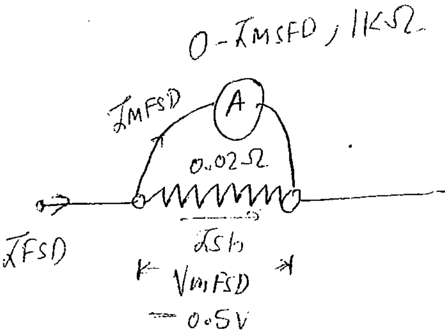
$$R_{in} = 5 \parallel 0.55\Omega$$
$$= 0.5\Omega$$

0-10 mA, 0.5Ω DC ammeter

Que - A moveing coil ammeter has fixed shunt a 0.02Ω with a coil resistance of $R = 1k\Omega$ & needs potential difference of 0.5 V accross it for full scale deflection (1) Calculate the current it correspond to (2) Find the value of shunt when total current is 2Amp.

Soln:-





(1) $I_{MFSD} = \dfrac{0.5V}{1k\Omega} = 0.5\ mA$

$I_{sh} = \dfrac{0.5V}{0.02\Omega} = 25A$

We know $R_{sh} = \dfrac{R_m}{m-1}$, $m = \dfrac{R_m}{R_{sh}} + 1$

$= \dfrac{1k\Omega}{0.02\Omega} + 1 = 500K$ ~~$I_{FSD} = 0.5$~~

$I_{FSD} = m I_m = 50K \times I_{mFSD}$

$I_{FSD} = 0.5mA + 25A$

$I_{mFSD} = 0.5\ mA$

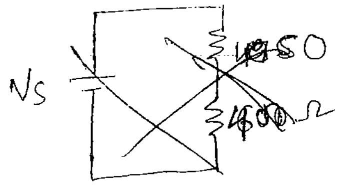
$I_{FSD} = 10A$

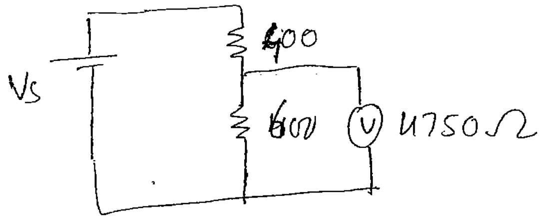
$R_{sh} = \dfrac{1k\Omega}{\dfrac{10A}{0.5mA} - 1} = 0.05\Omega$

Date 14/03/12

Que- A voltmetor with internal resistance of 4750Ω this used to measure the voltage accross a resistance of 600Ω connected in series with a Dc source of internal resistance of 400Ω what is the error

Sol





$V_{true} \Rightarrow$ voltage accross 600Ω

$$= V_s \times \frac{600}{600+400}$$

$$= 0.6V_s$$

$$R_{eff} = 600 \parallel 4750$$

$$= 532.7\,\Omega$$

$V_{meas} = V'$ accross 532.7Ω

$$= V_s \times \frac{532.27}{400+532.7}$$

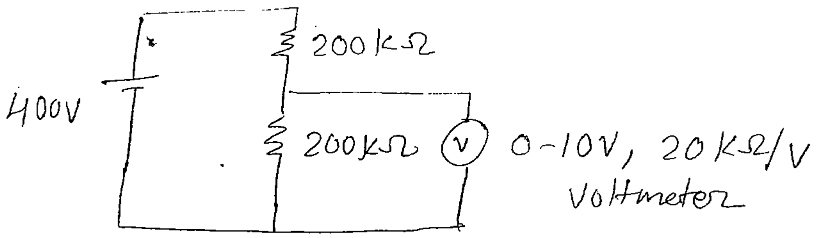
$$= 0.57V_s$$

Loading error $= \frac{0.57V_s - 0.6V_s}{0.6V_s} \times 100\%$

$$= -4.8\%$$

$$\simeq -5\%$$

Que ⇒ In a ckt shown in below fig voltage measured by a voltmeter with a sensitivity of 20,000 Ω/Volt & using the 10V range find the % error in measurement.



Soln :- It is given that $V_{FD} = 10V$, $S_{dc} = 20 k\Omega/V$

* $V_{true} = V_{200\Omega}$

$$= 400V \times \frac{200k\Omega}{400k\Omega} = 200V$$

* $R_V = \frac{20k\Omega}{V} \times 10V = 200\Omega$

* $R_{eff} = R_L \| R_V = 200k\Omega \| 200k\Omega$

$R_{eff} = 100k\Omega$

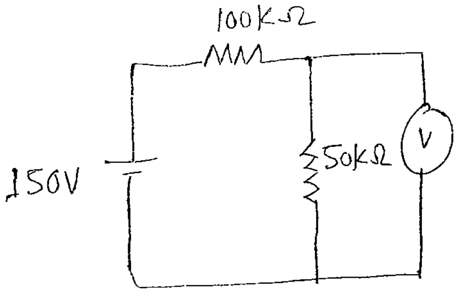
$V_{meas} = V_{100k\Omega} = 400V \times \frac{100k\Omega}{300k\Omega}$

$= 133.33V$

$$\% \text{ error} = \frac{133.33V - 200V}{200V} \times 100\%$$

$$= -33.33\%$$

Que :- Explain briefly about sensitivity & loading effect of ammeter the voltage accross 50kΩ resistar in ckt shown in below fig. Measured with 2 voltmeter seaprately. Voltmeter ① have sensitivity of 1000 Ω/V & voltmeter ② has a sensitivity of 2000Ω /V. Both the meter are used on there 50V range calculate (1) Reading of each meter (2) The error in each reading expressed as % of the value



$$S_{dc} = \frac{R_V}{V_{FSD}}$$

$$= \frac{\frac{\cancel{V_{FSD}}}{I_{FSD}}}{\cancel{V_{FSD}}}$$

$$S_{dc} = \frac{1}{I_{FSD}}$$

(i) $V_{true} = V_{50k\Omega}$

$$= 150V \times \frac{50k\Omega}{150k\Omega} = 50V$$

* Voltmeter ①

↳ $R_V = 1k\Omega/V \times 50V = 50k\Omega$

$R_{eff} = 50k\Omega \,||\, 50k\Omega = 25k\Omega$

$$V_{measu} = 150 \times \frac{25k\Omega}{125k\Omega} = 30V$$

* Voltmeter ②

$R_V = \cancel{1}\ 2\frac{k\Omega}{V} \times 50V = 100k\Omega$

$R_{eff} = 50\Omega \,||\, 100k\Omega = 33.3k\Omega$

$$V_{meas} = 150 \times \frac{33.3k\Omega}{133.3k\Omega} = 37.5V$$

reading of V_1 is $= 30V$

& reading of V_2 is $= \underline{\underline{37.5V}}$ ✓

(ii) % error of voltmeter ① $= \frac{30V - 50V}{50V} \times 100\%$

$= -40\%$

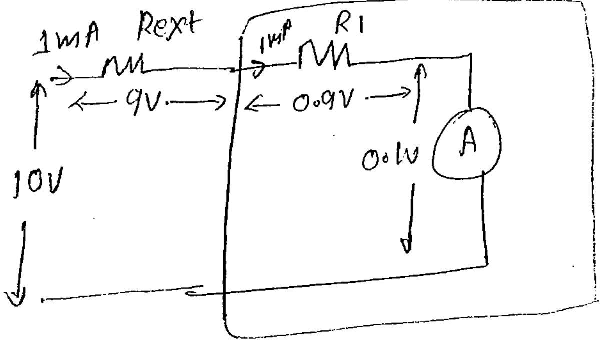
% Error in reading of V② $= \frac{37.5 - 50V}{50V} \times 100\%$

$= -25\%$

Que- A Galvanometer with internal resistance of 100Ω & fullscale current rating of 1mA ~~to~~ is used to realize a dc voltmeter with a full scale range of 1V. The full scale range of this meter can be extended to 10V by connecting an external resistance of value ...

Sol $R_1 = \frac{1V - 0.1V}{1mA} = \frac{0.9V}{1mA} = 900Ω$

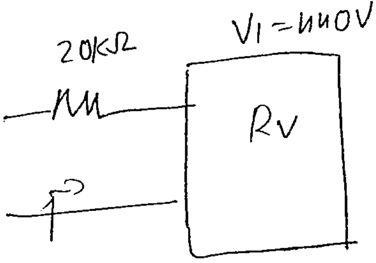
$R_1 = 0.9kΩ$

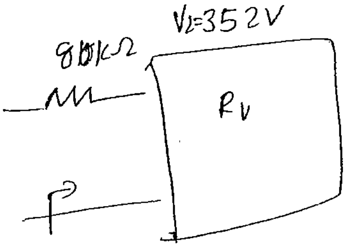


$$Rext = \frac{10V - 1V}{1mA} = 9kΩ$$

Que- An analog voltmeter used as external multipier settings with a multiplier setting of 20kΩ it read 440V & with 80kΩ it reads 352V. for multiplier setting 40kΩ voltemeter read ....

(a) 371 (b) 383 (c) 394 (d) 406





reading of voltmeter $\propto 1/R$

$$\frac{V_1}{V_2} = \frac{R_2}{R_1}$$

$$\frac{440}{352V} = \frac{80kΩ + R_V}{20kΩ + R_V}$$

$8800kΩ + 440R_V = 28160 + 352R_V$

$R_V = 220kΩ$

$$\frac{V_1}{V_3} = \frac{R_3}{R_1}$$

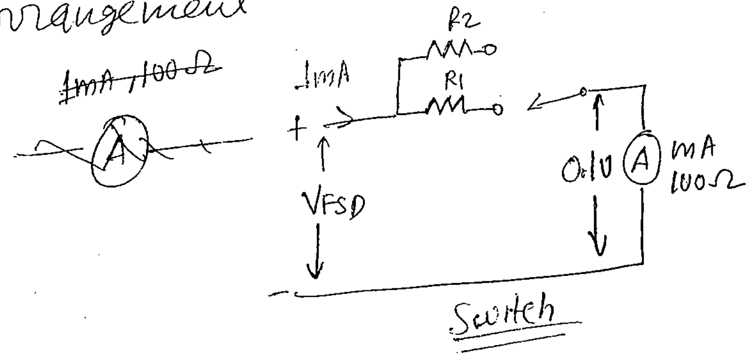
$$\frac{440}{V_3} = \frac{40k\Omega + 220k\Omega}{20k\Omega + 220k\Omega}$$

$$\boxed{V_3 = 406\ V}$$

Que. Designe a multirange ammeter using a 1mA ammeter with internal resistance of 100Ω required voltage ranges are 0-1V & 0-10V find the value of multiplier resistor for below given voltmeter designe (1) Multi range voltmeter with switched multiplier resistor

(2) Multirange voltmeter with series connected multiplier resistor i.e using potential divider arrangement

Soln.



1V range

$$R_1 = \frac{1V - 0.1V}{1mA}$$

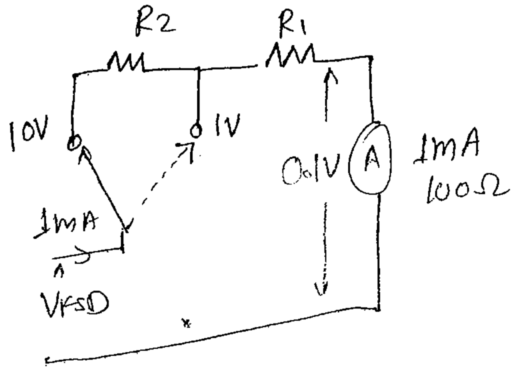
$$= 0.9k\Omega$$

10V range

$$R_2 = \frac{10V - 0.1V}{1mA}$$

$$= 9.9k\Omega$$

Series



10V range

$$R_1 + R_2 = \frac{10V - 0.1V}{1mA}$$

$$0.9k\Omega + R_2 = 9.9k\Omega$$

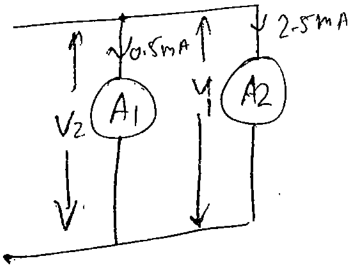
$$R_2 = 9k\Omega$$

1V range

$$R_1 = \frac{1V - 0.1V}{1mA} = 0.9k\Omega$$

Que:- 2 mA with full scale currents of 1mA & 10mA read 0.5mA
are connected in parallel & they
2.5 mA respectively there internal resistance is
the ratio of ....

Soln. -



$V_1 = V_2$

$I_1 \times R_1 = I_2 \times R_2$

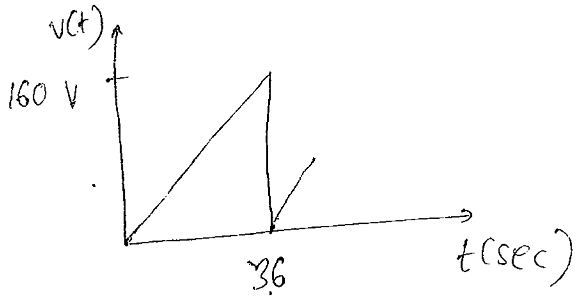
$0.5 \times R_1 = 2.5 \times R_2$

$$\frac{R_1}{R_2} = \frac{2.5}{0.5}$$

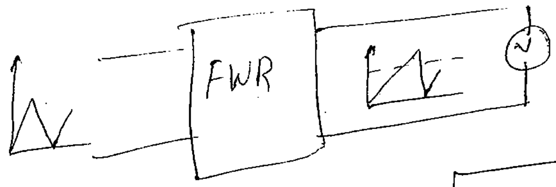
$$\frac{R_1}{R_2} = \frac{5}{1}$$

(a) 10:1
(b) 1:10
(c) 5:1
(d) 1:5

Que:- A sawtooth voltage has peak value of 160V at time periode of ~~3~~ 3.6 sec As shown in below fig. Calculate the error at measuring this voltage with an ~~Hew~~ avg reading voltmeter calibbated in terms of Rms value of sinusoidal wave.



soln

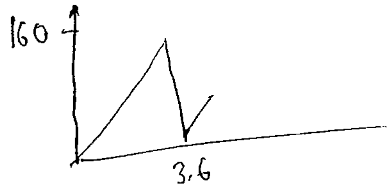


→ Voltage $V_{rms\,(true)} = \sqrt{\frac{1}{3.6}\int_0^{3.6}\left(\frac{160}{3.6}t\right)^2 dt}$ V

$= \sqrt{\frac{160^2}{(3.6)^3}\times\frac{(3.6)^3}{3}}$

$= 92.376$ V → Actual or true RMS voltage (i.e to be preffered)

* The o/p of FWR



The dc voltmeter reads Avg value of o/p of FWR

$V_{dc} = 1/3.6 \int_0^{3.6} \frac{160}{3.6}t\,dt$

$= 80V$

They indicated rms is 1.11 Vdc since the scale is calibrated in terms of rms of sinewave

Vrms (ind) = 1.11 × 80 = 88.8V

= measured rms value

→ error $= 88.8 - 92.37\,V =$
$= -3.57\,V$

% wave form error $= \dfrac{-3.57}{92.37\,V} \times 100\%$

$= -3.86\%$

i.e the reading of FWR voltmeter while measuring above voltage is less than true rms by 3.8% of true rms

[Note: If given as objective Que then.

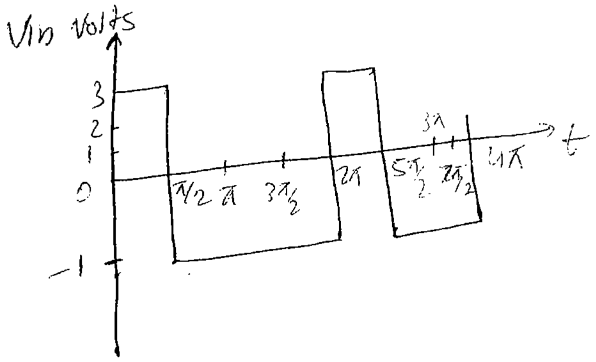
We know $FF_{saw} = 1.154$

$\% \text{ error} = \left[\dfrac{1.11}{FF_N} - 1\right] \times 100\%$

$= \left[\dfrac{1.11}{1.154} - 1\right] \times 100\%$

$= -3.86\%$

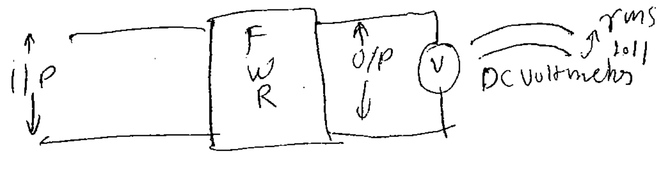
Que - The periodic voltage waveform as shown in below fig is applied to (1) True rms meter (2) An avg measuring, rms indicating meter. (3) Peak measuring rms indicating meter. Determine the reading of each instrument.

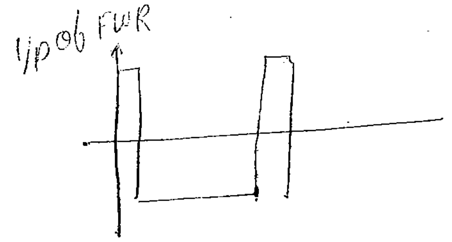


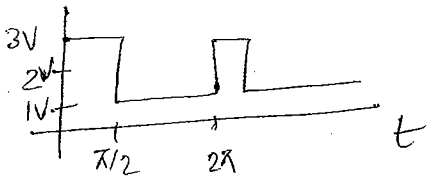
Soln

1) $V_{rms}\text{ (True)} = \sqrt{3} = 1.73$

2) Given meter is Avg msg _ rms ind meter







DC voltmeter measures Vdc of o/p of FWR

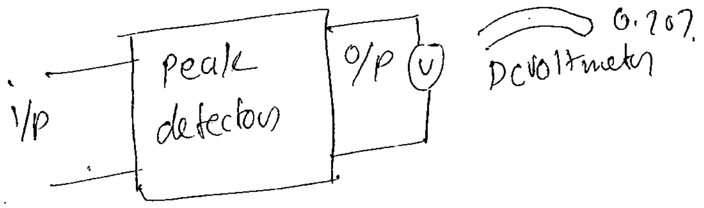
$$V_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi/2} 3V\,dt + \int_{\pi/2}^{2\pi} 1V\,dt\right]$$

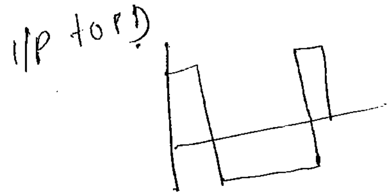
$$= \frac{1}{2\pi}\left(3\pi/2 + (2\pi - \pi/2)\right)]$$

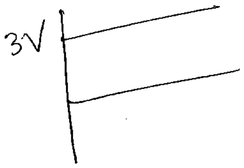
$$= 1/2\pi\left[3\pi/2 + 3\pi/2\right] = \frac{3}{2} = 1.5\,V$$

$\therefore V_{rms} = 1.11 \times 1.5 = 1.665\,V$.

(iii) Given meter is peak rms indicating meter







DC voltmeter measures Vdc of o/p of peak detector
(i.e. Vp of i/p) $V_{dc} = 3V$

$V_{rms}(ind) = 0.707 \times 3\,V = 2.121\,V$

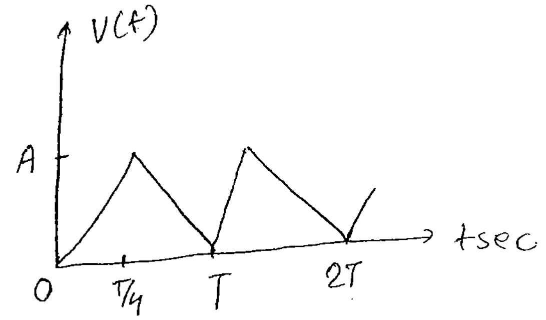
Q. from above 2 meter calculate the amount of error introdu into voltage measurement & expressed it as a % of true value.

$$\% \text{ error} = \frac{V_m - V_t}{V_t} = \cancel{1.665}\ \frac{2.121 - 1.73}{1.73}$$

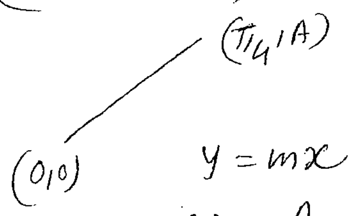
$= 22.54\%$.

Que:- An avg responding electronic voltmeter has its scale calibrated to indicate correctly the rms value of sinusoidal voltage calculate error in its reading if the instrument is used for measureing value of asymmetrical triangular wave voltage.

Solⁿ:-



$(0 < t < T/4)$

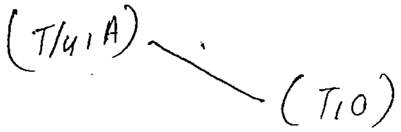


$y = mx$

$v(t) = \frac{A}{T/4} \times t$

$$\boxed{V(t) = \frac{4A}{T} \times t}$$

$T/4 < t < T$



$y - y_1 = m(x - x_1)$

$v(t) - A = \frac{-A}{T - T/4}(t - T/4)$

$= \frac{4}{3}\frac{A}{T}(t - T/4)$

$$v(t) = \frac{4A}{T}t \; ; \quad 0 < t < T/4$$

$$= \frac{4A}{3T}(T - t) \; ; \quad T/4 < t < T$$

$$\rightarrow V_{rms}(\text{true}) = \sqrt{\frac{1}{T}\int_0^T v^2(t)\,dt}$$

$$= \sqrt{\frac{1}{T}\int_0^{T/4}\left(\frac{4A}{T}t\right)^2 dt + \frac{1}{T}\int_{T/4}^{T}\left(\frac{4A}{3T}(T-t)\right]^2 dt}$$

$$V_{rms}(\text{true}) = \sqrt{\left[\frac{16A^2}{T^3}\right]\int_0^{T/4} t^2\,dt^2 + \frac{(4A)^2}{9T^3}\int_{T/4}^{T}(T-t)^2\,dt}$$

$$V_{rms}(\text{true}) = \sqrt{\frac{1}{T}\left(\frac{4A}{T}\right)^2 \times \left(\frac{t^3}{3}\right)_0^{T/4} + \frac{(4A)^2}{9T^3} \times \left[\frac{(T-t)^3}{-3}\right]_{T/4}^{T}}$$

~~V_{rms} (true)~~ = $A/\sqrt{3}$

$$= \sqrt{\frac{(4A)^2}{3T^3} \times \frac{T^3}{4^3} + \frac{4A}{27T^3}(T-T/4)^3}$$

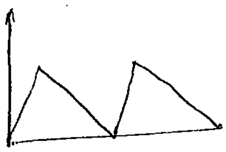
$$= \sqrt{\frac{(4A)^2}{3\cancel{T^3}} \times \frac{\cancel{T^3}}{4^3} + \frac{(4A)^2}{27\cancel{T^3}} \times \frac{\overset{3}{\cancel{3^3}}\cancel{T^3}}{4^3}}$$

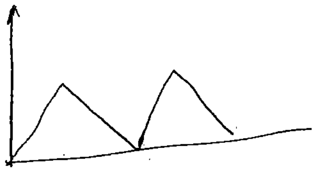
Vrms (true) $= \frac{A}{\sqrt{3}} = 0.577A$

The electronic AC voltmeter consist FWR at primary stage whose o/p is fed to PMMC voltmeters

o/p of FWR = i/p to DC voltmeter

i/p to FWR





DC voltmeter measures Vdc of o/p of FWR

$$V_{dc} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{T}\int_0^{T/4} \frac{4t}{T}\,dt + \frac{1}{T}\int_{T/4}^{T} \frac{4A}{3T}(T-t)\,dt$$

$$= \frac{4A}{T^2}\int_0^{T/4} n\,dt + \frac{4A}{3T^2}\int_{T/4}^{T}(T-t)\,dt$$

$$= \frac{4A}{T^2} \times \frac{T^2}{4^2 \times 2} + \frac{4A}{3T^2} \times \frac{(3T/4)^2}{2}$$

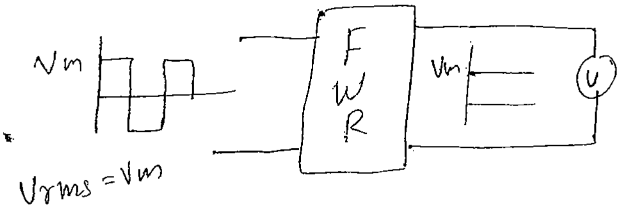
$$= A/2$$

Vrms (ind) $= 1.11 \times A/2 = 0.555A$

error $=$ ~~308~~ $\frac{0.555 - 0.577}{0.577} = -0.038$

Que.- An electronic voltmeter consisting FWR & avg ckt give correct rms value for a square wave i/p its reading for 2 volt peak to peak sinusoidal i/p will be ___

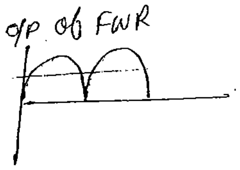
soln =>



DC voltmeter
D i/p = Vdc
= Vm

objective = 1 X response

scale calibration fator is 1



$$V_{dc} = \frac{2V_m}{\pi}$$
$$= \frac{2}{\pi} \quad (\because V_m = 1V)$$

$$V_{rms} = 1 \times V_{dc}$$
$$= 1 \times \frac{2}{\pi} = \frac{2}{\pi} V$$

Essential statement

* A FWR Voltmeter reads the true rms value of i/p waveform

reason - The FWR voltmeter (AC) has a rectifier unit first which feeds its o/p to PMMC indicating instrument

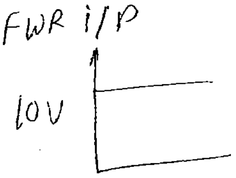
Essential is wrong, reason is true

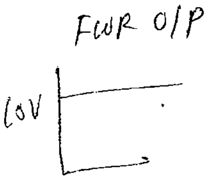
* A symmetrical square wave voltage is read I A avg response electronic voltmeter whose scale is calibrated in terms of rms value of a sinusoidal wave. The error in reading is ----

① −3.9% (b) +3.9% (c) −11% (d) 11%

$$\text{Error} = \frac{1.11 - 1}{1} = 0.11 \text{ or } +11\%$$

Que :- An avg response rectifier type electronic voltmeter as dc voltage of 10v applied to ~~its~~ it what is meter reading





Vdc = 10V
= 10×1.11
= 11.1

Que :- What is the advantag electronic voltmeter over non electronic voltmer

(a) ~~High i/p impedance~~ Low power consuption

(b) low i/p impedance

(c) The ability to measure wide ranges of voltage & resistance

(d) Large portability

Que :- For measurement of the voltage of the order of mV the voltmeter used is

(1) Rectifier amplifier VTVM

[✓ (2)] Amplifier rectifier type VTVM

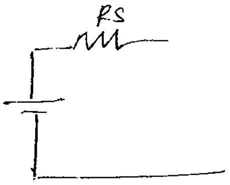
(3) Diode peak VTVM.

(4) Slight wire (VTVM)

Que.. PMMC voltmeter has a sensitivity of 20kΩ/volt A reading of 4.5 Ω is obtained when measuring a voltage source with the internal resistance on it 5 volts scale. when the scale is change to 10volts a reading 6 volts. Is obtained. The value of the voltage source & its internal resistance are ....

(a) 10 V, 100 kΩ (b) 9V, 100 kΩ

(c) 10 V, 200 kΩ (d) 9 V, 200 kΩ.



Soln:- $S = 20k\Omega/\text{volt}$

* 5 V scale

$\rightarrow R_V = 20 \frac{k\Omega}{V} \times 5V$

$R_V = 100k\Omega$

$\rightarrow \text{Reading} = V_S \times \frac{100\,k\Omega}{R_S + 100\,k\Omega}$

$4.5 = V_S \times \frac{100\,k\Omega}{R_S + 100k\Omega}$

$V_S = \frac{4.5V}{100k\Omega}\left[R_S + 100\,k\Omega\right] - ①$

* 10 V scale

$R_V = 20 \frac{k\Omega}{V} \times 10\,V = 200\,k\Omega$

$\text{rdg} = V_S \times \frac{200\,k\Omega}{R_S + 200k\Omega}$

$6V = V_S \times \frac{200\,k\Omega}{R_S + 200k\Omega}$

$V_S = \frac{6\cancel{k}V}{200k\Omega}\left[R_S + 200k\Omega\right] - ②$

equating eqn① with eqn②

$\frac{4.5\,V}{100k\Omega}\left[R_S + 100k\Omega\right] = \frac{6V}{200k\Omega}\left[R_S + 200k\Omega\right)$

$\Rightarrow \quad R_s = 100k\Omega$

Putting R_s in eqn ①

$$V_s = \frac{4.5}{\cancel{100k\Omega}}\left[\cancel{100k\Omega} \,||\, \overset{2}{100k\Omega}\right]$$

$$\boxed{V_s = 9 \text{ volt}}$$

Q meter

*Principle of operation
* Direction connection ckt diagram
* elements in the connection
* Working

} Done previously

* Mention error, % error & correction factor

Que- Explain with the help of ckt diagram the principle of working of Q meter.

Que: Describe a method of measuring the distributive capacitance of coil derive a necessary expression.

Soln: * Q meter in direct connection can be used for measuring of Cd of coil
* Direction connection of ckt diagram
* elements in connection
* 2 steps of resonant state
  Mention reading of each step
* Derivation for Cd.
* Ex $\left.\begin{array}{l} f \longrightarrow 2f \\ C_1 \longrightarrow C_2 \end{array}\right\} C_d = \frac{C_1 - 4C_2}{3}$

Que: A coil was tested using a Q meter and the following result was obtained

Oscillator frequency	3 MHz	6 MHz
Tunning Capacitance setting	251 pF	50 pF

Find self capacitance of coil

Soln :- $n = \frac{6MHz}{3MHz} = 2$

$$Cd = \frac{251PF - 4 \times 50PF}{3} = \underline{17\ PF}$$

Que :- (a) Describe the method of measuring the value of q factor of an unknown inductance in the range 1μH - 1mH with high accuracy

(b) An unknown inductance resonant at freaquency of 1MHz with an external capacitance of 210 PF (Tuning capacitance). & has a q of 100. If the frequency of the source is doubled it is found that the tunning capacitor required for resonant is 45 PF. Determine the value of unknown inductance & other component associated with it in the equivalent ckt

Que :- In a Q meter measurement to determine the self capacitance of a coil the 1st resonant occured at f_1 with $C_1 = 300PF$ the 2nd resonnance occareed at $f_2 = 2f_1$ with $C_2 = 60PF$

The self capacitance of Cs - - - -

$$= \frac{300 - 2^2 \times 60}{3} = 20PF'$$

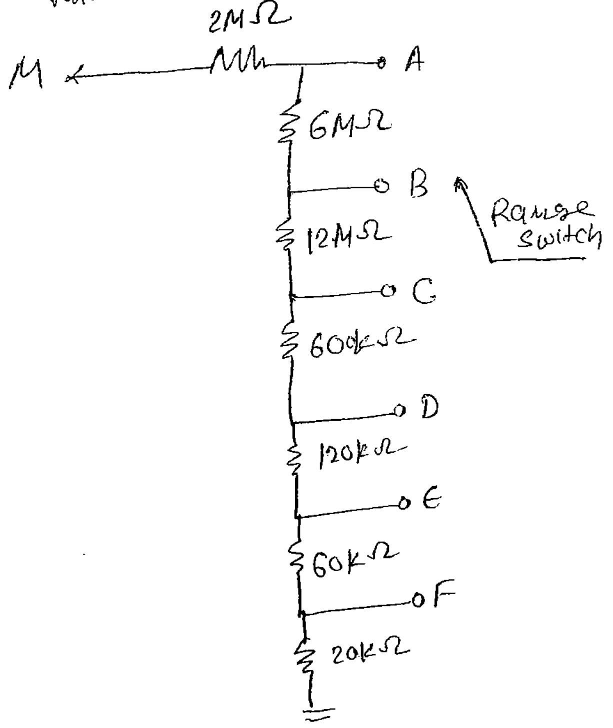
Que - 2003 Assertion → The Qmeter measures the Q factor of a coil when the ckt is at resonance (True)

Reason → The Q factor of coil depends only on its inductance & not on it resistance (False)

Que - 2000 Assertion ⇒ The basic principle of operation of a q meter is based on the property of seies resonance ckt (True)

Reason ⇒ If a fixed voltage is appled to a series resonant ckt the Voltage developed accross it capacitor is q time the applied voltage (True)

Que:- The figure shows i/p attenuation of multimeter the meter read true scale with 12V at M & range s/w at B what is the required voltage at M to obtaine full scale deflection with the range s/w position at D



(a) 1.2V

(b) 150V

(c) 120 V

(d) 147 V

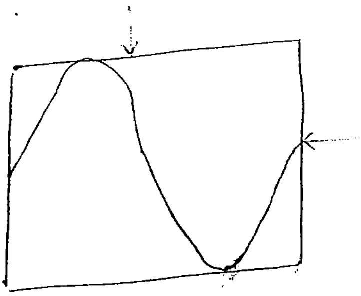
Date
12/04/2012

Que:- An analog single channel CRO is used to measure a time varying signal 2 sin 100πt Ω. Identify the image of signal displayed on screen for the following relation betwn signal frequency & seep frequency

① $\frac{f_{signal}}{\cancel{f_{sweep}}} = f_{sweep}$ (2) $f_{signal} = \frac{3}{4} f_{sweep}$

(3) $f_{signal} = 1.5\, f_{sweep}$

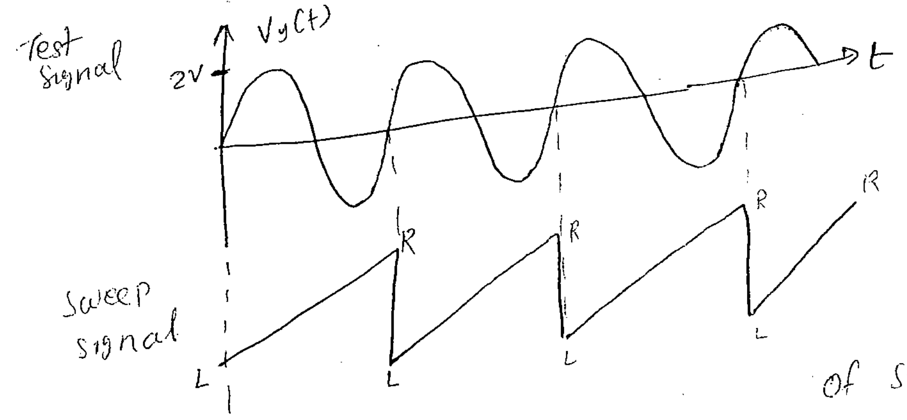
(4) $f_{signal} = 2\, f_{sweep}$



~~Assume~~ ~~in terms~~

soln ⇒ (1) $f_{signal} = f_{sweep}$

i.e $T_{signal} = T_{sweep}$



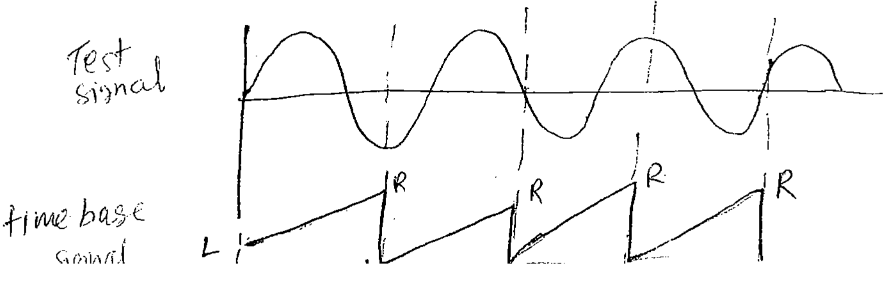
of signal
→ 1 cycle Displayed

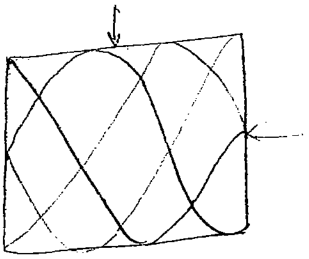
$\left(\because \frac{f_{signal}}{f_{sweep}} = 1\right)$

→ steady display (∵ Same Portion of 1 cycle)

(2) $f_{signal} = \frac{3}{4} f_{sweep}$

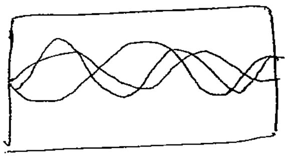
$T_{signal} = \frac{3}{4} T_{signal}$ (75% of signal Portion)





Jumble (∵ different position of displayed)

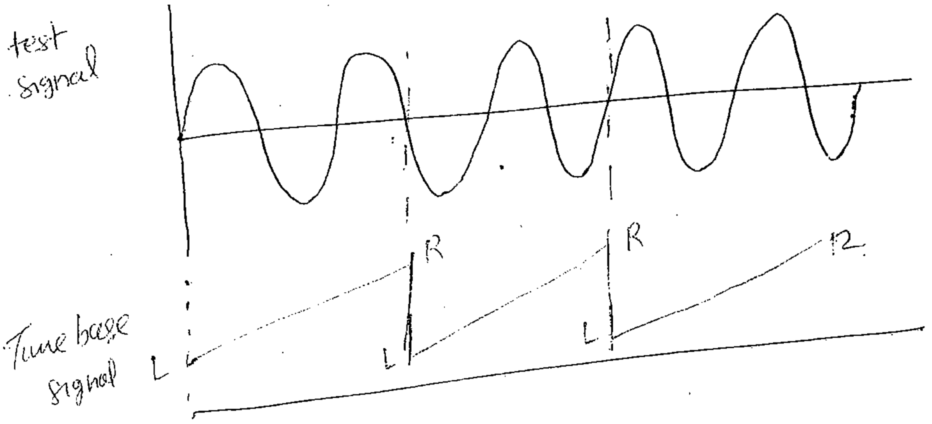
Ex :-

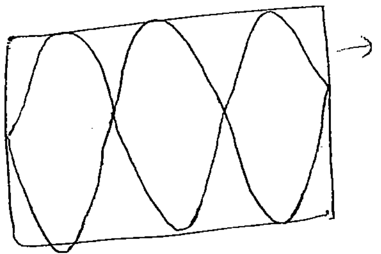


Note ⇒ To avoid such Jumble i.e to get a steady display of image the user has to either synchronised by adjusting Time/div or select proper triggering point

③ $f_{signal} = 1.5 f_{sweep}$

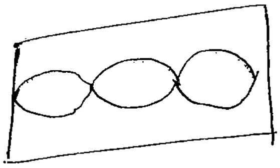
$T_{signal} = 1.5 T_{sweep}$





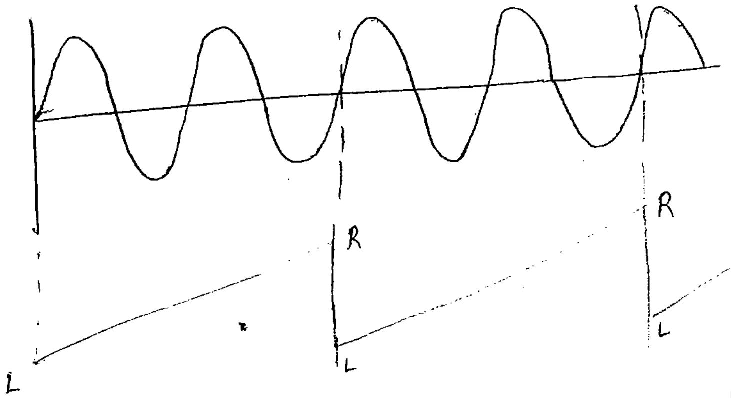
Jumble (Different 1.5 cycle of signal displayed)

Ex :-



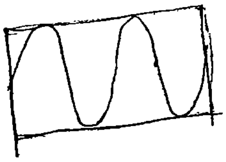
④ $f_{signal} = 2 f_{sweep}$

$T_{signal} = 2 T_{sweep}$



⇒ 2 Cycles of signal displayed

(∵ $\frac{f_{signal}}{f_{sweep}} = 2$)



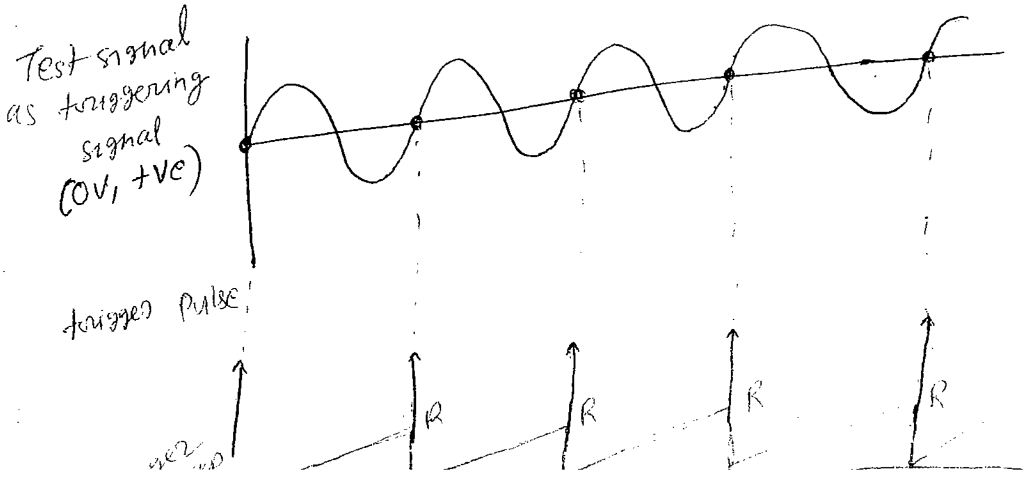
→ steady display
(∵ Same 2 cycles are repeatedly displayed)

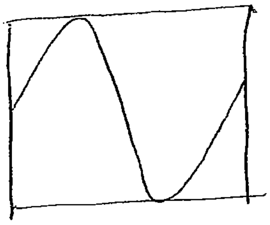
Que :- A single channel analog CRO is used to measure a time varying signal 2 sin 100 πt. Internal trigger source is choosen. Draw the image displayed on the screen for the following case

1) fsignal = fsweep & trigger point 0V, +ve
2) fsignal = fsweep & trigger point 0V, -ve
3) fsignal = 1.5 fsweep & trigger point 0V, +ve
4) fsignal = 3/4 fsweep & trigger point 0V, +ve

(1) Sol^n $f_{signal} = f_{sweep}$ & (0V, +ve)

$T_{sweep} = T_{signal}$, t.V.L = 0V, t-S = +ve





→ 1 cycle of steady image of signal

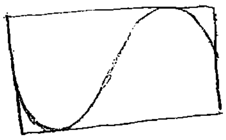
↑ ($\because \frac{f_{signal}}{f_{sweep}} = 1$) (Proper triggering)

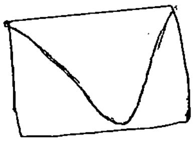
② $f_{signal} = f_{sweep}$ & (0V, -ve)

$T_{signal} = T_{sweep}$

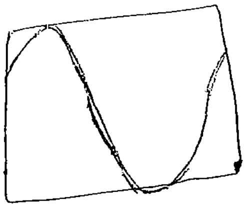
→ 1 cycle of signal displayed since $\frac{f_{signal}}{f_{sweep}} = 1$

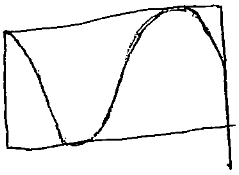
& it will shown from 0V & falling side.



Note ⇒ For 1:1 ratio & (2V, -ve) ⇒ 

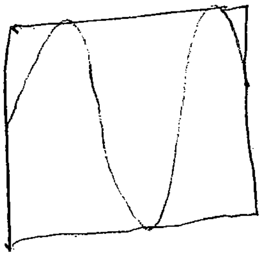
③ fsignal = ~~1.5 fsweep & (0V, +ve)~~

→ For 1:1 ratio & (+1V, +ve) ⇒ 

⇒ For 1:1 ratio & (+1V, -ve) 

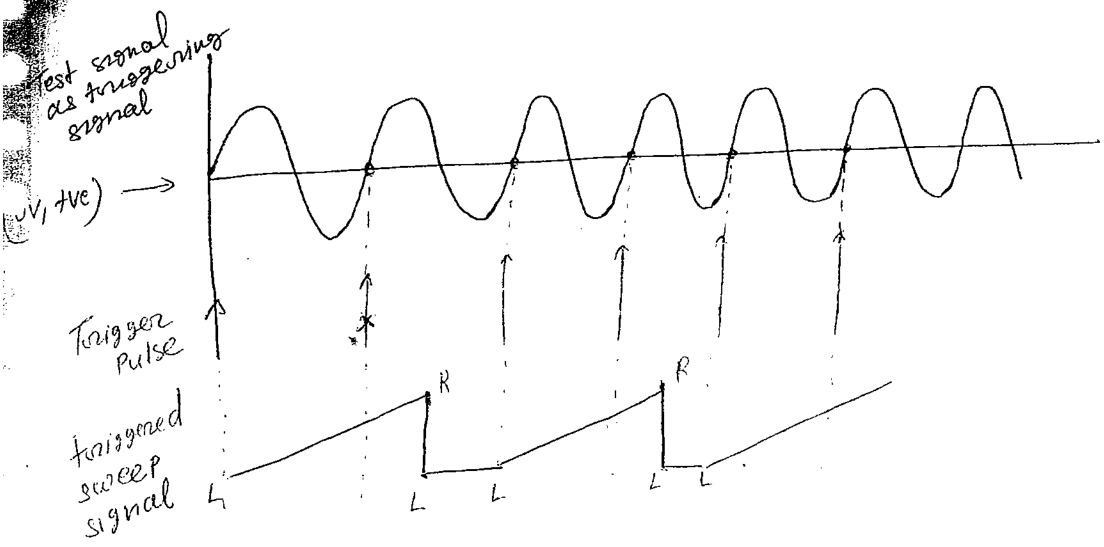
③ $f_{signal} = 1.5 f_{sweep}$ & (0V, +ve)

T_{sweep} ~~= 1.5 Tsignal~~   t.V.L = 0V   ts = +ve

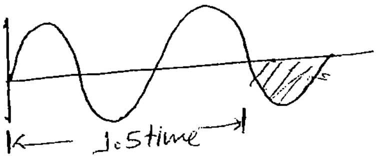


→ 1.5 cycle of steady image of signal

↑ ($\because \frac{f_{signal}}{f_{sweep}} = 1.5$)   ↑ (∵ Proper triggering)

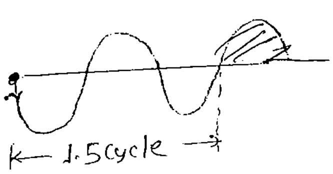


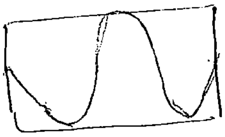
(0V, +ve)



Note:- $\frac{f_{signal}}{f_{sweep}} = 1.5$ & 0V, -ve

(0V, -ve)

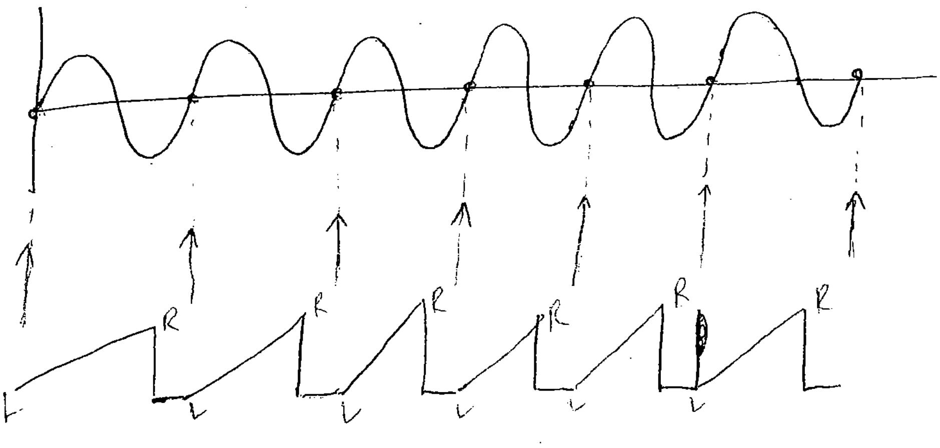


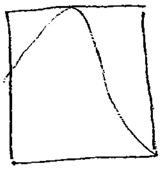


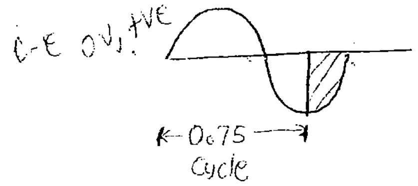
④ $f_{signal} = \frac{3}{4} f_{sweep}$ (0V, +ve)

→ $T_{sweep} = 3/4 \; T_{signal}$

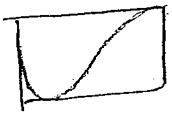
t.V.L = 0V , t.S. = +ve



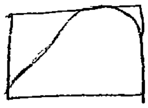




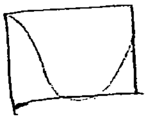
Note :- ⇒ 3/4 & (0V, -ve) ⇒



⇒ 3/4 & (-2V, +ve) ⇒



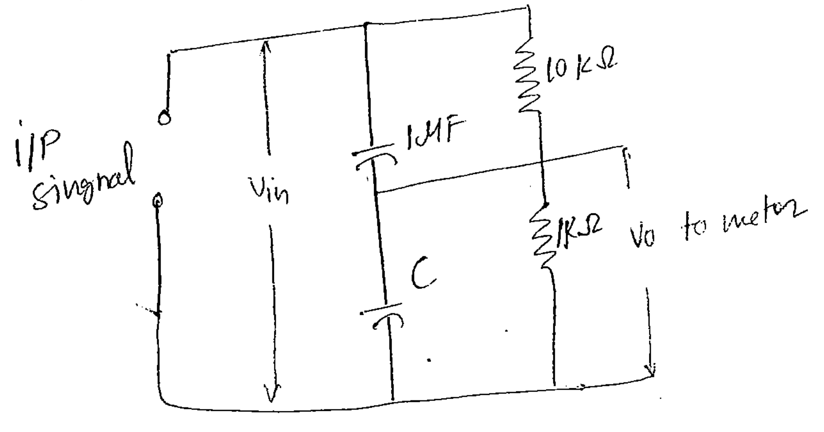
⇒ 3/4 & (+2V, -Ve) ⇒



Not ⇒ Improper triggering always need to rumble whereas proper triggering produces steady image of signal on screen

(

Que ⇒ The arrangement shown in the given figure represents a RC potentiometer for measuring ac voltage what should be the value of C so that Vo/Vin is independent of frequency of the i/p signal



[✓ (a)] 10 μF

(b) 11 μF

(C) 0.1 μF

(D) 0.09 μF

* $R_1C_1 = R_2C_2$ to make $\frac{V_o}{V_{in}}$ independent of freque.

$10 k\Omega \times 1 \mu F = 1 k\Omega \times C$

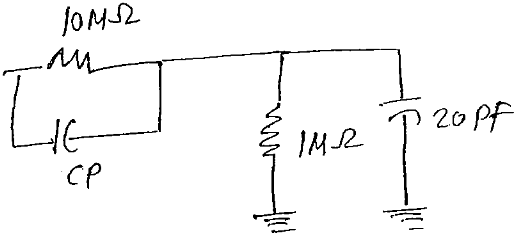
$\therefore C = 10 \mu F$

Que :- An oscilloscope has i/p impedance consisting of 1MΩ & 2pF in parallel a high impedance + connected to i/p ~~ba.~~ of 10 MΩ Resistance. Thus of this oscilloscope 10 MΩ resistance - - -

1MΩ || 20PF
10MΩ || - - -

(a) Need not to be shunted
(b) should be shunted by 20 PF
should be shunted by 200 PF
(d) should be shunted by 2 PF

Sol



$R_1C_1 = R_PC_P$

$1M\Omega \times 20PF = 10M\Omega \times C_P$

$\therefore \underline{C_P = 2PF}$

or $\frac{V_i}{V_S} = \frac{R_i}{R_P+R_i} = \frac{1M\Omega}{10M\Omega+1M\Omega}$

$= \frac{1}{11}$

Now $\frac{V_i}{V_S} = \frac{C_P}{C_P+C_i} \Rightarrow \frac{1}{11} = \frac{C_P}{C_P+20PF}$

$C_P + 200pF = 11C_P \Rightarrow \underline{C_P = 2PF}$

or $\frac{V_i}{V_S} = \frac{1}{11}$ i.e 11:1 Probe

→ $V_S \downarrow$ by 11 times
→ $R_P = 10R_i$ &
$C_P = \frac{C_i}{10}$ - - - > $C_P = \frac{20PF}{10} = \underline{2PF}$
→ $\uparrow R_{eff} = 11R_i$
$\downarrow C_{eff} = \frac{C_i}{11}$

Que ⇒ The oscilloscope has an i/p capacitance of 50PF under resistance of 2~~0~~MΩ & voltage divider ratio (K) of 10 what are the parameter a high Probe.

$$C_i = 50PF \qquad R_i = 2M\Omega$$

$$K = 10 \; - - - - \; = \frac{V_s}{V_i}$$

$$\text{i.e} \quad V_i = \frac{1}{10} V_s$$

→ 10 time attenuation

$$R_P = (10-1) R_i \Rightarrow R_P = 9R_i$$

$$R_P = 9 \times 2 M\Omega \Rightarrow \underline{R_P = 18 M\Omega}$$

$$C_P = \frac{C_i}{(10-1)} = \frac{C_i}{9}$$

$$= \frac{50}{9} P.F. = 5.55 PF$$

Que - The bandwidth of CRO is from 0 to 20MHz. The fastest rise time which a square wave have in order that it is accuratly reproduced by the CRO is - - - - -

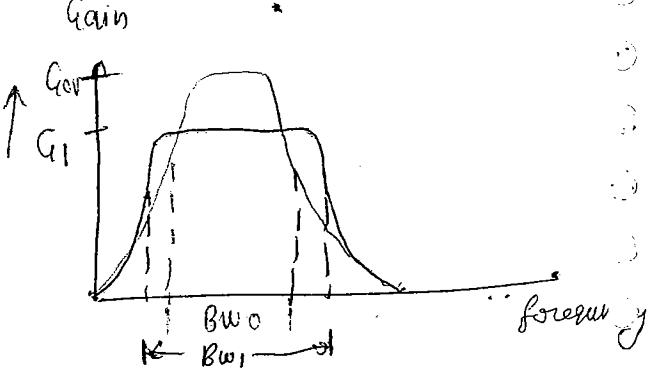
$$t_r \times B.W. = 0.35$$

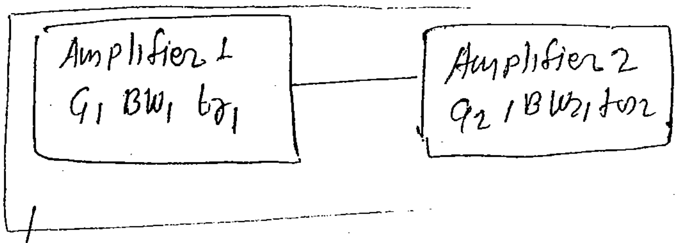
$$t_r = \frac{0.35}{20MHz} = \frac{0.035}{2} \mu S$$

$$= 17.5 \; \mu sec$$

Que - A CRO with a rise time of 150 nsec measures the rise time of signal as 20 nsec. what is the actual rise time of the signal

[Pre-requisite





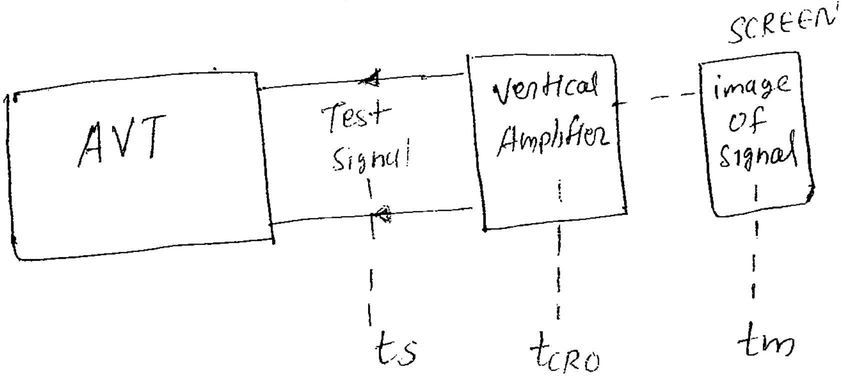
$\uparrow G \times BW \downarrow \sim k$

$t_r \times BW = 0.35$

$$G_{ov} = G_1 \times G_2$$

$$t_r = \sqrt{t_{r_1}^2 + t_{r_2}^2}$$

→



t_s = Actual or true rise time of signal

t_{CRO} = CRO rise time (i.e Vertical Amp rise time)

t_m = measured rise time is overall rise time

$$t_m = \sqrt{t_s^2 + t_{CRO}^2}$$

Soln :-

T_{CRO} = 15 nsec

t_m = 20 nsec

$$20\,ns = \sqrt{t_s^2 + (15\,ns)^2}$$

$$t_s = \sqrt{(20\,ns)^2 - (15\,ns)^2}$$

$$= 13.23\ ns$$

Que ⇒ A CRO has a rise time ~~was~~ of 20 ns. The rise time of a signal measured by this CRO is 25 ns. Find the true rise time of signal.

Soln

$$t_m = \sqrt{t_s^2 + t_{CRO}^2}$$

$$25 = \sqrt{t_s^2 + (20)^2}$$

$$t_s = \sqrt{(25ns)^2 - (20ns)^2}$$

$$t_s = 15\ ns$$

Que ⇒ A CRO is operated with the x & y settings of 0.5 msec /cm & 100 mv/cm The screen of CRO is 10cm/8cm. the cycle of frequency 200Hz & RMS amplitude of 300 mvolts is applied to the twice the screen will shows - - - -

(a) 1 Cycle of Undistorted sine wave.

›(b) 2 Cycles of undistorted sine wave

(c) 1 cycle of the sine wave with clipped amplitude

›(d). 2 cycle of the sine wave with clipped amplitude.

Given here 0.5 ms/cm 100 mV/cm

10cm X 8cm screen

1cycle or 2 cycle

$$n = \frac{f_{signal}}{f_{sweep}} = f_{signal} \times T_{sweep}$$

$$= 200Hz \times \left[10cm \times 0.5 \frac{ms}{cm}\right]$$

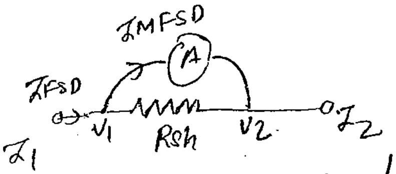
$$= 200 \times 5\ msec$$

$$= 1\ Cycle$$

∴ option (b) & (d) are eleminated

$R_{in} = R_m \| R_{sh} = 50\Omega \| 2.63\Omega$

$\boxed{R_{in} = 2.5\Omega}$



Note:- $R_{sh} < 1\Omega$

Que :- A (0-200) μA DC ammeter is to be used in 50 volt dc orange. the internal resistance of the ammeter is 100Ω. Then the value of Rse is ---

Given $I_{MFSD} = 200\mu A$
$R_m = 100\Omega$
$V_{FSD} = 50V$

Soln :-

$$200\mu A = \frac{V}{R_{se} + R_i + 100}$$

$$200 \times 10^{-6} = \frac{50}{100 + R_{se}}$$

$$100 + R_{se} = \frac{50}{200 \times 10^{-6}} \Rightarrow R_{se} = 0.25 \times 10^{6} - 100$$

$$= 249.9\ k\Omega$$

$$R_{se} = R_V - R_m$$

$$= \frac{50V}{250k\mu A} - 100\Omega$$

$$= 250k\Omega - 100\Omega$$

$$= 249.9k\Omega$$

Que :- The sensitivity of a 200 μA meter movement where it is used as a dc voltmeter is given by ---

(a) 500 Ω/mV (b) 5 Ω/V (c) 0.5 Ω/mV (d) 5 Ω/mV

Soln :-

$$\frac{1}{I_{FSD}} = \frac{1}{200\mu A} = 0.5 \times 10^{4} \frac{\Omega}{V}$$

$$= 5\frac{k\Omega}{V} = \frac{5\Omega}{mV}$$

Que :- (0-50)V dc voltmeter having sensitivity of 5kΩ/V is constructed employing a dc ammeter if Rin of ammeter is 100Ω then the value of Rse = ---

$S = R/V$

$V_{FSD} = 50\ V$, $S_{dc} = 5k\Omega$, $R_m = 100\Omega$

$\therefore R_{se} = R_V - R_m = S_{dc} \times V_{FSD} - R_m$

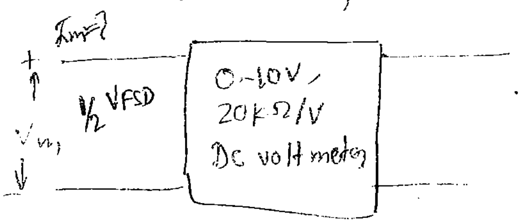
$= 250 k\Omega - 50\Omega$

$= 249.9 k\Omega$

Gate(ccc)

Que A dc voltmeter with figure of merite of 20kΩ/volt is used to measured Half full scale voltage in 10V dc orange. then current thorough meter is ----

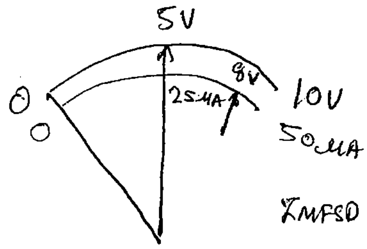
$S_{dc} = 20 k\Omega/volt$, $V_{FSVD} = 10V$



$R_V = 20 \frac{k\Omega}{Volt} \times 10 V$

$= 200 k\Omega$

$V_m = \frac{1}{2} \times 10 V \Rightarrow 5V$



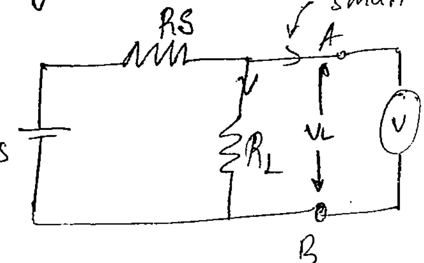
$\therefore I_m = \frac{5V}{200k\Omega} \Rightarrow 25 \mu A$

$I_{MFSD} = \frac{1}{20k\Omega/V}$

$= 50\mu$

Loading effect ⇒

Loading effect Due to voltmeter resistance :-



✓ small portion of load current is drawn by voltmeter from CUT & measured

If $R_V >> R_L$

∞ -ve gap is filled by R_V

* True ckt condn : -

$R_L\,(\text{true}) = R_L \,||\, \infty$

$= R_L$

$V_L\,(\text{true}) = V_S \times \frac{R_L}{R_S + R_L}$

= Actual voltage or true voltage

Measured value < True value

* Measured ckt condn.

$R_L\,(\text{eff}) = R_L \,||\, R_V$

$= R_{LV}$

$V_L\,(\text{eff}) = V_S \times \frac{R_{LV}}{R_S + R_{LV}}$

= Measured voltage or indicate voltage or observed voltage

= reading of voltmeter

* Introduction of a voltmeter in parallel with load resistance (R_L) makes the voltmeter to be a part of load of the circuit under test such as voltmeter indicates value less then the true value.

* This is known as loading effect which is due to voltmeter resistance (R_V) & corresponding difference betwn measured & true voltages is called as loading error

loading error = Vmeasure − Vtrue

$$\boxed{\%\ \text{Loading error} = \frac{V_{measure} - V_{true}}{V_{true}} \times 100\ \%}$$

* Loading effect is very much deside effect (since voltmeter measures current drawn from CUT) whereas the amount of error in reading must be minimised.

* To ↓ L.E. , a voltmeter should have High resistance

$R \gg R$

* $R_v(min) = 10 R_L$ ---- for 90% Accuracy

$= 100 R_L$ ---- for 99% Accuracy

$$\boxed{R_v(min) \geq 10 R_L}$$

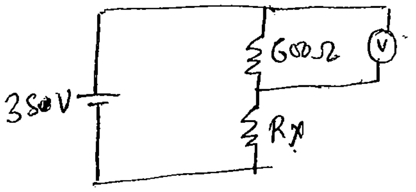
Selection criteria for a voltmeter

* Higher the resistance is better for voltmeter
* A voltmeter with High resistor & high sensitivity causes Min^m (or less) loading
* The internal resistance of ideal voltmeter is ∞ but an ideal voltmeter can not be realized or constructed.

Imp

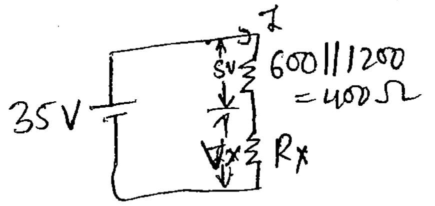
* Que:- A 35V dc source is connected to series combination of 600 Ω & unknown resistance Rx. A voltmeter connected across 600 Ω read 5 Volts. If the Voltmeter resistance is 1.2 kΩ, then value of Rx is ....

(a) 1.2 kΩ (b) 2.4 kΩ (c) 3.6 kΩ (d) 4.8 kΩ



$R_v = 1.2 k\Omega$
rdg = 5V

$$5 = 35 \times \frac{\left(\frac{600 \times 1.2k\Omega}{600 + 1.2k}\right)}{\left(\frac{600 \times 1.2k}{600 + 1.2k}\right) + R_x}$$



$$I = \frac{5V}{400\Omega}$$

$$V_x = I R_x$$

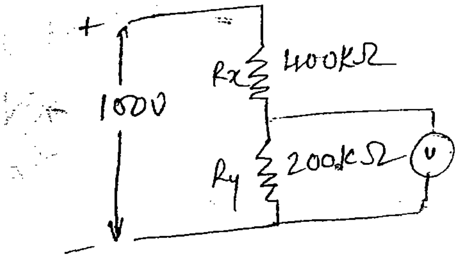
$$35 - 5 = \frac{5V}{400\Omega} \times R_x$$

$$\therefore R_x = 30V \times \frac{400\Omega}{5}$$

$$= 2400\Omega$$

$$= 2.4 k\Omega$$

Que:- In a ckt shown in below fig a voltmeter with figure of merite of 2 kΩ/volt is connected accross 200kΩ the range of voltmeter is 0 - 100V



(a) The reading of voltmeter is ----

(b) % error in reading is - - -

$$S = \frac{2\,k\Omega}{Volt}$$

$$R_y \parallel R_V = \frac{200 \times 2 (100)}{400}$$

$$= 100\ \Omega$$

$$V = V_S \cdot \frac{R_{LV} \cdot \cancel{R_S}}{R_V + R_S} = 100 \times \frac{100}{400 + 100}$$

$$= 20\,Volt$$

$$V_L = V_s \frac{R_L}{R_S + R_L} = 100 \times \frac{200}{100 + 400} = 33.33\ V$$

$$\%\ \text{Loading error} = \frac{20 - 33.33}{33.33} \times 100$$

$$= -39.93\ \%$$

ote :-

* The Basic indicating device in all electronics device is nothing but PMMC

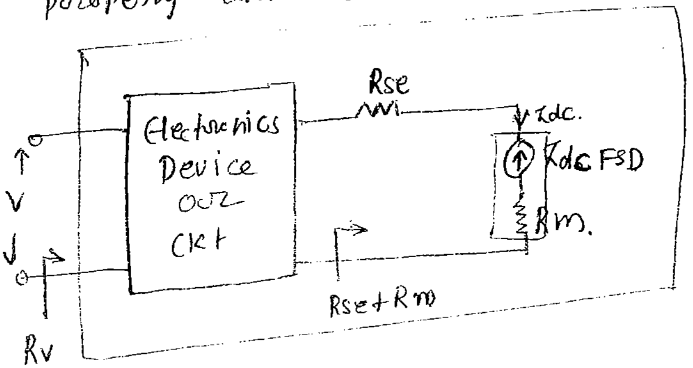
* CC is offered high i/p resistance in transistor.

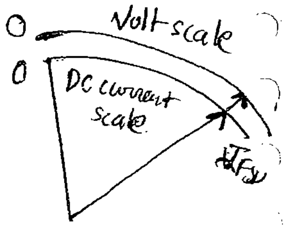
$$MI :\ \theta = \frac{1}{2} I^2 \frac{dL}{d\theta}$$

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

$$\theta = k I^2$$

Electronics voltmeter :- An electronic voltmeter consist of an electronic device. ~~or~~ ckt whose o/p is fed to a PMMC instrument & scale properly calibrated





$$\boxed{E\ D/C + Rse + PMMC = \text{Electronic Voltmeter}}$$

Types of electronics device	Type of electronic voltmeter	
DC Amplifier	DC amplifier Voltmeter or Amplifier type voltmeter	Electron DC Voltmeter (0-IdcFSD
Rectifier	Rectifier type voltmeter.	Electron AC Vo.. (0- →0-Vm
Peak Detector	Peak responding Voltmeter	
RMS Detector	Thermocouple voltmeter	

Note → Indicating device in AC voltmeter is PMMC.

Amplifier type Voltmeter :-

1. **DC Amplifier voltmeter :-** An amplifier type voltmeter consist of an amplifying device whose o/p is feeded to a PMMC.

The design objective is to achive very high i/p resistance very high sensitivity. ~~A 0-1 mA~~

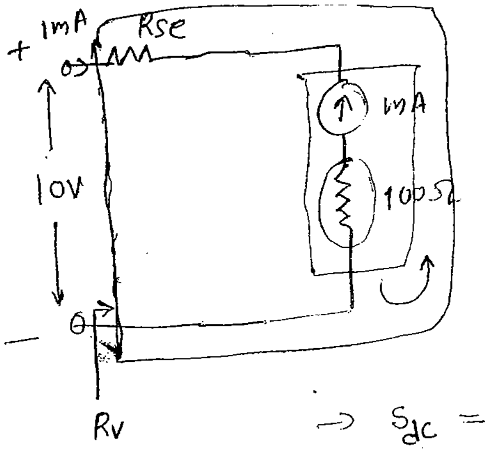
Que:- A 0-1 mA, 100Ω DC milliammeter is used to design the following voltmeter

(1) 0-10 Volt conventional DC voltmeter

(2) 0-10 Volt electronic DC voltmeter using a BJT with current gain of 100

(3) Calculate required multipler resistance, i/p resistance & sensitivity both the voltmeter

Sol^n:- (1) 0-10V electromechanical DC voltmeter



0-1mA

100 Ω

→ $R_V = \frac{10V}{1mA}$ ⇒ 10KΩ

→ $R_{se} = 10K\Omega - 100\Omega$

$R_{se} = 9.9 K\Omega$

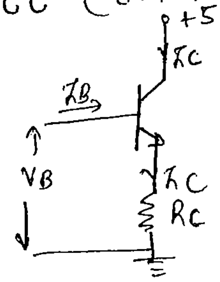
→ $S_{dc} = \frac{10K\Omega}{10V} = \frac{1K\Omega}{V}$

OR

$sdc = \frac{1}{1mA} = \frac{1K\Omega}{V}$

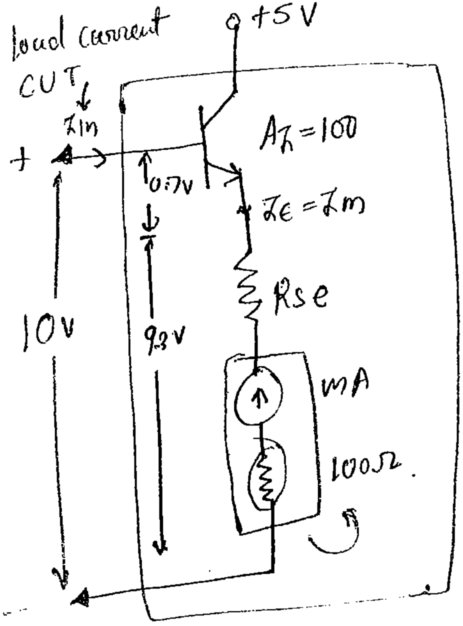
(2) 0-10V electronics voltmeter

* ~~CE~~, ~~CB~~, CC✓ (Emitter follower)



* Common collector is known as emitter follower (CC type)

Portion of load current drawn by CUT



Transistor Voltmeter or Emitter follower voltmeter

→ $A_I = \frac{I_G}{I_B}$

$= \frac{I_m}{I_{in}}$

For FSD

$A_I = \frac{I_{MFSD}}{I_{in max}}$

$100 = \frac{1mA}{I_{in max}}$

∴ $I_{in max} = 10 \mu A$

→ $R_V = \frac{10V}{10\mu A} = 1M\Omega$

$V_G = R_G \times I_G$

$V_B - V_{BE} = (R_{se} + R_m) I_{MFSD}$

$10V - 0.7V = (R_{se} + 100\Omega)\ 1mA$

$\frac{9.3V}{1mA} = R_{se} + 100\Omega$

∴ $R_{se} = \frac{9.3V}{1.mA} - 100\Omega$

$= 9.2 K\Omega.$

$$S_{dc} = \frac{10 M\Omega}{10 V} = 0.1 \frac{M\Omega}{V} = 100 \frac{k\Omega}{V}$$

Or

$$S_{dc} = \frac{1}{10 \mu A} = 0.1 \frac{M\Omega}{V} = 100 \frac{k\Omega}{V}$$

* sensitivity ↑ sense small current
* It required high i/p resistance.

Conclusion:- * A regular conventional DC voltmeter is not suitable for voltage measurement in ~~low~~ high resistive ckt (100kΩ, 200kΩ since the cause high loading as such a electronics dc voltmeter design.

Advantages of electronics amplifier voltmeter :-

1. Electronic Amplifier voltmeter offer very high input resistance in the range of MΩ.
2. ~~Com~~ Electronic amplifier voltmeter offer very high sensitiv is a order of MΩ/V or Ω/μV.
3. Amplifier voltmeter causes minm loading even if used accou high resistive loads
4. Electronics amplifier voltmeter can sense ~~of~~ or detect very low level signal. (current in the order of μA & voltag in the order of mV)
5. Amplifier voltmeter offer faster response, better accuracy & wide frequency range. because of exsistance of solid state electronics device
6. This voltmeter can be called as electronic dc voltmeter amplifier type voltmeter or DC amplified voltmeter

E.g. - (1) Emitter follower voltmeter or transistor voltmeter
(2) OPAMP volt meter
(3) FET input voltmeter.

All the above electronic dc voltmeter do require external supp for there operation & are sensitive to temperature.

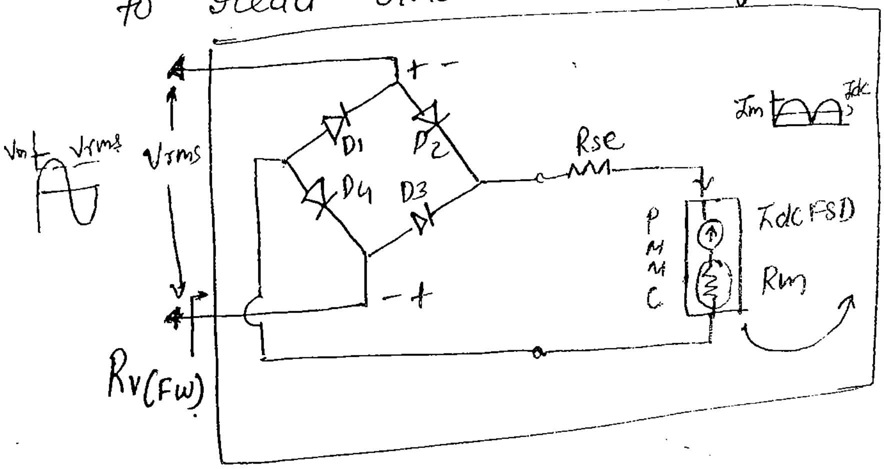
Electronics AC voltmeters:-

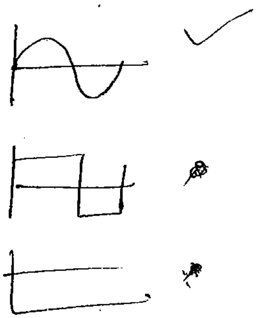
Conventional electromechanical AC meter (Moving iron type & electro-dynamometer type) are not true R.M.S meter since they don't follow perfect square law. as such electronics ac voltmeter are designed to achive the objective of true R.M.S measurement

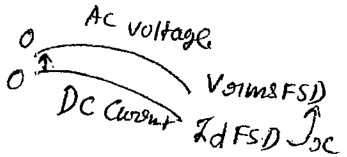
- There are three type namely rectifier type, peak type & thermocouple type.

* Full wave bridge rectifier type AC voltmeter :-

A rectifier voltmeter consist a full wave bridge rectifier whose o/p is fed to a PMMC. whose scale is calibrated to read rms ~~ac~~ voltage of i/p (Sinusoidal only)







- frequency range is ~~Aco~~ Audio frequncy

* objective of design : $V_{rms} = \frac{1}{\sqrt{2}} V_m$ ($\because$ Sinusoidal i/p is considered)

* Response of $I_{dc} = \frac{2 I_m}{\pi}$

* Relation between I_{dc} & I_{rms} for scale calibration:

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{(2R_d + R_{se} + R_m) I_m}{\sqrt{2}}$$

$$V_{rms} = \frac{1}{\sqrt{2}} (2R_d + R_{se} + R_m) \frac{\pi I_{dc}}{2}$$

$$\boxed{V_{rms} = \frac{\pi}{2\sqrt{2}} (2R_d + R_{se} + R_m) I_{dc}}$$

✓ * $V_{rms} = 1.11 (2R_d + R_{se} + R_m) I_{dc}$ * or ✓ * $\boxed{V_{rms} = 1.11 V_{dc}}$ *

* A rectifier voltmeter is an avg measuring, r.m.s indicating meter with a linear r.m.s scale. that works for both ac & dc i/p

* ~~The~~ rms scale is linear since it is derived from a linear dc scale considering sinusoidal wave as i/p. as such rectifier voltmeter is also called as derived r.m.s meter

* Rectifier voltmeter give no error for sinusoidal i/p. but introduces error into reading for non sinusoidal i/p (which are known as waveform error)

1. Full wave rectifier voltmeter resistance ($R_{v(FW)}$)

* $$\boxed{R_{v(FW)} = 2R_d + R_{se} + R_m}$$

* $$R_{v(FW)} = \frac{1}{1.11} \frac{V_{rms\ FSD}}{I_{dc\ FSD}}$$

$$\boxed{R_{v(FW)} = 0.9 \frac{V_{rms\ FSD}}{I_{dcFSD}}}$$

$V_{rms\ FSD}$ → required AC voltage rang

I_{dcFSD} → Available DC current ran

~~thus~~ ~~required~~

* $$\boxed{R_{v(FW)} = \text{Ac sensitivity} \times \text{AC Volt range}}$$

2. Required R_{se}:

* $$\boxed{R_{se} = R_{v(FW)} - 2R_d - R_m}$$

3. D.C. sensetivity:

* $$\boxed{S_{dc} = \frac{1}{I_{dcFSD}}}$$

4. AC sensitivity

* $$S_{ac(FW)} = \frac{R_{v\ (FW)}}{V_{rms\ FSD}}$$

$$= \frac{0.9 \frac{V_{rms}FSD}{I_{ds}FSD}}{V_{rms}FSD} = 0.9 \times \frac{1}{I_{dc}FSD}$$

*

$$\Rightarrow \boxed{S_{AC}(FW) = 0.9\, S_{dc}.}$$

5. Reading of FWR voltmeter :

For any i/p

$$\boxed{V_{rms}(\text{indicated}) = 1.11\, V_{dc}}$$ *

where V_{dc} = avg value of o/p of FWR

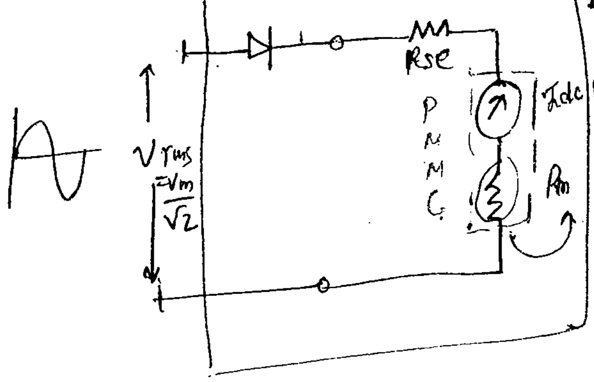
* Error will be present in the reading for non sinusoidal i/p

$$\boxed{\%\text{ error of non sinusoidal i/p} = \frac{V_{rms}(\text{ind}) - V_{rms}(\text{true})}{V_{rms}(\text{true})}}$$ → Amount of waveform error

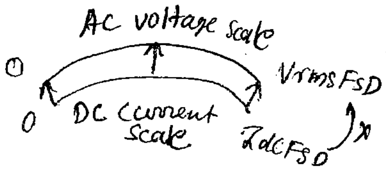
where $V_{rms}(\text{ind})$ = reading
$= 1.11\, V_{dc}$

& $V_{rms}(\text{true})$ = Actual rms value of given non sinusoidal i/p

2. Half wave rectifier voltmeter :—



$I_{dc} = \frac{I_m}{\pi}$



$$* \; V_{rms} = \frac{\cancel{V_m}\,\pi}{\sqrt{2}} (R_d + R_{se} + R_m) I_{dc}$$

$$= 2.22\,(R_d + R_{se} + R_m)\, I_{dc}$$

$$= 2.22\, I_{dc}.$$

* $R_{V(FW)} = R_d + R_{se} + R_m$

$R_{V(HW)} = 0.45 \dfrac{V_{rms\,FSD}}{I_{dc\,FSD}}$

$R_{V}(HW) =$ AC sensitivity X AC voltage range

* $R_{se} = R_V(HW) - R_d - R_m$

* $S_{dc} = \dfrac{1}{I_{dc\,FSD}}$

* $S_{AC\,(HW)} = \cancel{R_{dc}\,FSD}\ \dfrac{R_V(HW)}{V_{rms\,FSD}}$

$S_{AC\,(HW)} = 0.45\, S_{dc}$

* $V_{rms(ind)} = 2.22\, V_{dc}$ --- rdg

* $\%\ error = \dfrac{V_{rms}(ind) - V_{rms}(true)}{V_{rms}(true)} \times 100\%$

$1mA \downarrow 10V$

FWR: $0.9 \times \dfrac{10V}{1mA} \Rightarrow 9k\Omega$

HWR: $0.45 \times \dfrac{10V}{1mA} \Rightarrow 4.5k\Omega$

Note:- *

$$\begin{tikzcd}
S_{dc} & > & S_{AC(FW)} \arrow[rr, bend left, "\times 0.5"] & > & S_{AC(HW)} \\
R_V \arrow[rr, bend right, "\times 0.9"'] \arrow[rrrr, bend right=50, "\times 0.45"'] & > & R_{V(FW)} & > & R_V(HW)
\end{tikzcd}$$

* Conventional rectifier type AC voltmeter is fullwave rectifier type voltm since it offer more i/p resistance & more sensitivity (2 tim) then Half wave rectifier voltmeter.

* It loading error is more in ac measurement compaire to dc measurement

High ⟶ Low

$R_{V(FET\,Vr)} > R_V(EFVr) > R_V > R_V(FWVr) > R_V(HWVr)$

$S_{dc}(FET\,Vr) > S_{dc}(EFVr) > S_{dc} > S_{AC}(FW\,Vr) > S_{AC}(HW\,Vr)$

|← Electronic DC Voltmeters (Amplifier Type) ⟶|← Electro-mechanical conventional DC voltmeter ←| Electronics AC voltmeter (Rectifier type) ⟶|

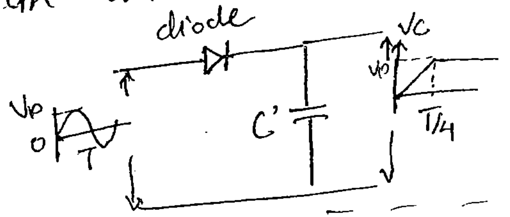
They are designed like amplifier - rectifier type or rectifier-amplifier type.

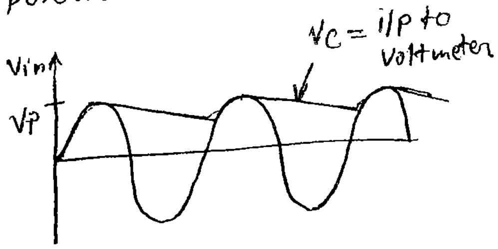
5. Peak responding Voltmeter :-

A peak volt meter consist of a peak detector circuit whose o/p is fed to PMMC & scale calibreated to read r.m.s voltage of input (sinusoidal only)

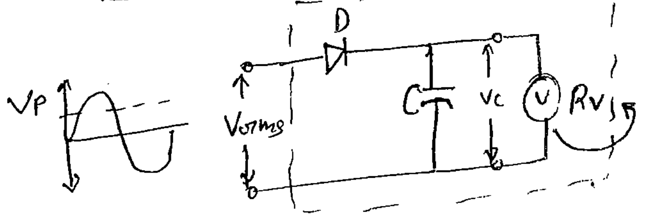
* Peak detector

Introduce a PMMC instrument voltmeter accross the capacitor (which provide discharge path)

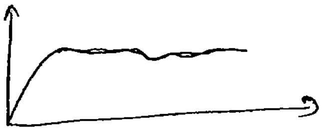




*



* The moving coil voltmeter connected accross capacitor measure average value of its input i.e Vc



∴ Measured average value = Peak value

i.e. $V_{dc} = V_p$

between Peak to peak capacitor gets discharge & then charge Rv & C Providing ~~di~~ charging path & C & Rv provide discharge path

$$\boxed{\text{Measured avg value} = \text{Peak value}}$$

* Objective of Peak voltmeter design ⇒

$$V_{rms} = \frac{1}{\sqrt{2}} V_p$$

Response of Moving coil voltmeter ⇒ $V_{dc} = V_p$

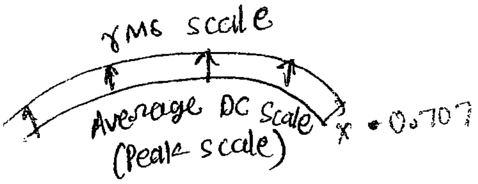
Average response itself Peak response

* relation

$$\boxed{V_{rms} = \frac{1}{\sqrt{2}} V_p}$$

where $V_p = V_{dc}$

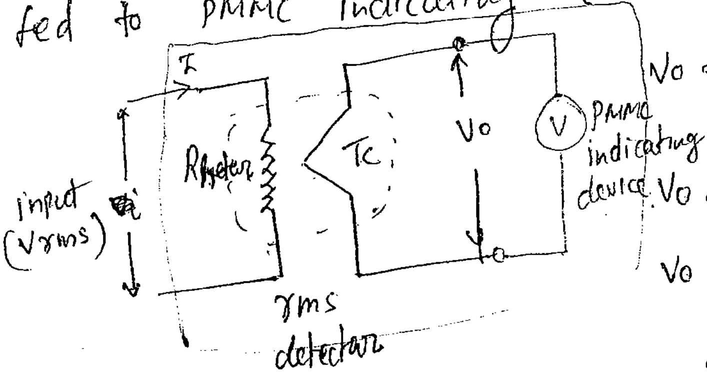
$$\Rightarrow \boxed{V_{rms} = 0.707 V_P}$$



- * At peak voltmeter is a peak responding, rms indicating voltmeter having linear r.m.s scale & works for both ac & dc
- * It is derived r.m.s meter
- * Gives no error for sinusoidal i/p but introduces error for non sinusoidal i/p i.e a peak voltmeter is prone to waveform error
- * Range of frequency is audio frequency
- * Reading of peak voltmeter for any given input is 0.707 times of Vdc i.e 0.707 of Vp

5. Thermocouple Type voltmeter :-

DC voltmeter consist of an rms detector whose o/p is fed to PMMC indicating device.



V_o = conact potential is a func^n of rise in Junc^n temp

$V_o \propto$ rise in Junc^n. temp

$V_o \propto$ Power delevered to Rheater.

$\propto I_{rms}^2 \cdot R_{heater}$

$\propto \frac{V_{rms}^2}{R_{heater}}$

* PMMC deflection $\theta \propto V_o$

$\Rightarrow \theta \propto V_{rms}^2$

$\Rightarrow \boxed{\theta = k V_{rms}^2}$ → Perfect square law

30/11

Since K is ~~Pow~~ perfect const that depends on distance betwn Rheater & T.C type of metals used in T.C

$V_{rms} = 1.11\ V_{dc}$

$V_{rms} = 0.707\ V_P$

- A thermocuple instrument is a true R.M.S meter since it follows perfect square law
- It measure true RMS value of i/p irrespective of shape & nature.
- The scale of thermocouple instrument is a perfect non linear scale. since it is designed from pefect square law
- Thermocupled instrument using heating effect of ~~inst~~ current as such it can be used for measurement at very high frequncy (radio frequency)
- A Thermocouple instrument is a true rms measuring, true rms indicating meter with non linear scale. & work for both dc & ac.
- Wave form errors are not present by using thermocouple instrument

① loading effects is poy due to instrument having ---

(a) high i/p in ~~instrument~~ resistance.

(b) low full scale voltage.

(c) Low sensitivity ✓

(d) None

② The i/p stage of an electronic voltmeter consist of ----

(a) UJT (b) FET ✓ (c) SCR ~~se~~ (D) BJT

③ Identify the voltmeter that required an external supply for

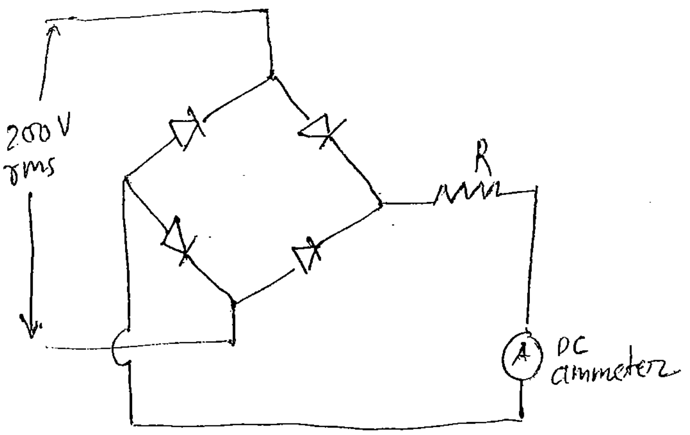
(a) Moving coil (b) M.I.V (c) ~~MIV~~ T.C V (d) Amplifier Type ✓

④ Identify the decreasing order of voltmeter in terms of there sensitivity

(1) A 1000 Ω/V dc voltmeter
(2) Half wave rectifier type ac voltmeter
(3) FET i/p voltmeter
(4) Bridge rectifier type ac voltmeter

Ans ⇒ 3, 1, 4, 2

Que :- In a rectifier voltmeter shown below, the ammeter used as full scale calibrating of 25 mA. The internal resistance of the ammeter is 100 Ω each diode has f/w resistance of 500 Ω & an infinite r/w resistance then the value of R is ....



(a) 7.1 kΩ
(b) 7.9 kΩ
✓(c) 6.1 kΩ
(d) 6.9 kΩ

$I_{MFSD} = 25 mA$ $\qquad V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{200}{\text{[illegible]}}$ V.

$R_{in} = 100 \Omega$ $\qquad R_d = 500$

$$R_{se} = \frac{0.9 \, V_{rms FSD}}{I_{dC Fsd}} - 2R_d - R_m$$

$$= \frac{0.9 \times 200}{25 \times 10^{-3}} - 2(500) - 100 \Omega$$

$$= 7.2 k\Omega - 1000 - 100 \Omega$$

$$= 7.2 k\Omega - 1.1 k\Omega$$

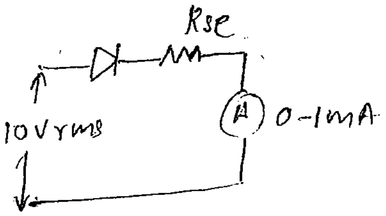
$$= 6.1 k\Omega$$

Que:- 0-1 mA Ammeter having internal resistance of 100 Ω is to used in 10 V AC range, with the help of Half wave rectifier assume diodes are ideal the value of Rse is ....

$R_{se} = 0.45 \times \frac{10}{1 \times 10^{-3}} - 100$

$= 4.5k\Omega - 100$

$= 4.4 K\Omega$



Que. A rectifier type AC voltmeter has dc sensitivity of 10kΩ/V. Then its i/p resistance in 10V ac range is .....
(a) 100kΩ (b) 4.5kΩ (c) 9kΩ (d) 90kΩ.

$S_{ac} = \frac{R_V}{V_{rms}}$, $S_{AC} = 0.9\, S_{dc}$

$V_{dc} = 10 \frac{\cancel{k}V}{\Omega}$, $V_{rms} = 10V.$

~~Rse~~ ~~2Fd~~ = AC sensitivity × AC volt range

$R_{V(FW)} = 0.9\, S_{dc} \times 10$

$= 0.90 \cancel{k} \times 10 \frac{K\Omega}{V} \times 10$

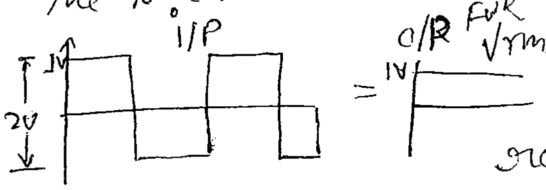
$= 90 K\Omega$

Que Loading error is pre dominant in ---
(a) DC measurement (b) AC (c) both AC & DC (d) None

10, 20S

Que :- A rectifier type ac voltmeter is used to measure a symmetrical square wave voltage with zero mean the peak to peak amplitude of square wave is 2Ω.
(a) Then the voltmeter indicate ----
(b) The % error Introduce into the reading is .....

Soln :-



FVR V_{rms} (true) = V_m
= 1V

reading = 1.11 Vdc

Vdc = avg value of o/p of full wave rectifier

reading of FWR $V_r = \frac{\pi}{2\sqrt{2}} V_{dc}$ or 1.11 Vdc.

Vdc = 1V

$V_r = 1.11 \times 1V\cancel{dc}$
$= 1.11\,V = V_{rms}$ (ind)

error = $V_{rms}(true) - V_{rms}$

$= 1.11V - 1V$

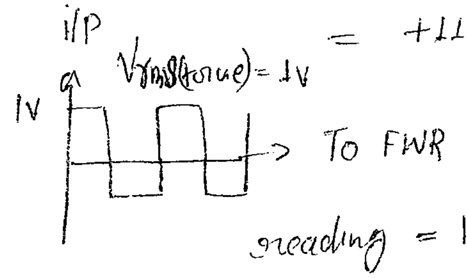
$= +0.11 V$

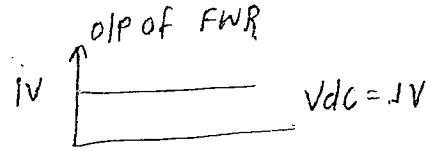
% error in reading $= \frac{1.11 - 1}{1} \times 100\%$

$= \frac{+0.11}{1} \times 100\%$

$= +11\%$

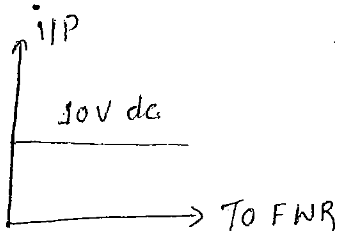
Note :-

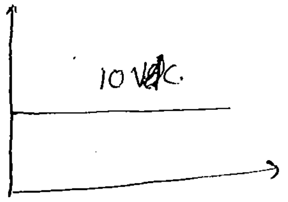




reading $= 1.11 \times 1V = 1.11 V$

Que :- A 10Vdc is applied ~~when~~ wave electronic voltmeter that uses FWR. Then the reading of the voltmeter is ----





reading $= 1.11 \times 10 = 11.1 V$.

error $= 11.1 - 10 = 1.1 V$

% error = 11%

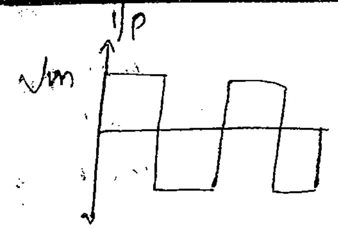
Que :- An electronic avg measuring voltmeter whose scale is calculated to read RMS value of sinusoidal waveform uses a half wave rectifier. when used to measured symmetrical square wave with zero mean it indicate 24 volts then the actual rms of the input is - - -

(a) $\frac{24\sqrt{2}}{\pi}$ V (b) $\frac{48\pi}{\sqrt{2}}$ V (c) $\frac{24\pi}{\sqrt{2}}$ V (d) $\frac{48\sqrt{2}}{\pi}$ V

for Half wave rectifier

$= 2.2 V_{dc} = \frac{24}{2.2} = 10.90$ Volt

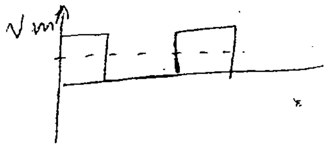
~~2.22 × 10.90~~ =



FWR

$V_{rms}(true) = ?$
$= V_m$

$rdg = 2.22\ V_{dc}$
$24V = \pi/\sqrt{2}\ V_{dc}$
$V_{dc} = \frac{24\sqrt{2}}{\pi}$ V FWR



o/p of HWR

$V_{rdg} = 2.22\ V_{dc}$
$rdg = \pi/\sqrt{2} \times V_{dc}$
$24V = \frac{\pi}{\sqrt{2}} \times \frac{V_m}{2}$
$\therefore V_m = \frac{48\sqrt{2}}{\pi}$ V
= actual rms of i/p square wave

A direct voltage is applied to a peak voltmeter which read 45 volts. Then the value of applied voltage is ....

$V_{dc} = 0.707\ V_p$
$45 = 0.707 \times V_p$
$V_p = \frac{45}{0.707} = 63.65$ Volt

~~Q meter~~

If i/p ~~to~~ to rectifier volt is 1+1 sin t
$\underline{1} + \sin 314t$

$$\sqrt{1^2 + (1/\sqrt{2})^2} = \sqrt{\frac{3}{2}}\ \text{Volt}$$

Q-meter :- * Q-meter stands for quality factor meter which is series RLC ckt. As such the principle of operation behind the ~~to~~ working of Q-meter is series resonance.

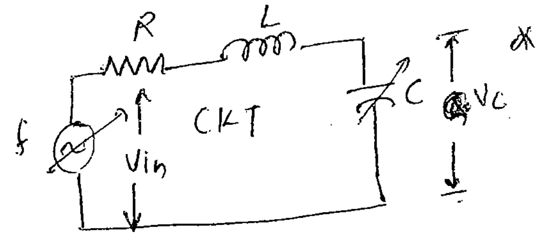
* There are 3 types of connection of Q meter
  1. direct connection
  2. Series connection
  3. Shunt or parallel connection

* Direct connection is used for measurement of electrical properties of a given test coil like
  True Q of coil (Q-coil)
  self inductance of coil (L)
  self capacitance (or) distributed capacitance of coil (Cd)
  Becasuse there is calibrated Q scale & it is not quanty ~~b~~ but it is property.

* In series connection element are connected in series & is used for measurement of low impedance.

* In shunt connection element are connected in parallel & is used for measurement of high impedance.

Properties of series RLC ckt "at resonance"



* resonance condn

$$X_L = X_C \quad , \omega L = \frac{1}{\omega C}$$

$$2\pi f L = \frac{1}{2\pi f C}$$

To resonant fixed frequency as vary capacitance

i.e fix frequency as f_x

$$2\pi f_x L \neq \frac{1}{2\pi f_x C}$$

vary C.

At C_x : $2\pi f_x L = \frac{1}{2\pi f_x C_x}$

(1) resonant frequency

$$f_x = \frac{1}{2\pi\sqrt{LC_x}}$$

(2) Impedance of the ckt

$$Z = R + J\left(\omega L - \frac{1}{\omega C_x}\right)$$

If inductive reactance = inductive capacitance

$$\boxed{Z = R}$$

(3) At resonant voltage accross capacitor:

$$V_{Cx} = I X_C$$

$$V_{Cx} = \frac{V_{in}}{Z} \times X_C$$

$$V_{Cx} = \left[\frac{X_C}{R}\right] V_{in}$$

here $\boxed{Q = \frac{X_C}{R}}$

$$V_{Cx} = Q \; V_{in}$$

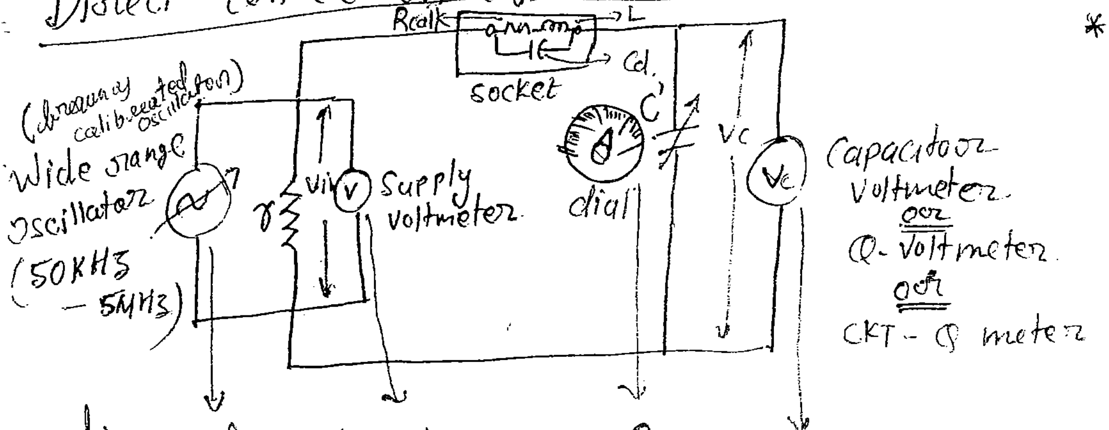
$$\boxed{V_{Cmax} = Q \cdot V_{in}}$$

* At resonance the series RLC ckt behaves as "voltage magnifier" i.e the oscillatory voltage injected into ckt is magnified by Q.-times & appears accross the capacitor.

∴ At resonance voltage accross capacitor is max^m.

(Note:- ideal behind Q-meter design } $Q = \frac{V_{Cmax}}{V_{in}}$)

Direct connection of Q-meter ⇒



Capacitor voltmeter or Q-voltmeter or CKT-Q meter

* Very High frequency we used Thermocoupled voltmeter.

$$\boxed{Q = \frac{1}{V_{in}} \times V_{cmax}}$$

readings- frequency (f), Vin ; C ; Vc or Qckt

→ Introduce the test coil into socket & resonent

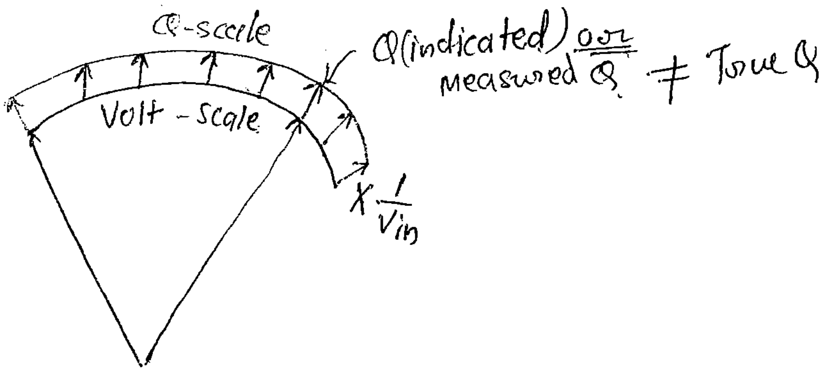
↳ F_{fix} & Vin , Vary capacitance till capacitor voltmeter show maxm deflection

Note down the reading f ⇒ resonant frequency, Vin. C, Vcmax

$$\therefore Q = \frac{V_{cmax}}{V_{in}}$$

$$= \frac{\text{capacitor Voltmeter reading}}{\text{supply-voltmeter reading}}$$

* To avoid such calculation the designer provides a Q-scale callibrated from voltage scale of capacitor Voltmeter



* Source must be occurating high stability

* Capacitive voltmeter is also known as Q voltmeter (Measured Q)

$$Q_{true} = \frac{\omega L}{R_{coil}} \text{ or } \frac{1}{\omega C R} = Q\ coil$$

But

$$Q_{meas} = \frac{\omega h}{R_{coil} + r} \text{ or } \frac{1}{\omega (C + Cd)(R_{coil} + r)}$$

* Measured Q ≠ True Q

* The indicated Q i.e measured Q by Q-voltmeter is not the true Q of the coil but it is entire ckt Q.

Error in Q measurement :- * Measured Q is always less than true Q because of two error occure namely are r & Cd

r = Insertion resistance or shunt resistance (Rsh)
= 0.02 Ω

Cd = self capacitance or distributed capacitance of coil

$$\boxed{\%\ \text{error} = \frac{Q_{measure} - Q_{true}}{Q_{true}} \times 100\ \%}$$

$$\boxed{\text{error} = Q_{measure} - Q_{true}}$$

Note :- (1) True Q is actual coil Q or coil Q.
(2) Measured Q is indicated Q is observed-Q is circuit-Q

* Error in Q meter due to 'r'

$$Q_{meas} = \frac{\omega L}{R_{coil} + r}$$

$$Q_{true} = \frac{\omega L}{R_{coil}}$$

$$* \boxed{\text{error} = Q_{meas} - Q_{true} = \frac{\omega L}{R_{coil} + r} - \frac{\omega L}{R_{coil}}}.$$

$$\boxed{\%\ \text{error} = \frac{\frac{\omega L}{R_{coil} + r} - \frac{\omega L}{R_{coil}}}{\frac{\omega L}{R_{coil}}} \times 100}$$

$$* \boxed{\begin{array}{c}\%\ \text{error} \\ (\text{due to } r)\end{array} = \frac{-r}{R_{coil} + r} \times 100\ \%}$$

* Correction factor :-

$$\frac{Q_{true}}{Q_{measure}} = \frac{\frac{\cancel{\omega L}}{R_{coil}}}{\frac{\cancel{\omega L}}{R_{coil} + r}} = \frac{R_{coil} + r}{R_{coil}}.$$

$$\boxed{Q_{true} = \underset{\downarrow}{Q_{meas}} \underbrace{\left[\frac{R_{coil} + r}{R_{coil}}\right]}_{K_r}}$$

- In general error in Q - measurement due to r can be neglected since r << Rcoil

(*) Error in Q measurement due to "Cd"

- $$Q_{meas} = \frac{1}{\omega(C+C_d)(R_{coil}+r)}$$

$$\cong \frac{1}{\omega(C+C_d)R_{coil}} \quad (\because r << R_{coil})$$

$$Q_{true} = \frac{1}{\omega C R_{coil}}$$

$$\text{error} = Q_{meas} - Q_{true}$$

$$= \frac{1}{\omega(C+C_d)(R_{coil}+r)} - \frac{1}{\omega C R_{coil}}$$

$$\% \text{ error} = \frac{\frac{1}{\omega(C+C_d)(R_{coil}+r)} - \frac{1}{\omega C R_{coil}}}{\frac{1}{\omega C R_{coil}}} \times 100$$

$$\boxed{\underset{(\text{due to } C_d)}{\% \text{ error}} = \frac{-C_d}{C+C_d} \times 100\,\%}$$

↓ resonating capacitance

- Correction factor $= \frac{Q_{true}}{Q_{meas}}$

$$\frac{Q_{true}}{Q_{measure}} = \frac{\frac{1}{\omega C R_{coil}}}{\frac{1}{\omega(C+C_d)R_{coil}}}$$

$$\frac{Q_{true}}{Q_{measure}} = \frac{C+C_d}{C}$$

$$\boxed{Q_{true} = Q_{measu}\left(1+\frac{C_d}{C}\right)}$$

Where Q_{true} = coil Q (?)

Q_{measu} = Q - voltmeter reading

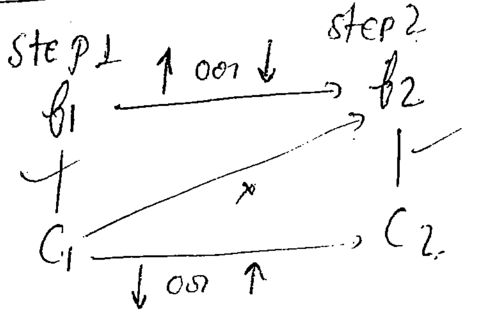
C = tuning or resonating capacitance

Cd = self capactance of coil (?)

Note:- To get the value Qtrue of coil, Cd must be known. Therefore measure Cd first.

① Measurement of Cd of coil (shunt capacitance)

* Introduce a test coil into socket of Q-meter & resonant twice at f_1 for first coil & f_2 for second coil.



Note down reading in both steps

* step ① readings : frequency f_1, Vin, C_1, Q_1, V_{C1}

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+Cd)}} \quad — ①$$

$$V_{C_1} = Q_1 \, Vin$$

step ② readings ; f_2, Vin, C_2, Q_2, V_{C2}

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2+Cd)}} \quad — ②$$

$$V_{C_2} = Q_2 \, Vin$$

$\therefore f_2 = n f_1$

$$\frac{eq^n ①}{eq^n ②} = \frac{f_1}{f_2} = \frac{1/2\pi\sqrt{L(C_1+Cd)}}{1/2\pi\sqrt{L(C_2+Cd)}}$$

$$\frac{\cancel{f_1}}{n\cancel{f_1}} = \sqrt{\frac{\cancel{L}(C_2+Cd)}{\cancel{L}(C_1+Cd)}}$$

Squaring both side

$$\frac{1}{n^2} = \frac{C_2 + C_d}{C_1 + C_d}$$

$$n^2 C_2 + n^2 C_d = C_1 + C_d$$

$$n^2 C_d - C_d = C_1 - C_2 n^2$$

$$\boxed{C_d = \frac{C_1 - C_2 n^2}{n^2 - 1}}$$

② Measurement of "L of coil"

* first measured 'Cd' of coil

Then we know $f = \frac{1}{2\pi\sqrt{L(C+C_d)}}$

$$f^2 = \frac{1}{4\pi^2 L(C+C_d)}$$

$$\boxed{L = \frac{1}{(2\pi f)^2 [C+C_d]}}$$

$$\boxed{L = \frac{1}{\omega^2 [C+C_d]}}$$

* Use either step ① reading = f_1, C_1

or step ② reading = f_2, C_2

To measure 'L of coil'

$$L = \frac{1}{(2\pi f_1)^2 (C_1 + C_d)}$$ or

$$L = \frac{1}{(2\pi f_2)^2 (C_1 + C_d)}$$

⑤ Measurement of Q true of coil

- First measure Cd of coil'
- Then we know $\boxed{Q_{true} = Q_{measu}\left(1 + C_d/C\right)}$
- Use either step ① reading ;- Q_1 , C_1
  or step ② reading Q_2 , C_2

along with Cd
to measure 'true Q of coil'

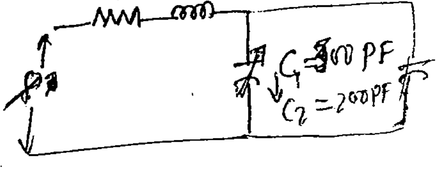
$$Q_{true} = Q_1\left(1 + \frac{C_d}{C_1}\right) \quad \underline{or}$$

$$Q_{true} = Q_2\left(1 + \frac{C_d}{C_2}\right)$$

1/8/2021

<u>Que</u> :- A Reading of 120 is obtained when a stranded conductor is connected to the ckt of Q meter & the variable capacitor is adjusted to a value 300 PF a loss less capacitor Cx is then connected in parallel with variable capacitor & same reading was obtained where the variable capacitor is read just ~~one~~ ~~straight~~ to a value of 200 PF the value of Cx = - - -

① 200 PF ② 120 PF ③ 100 PF (d) 50 PF



$$Q_1 = \frac{1}{\omega C_1 R} = 120$$

$$Q_2 = \frac{1}{\omega (C_2 + C_x) R} = 120$$

$$\therefore Q_1 = Q_2$$

$$\frac{1}{\cancel{\omega} C_1 \cancel{R}} = \frac{1}{\cancel{\omega}(C_2 + C_x)\cancel{R}}$$

$$C_1 = C_2 + C_x$$

$$300\,PF = 200\,pF + C_x$$

$$C_x = 100\,PF$$

Que:- A coil is tested with a q meter under selfcapacitance of coil is found to be 820 PF. Resonance has occured at a frequency of 10^6 rad/sec with a capacitance of 9.18 nf. Then the self inductance of coil ---

(a) 100mH (b) 100 H (c) 150 μH (d) 100 μH

$$L = \frac{1}{\omega^2 (C + Cd)}$$

$$= \frac{1}{(10^6)^2 (820 \times 10^{-12} + 9.18 \times 10^{-9})}$$

$$= \underline{100 \mu H}$$

Note

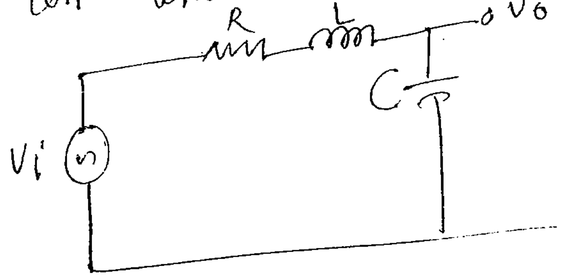
% error in Q $= \frac{-Cd}{C + Cd} \times 100\%$

Que:- A Q meter is supply with an oscillator having 500mV o/p voltage by testing an unknown coil reading of Q voltmeter is 10 volt then Q factor of coil is ---

Soln:- $Q = \frac{V_{Cmax}}{V_{in}} = \frac{10V}{500\,mV} = 20$

2005

Que:- The ckt shown in below fig the Q factor of the coil whose resistance R & inductance L is



(a) $\frac{V_1 - V_0}{V_1}$

(b) $\frac{V_0}{V_i}$

(c) $\frac{V_0 - V_1}{V_0}$

(d) $\frac{V_1}{V_0}$

ue:- A coil is to resonance at 500 KHz with resenant capacitance 360 PF. when the freancy is orised to 1 MHz resomacy obtained at 72 PF. Then the self C of coil is -----
(Also self inductance of coil)

Soln:-

$$\begin{tikzcd}
500\,KHz \arrow[r, "\uparrow", "Cd=?"'] \arrow[d] & 360\,PF \arrow[d, dash] \\
100\,KHz \arrow[r, "L=?", "\downarrow"'] & 72\,PF
\end{tikzcd}$$

$$n = \frac{1\,MHz}{300\,KHz} \Rightarrow 2$$

$$C_d = \frac{360\,PF - (2)^2 72\,PF}{(2)^2 - 1}$$

$$Cd = \frac{360\,PF - 288\,PF}{4 - 1}$$

$$Cd = 24\,PF$$

Que:- A coils chords to resonance at 500 KHz with a resonating capacity of 36[illegible] PF at 250 KHz the resonance is obtained with a resonating capacity of coil is ---- 160 PF then distributed capacitance iob

Soln:- $n = \frac{250\,KHz}{500\,KHz} = \frac{1}{2}$

$$Cd = \frac{36\,PF - (\frac{1}{2})^2 160}{(\frac{1}{2})^2 - 1}$$

$$Cd = \frac{36\,PF - 40}{\frac{1}{4} - 1}$$

$$Cd = 5.33\,PF$$

Que :- A coil with a resistance of 10 Ω is connected in a direct measurement mode of Q meter resonance occur with oscillator frequency 1MHz & resonating capacity set as 65 PF Then the magnitude of ~~perse~~ % Error introduced in meas of Q by insuffient resistance 0.02Ω is - -

Soln :-

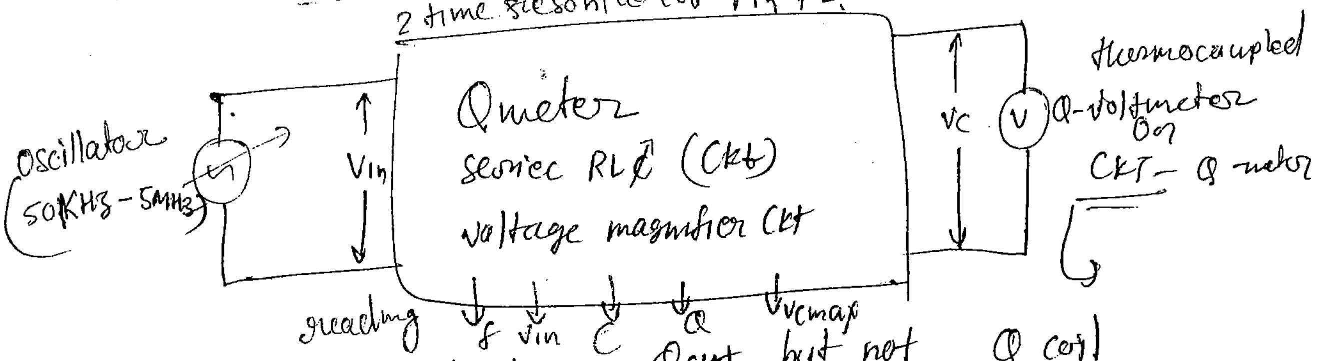
$$\frac{-r}{r+R_{coil}} \times 100\%$$

$$\frac{-0.02\Omega}{10.02\Omega} \times 100\%$$

$$-0.2\%$$

Que :- Principle of operation behind the work of Q met

→ series resonance



* Indicates Qckt but not Q coil becoz of 2 error s : r & Cd.

* With respect to r

$$\frac{Q_{measu}}{Q_{true}} = 1 + \frac{r}{R_{coil}}$$

$$\%\ error = \frac{-r}{r+R_{coil}} \times 100\% \longrightarrow \text{negligible } (\because r << R_{ckt})$$

* With respect to Cd

$$\frac{Q_{true}}{Q_{measu}} = 1 + \frac{C_d}{C}$$

* % error $= \dfrac{-Cd}{Cd+C} \times 100\%$

$$\boxed{\begin{aligned} f &= \frac{1}{2\pi\sqrt{L(C+Cd)}} \\ Q &= \frac{V_{cmax}}{V_{in}} \end{aligned}}$$

asured
ing
ect
rrion

① $Cd = \dfrac{C_1 - n^2 C_2}{n^2 - 1}$; $n = \dfrac{f_2}{f_1}$

② $L = \dfrac{1}{\omega^2 (C+Cd)}$

③ $Q_{true} = Q_{measure} \left(1 + Cd/C\right)$

Que.-- Explain working of Q meter. To find the self capacitance of coil the Q meter the resonance was obtain with
(1) Tunning capacitor of 1530 PF at 1 MHz
(2) Tunning capacitor of 162 PF at 3 MHz
what is the value of self capacitance

Soln Given data, Tunning capacitor $f_1 = 1 MHz$, $C_1 = 1530 PF$
$f_2 = 3 MHz$, $C_2 = 162 PF$
We know $Cd = \dfrac{C_1 - n^2 C_2}{n^2 - 1}$, $n = \dfrac{f_2}{f_1} = \dfrac{3}{1} = 3$

$$Cd = \frac{1530 PF - (3)^2 \times 162 PF}{3^2 - 1} = 9 PF$$

Resolution of DVM :-

* The smallest possible incremental change allowable in the i/p is known as resolution of DVM

$$\text{resolution} = \frac{1}{10^N} \dashrightarrow \text{scale resolution}$$

where N total number of FULL digits

$$\left.\begin{array}{l}\text{resolution in a}\\ \text{selected voltage}\end{array}\right\} = \frac{1}{10^N} \times \text{selected volt - range}$$

(Note:- Resolution is nothing but min count)

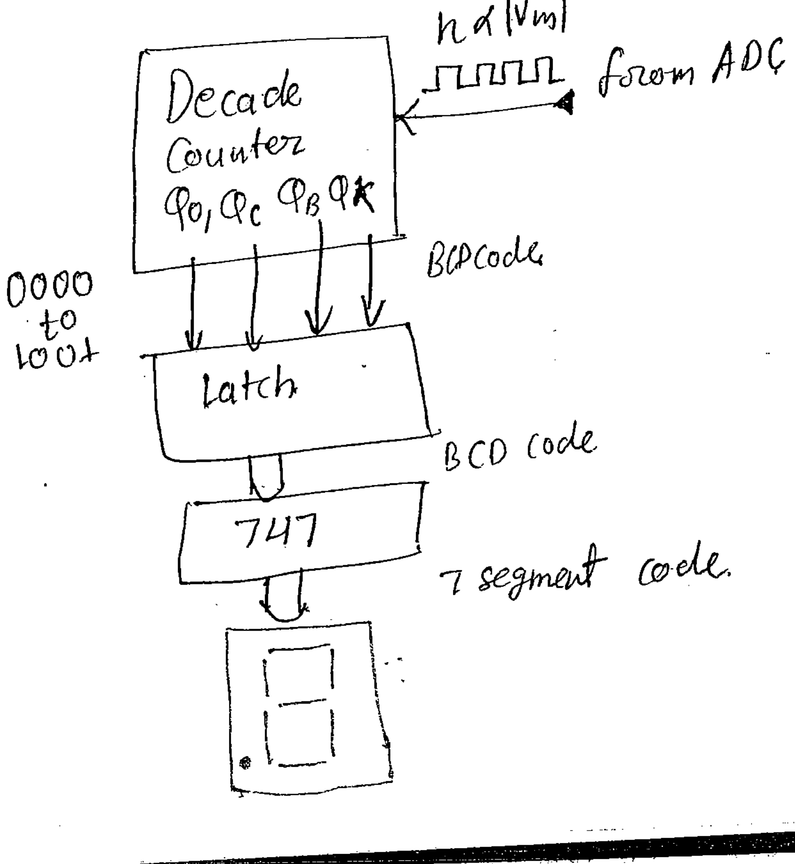
* sensitivity of DVM ⇒ The smallest voltage that can be sensed, measured & displayed in lowest voltage range. is known as sensitivity of DVM.

$$\text{Sensitivity} = \text{resolution} \times \text{lowest volt range}$$

$$= \frac{1}{10^N} \times \text{lowest Volt range}$$

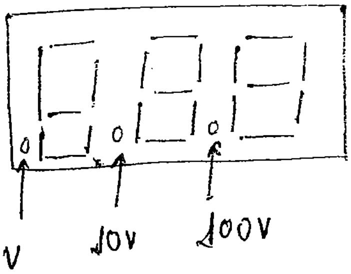
(Note:- Sensitivity is nothing but min of mins).

* FULL digit

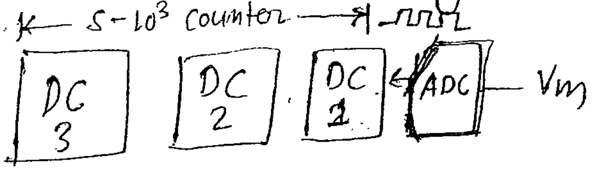


display driver

* 3.- digit DVM



* Behind the display



Dc → Decode counter

→ Count roll-over

0 0 0 = reset count

0 0 1 = Min count --- (count) (resolution)

0 0 2

⋮

0 0 9 DC2

0 1 0

0 1 1

⋮

0 9 9 DC3

1 0 0

⋮

9 9 9 = MAX count (FSR)

Counter Range

*. Count Range of 3 digit DVM

from 0 to 999

Scale = min + MAX

= 001 + 999

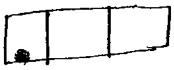
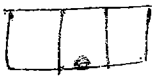
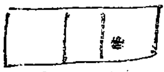
= 1000 counts

= 10^3 Couts

→ resolution of 3digit ~~count~~ DVM :-

$$r = \frac{1}{10^3} = \frac{1}{1000} = 1:1000 = 0.001 = 0.1\%$$

→

Switch Position	selected Volt range	Min Voltage	MAX Voltage
A (TOP)	0-1V range 	.001V	0.999V
B	0-10V range 	0.01V	9.99V
C (Bottom)	0-100V range 	00.1V	99.9V

1V range

Sensitivity ← .001 } 1mV
.002

10V range

0.01 } 10mV
0.02

100V range

00.1 } 100mV
00.2

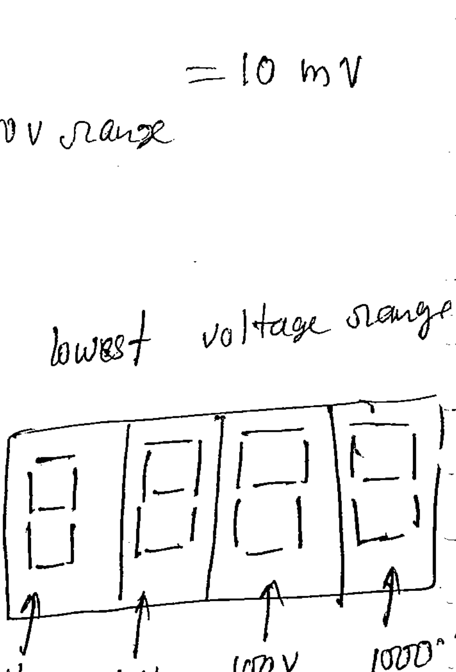
* resolution of 3 digit DVM = 0.001 = $1/10^3$
i.e known as sclale revolution

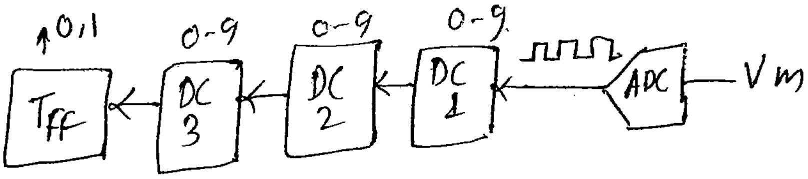
* resolution of 3 digit DVM in 1V range = $\frac{1}{10^3} \times 1V$
= 1mV

* resolution of 3 digit DVM in 10V range = $10 \times \frac{1}{10^3}$
= 10 mV

* resolution of 3 digit DVM in 100V range
= $\frac{1}{10^3} \times 100$
= 100mV

* sensitivity of 3 digit DVM in lowest voltage range of 1V is
⇒ $\frac{1}{10^3} \times 1V$ ⇒ 1mV





TFF → Toggel flip Flop

$\frac{1}{2}$ digit

* Max^{m} value the digit can show $\frac{\text{Max count}}{\text{Total count}}$ $\frac{0-3}{4}$, $\frac{0-5}{6}$

½, ¾, 5/6 digit used for stand of countrange.

* scale is going to change
* sensitivity is not to change
*

Date
07/08/2011

Extension Digit

* This digit are used for extending a count range of n digit DVM.
* specification : $\frac{X}{Y}$ digt

where X = MAX count

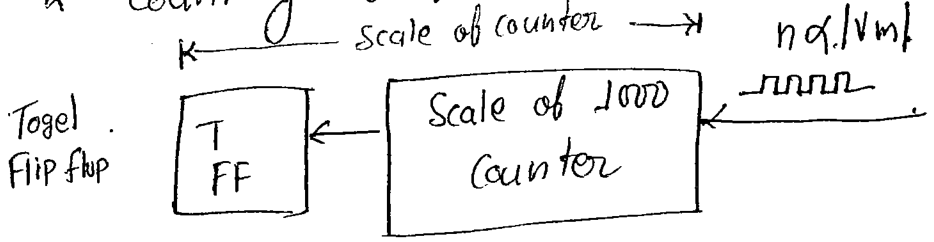
Y = Total count or scale (multiplication factor)

Available Ext digits	Count range
½ digit	→ 0, 1
¾ digit	→ 0, 1, 2, 3
5/6 digit	→ 0, 1, 2, 3, 4, 5

Note :- No decimal point for extension digit.

Ⓐ 3½ digit DVM.

* Counting unit:



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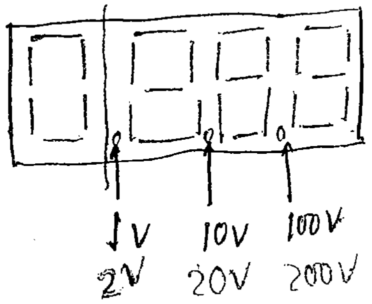


Count roll over

0 000

0 001

(½ digit)
Half digit
S/W ON
Due to flipflop

0·999

1 000

1 0 01

1 9 9 9

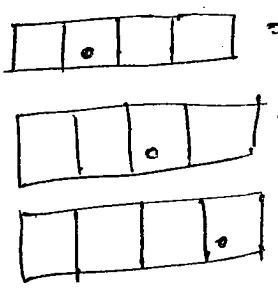
- reset count = 0
- Min count = 0001 → 1 count or resolution
- MAX count = 1999

- Scale = 0001 + 1999
  = 2,000 counts
  = 2×10^3 counts

Scale of 3½ digit DVM is 2 times of scale of 3 digit DVM

- resolution of 3½ digit DVM

$$\gamma = \frac{1}{10^3} = \frac{1}{1000} = 0.001 \text{ or } 0.1\ \%$$



	Min^m	Max^m
* 1V range ⇒	0.001V	1.999 V ⇒ 2V range
10V range ⇒	00.01V	19.99 V ⇒ 20V range
100V range ⇒	000.1V	199.9 V ⇒ 200V rang

OVER RANGING
(Due to ½ digit turn ON)

: resolution of 3½ digit ~~resolu~~ in Voltage range

* resolution of 3½ digit in 10 V range

$$= \frac{1}{2\times 10^{3}} \times 200$$

$$= 10\ mV = 0.01V$$

Resolution of 3½ digit in 100 V range

$$= \frac{1}{2\times 10^{3}} \times 200$$

$$= \frac{1}{10} = 100\ mV$$

$$= 000.1\ V$$

* Note:- * Because of extension digits resolution & sensiti are not alter whereas the scale will extend
  * The scale of n ½ digit DVM is 2 times of scale of n DVM
* Similarly the n ¾ digit DVM is 4 times of scale n digit DVM
  * n 5/6 digit DVM is 6 times of scale of n digit DVM

ⓧ Types of ADCs

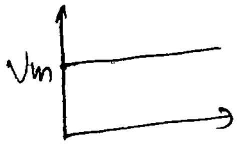
* FLASH type ⟶ Fastest ADCs
* Succesive Approx - type, * Counter type * Ramptype
* Dual slope integrating type → slowest (∵ ∫)

Decrea

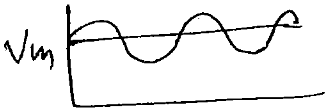
↑ conversion time $\propto \frac{1}{\text{~~time~~ speed}}$ ↓

* Flash type or simultanously or Parallel comparator type same

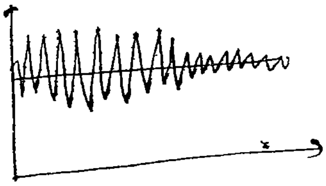
$$\frac{1}{T_0}\int_0^{T_0} V_m\, dt = \text{Avg value of } V_m.$$



$\Rightarrow V_m$



$\Rightarrow V_m$



$\Rightarrow \cong V_m$

~~Given~~ * There are two types of ADC namely Interating type (Dual slope type) & Non integrating type ADCs (Flas, succesive, counter, Ramp type)

In integrating type ADCs an integrator are present in i/p side as such the unknown analog DC to be measured ~~DC~~ V~~alue~~ ~~to~~ will be integrated for a fixed time period which gives a measurement of true avg value

As such even if there is either AC signal super imposed or noise as present on the dc voltage to be measured, errors will not be introduced into measurement i.e noise effect is supressed or eliminated. due to exsitance of Indicator Therefore Dual slop integrating type ADCs is the most widely used ADC. since it offer highest noise ~~reduction~~ rejection, highest stability & highest accuracy

* The basic principle of opertion of dual slop ~~design~~ type. design is voltage to time conversion.

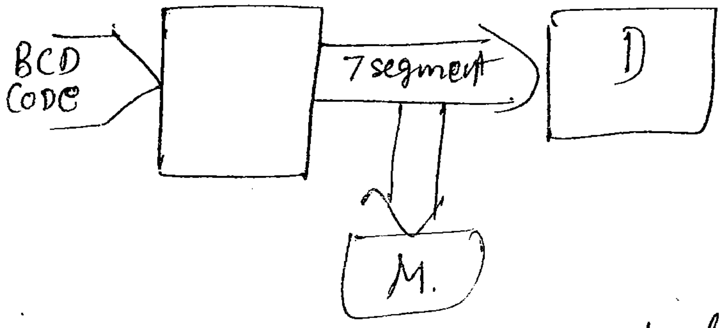
*) Advantages: of Digital Voltmeter (over analog meter)

*① The i/p resistance of a digital voltmeter ~~ust~~ is in the order of MΩ. As such loading effect on ckt under test minimized.

② DVM ~~offer~~ offer superior resolution comparative analog meter. superior resolution --- $1 : 10^6$ in order of

③ DVM offer better accuracy. in order of ~~+ or~~ − ± 0.005 %

④ The output of DVM.s is available in digital form



- * As such the reading speed of the user increases;
- * Observational · error (Parallax error) are almost eliminated
- * Further processing (storage) is make possible.

Note :- Any DVM can not present value full context of the selected voltage range.

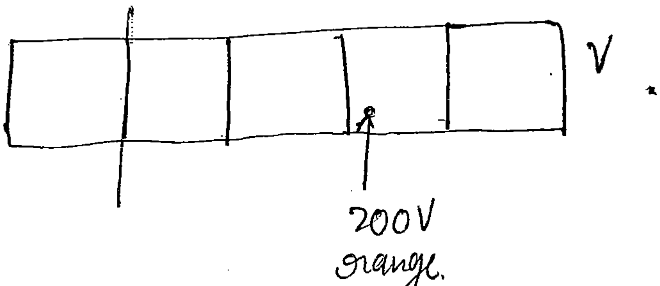
Que ① A 4½ DVM has the error specification 0.2% reading + 10 counts If a dc voltage of 100 V is read on its 200V full scale. The maxm error that can be expected in the reading.

(a) ± 0.1 % (b) ± 0.2% (c) ± 0.3% (d) ± 0.4%

Soln:- $4\frac{1}{2}$ digit DMM, 0-200 V range

reading ⇒ 100 V

Accuracy specification ⇒ 0.2 % of reading + 10 count



→ reading 100.00

→ 1 count : 000.01 V

⇒ 0.01V

∴ error = $\frac{0.2}{\cancel{100}} \times \cancel{100V} + (10 \times 0.01V)$

$\simeq 0.2 + 0.1$

$= 0.3\ V$

% error = $\pm \frac{0.3V}{100V} \times 100$ %

$= \pm 0.3\%$ Ans

Que:- A 4 digit DVM with 100 mV lowest full scale range could have a sensitivity of how much value by resolution of this DVM is 0.0001 ?

(a) 0.1 mV ✓(b) 0.01 mV (c) 1.0 mV (d) 10 mV

Soln:- 4 digit dVM or DMM, Lowest voltage range 100 mV

resolution = 0.0001

$S = \frac{1}{10^4} \times 100mV = 0.001 \times 100mA$

$= 0.01\ mV$

Que:- A digital voltmeter has a read out range from 0-9999 counts. the resolution of this instrument for full scale reading of 9.999 volts will be.

— — —

(a) 10 μV ✓(b) 1 mV (c) 100 μV (d) 10 mV

$\frac{1}{10^4} \times 9.999 = 0.9999V$

$\simeq 1\ mV$

Soln:- Given DVM has 4 digit

$FSR = \underset{10V\ range}{\underline{9}}.\underline{9}\,\underline{9}\,\underline{9}$ ⇒ resolution $= \frac{1}{10^4} \times 10V$

$= \frac{1}{10^3} = 1mV$

Que:- A digit dual slople integrating tupe d DVM reva' in its 10 V rang of operation is _____ ?

Soln:- resolution $= \frac{1}{104} \times 10^V$

$= 1 mV$ <u>Ans</u>

Que:- ~~A 4½ digit~~ A DVM has 4 ½ digit display. + 1 volt range can read upto

$\underline{1}\,.\,\underline{9}\;\underline{9}\;\underline{9}\;\underline{9}$ V

Que A voltage 0.5245 V be displayed as --- on 4½ digit d DVM in 10 volt rang

0	0	.5	2	4

V

Note:- $V_m = 0.999$ V measured by 3 digit DVM displayed as

In 1V range →

.9	9	9

V

In 10V range →

0	.9	9

In 100 V ra →

0	0	.9

Que Over ranging in DVM implies that

(a) all foubl digit are switched ON

(b) ½ digit is switched ON

(C) ½ digit is switched OFF

(d) All full digit are switched OFF

ap

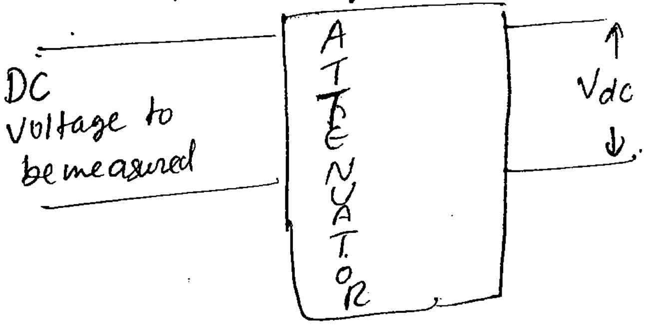
Que :- what is a range for a 4½ digital meter (counter range)

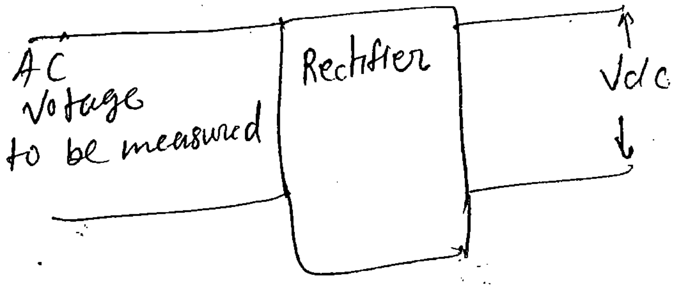
0 - 1.9999

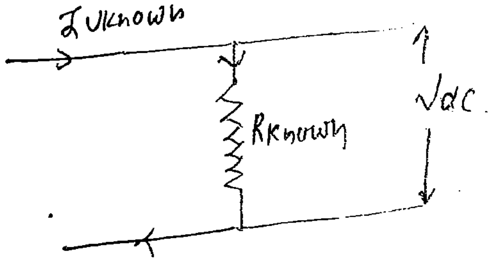
Date 09/08/2011

Multimeter :- A multimeter is used to measure dc voltage, AC voltage, dc current, ac current & resistance

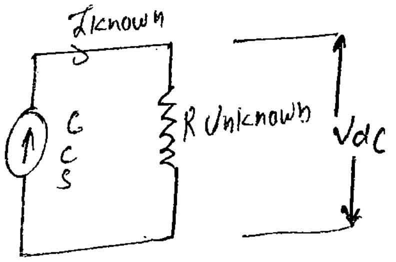
required i/p interfaces

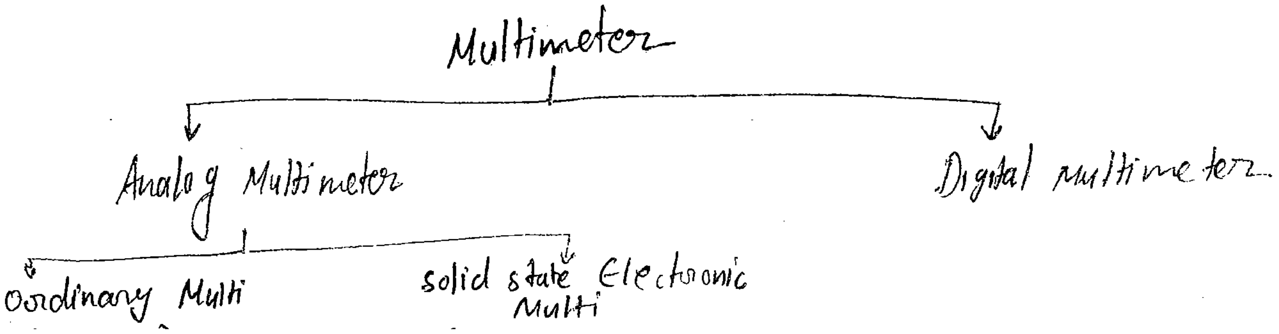






Note :-
EMM > VOM
in terms of Rv & Sv



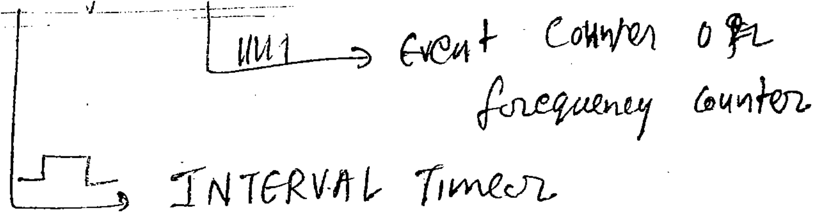


Note:- # EMM > VOM in terms of Rv & Sv

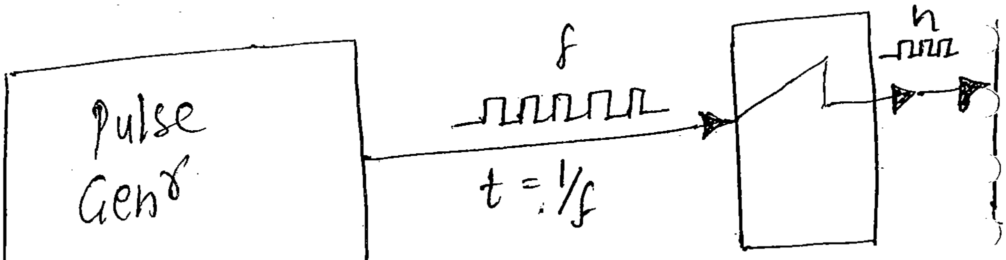
Electronic voltmeter > VOM in term of Rv & Sv

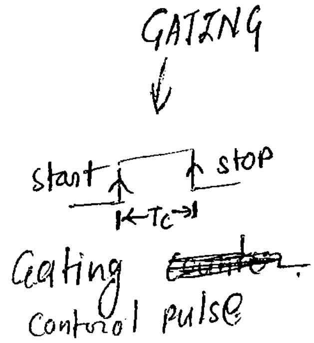
* Electronic voltmeter gives accurat oor reliable measurement than ordinary multimeter

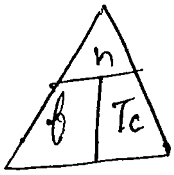
Ⓧ Electronic Timer/Counter



* This electronic measuring unit is used for measurement unknown timeperiod & unknown freauncy







* Unknown Time period measurement

$$\boxed{T_c(\text{unknown}) = \frac{n}{f_{\text{known}}}}$$

* Unknown frequency measurement

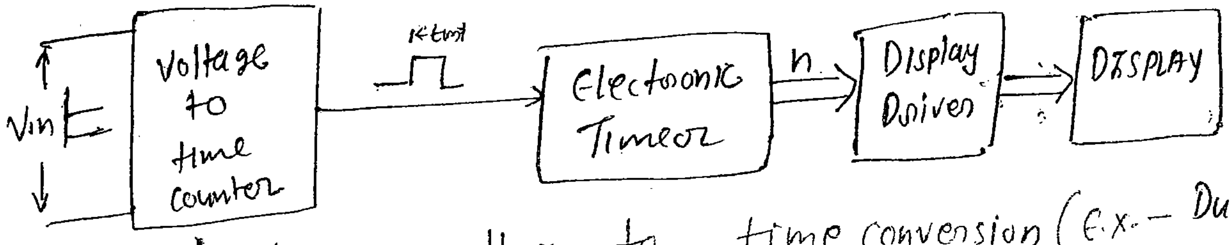
$$\boxed{f_{\text{unknown}} = \frac{n}{T_{c\,\text{known}}}}$$

Note:- * For time period measurement it is operated in periode mode whereas for freauncy measurent it is operated at count mode

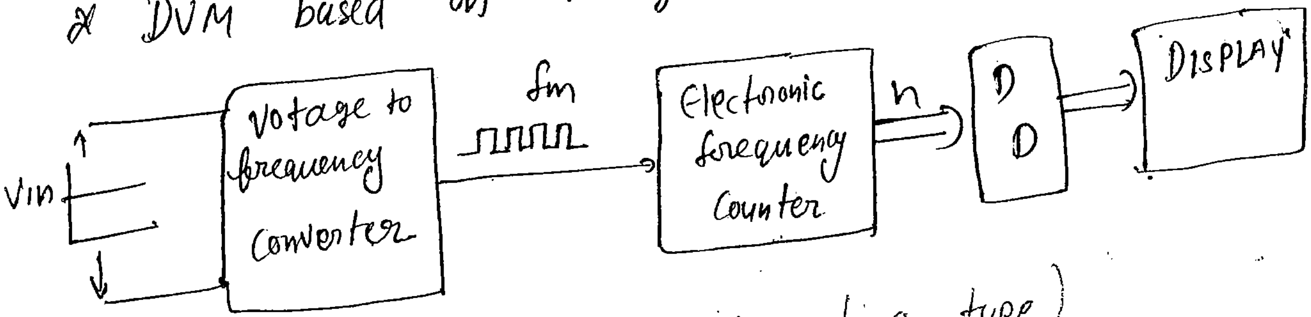
* In digital frequency meter additional i/p interface will be there like a ~~Symmetrical~~ schmit

which converts i/p waveform into pulses.

*



- DVM based on voltage to time conversion (Ex.- Dual slope integrating type, Ramp type)
- DVM based on voltage to frequency conversion.

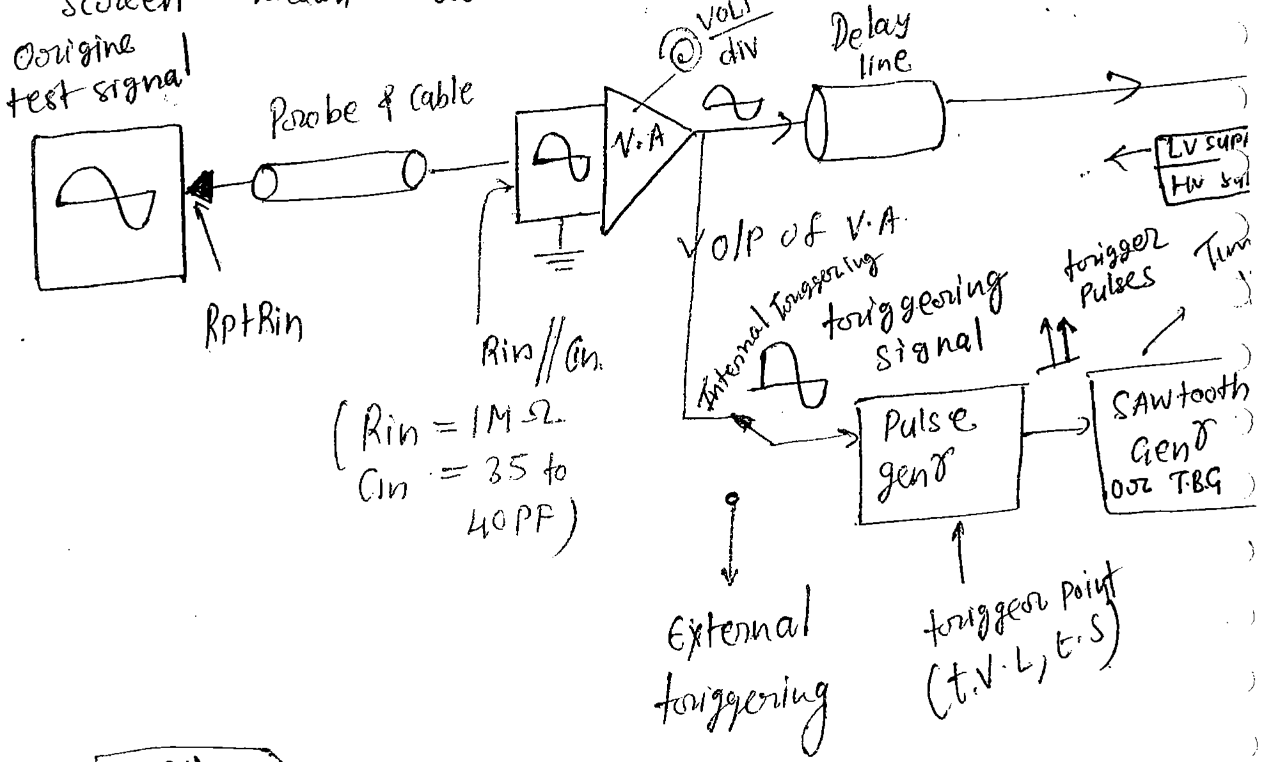


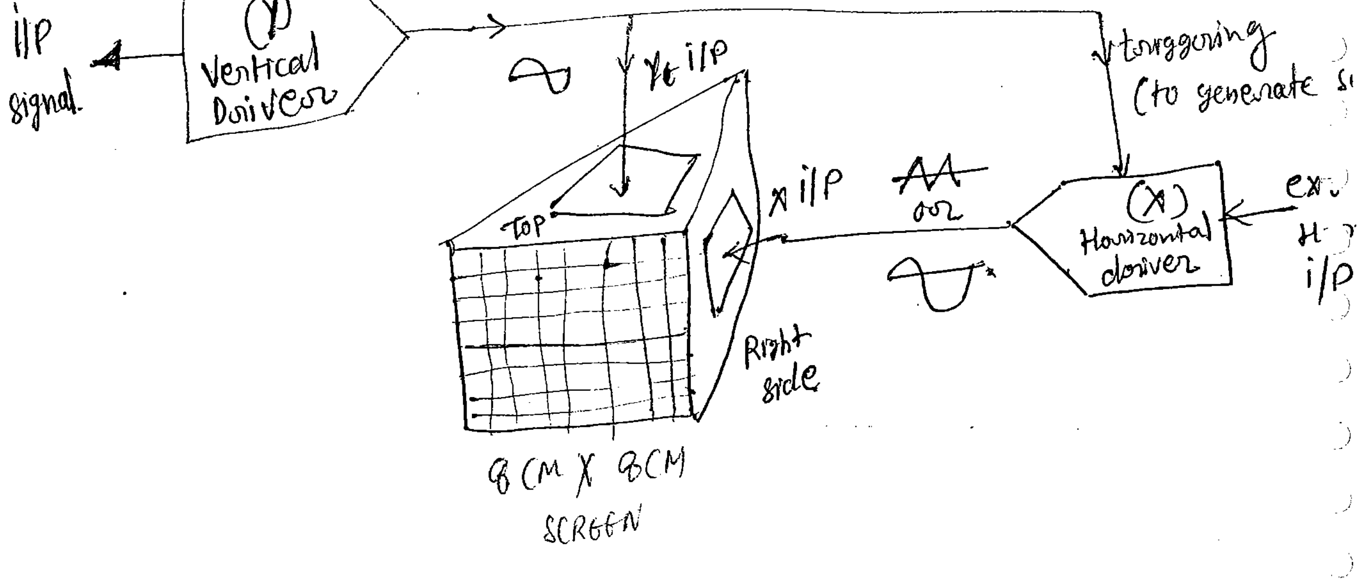
(Exs.:- single slope integrating type)

- Most widely used ADC's is Dual slope integrating type

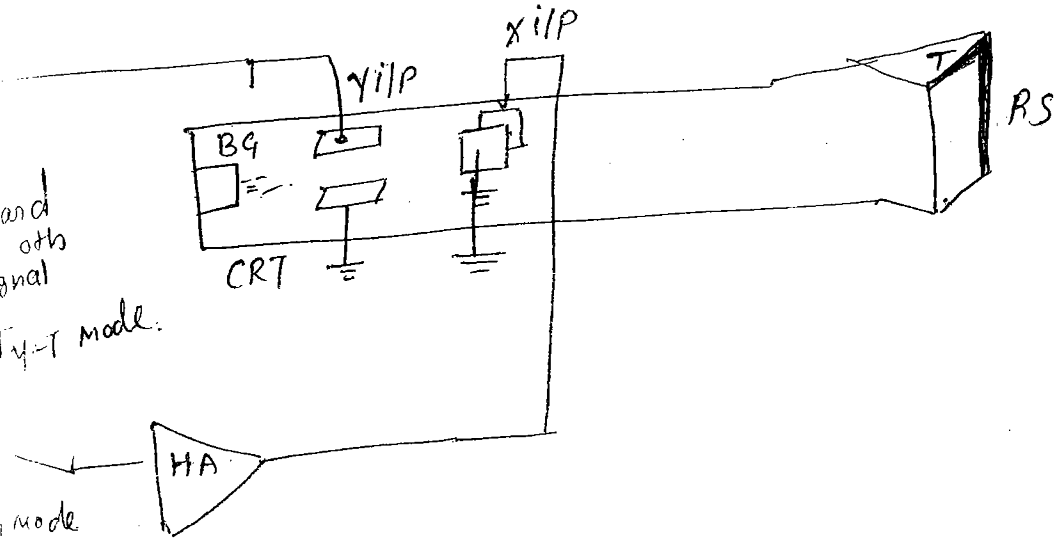
C.R.O (CATHODE RAY ~~osc~~ OCSALOSCOPE

- CRO is an electronic peak volt-meter which works for both ac & dc. There are two mode of operation for the CRO Namely (a) Yt mode & (b) XY mode.
- In Yt mode the test signal being sensed displayed on the screen known as Yt plot.
- In XY mode lesscajious figure are displayed on screen known as XY plot.





Q2



dard
oth
signal
Ty-T mode.

mode

ternal
horizontal
input
dc votage, Sine wave

- The basic bulding block of CRO are vertical system, horizontal system, display system
- The vertical system provide a path for the test signal to reach Y input of CRT whereas the horizotal system provide a path for either internal generated sweep signal or externally applied ~~signo~~ any signal to reach X input of CRT.

* CRT provide a path for electron beam generated at one end to reach its target (Florsecent screen) on the further end. As such during this travel the cathode ray beam gets deflected because of Y input voltage & X input voltage interm a tipical image will be displayed on the screen.

$$\boxed{\text{CRO = signal path + Horizontal-path + } e^- \text{ beam}}$$

* The test signal is sensed using the probe of slo & then transmitted ~~Ve~~ to vertical terminal through a cable.

* The vertical amplifier receives the test signal whe it is either attenuated ~~of~~ or amplified as th user adjust sensitivity control (Volt / Div)

* Since vertical amplifier is receiving test signal most of the feature of CRO like i/p resistan bandwidth, rise time & gain are decided by verti amplifier

* The i/p resistance of CRO will be range of M

Note :- Gain × Band width = k
risetime × Band width = 0.35)

* A delay line is inserted between the o/p of Vertical amplifier ~~under~~ & Y input of CRT which delays test sign by a time amount slightly greater then horizontal time delay. As such horizontal signal reaches to X input prior to the test signal reaches to Y input.

In internal triggering the o/p of vertical amplifier is used as triggering signal.

The triggering ckt produces a trigger pulse whenever the triggering signal coinsides the preselected triggering point (trigger voltage level, Trigger slope)

The trigger pulses emitted by the pulse genr are applied to time base genr which generates sawtooth signal upon receving each trigger pulse.

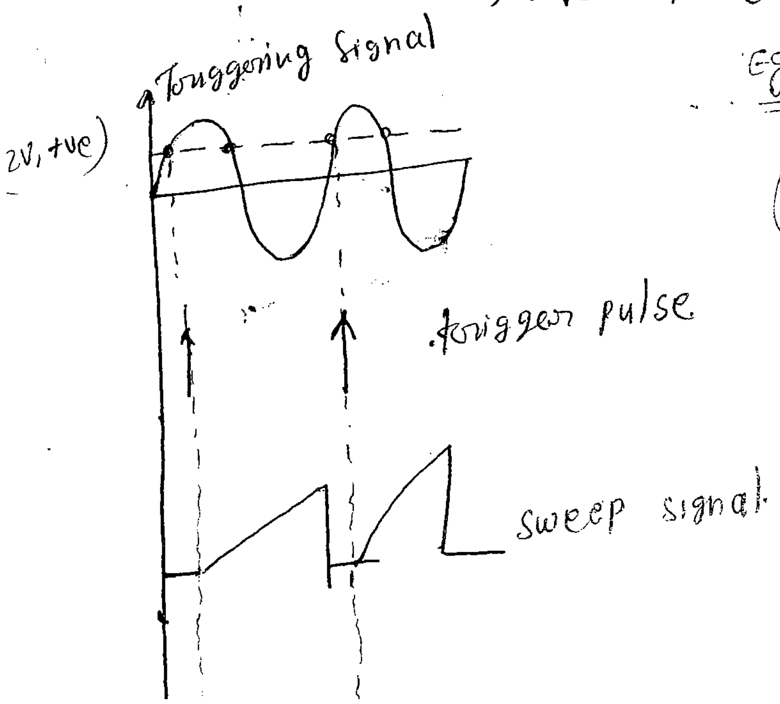
In Y-t mode the standard sweep ~~single~~ signal is applied to the Xin where as in X-Y mode any signal externally applied is driven to Xin.

The sweep frequency can be adjusted by the useor with the help of time per div control

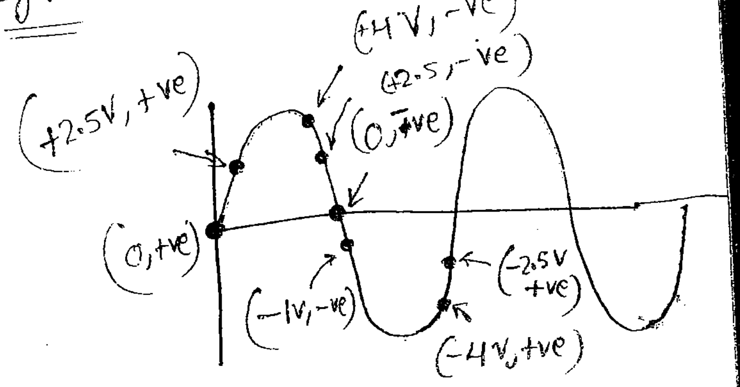
Note :-

t.v.L → +ve
→ 0
→ -ve

t.S → +ve slope (rising side i.e -ve P to +ve P)
→ -ve slope (falling side i.e +ve P to -ve P)



Eg :-

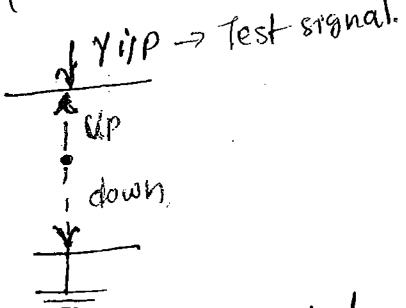


- CRT is an evacuated gas tube consisting being gen at one end & beam target at another end

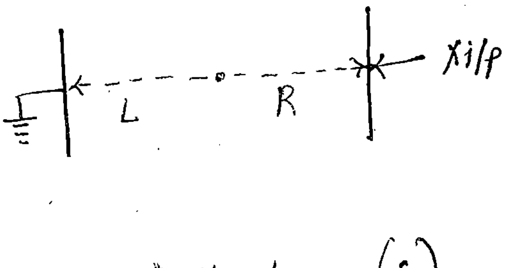
In the CRT cathode ray beam is generated, accelerated, focused in sharp beam, deflected d to Y input & X input voltages & finally strikes flourscent screen.

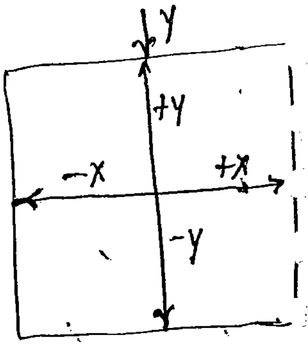
Deflection plate Assembly :-

- A total no. of 4 plate are there existing as 2 plate namely V.D.P & H.D.P.
- The V.D.P. are horizontally mounted which defelect e beam vertically (up - down direction)



- The H.D.P are vertically mounted which deflect the ē bo horizontally (right - left movement)





Deflection sensitivity :- (S)

- The amount of deflection produced per unit voltag applied to corresponding deflectiong plate. is known Delflection sensitivity.

* $\delta = \frac{\text{deflection}}{\text{Voltage}}$ in $\frac{\text{divs}}{\text{Volt}}$ or $\frac{\text{Cms}}{\text{Volt}}$

* $S_V = \frac{y}{V_y}$ ... Vertical deflection sensitivity

$S_H = \frac{x}{V_x}$ .... Horizontal deflection sensitivity

NOTE :- $S_V = \frac{d}{V_d}$ $d \to$ amount of distance travelling vertical in screen; $V_d \to$ Deflelection signal voltage (test signal)

$= \frac{L \cdot D}{2 S V_a}$

L = Length of each VDP

D = Distance between VDPs & screen

S = Separation distance between both VDPs

Va = anode voltage (accelarating anode)

⊛ Deflection Factor :-

* It is reciprocal of sensitivity

$D_f = 1/S$ in volts/div. or volts/cm

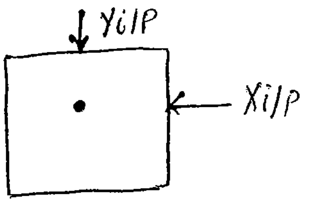
NOTE :- $S \to$ How many div for unit volt.

$D_f \to$ How many volts for 1 div deflection.

* Amount of Deflection = Deflection sensitivity X Applied voltage

⊛ DC voltages to Xi/p & Yi/p

*



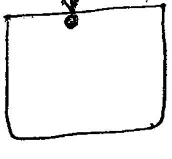
$V_y = +2V$, $S_V = 2\ cm/v$

$\therefore y = S_V \times V_y$

$= 2\frac{cm}{V} \times (+2v)$

$= 4cm$

* +2V



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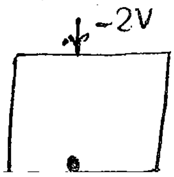

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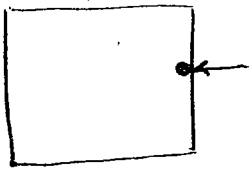
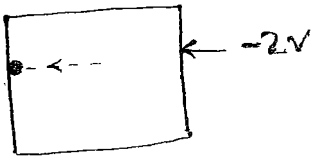


$V_x = +2V$

$S_H = 2cm/V$

$x = 4cm$

*



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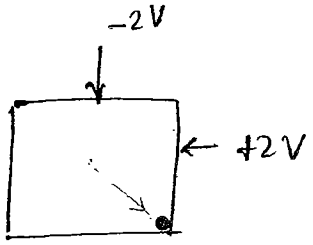

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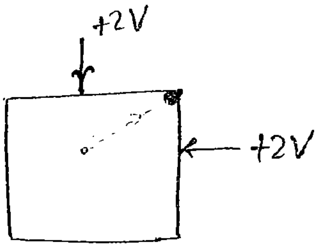

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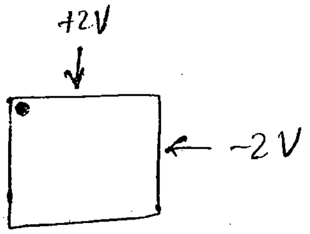

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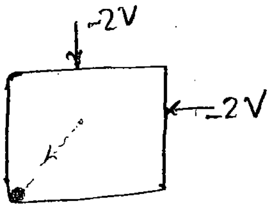

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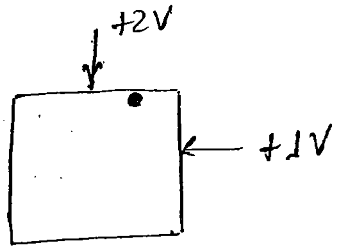

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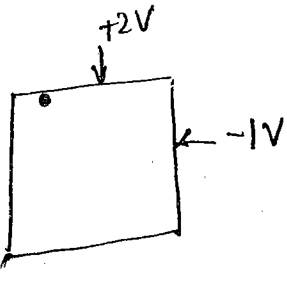

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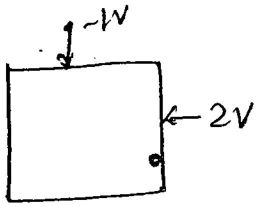
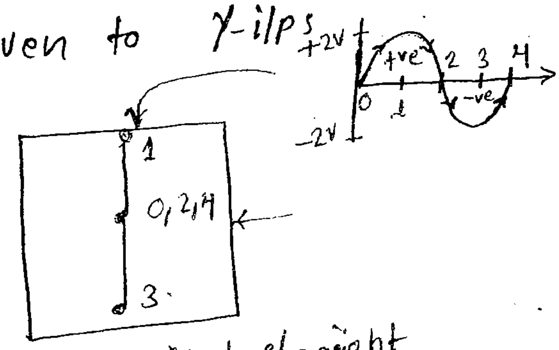


Test signal to the Y- Input :- (sense signal)

Consider a sinusoidal signal is sensed using probe of slope & driven to Y-ilps

$SV = 2\frac{cm}{V}$

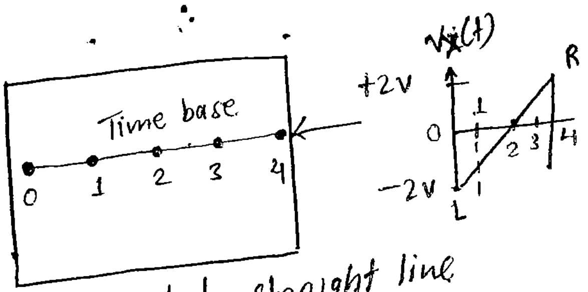


t_0 → center
t_1 → Top
t_2 → center
t_3 → Bottom
t_4 → center

Vertical straight line.

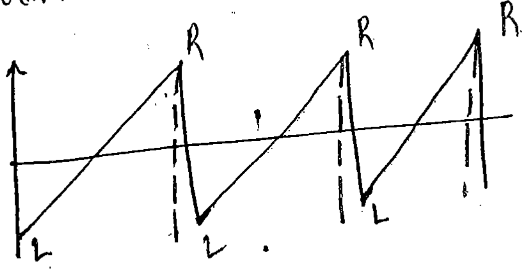
Standard sweep signal to X- inputs :-

$SH = 2\frac{cm}{V}$



0 → -2V
1 → -1V
2 → 0V
3 → +1V
4 → +2V

Horizontal straight line



standard sweep
L to R : trace
R to L : retrace or flyback

Due to the sweep voltage applied X-input the e^- beam (spot on the screen) is slept accoross the screen of the CRO

E.g. - Total horizontal div = 10

$$\frac{Time}{div} = 10\frac{\mu s}{cm}$$

$$T_{sweep} = 10\ cm \times 10\frac{\mu s}{cm} = 100\mu sec$$

$$T_{seep} = \text{Total No. of Horizontal} \times \frac{Time}{div}$$

$$f_{sweep} = \frac{1}{T_{sweep}}$$

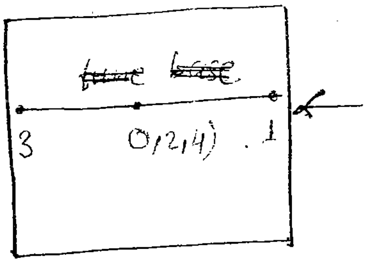
⊛ eXternal Signal to X i/p ⇒

* In X-Y mode any signal can be applied to x i/ps via external Horizontal input.
Consider a sinusoidal signal is externally applied

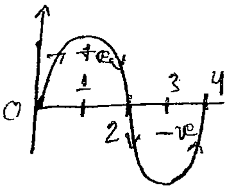
$V_x(t) = 2\sin 314t$ volt

$S = 2\,cm/V$

$t_0 \rightarrow 0V$
$t_1 \rightarrow +2V$
$t_2 \rightarrow 0V$
$t_3 \rightarrow -2V$
$t_4 \rightarrow 0V$



Horizontal straight line



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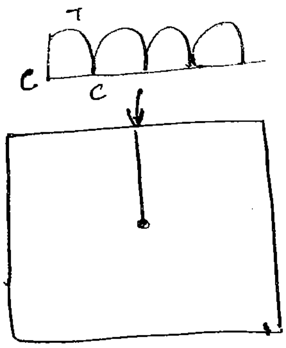

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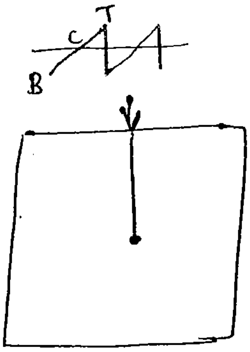

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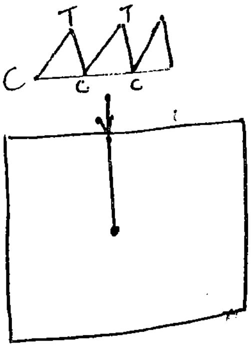

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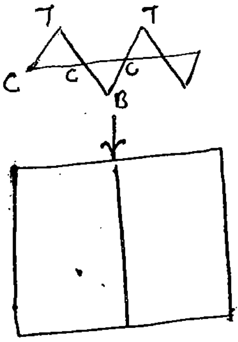

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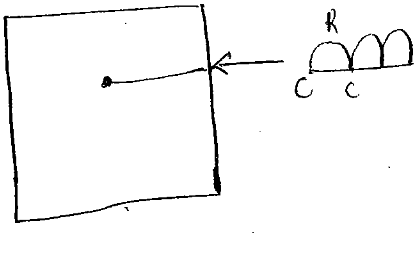

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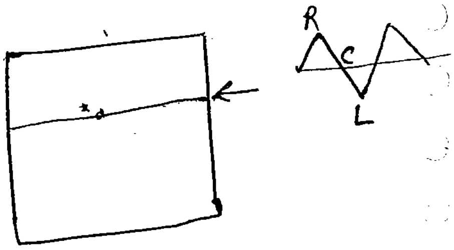
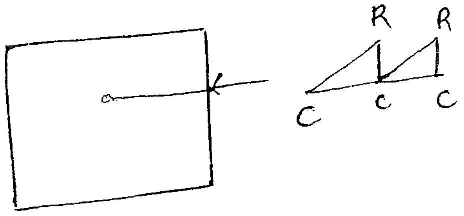




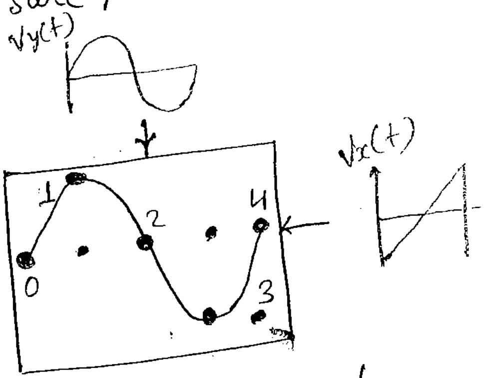
) Y-t MODE OF operation ⇒

In y-t mode the sensed test signal is applied to y i/p & standard sweep signal (Internally generated) is applied to X i/p

$$\boxed{t_{signal} = t_{sweep}}$$

Time/div.

Vx	Vy
-2V	0V
-1V	+2V
0V	0V
+1V	-2V
+2V	0V.



* Amplitude variation of X i/p signal is displayed on screen w.r.t 't'

$\boxed{\text{i.e. } Y-t \text{ plot}}$

(*) Measurement using Y-t plot

(1) Peak to Peak voltage measurement

$$\boxed{V_{PP} = N_V \times \frac{\text{VOLT}}{\text{div}}}$$

Where V_{PP} = Peak to peak amplitude of test signal displayed

N_V = No. of vertical divisions between peak to peak points of signal displayed.

$\frac{\text{VOLT}}{\text{div}}$ = Y-sensitivity setting or Vertical setting or Gain setting

(2) Amplitude measurement (i.e. Peak voltage)

$$\boxed{V_P = \frac{V_{P-P}}{2}}$$

③ RMS & dc voltage measurement :-

④ Signal Timeperiode measurement

$$\boxed{T = N_H \times \frac{\text{Time}}{\text{div}}}$$

where - T = test signal timeperiode

N_H = No. of Horizontal division occupied by one cycle. of test signal displayed.

Time/div = X sensitivity setting. or Horizonta setting or sweep setting or time base setting or scale setting or line setting

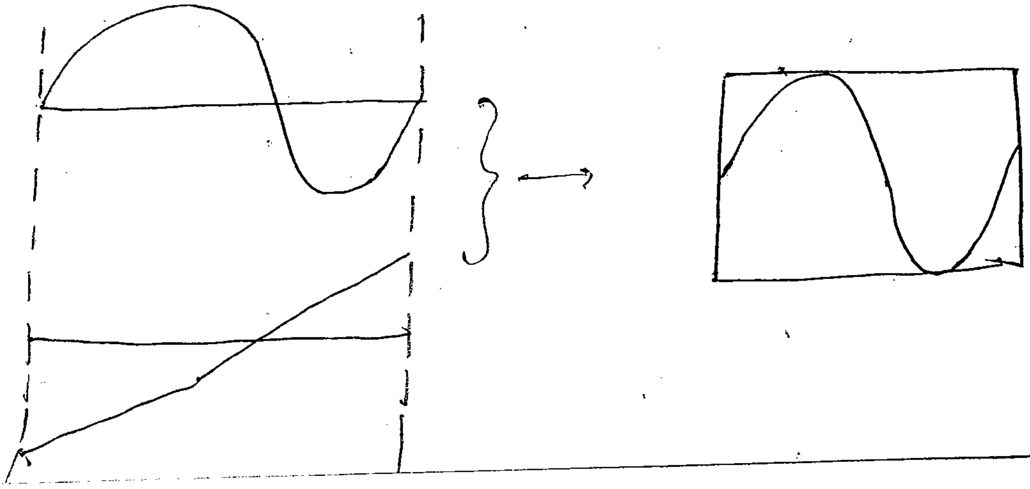
⑤ frequency measurement :-

$$\boxed{f_{signal} = \frac{1}{T_{signal}}}$$

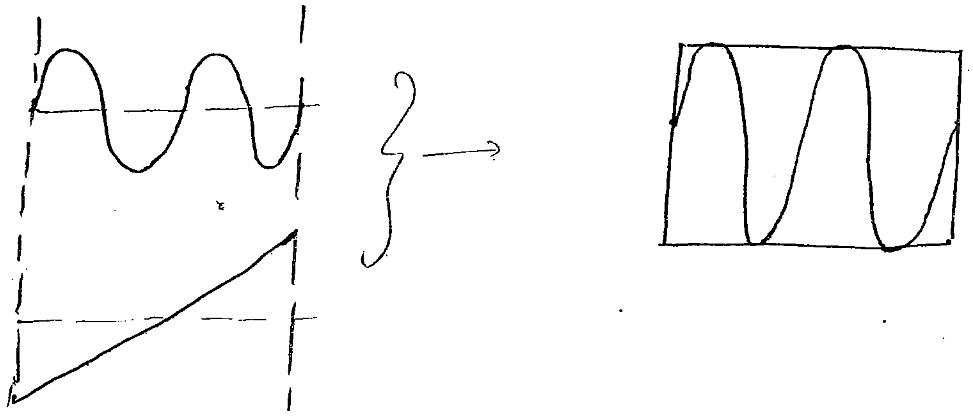
(*) fsignal Vs f~~measurement~~ sweep :-

* what ever with the position of test signal dur linear rise of sweep signal will be displayed on the screen.

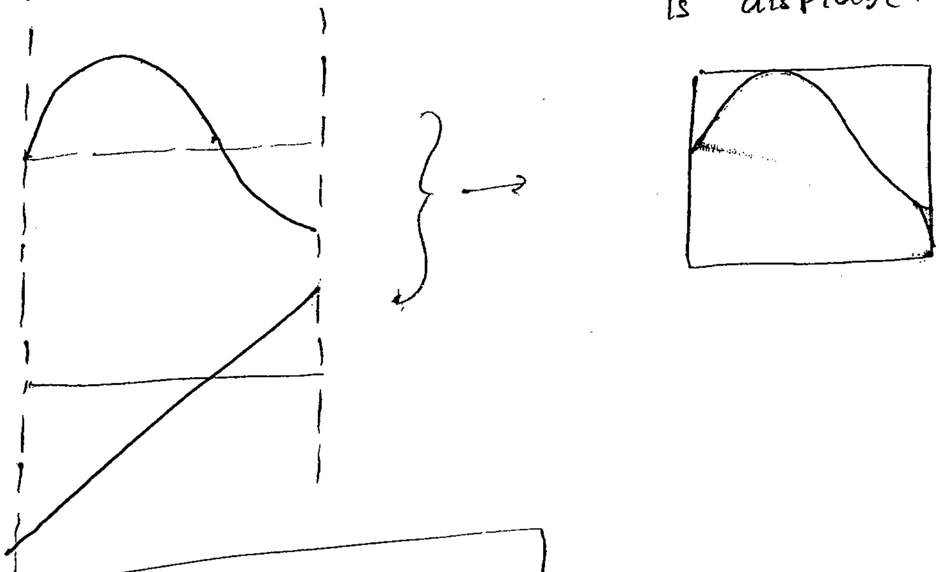
(1) fsignal = Fsweep → 1cycle of signals is displayed



$f_{signal} > f_{sweep}$ → A No. of cycles of signal displayed



$F_{signal} < f_{sweep}$ → less than 1 cycle of signal is displayed



* $\boxed{f_{signal} \geq f_{sweep}}$

i.e min^m signal frequency = sweep frequency

* $\boxed{f_{signal} = n\, f_{sweep}}$

where $n \geq 1$

* n = no. of cycles of signal displayed

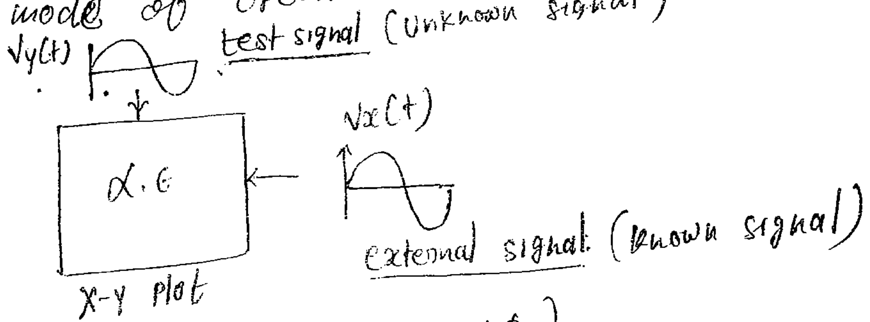
* $$\boxed{n = \frac{f_{signal}}{f_{sweep}}}$$

$$\boxed{n = \frac{T_{sweep}}{T_{signal}}}$$

Date 28/08/11

X-Y Mode of operation

* If sensed tested signal is driven for Y-inputs & externa horizontal signal is driven to X-inputs then it is know as X-Y mode of operation.



$$V_y(t) = V_y \sin(2\pi f_y t + \phi)$$

$$V_x(t) = V_x \sin(2\pi f_x t +)$$

where V_y & V_x are amplitudes

f_y & f_x are vertical & Horizontal frequencies

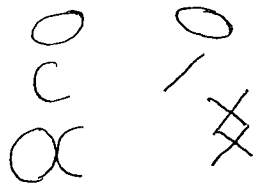
ϕ = phase difference

3 types of L.F.S (lissajous figure signal)

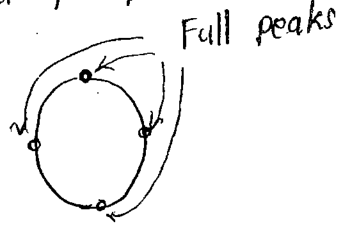
Closed loop L.F.S.

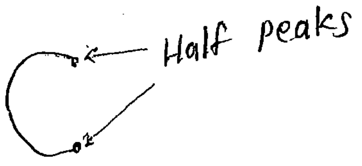
Open loop LF.S.

Mixed / Hybrid L.F.S



Note:-



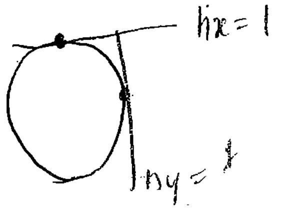


* Use in Lissajous figure two types of measurement ca be carried out namely unknown frequency measurement phase measurement

*① Frequency measurement using Lissajous figure

Tangent method

Eg:



$f_y/f_x = 1/1$

$f_y : f_x = 1:1$ (Vertical & Horizo frequency ra

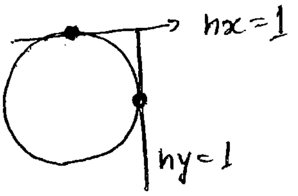
Tangent Method

Draw vertical & Horizontal both tangent line to the L.F. touching Peaks

$$\boxed{f_y = f_x \times \frac{n_x}{n_y}}$$

where n_x = no. of peak as touch by Horizontal tangent line

n_y = no. of Peak as touch by vertical tangent line



$\therefore f_y/f_x = 1/1$

If $f_x = 1KHz$

then $f_y = 1KHz \times 1$
$= 1KHz$

Intersection method

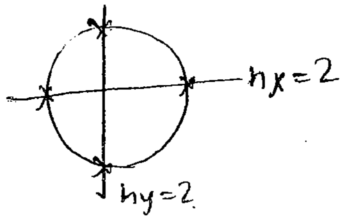
* Draw both vertical & Horizontal line passing through the L.F.

Rule: Never draw a line Via pre-existing intersection

$$\boxed{f_y = f_x \times \frac{n_x}{n_y}}$$

where n_x = no. of cuts as made by horizontal line

n_y = no. of cuts as made by vertical line



$\therefore \frac{f_y}{f_x} = \frac{2}{2} = \frac{1}{1}$

If $f_x = 1KHz$

then $f_y = 1KHz \times 1 = 1KHz$

~~Case~~ ② Phase measurement using L.F. :-

Condition :- Equal amplitude :- $V_y = V_x = V$

Equal frequency :- $\omega_y = \omega_x = \omega$

or $f_y = f_x = f$

Equal sensitivities :- $S_V = S_H = S$

i.e. 2 sinusoidal signal having same amplitude & frequency are applied to Y & X i/p

$$V_y(t) = V \sin(2\pi f t + \phi)$$

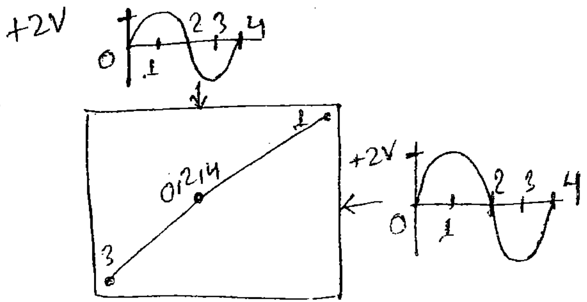
$$V_x(t) = V \sin(2\pi f t)$$

↓

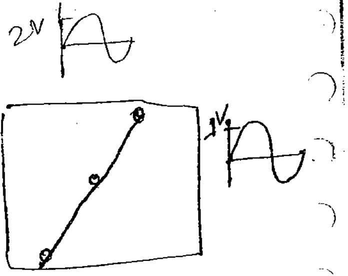
?

Case ① $\phi = 0°$ or $360°$

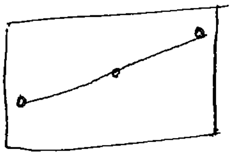
	Vx, Vy
t_0	(0,0)
t_1	(+2V, +2V)
t_2	(0,0)
t_3	(-2V, -2V)
t_4	(0,0)



t_0	(0,0)
t_1	(1,2)
t_2	(0,0)
t_3	(-1,-2)
t_4	(0,0)



It is diagonal straight line making 45° ~~form~~ with +ve X axis.



In - PHASE

$\boxed{\phi = 0° \text{ or } 360°}$

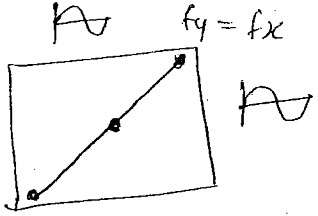
Note :- ① * $f_y = f_x$, $\phi = 0°$ or 360° no change

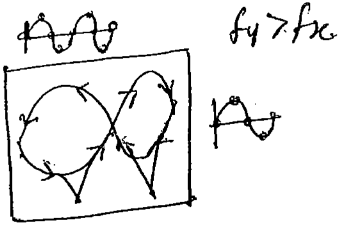
Slope exactly 45°

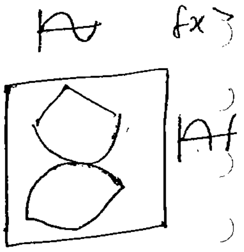
* $V_y > V_x$ then slope is greates then 45°

* $V_x > V_y$ then slope is less then 45°

② $V_y = V_x$, $\phi = 0°$ or 360°



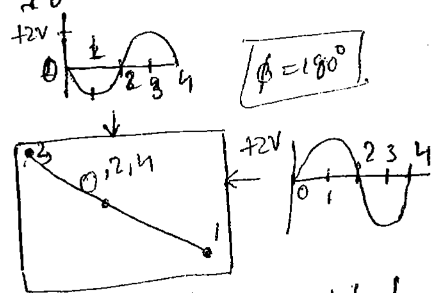




Case ② $\phi = 180°$

$\boxed{\phi = 180°}$

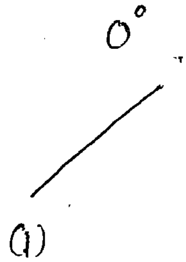
	Vx, Vy
t_0	(0 0)
t_1	(+2V, -2)
t_2	(0,0)
t_3	(-2,+2)
t_4	(0,0)

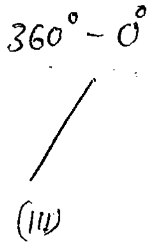


A diagonal straight line making 135° with +ve x

or ~~45°~~

Conclusion w.r.t Case ① & case ②





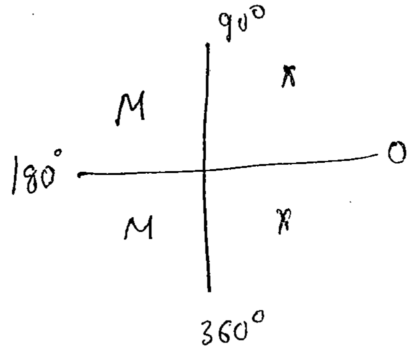
0° mirror figure is 180± 0°

∴ $\boxed{\text{L.F }[\phi] \text{ \& L.F. } [360° - \phi] \text{ are same figure}}$

$\boxed{\text{L.F. }[\phi] \text{ \& L.F. } [180° \pm \phi] \text{ are mirror}}$

Ex: If L.F. for 30° is known then L.F. for 360−30 i.e 330° will be same

& L.F. for 180−30° i.e 150° } will be mirror
180 +30° i.e 210° }

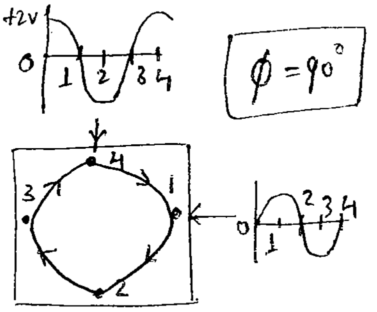


0 − 180° → Clockwise

180° − 360° → Anticlockwise

Case ③ $\phi = 90°$

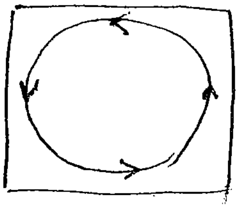
	V_y, V_x
t_0	(2 , 0)
t_1	(0 , 2)
t_2	(−2 , 0)
t_3	(0 , −2)
t_4	(2 , 0)



$\boxed{\phi = 90°}$

Circle & it is clockwise rotating

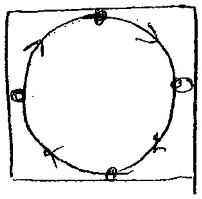
$\boxed{\phi = 270°}$ Circle Anticlockwise



Note:- If $\phi = 90°$ circle is observed 360° − 90° = 270°
Circle is displaye repeated.
$f_y = f_x$, $\phi = 90°$

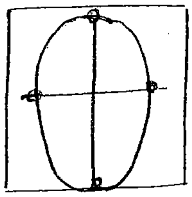
at $\phi = 90°$

$V_y = V_x$



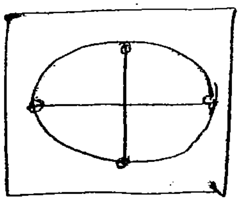
Circle.

$V_y > V_x$



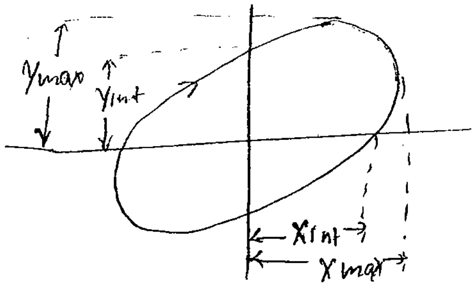
Ellipse with y-axis as major axis

$V_x > V_y$



Ellipse with x-axis as major axis

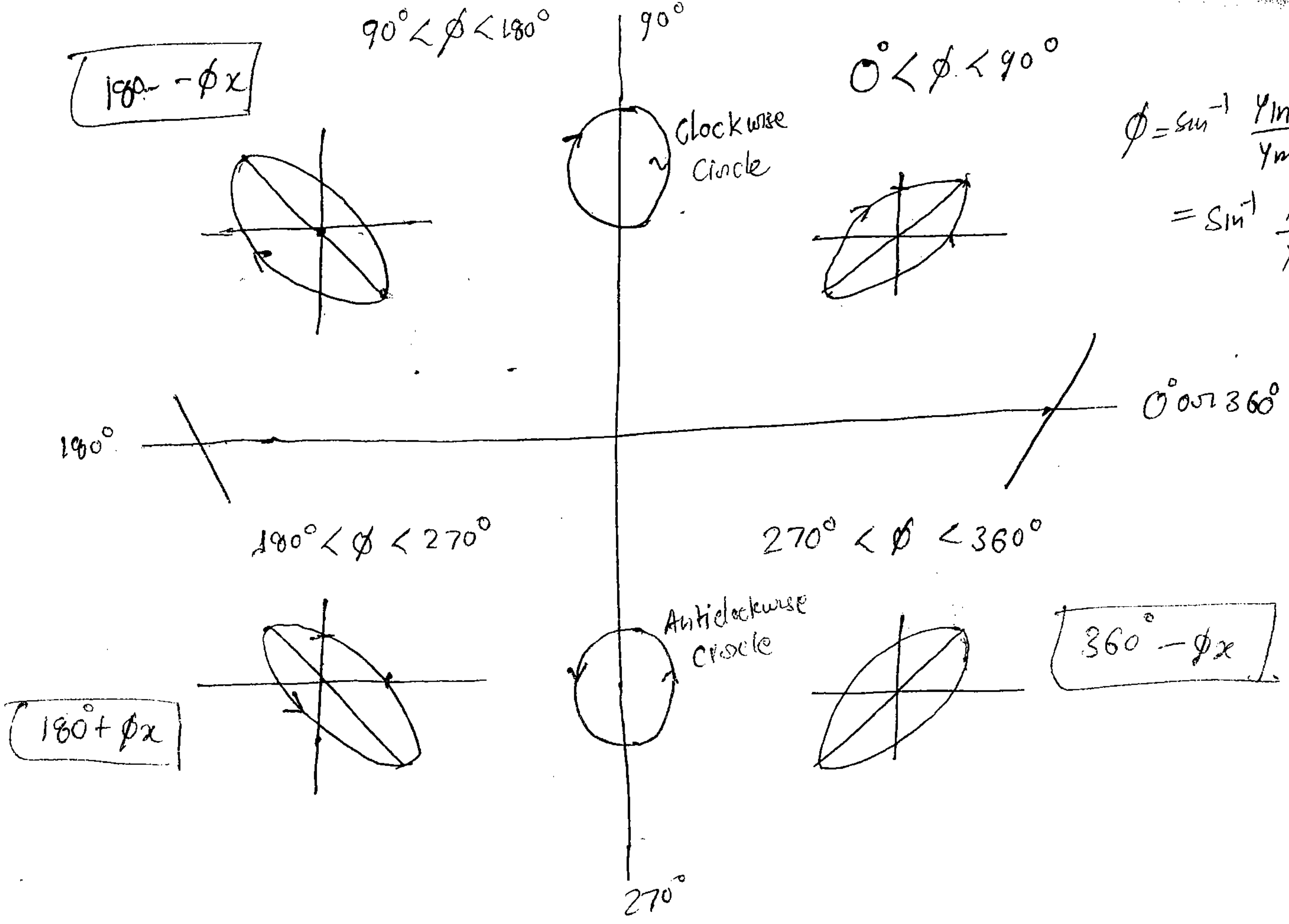
* Except for 0°, 90°, 180°, 270°, 360° an ellipse will be observed for any other phase difference.



$$\boxed{\phi = \sin^{-1}\left[\frac{Y_{int}}{Y_{max}}\right]}$$

or

$$\boxed{\phi = \sin^{-1}\left[\frac{X_{int}}{X_{max}}\right]}$$



$$\phi = \sin^{-1}\frac{Y_{Int}}{Y_{max}}$$
$$= \sin^{-1}\frac{X_{int}}{X_{max}}$$

Date
24/08/11

Que:- If the bandwidth of oscilloscope is given as dc to 10 MHz. What is the fastest rise time time a sine wave can have to be produce accuratly by the oscilloscope.

Sol:- for any amplifier for $\times$ B.W. = 0.35

$$\therefore t_2 = 0.35$$
$$= 0.035 \mu s$$
$$= 35 nsec$$

Note:- B.W. of CRO = 20 MHz

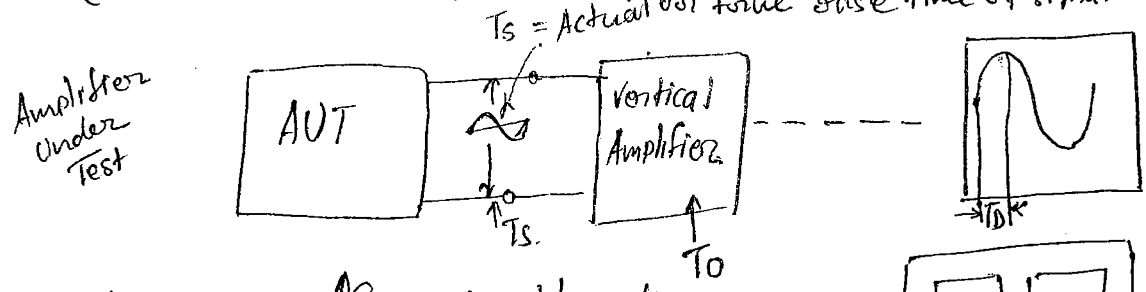
$$t_r = \frac{0.35}{20 MHz} = 17.5 nS.$$

Gate 20..

Que:- The relationship between Ts (rise time of signal), To (rise time of oscilloscope) is To (rise time of signal observed) is equal to ____

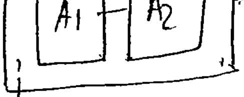
(a) $T_s + T_0$ (b) $\sqrt{T_s^2 + T_0^2}$ (c) $\sqrt{T_s^2 - T_0^2}$ (d) $T_s - T_0$

Ts = Actual or true rise time of signal



Note:- $\uparrow$Gain $\times$ BW$\downarrow$ = K

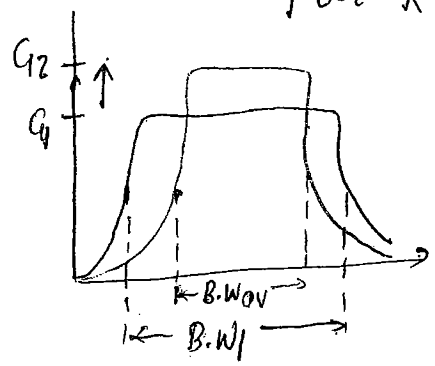
$\uparrow t_r \times$ BW$\downarrow$ = 0.35.



→ overall gain = $G_1 G_2$

→ overall rise time = $\sqrt{t_r^2 +$

→ Overall bandwidth = $\frac{0.35}{\sqrt{t_{r1}^2 \cdot t}}$



T_s = Actual or true rise time of signal

T_o = CRO rise time or VA rise time.

T_D = Detected rise time (overall rise time)
(measure rise time)

nGS

Que:- A CRO with a rise time of 15~~0~~ ns measure the rise time of a signal ~~as~~ 20 ns. Then actual rise of the signal is ----

Soln:- $T_o = 15ns$ (rise time of vertical Amplifier)

$T_D = 20$ nsec (rise time by measured

$$T_D = \sqrt{T_s^2 + T_o^2}$$

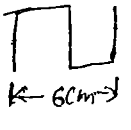
$$T_s = \sqrt{T_D^2 - T_o^2}$$

$$T_s = \sqrt{(20)^2 - (15)^2} = \sqrt{400 - 225}$$

$$T_s = 13.23\,ns$$

Que:- One cycle of square wave signal is observed on the screen of an oscilloscope is found to occupy 6 cm. at a scale setting of 30 μsec/cm. What is signal frequency.

Soln:-



$$\frac{Time}{div} = 30\,\frac{\mu s}{cm}$$

$$T = N_H \times \frac{Time}{div}$$

$$= 6\,cm \times 30\,\frac{\mu s}{cm} = 180\,\mu s$$

$$f_{square} = \frac{1}{180\,\mu s} = 5.55\,kHz.$$

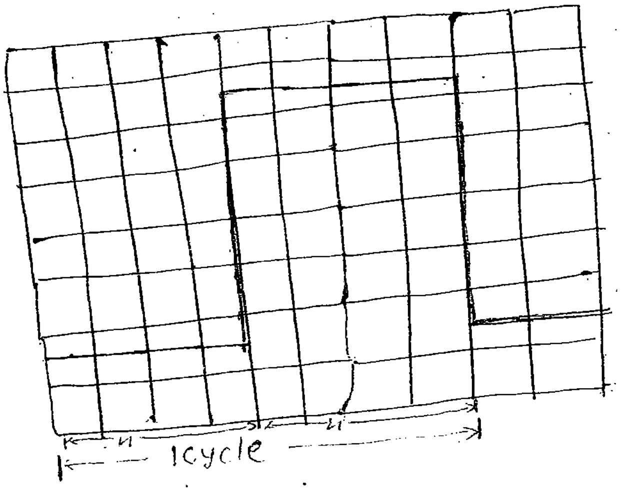
Que :- A symmetrical square wave of frequency 25 KHz & Peak to peak amplitude of 10V is fed to Y i/p of an oscilloscope. The screen appears as shown in below figure then X, Y sensitivity is .....

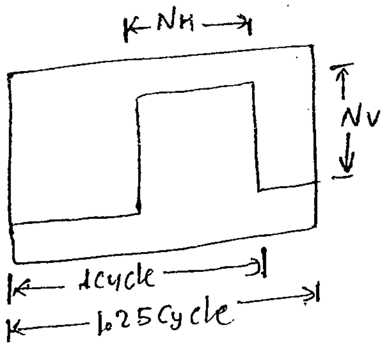
Solⁿ:-

Given data

$V_{PP} = 10V$

& $f = 25KHz$





$N_H = 8$

$N_V = 5$

$T = N_H \times \frac{Time}{div}$

$=$ [illegible]

$$\frac{Time}{dive} = \frac{T}{N_H} = \frac{1}{f \times N_H}$$

$$= \frac{1}{25 \times 8} = \frac{1}{200} = 5 \mu s/div$$

$$V_{PP} = N_V \times \frac{VOLT}{div}$$

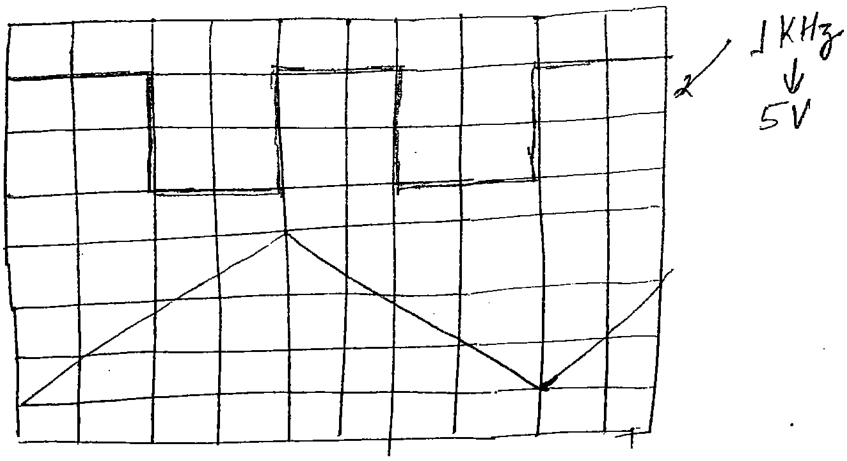
$$\frac{VOLT}{div} = \frac{V_{PP}}{N_H} = \frac{10V}{5 div}$$

$$= \frac{2V}{div}$$

Ans:- 2V/div & 5 μsec/div

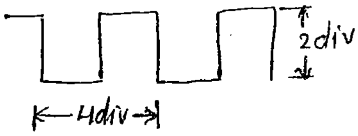
Gate 2006

Que - A student connect 1KHz, 5 Vp-p square wave ~~calibo~~ ~~calculation~~ ~~curved~~ calibration pulse to channel ~~1 of~~ the slope & observed the screen to be as shown in up trace of the figure & unknown signal is connected to ~~sgn~~ channel 2at the scope produces the lower trace if the time per div. & volt per div of both channel is same then peak to peak amplitude & period of the unknown signal are respectively ----- .



Note:-
CRO that consist two vertical channel but only one electron gun is there.

Sol^n:- Channel-1 display



$f = 1KHz$

$V_{PP} = 5V$

We know : $V_{PP} = N_V \times \frac{VOLT}{div}$

$5 = 2 \times \frac{VOLT}{div}$

$\frac{VOLT}{div} = \frac{5}{2} = 2.5$

$T = N_H \times \frac{Time}{div}$

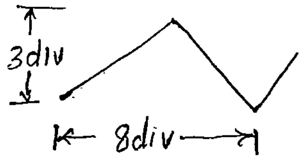
$\therefore \frac{Time}{div} = \frac{T}{N_H}$

$= \frac{1}{1KHz \times 4divs}$

$= \frac{1msec}{4\ divs}$

$= 0.25\ msec/div$ Ans

Channel-2 display



$V_{PP} = N_p \times \frac{VOLT}{DIV}$

$V_{PP} = 3 \times 2.5 \frac{V}{div}$

$= 7.5V$

T = 8 div × 0.25 ms/div.

= 2 ms Ans

Que.- The CRO screen has 10 div on horizontal squar is a voltage signal 5 sin(314t + 45°) is examined with a time base setting of 5 msec/div. then the no. of cycle of signal displayed on the screen will be ---.

(a) 2 (b) 2.5 (c) 4 (d) 4.5

Soln:- ~~Given~~ Signal frequency ≥ fseep.

$$n = \frac{F_{signal}}{f_{sweep}}$$

$$= \frac{T_{sweep}}{T_{signal}}$$

$$V_y(t) = 5 \sin(314t + 45°)$$

$$= \frac{\text{Total } N_H}{\text{Time/div}}$$

Sweep time periode = Total N_H × TIME/div

= 10 divs × 5 ms/div

= 50 ms

given that f_{signal} = 50Hz

∴ T_{signal} = 1/50 Hz

= 20 msec

$$n_s = \frac{50\,msec}{20\,msec} = 2.5\,msec$$

OR

$$T = N_H \times \frac{Time}{div}$$

$$20 = N_H \times 5 \frac{ms}{div}$$

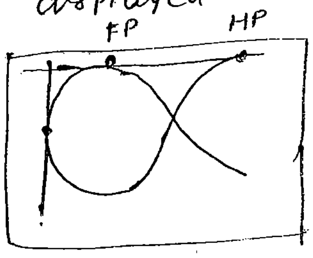
$$N_H = \frac{20\,ms}{5\,ms}\ divs = 4\ divs = 1cycle$$

4div — 1 cycle

10 div — ? $= \frac{10\ div \times 1\ msec}{4\ div}$

Gate 2004 $= 2.5$ m sec

Que:- A CRO is operated in xy mode the below given L.f. is displayed on the screen



$n_x = 1 + \frac{1}{2} = \frac{3}{2}$

$n_y = 1$

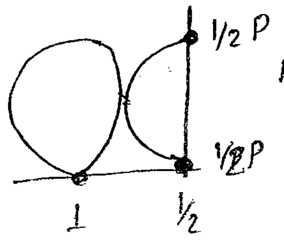
Then the Horizontal to vertical frequency ratio is ....

(a) 1 : 3 [✓ (b) 2 : 3] (c) 3 : 2 (d) 3 : 1

$$\frac{f_y}{f_x} = \frac{N_x}{n_y} \quad , \quad \frac{f_x}{f_y} = \frac{N_y}{N_x}$$

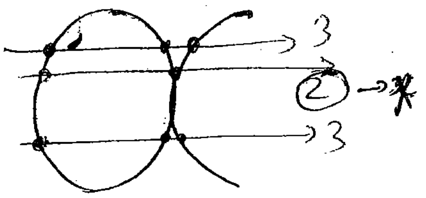
$$\frac{f_x}{f_y} = \frac{1}{3/2} = \frac{2}{3}$$

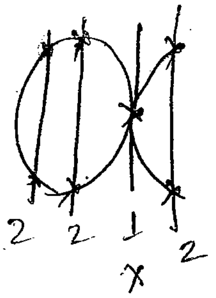
$$\boxed{\begin{array}{l} f_y = f_x \frac{n_x}{n_y} \\ \frac{f_y}{f_x} = \frac{n_x}{n_y} \\ \frac{f_x}{f_y} = \frac{n_y}{n_x} \end{array}}$$



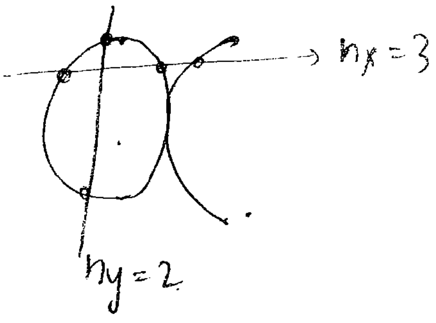
$N_y = \frac{1}{2} + \frac{1}{2} = 1$

$N_x = 1 + \frac{1}{2} = \frac{3}{2}$





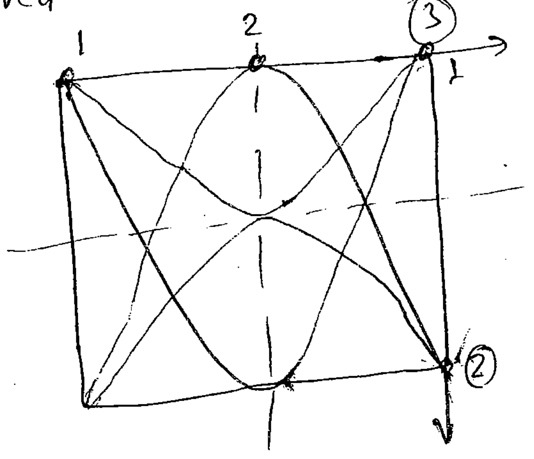
Rule is not voleted



$$\therefore \frac{f_y}{f_x} = \frac{3}{2}$$

$f_x : f_y = 2/3$ Ans

Que: 2 sinusoidal signal are applied having frequency f_x & f_y bothe i/p of CRO then the below lessajous pattern is observed on the screen



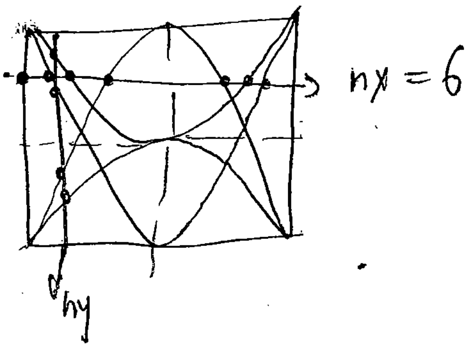
If the Horizontal frequency is 1KHz the Vertical frequency is ___

(a) 1KHz (b) 2KHz ✗(c) 1.5KHz (d) 2.5KHz

3/2 = ~~1.5KHz~~

★★

$$\boxed{f_y n_y = f_x n_x}$$

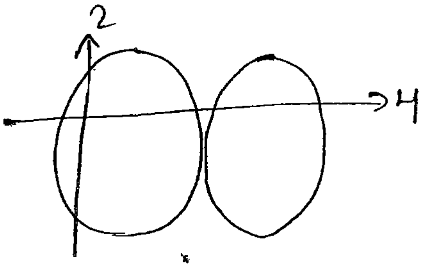


$f_y = 1\,\text{KHz} \times 3/2$

$= 1.5\,\text{KHz}$

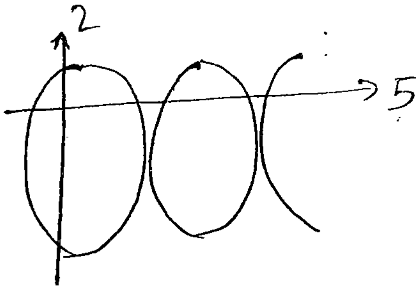
$f_y = 1\,\text{KHz} \times 6/4$

$= 1.5\,\text{KHz}$



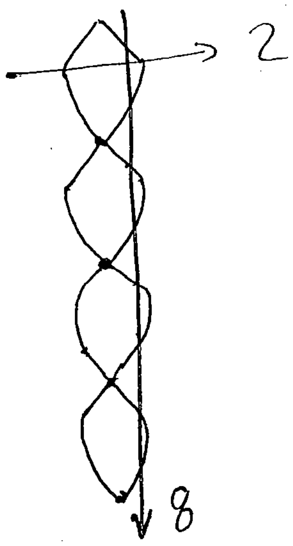
$4/2 = 2/1 = 2:1$

$f_y = 2KHz$



$5/2 = 5:2$

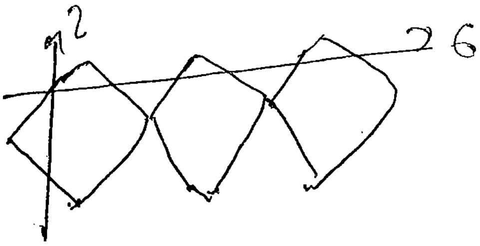
$f_y = 2.5 KHz$



$\frac{2}{8} \Rightarrow 1:4$

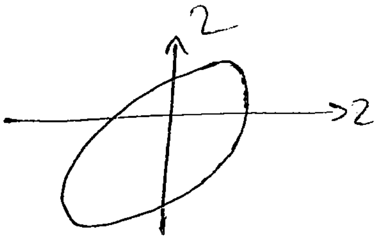
$f_y = 1KHz \times 1/4$

$= 250Hz.$



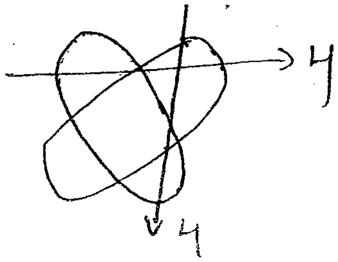
$6/2 \Rightarrow 3:1$

$f_y = 3 KHz.$



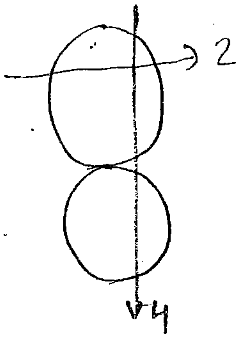
$\frac{2}{2} = 1:1$

$f_y = 1 KHz$



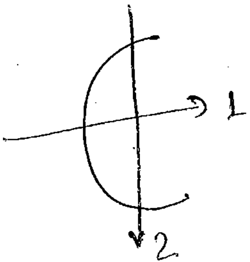
$\frac{4}{4} = \boxed{1:1}$

$f_y = 1KHz$



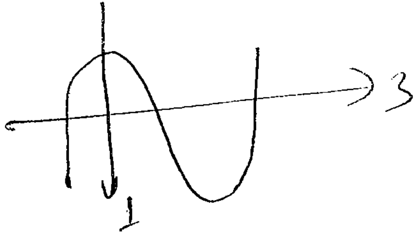
$\frac{2}{4} = \frac{1}{2} = 1:2$

$f_y = 500Hz$



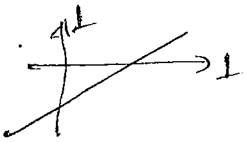
$= 1/2 = 1:2$

$f_y = 500Hz$



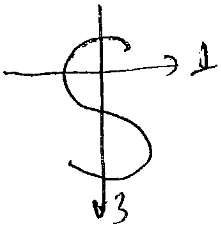
$3/1 = 3:1$

$f_y = 3KHz$



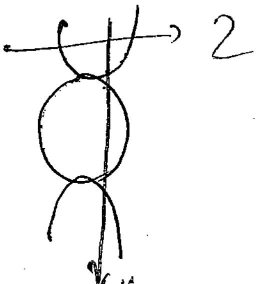
$1/1 = 1:1$

$f_y = 1KHz$



$1/3 = 1:3$

$f_y = 333.3 Hz$



$2/4 = 1:2$

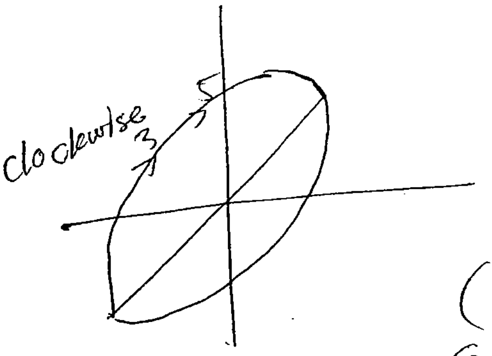
$f_y = 1KHz \times 1/2$

$= 500 Hz$

~~An~~ equal amplitude i/p is applied both i/p of CRO an elipe whose measure axis makeing a Postive slope of 45° if X axis is displayed on the screen the Peak Y diffection is 5 div & intersection with y axis is 3 division.

(a) The phase difference betwn both the i/p signal is ....

(b) The verical to horizontal frequency ratio is ....



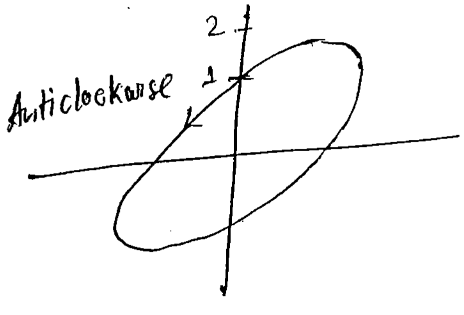
$$\phi = \sin^{-1}\left(3/5\right)$$

$$= 37^\circ$$

(1) Phase difference $= \underline{37^\circ}$

(2) $f_y : f_x = 1:1$

An oscilloscope is operated in X-Y mode the below given ellipes is observed on screen.



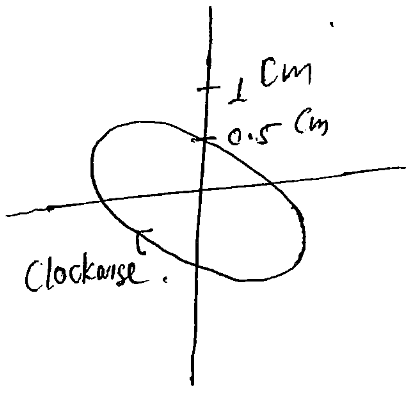
Then the pase difference between the both i/p signal is ....

$$\phi = 360^\circ - \sin^{-1}\left(1/2\right)$$

$$= 360^\circ - \sin^{-1}\left(0.5\right)$$

$$= 360 - 30^\circ$$

$$= \underline{330^\circ}$$

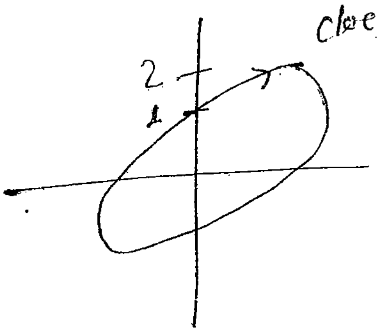


$$\phi = 180 - \sin^{-1}\left(\frac{0.5}{1}\right)$$

$$\phi = \cancel{30} 180^\circ - 30 = 150^\circ$$

Que

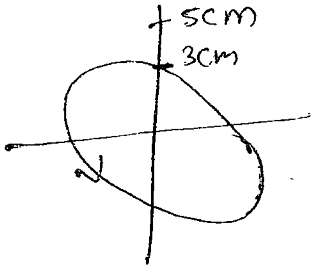
(A)



$\phi = \sin^{-1}(1/2)$

$= 30^0$

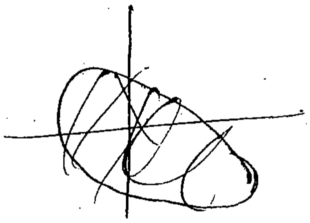
(B)



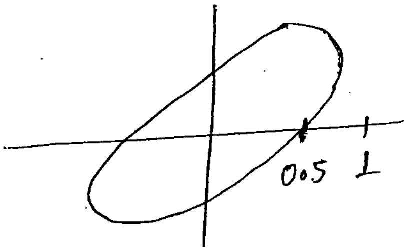
$\phi = 180^0 + \sin^{-1}(3/5)$

$= 180^0 + 37^0$

$= 217^0$



(D)

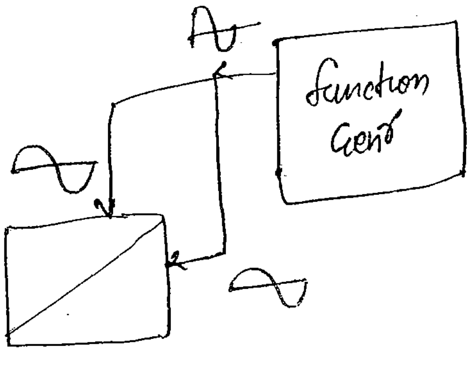


$\phi = \sin^{-1}\left(\frac{0.5}{1}\right)$

$\phi = 30^0$

Que:- The sinewave o/p. of a funcn genr is fed to both horizontal & vertical i/p of a CRO. Then the pattern displayed on the screen is -----

(a) Ellipse (b) Circle (c) Parabola [✓ (d) Straight line]



Que :- Two voltage error 10 sin 314t & 10 sin 314t are both i/p of CRO. The resulting L.F. on the screen is ---

(a) Circle (b) Parabola [✓ (c)] ~~Straight line~~ slant line

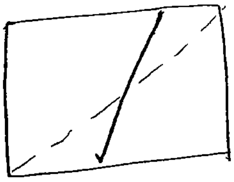
(d) ellipse

$V_y = V_x$ 0 $f_y = f_x$

slant line

Que Voltage 100 sin 1000t & 50 sin 1000t are connected to Y & X terminal of a CRO then the resulting L.F. is ----

$V_y > V_x$ 0 $f_y = f_x$

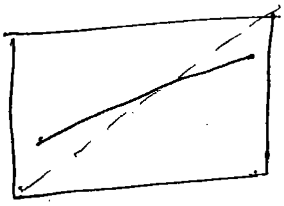


Diagonal line making greater then 45° with +ve axis

ⓐ 50 sin 1000t → Y i/p

100 sin 1000t → X i/p

$V_y < V_x$



slant line < 45° with X- axis

Que :- The vertical & Horizontal i/p's of CRO

$10 \cos(100t + \phi)$, $10 \sin(100t + \phi)$

The L.F. in screen is -----

$V_y = V_x$ $\phi = 90°$ $f_y = f_x$

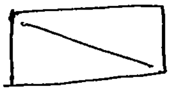
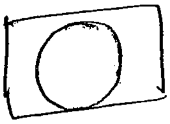
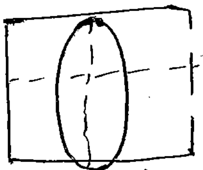
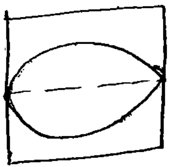
∴ a Circle

Que:- A circle is observed on a screen when 2 sinusoidal signal are applied to having frequency f_y & f_x Vertical & Horizontal i/p of a C.R.O.

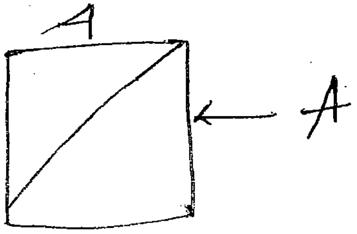
(a) The phase difference is both i/p => 90° or 270°

(b) The vertical to horizontal frequency => 1:1

Conclusions

Y i/p signal	X i/p signal	Display
10 sin 314t	−10 sin 314t	
10 sin 314t	10 cos 314t	
10 cos 314t	10 sin 314t	
10 cos 314t	5 sin 314t	 Ellipse
5 cos 314t	10 sin 314t	 Ellipse

Que :- A circle oscilloscope with 4cm×4cm screen has its own sweep o/p fed to its i/p if X & Y sensitivity are same the oscilloscope will display a ------



Both XY plot & Y-t plo

diagonal line

- An oscilloscope i/p impedance consist of 1 MΩ in parallel with 100 pF. A compensated 20:1 attenuator is obtained by connecting a parallel combination of

- - - - -

(a) 190 MΩ 100/190 PF

(b) 190 MΩ 100/20 PF

(c) 19 MΩ, 1900 PF

(d) 20 MΩ, 2000 PF

20:1 $\qquad V_i = V_s \times 1/20$

$$\frac{R_i}{R_P + R_i} = \frac{C_P}{C_i + C_P} = \frac{1}{20}$$

$$\frac{R_i}{\quad} \qquad R_P = 19 \times 1\,M\Omega$$

$$= 19\,M\Omega$$

$$C_P = \frac{C_i}{19}$$

$$C_P = \frac{100 \times 10^{-12}}{19}$$

$$C_P = \frac{100\,PF}{19}$$

$$\boxed{\begin{aligned} R_P &= (n-1)\,R_i \\ C_P &= \frac{C_i}{n-1} \end{aligned}} \; *$$

* A Probe is nothing but basic connecting medium that connects signal under measurement to vertical i/p terminal of CRO. & An ideal probe has to offered feature like almost zero loading & Good signal ~~de~~ fidicity based on the type of sense signal. The probe can be classified as

(1) Current probe (2) Voltage Probe

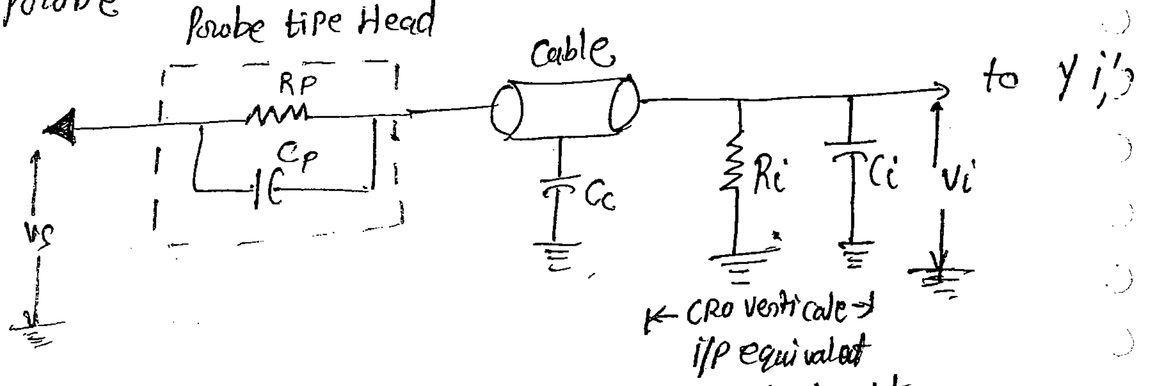
(3) logic probe etc

* Based on the cktiory in probe had the can be classified as Passive & active probe

* where a passive probe consist of R&C only & An active probe consist of active element like BJT, OPAMP, FET etc.

* ~~Passive~~ As such active probe are more expensive, bulky, offer more i/p resistance cause less loading then passive probes.

* A 10 to 1 High impedance Attenuation voltag Probe



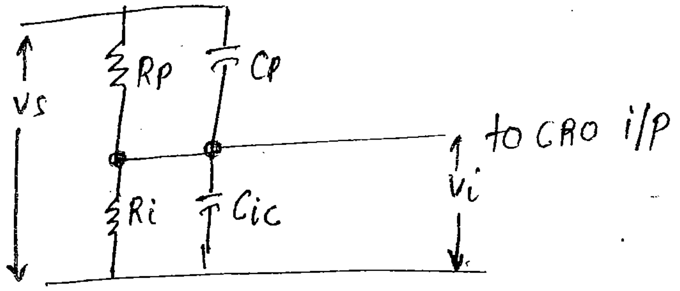
← CRO verticale → i/p equivalet equivalent ckt

($R_i = 1M\Omega$ & $C_i = 30pF$)

equivalent ckt

- At low frequency & medium frequency ~~medium frequency~~

⇒ Resistive loading.



$$\boxed{V_i = V_s \times \frac{R_i}{\underbrace{R_p+R_i}_{\text{Amount of Attenuation.}}}}$$

- At high frequency

⇒ Capacitive loading

$$V_i = V_s \times \frac{X_{ic}}{X_p + X_{ci}}$$

$$\boxed{V_i = V_s \frac{C_p}{\underbrace{C_{ic}+C_p}_{\text{Amount of attenuation}}}}$$

⇒ To achieve same (equal) attenuation at all frequencies the condition is

$$\frac{R_i}{R_p+R_1} = \frac{C_p}{C_p+C_{ic}}$$

$$\cancel{R_iC_p} + R_iC_{ic} = R_pC_p + \cancel{R_iC_p}$$

$$\boxed{R_iC_{ic} = R_pC_p}$$ ⇒ Compensation of Probe (varying Cp to achieve $R_iC_i = R_pC_p$)

* 10 : 1 Porobe means $V_i = V_s \times 1/10$

$$\boxed{\frac{R_i}{R_p + R_i} = \frac{C_p}{C_p + C_i} = \frac{1}{10}}$$

$$\Rightarrow \frac{R_i}{R_p + R_i} = \frac{1}{10}$$

* 10 to 1 Porobe
or
10 : 1 Porobe
or
10 times Porobe
or
10X Porobe

$$10R_i = R_p + R_i$$

$$\boxed{\therefore R_p = 9R_i}$$

$$\Rightarrow \frac{C_p}{C_p + C_i} = \frac{1}{10}$$

$$10C_p = C_p + C_i$$

$$\boxed{C_p = \frac{C_i}{9}}$$

* 100 : 1 Porobe means $V_1 = V_s \times 1/100$

$$\boxed{\frac{R_i}{R_p + R_i} = \frac{C_p}{C_p + C_i} = 1/100}$$

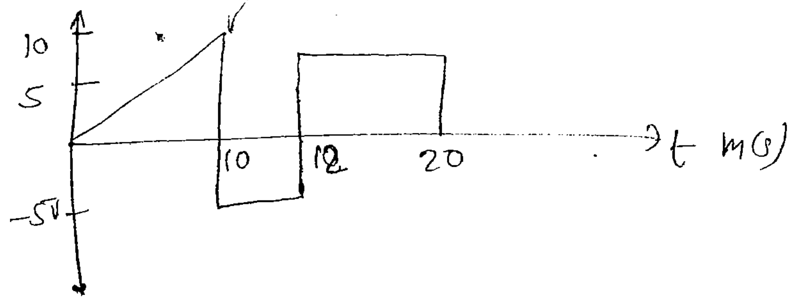
$$R_p = 100 R_i$$

$$\& \; C_p = \frac{C_i}{99}$$

* 1:1 Porobe is known as a direct porobe which is simple test lead

Que — A periodic voltage waveform observed on an osalloscope accross the load is shown
A pmmc meter connected accross the same row read .....

$v(t) = \frac{10V}{10ms} t = t \frac{V}{ms}$



* The pmmc voltmeter rdg - Vdc

$$= \frac{1}{20\,ms}\left[\frac{1}{2} \times 10V \times 10ms + (-5 \times 2ms) + (+5V \times 8ms)\right]$$

$$= \frac{1}{20}\left[\frac{100}{2} - 10 + 40\right)$$

$$= \frac{1}{20}[80] = 4\,V$$

OR

$$Vdc = \frac{1}{20ms}\int_0^{20ms} v(t)\,dt$$

$$= \frac{1}{20ms}\left[\int_0^{10ms} t\,\frac{V}{ms}\,dt + \int_{10ms}^{12ms} -5V\,dt + \int_{12ms}^{20ms} 5V\,dt\right]$$

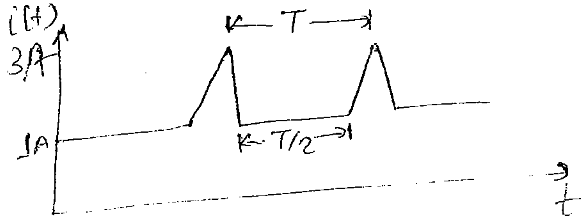
$$= \frac{1}{20ms}\left[\frac{V}{ms} \times \left(\frac{t^2}{2}\right]_0^{10} - 5V\,(t)_{10}^{12} + 5\,[t]_{12ms}^{20ms}\right]$$

$$= \frac{1}{20ms}\left[\frac{V}{ms} \times \frac{(10ms)^2}{2} - 5V \times 2ms + 5V \times 8ms\right]$$

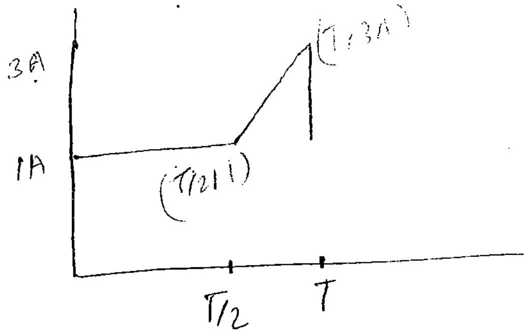
$$= \frac{1}{20}\left[\frac{100}{2} - 10 + 40\right]$$

$$= \frac{1}{20}[80] = 4V$$

Que - An ac ammeter is used to measure a current which is deped saw tooth superimposed on 1Amp dc calculate the reading of ammetr



Soln - We will suppoes to calculate RMS valu



$\frac{T}{2} < t < T$

$y - y_1 = m(x - x_1)$

$i(t) - 1 = \frac{3-1}{T-T/2}\left(t - T/2\right)$

$i(t) - 1 = \frac{2}{T/2}\left(t - T/2\right)$

$= \frac{4}{T}\left(t - T/2\right) \quad = \frac{4t}{T} - 2 + 1$

$= \frac{4t}{T} - 1$

$i(t) = \frac{1}{T}(4t - T)$

$i(t) = 1A \quad , 0 < t < T/2$

$= \frac{1}{T}(4t - T) \quad , T/2 < t < T$

AC Ammeter rdg = I_{rms}

$I_{rms} - \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt}$

$= \sqrt{\frac{1}{T}\int_0^{T/2}(1A)^2\,dt + \frac{1}{T}\int_{T/2}^{T}\left(\frac{1}{T}(4t-T)\right)^2 dt}$

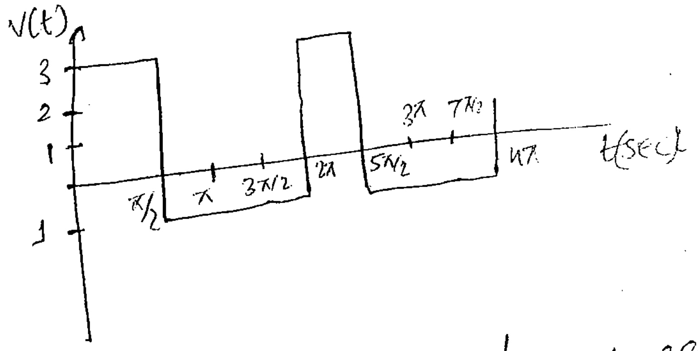
$$= \sqrt{\frac{1}{T} \times (t)_0^{T/2} + \frac{1}{T^3}\left[\frac{(4t-T)^3}{3 \times 4}\right]_{T/2}^{T}} \quad A$$

$$= \sqrt{\frac{1}{T} \times \frac{T}{2} + \frac{1}{12T^3}\left(27T^3 - T^3\right)} \quad A$$

$$= \sqrt{\frac{1}{2} + \frac{26T^3}{12T^3}} \quad = \sqrt{\frac{32}{12}} \quad A$$

$$= 1.63 \ A$$

Que - The periodic voltage of the form shown in below fig is applied to a true RMS meter determine the reading of the instrument



Soln: * True rms meter measure rms value of i/p

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} v^2(t)\, dt}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi/2} (3v)^2 dt + \frac{1}{2\pi}\int_{\pi/2}^{2\pi} (-1v)^2 dt}$$

$$= \sqrt{\frac{9}{2\pi} \times \left[t\right]_0^{\pi/2} + \frac{1}{2\pi} \times (t)_{\pi/2}^{2\pi}} \quad V$$

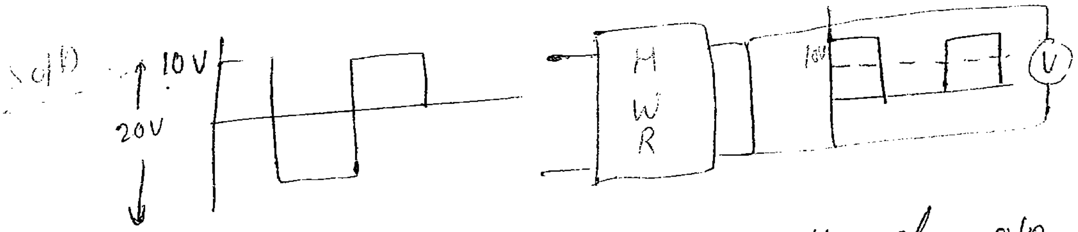
$$= \sqrt{\frac{9}{2\pi} \times \frac{\pi}{2} + \frac{1}{2\pi} \times \frac{3\pi}{2}} \quad V$$

$$= \sqrt{\frac{9}{4} + \frac{3}{4}} \quad V \quad = \sqrt{\frac{12}{4}}$$

$$= \sqrt{3} \ V$$

Que :- A symmeetrical voltage with zero mean haveing peak to peak amplitude of 20V. Is applied to a half wave rectifier. A dc voltmeter conected the o/p half wave rectifier read ----

Sol^n



* DC voltmeter reading = Vdc of o/p of HWR

$= 10 \times 1/2 = 5V$

Que :- Given 0-1mA meter with there internal resistance of 5Ω how did you exted its range to 10 mA

Sol^n → Avalable current range = 0-1mA

Required current range = 0-10mA

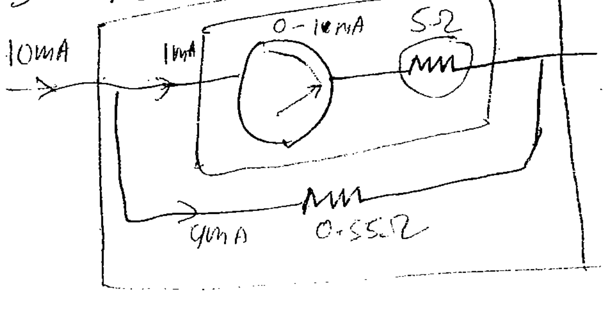
→ The internal range of Ammeter is 5Ω

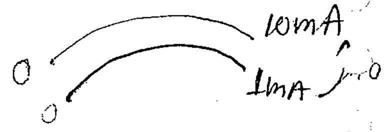
The current range of an ammeter can be extended by placeing a low valued shunt resistance (To bypass access amount of current) & ~~Calculai~~ calibreating the current scale in terms of extended range.

$$m = \frac{10mA}{1mA} = 10$$

$$R_{sh} = \frac{R_m}{m-1}, = \frac{5}{10-1} = \frac{5}{9} = 0.55\Omega$$

So $R_{sh} = 0.55\Omega$



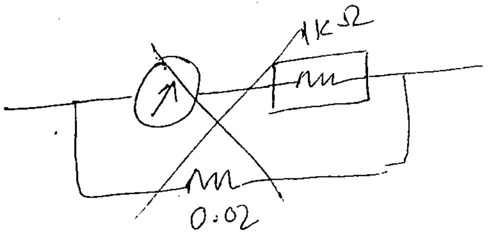


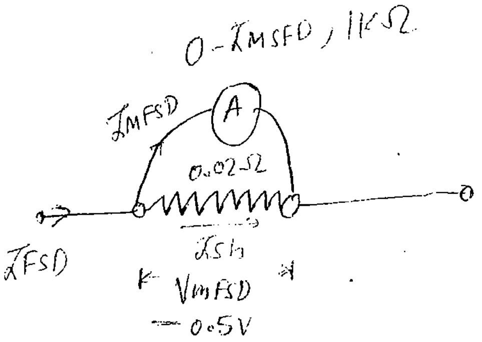
$$R_{in} = 5 \parallel 0.55\Omega$$
$$= 0.5\Omega$$

0-10 mA, 0.5Ω DC ammeter

Que - A moveing coil ammeter has fixed shunt ~~a~~ 0.02Ω with a coil resistance of R = 1kΩ & needs potential difference of 0.5 V accross it for full scale diflection (1) calculate the current it correspond to (2) Find the value of shunt when total current is 2Amp.

Soln:-





(1) $I_{MFSD} = \frac{0.5V}{1k\Omega} = 0.5\ mA$

$I_{sh} = \frac{0.5V}{0.02\Omega} = 25A$

We know $R_{sh} = \frac{R_m}{m-1}$, $m = \frac{R_m}{R_{sh}} + 1$

$= \frac{1k\Omega}{0.02\Omega} + 1 = 50K$ ~~$I_{FSD} = 0.5$~~

$I_{FSD} = m I_m = 50K \times I_{mFSD}$

$I_{FSD} = 0.5mA + 25A$

$I_{mFSD} = 0.5\ mA$

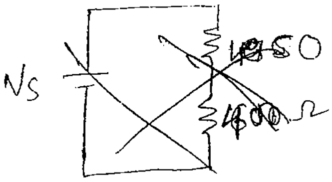
$I_{FSD} = 10A$

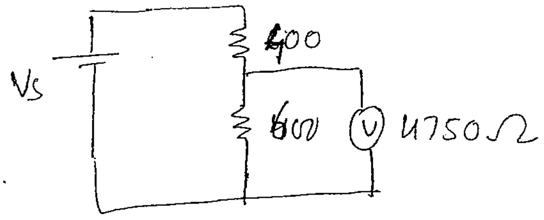
$R_{sh} = \frac{1k\Omega}{\frac{10A}{0.5mA} - 1} = 0.05\Omega$

Date 14/03/12

Que- A voltmetor with internal resistance of 4750Ω this used to measure the voltage accross a resistance of 600Ω connected in seeres with a Dc source of internal resistance of 400 Ω what is the error

Sol)





$V_{true} \Rightarrow$ voltage accross 600Ω

$$= V_s \times \frac{600}{600+400}$$

$$= 0.6V_s$$

$$R_{eff} = 600 \,||\, 4750$$

$$= 532.7\ \Omega$$

$V_{meas} = V'$ accross 532.7Ω

$$= V_s \times \frac{532.27}{400+532.7}$$

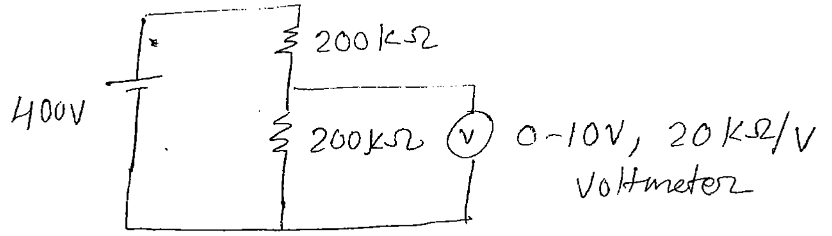
$$= 0.57V_s$$

$$\text{Loading error} = \frac{0.57V_s - 0.6V_s}{0.6V_s} \times 100\%$$

$$= -4.8\ \%$$

$$\simeq -5\ \%$$

Que ⇒ In a ckt shown in below fig voltage measured by a voltmeter with a sensitivity of 20,000 Ω/Volt & using the 10V range find the % error in measurement.



Solⁿ:- It is given that $V_{Fd} = 10V$, $S_{dc} = 20 k\Omega/V$

* $V_{true} = V_{200\Omega}$

$= 400V \times \frac{200k\Omega}{400k\Omega} = 200V$

* $R_V = \frac{20k\Omega}{V} \times 10V = 200\Omega$

* $R_{eff} = R_L || R_V = 200k\Omega || 200k\Omega$

$R_{eff} = 100k\Omega$

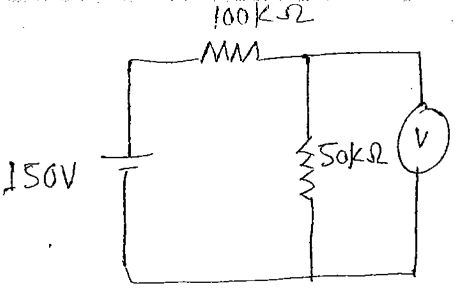
$V_{meas} = V_{100k\Omega} = 400V \times \frac{100k\Omega}{300k\Omega}$

$= 133.33V$

$\% \text{ error} = \frac{133.33V - 200V}{200V} \times 100\%$

$= -33.33\%$

Que:- Explain briefly about sensitivity & loading effect of ammeter the voltage accross 50kΩ resistor in ckt shown in below fig. Measured with 2 voltmeter seaparately. Voltmeter ① have sensitivity of 1000 Ω/V & voltmeter ② has a sensitivity of 2000Ω/V. Both the meter are used on there 50V range calculate (1) Reading of each meter (2) The error in each reading expressed as % of the



$$S_{dc} = \frac{R_V}{V_{FSD}}$$

$$= \frac{\frac{\cancel{V_{FSD}}}{\cancel{I}_{FSD}}}{\cancel{V_{FSD}}}$$

$$S_{dc} = \frac{1}{I_{FSD}}$$

(i)

$$V_{true} = V_{50k\Omega}$$

$$= 150V \times \frac{50k\Omega}{150k\Omega} = 50V$$

* Voltmeter ①

$$\hookrightarrow R_V = 1k\Omega/V \times 50V = 50k\Omega$$

$$R_{eff} = 50k\Omega \,||\, 50k\Omega = 25k\Omega$$

$$V_{measu} = 150 \times \frac{25k\Omega}{125k\Omega} = 30V$$

* Voltmeter ②

$$R_V = \cancel{1}\, 2k\frac{\Omega}{V} \times 50V = 100k\Omega$$

$$R_{eff} = 50\Omega \,||\, 100k\Omega = 33.3k\Omega$$

$$V_{meas} = 150 \times \frac{33.3k\Omega}{133.3k\Omega} = 37.5V$$

reading of V_1 is $= 30V$

& reading of V_2 is $= \underline{\underline{37.5V}}$ ✓

(ii) % error of Voltmeter ① $= \frac{30V - 50V}{50V} \times 100\ \%$

$= -40\%$

% Error in reading of V② $= \frac{37.5 - 50V}{50V} \times 100\ \%$

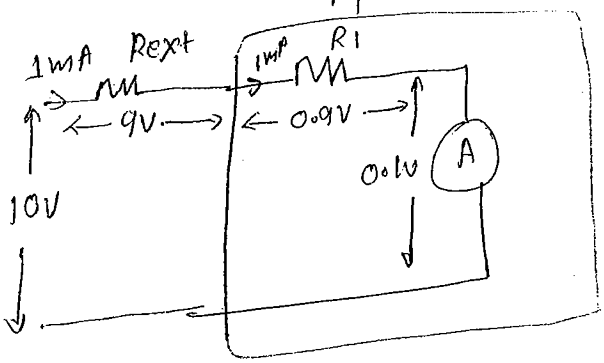
$= -25\%$

2:- A Galvanometer with internal resistance of 100Ω & full scale current rating of 1mA ~~to~~ is used to realize a dc voltmeter with a full scale range of 1V. The full scale range of this meter can be extended to 10V by connecting an external resistance of value:---

Sol

$$R_1 = \frac{1V - 0.1V}{1mA} = \frac{0.9V}{1mA} = 900\Omega$$

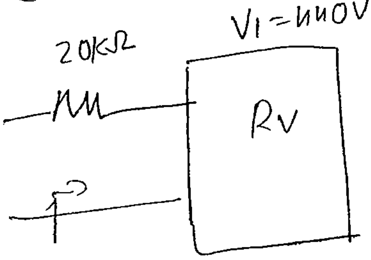
$R_1 = 0.9k\Omega$

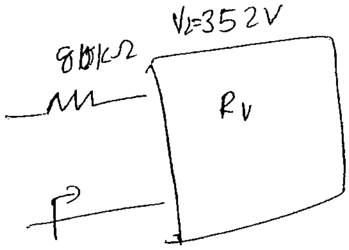


$$Rext = \frac{10V - 1V}{1mA} = 9k\Omega$$

Que - An analog voltmeter used as external multiplier settings. With a multiplier setting of 20kΩ it read 440V & with 80kΩ it reads 352V. For multiplier setting 40kΩ voltmeter read ---- .

(a) 371 (b) 383 (c) 394 (d) 406





reading of Voltmeter $\propto 1/R$

$$\frac{V_1}{V_2} = \frac{R_2}{R_1}$$

$$\frac{440}{352V} = \frac{80k\Omega + R_V}{20k\Omega + R_V}$$

$8800k\Omega + 440R_V = 28160 + 352R_V$

$R_V = 220k\Omega$

$$\frac{V_1}{V_3} = \frac{R_3}{R_1}$$

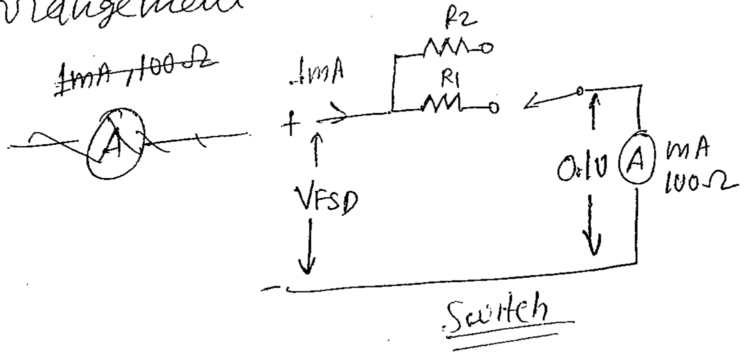
$$\frac{440}{V_3} = \frac{40k\Omega + 220k\Omega}{20k\Omega + 220k\Omega}$$

$$\boxed{V_3 = 406\,V}$$

Que: Designe a multirange ammeter using a 1mA ammeter with internal resistance of 100Ω. required voltage ranges are 0-1V & 0-10V. find the value of multiplier resistor for below given voltmeter designe (1) Multi range voltmeter with switched multiplier resistor

(2) Multirange voltmeter with series connected multiplier resistor i.e using Potential divider arrangement

Soln:-



1V range

$$R_1 = \frac{1V - 0.1V}{1mA}$$

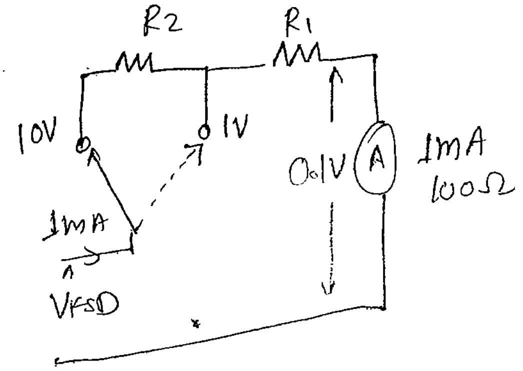
$$= 0.9k\Omega$$

10V range

$$R_2 = \frac{10V - 0.1V}{1mA}$$

$$= 9.9k\Omega$$

Series



10V range

$$R_1 + R_2 = \frac{10V - 0.1V}{1mA}$$

$$0.9k\Omega + R_2 = 9.9k\Omega$$

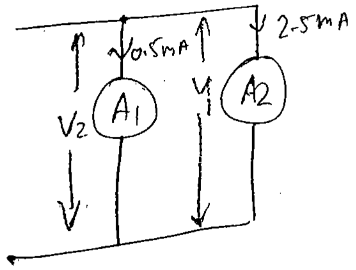
$$R_2 = 9k\Omega$$

1V range

$$R_1 = \frac{1V - 0.1V}{1mA} = 0.9k\Omega$$

Que:- 2 mA with full scale currents of 1mA & 10mA are connected in parallel & they read 0.5mA 2.5mA respectively there internal resistance is the ratio of ....

Soln. -



$$V_1 = V_2$$

$$I_1 \times R_1 = I_2 \times R_2$$

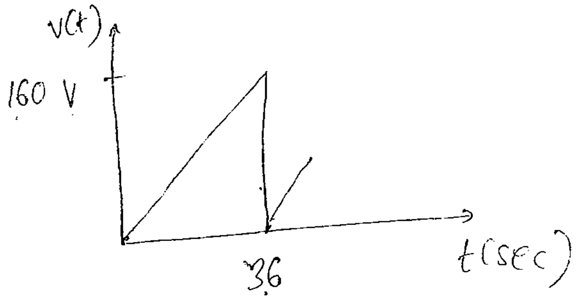
$$0.5 \times R_1 = 2.5 \times R_2$$

$$\frac{R_1}{R_2} = \frac{2.5}{0.5}$$

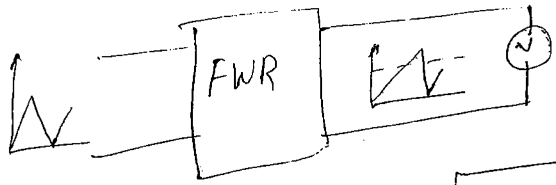
$$\frac{R_1}{R_2} = \frac{5}{1}$$

(a) 10:1
(b) 1:10
(c) 5:1
(d) 1:5

Que:- A sawtooth voltage has peak value of 160V at time periode of ~~3.06~~ 3.6 sec As shown in below fig. Calculate the error at measuring this voltage with an ~~[illegible]~~ avg reading voltmeter calibrated in terms of Rms value of sinusoidal wave.



soln

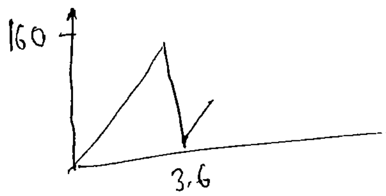


→ Voltage $V_{rms\,(true)} = \sqrt{\frac{1}{3.6}\int_0^{3.6}\left(\frac{160}{3.6}t\right)^2 dt} \text{ V}$

$= \sqrt{\frac{160^2}{(3.6)^3} \times \frac{(3.6)^3}{3}}$

$= 92.376$ V → Actual or true RMS voltage (to be preffered)

* The o/p of FWR



The dc voltmeter reads Avg value of o/p of FWR

$V_{dc} = 1/3.6 \int_0^{3.6} \frac{160}{3.6} t \, dt$

$= 80$V

They indicated rms is 1.11 Vdc since the scale is calibrated in terms of rms of sinewave

$V_{rms}(\text{ind}) - 1.11 \times 80 = 88.8$V

= measured rms value

→ error = 88.6 − 92.37 V = ~~−3.57~~
= −3.57 V

% wave form error ~~8~~ = $\frac{-3.57}{92.37V} \times 100\%$

= −3.86%.

i.e the reading of FWR voltmeter while measuring above voltage is less than true rms by 3.8% of true rms

[Note: If given as objective Que then

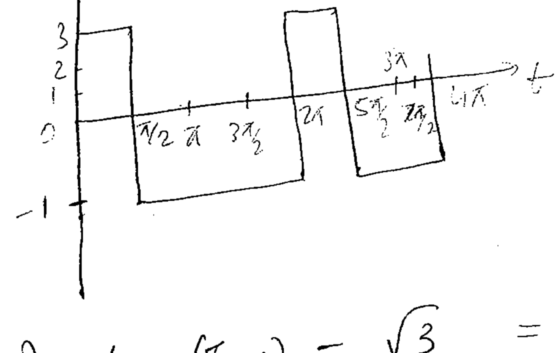
We know $FF_{saw} = 1.154$

$\% \text{ error} = \left[\frac{1.11}{FFw} - 1\right] \times 100\%$

$= \left[\frac{1.11}{1.154} - 1\right] \times 100\%$

$= -3.86\%$

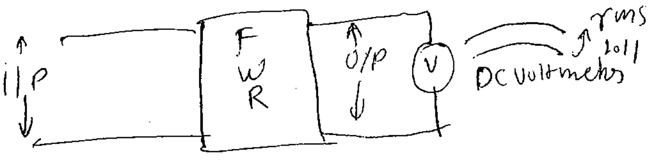
Que - The periodic voltage waveform as shown in below fig is applied to (1) True rms meter (2) An avg measuring, rms indicating meter. (3) Peak measuring rms indicating meter. Determine the reading of each instrument.



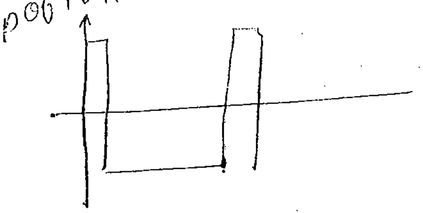
Soln

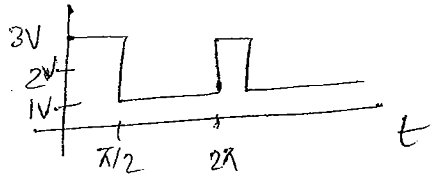
1) V_{rms} (True) = $\sqrt{3}$ = 1.73

2) Given meter is Avg msg _ rms ind meter



I/p of FWR





DC voltmeter measures Vdc of o/p of FWR

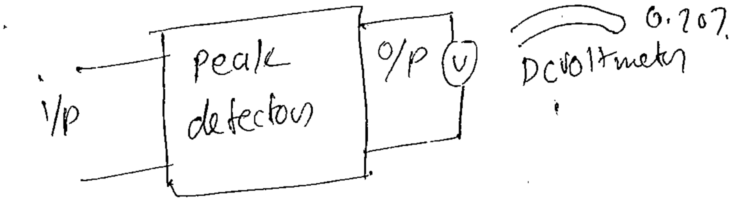
$$V_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi/2} 3V dt + \int_{\pi/2}^{2\pi} 1V\, dt\right]$$

$$= \frac{1}{2\pi}\left(3\pi/2 + (2\pi - \pi/2)\right]$$

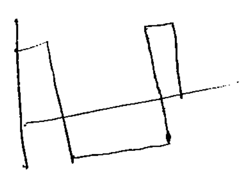
$$= 1/2\pi\left[3\pi/2 + 3\pi/2\right] = \frac{3}{2} = \underline{1.5\ V}$$

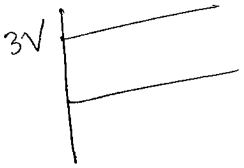
$\therefore V_{rms} = 1.11 \times 1.5 = 1.665\,V.$

(III) Given meter is peak rms indicating meter



. i/p to PD





DC voltmeter measures Vdc of o/p of peak detector (i.e. Vp of i/p)

$V_{dc} = 3V$

$V_{rms}(ind) = 0.707 \times 3\,V = 2.121\,V$

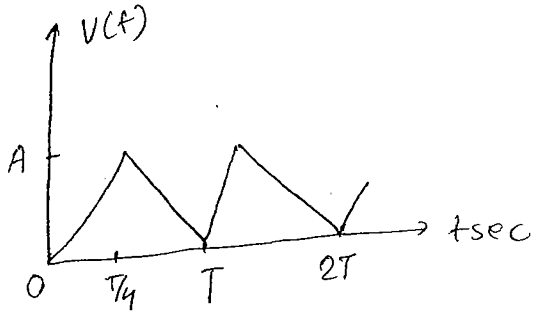
Qu. from above 2 meter calculate the amount of error introduced into voltage measurement & expressed it as a % of true value.

$$\%\ error = \frac{V_m - V_t}{V_t} = \cancel{1.665}\ \frac{2.121 - 1.73}{1.73}$$

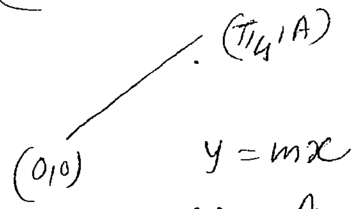
$$= 22.54\%.$$

Que :- An avg responding electronic voltmeter has its scale calibrated to indicate correctly. the rms value of sinusoidal voltage calculate error in its reading if the instrument is used for measureing value of asymmetrical triangular wave voltage.

Sol^n:-



$(0 < t < T/4)$

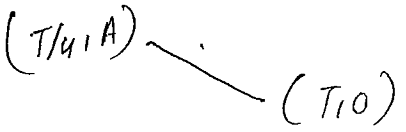


$y = mx$

$V(t) = \frac{A}{T/4} \times t$

$$\boxed{V(t) = \frac{4A}{T} \times t}$$

$T/4 < t < T$



$y - y_1 = m(x - x_1)$

$V(t) - A = \frac{-A}{T - T/4}(t - T/4)$

$= \frac{4}{3}\frac{A}{T}(t - T/4)$

$$V(t) = \frac{4A}{T}t \, ; \quad 0 < t < T/4$$

$$= \frac{4A}{3T}(T - t) \, ; \quad T/4 < t < T$$

$$\rightarrow V_{rms}(\text{true}) = \sqrt{\frac{1}{T}\int_0^T V^2(t)\,dt}$$

$$= \sqrt{\frac{1}{T}\int_0^{T/4}\left(\frac{4A}{T}t\right)^2 dt + \frac{1}{T}\int_{T/4}^{T}\left(\frac{4A}{3T}(T-t)\right]^2 dt}$$

$$V_{rms}(\text{true}) = \sqrt{\left[\frac{16A^2}{T^3}\right]\int_0^{T/4} t^2 dt^2 + \frac{(4A)^2}{9T^3}\int_{T/4}^{T}(T-t)^2 dt}$$

$$V_{rms}(\text{true}) = \sqrt{\frac{1}{T}\left(\frac{4A}{T}\right)^2 \times \left(\frac{t^3}{3}\right)_0^{T/4} + \frac{(4A)^2}{9T^3} \times \left[\frac{(T-t)^3}{-3}\right]_{T/4}^{T}}$$

~~Vrms (true) =~~ $\frac{\cancel{A}}{\sqrt{3}}$

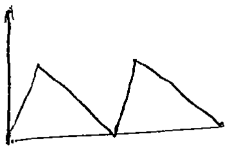
$$= \sqrt{\frac{(4A)^2}{3T^3} \times \frac{T^3}{4^3} + \frac{4A}{27T^3} (T - T/4)^3}$$

$$= \sqrt{\frac{(4A)^2}{3\cancel{T^3}} \times \frac{\cancel{T^3}}{4^3} + \frac{(4A)^2}{27T^3} \times \frac{\cancel{3^3}\cancel{T^3}}{4^3}}$$

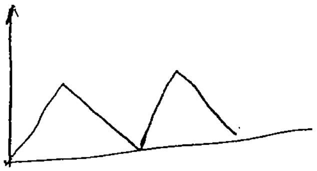
Vrms (true) $= \frac{A}{\sqrt{3}} = 0.577A$

The electronic AC voltmeter consist FWR at primary stage whose o/p is fed to PMMC voltmeters

i/p to FWR



o/p of FWR = i/p to DC voltmeter



DC voltmeter measures Vdc of o/p of FWR

$$V_{dc} = \frac{1}{T} \int_0^T v(t)\, dt$$

$$= \frac{1}{T} \int_0^{T/4} \frac{4t}{T} dt + \frac{1}{T} \int_{T/4}^{T} \frac{4A}{3T} (T-t)\, dt$$

$$= \frac{4A}{T^2} \int_0^{T/4} n\, dt + \frac{4A}{3T^2} \int_{T/4}^{T} (T-t)\, dt$$

$$= \frac{4A}{T^2} \times \frac{T^2}{4^2 \times 2} + \frac{4A}{3T^2} \times \frac{(3T/4)^2}{2}$$

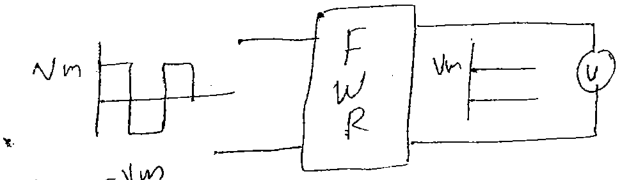
$$= A/2$$

$$V_{rms}\ (ind) = 1.11 \times A/2 = 0.555A$$

$$\text{error} = \cancel{328}\ \frac{0.555 - 0.577}{0.577} = -0.038$$

Que.- An electronic voltmeter conissting FWR & avg ckt give correct rms value for a square wave i/p its reading for 2 Volt peak to peak sinusoidal i/p will be.__

soln ⇒



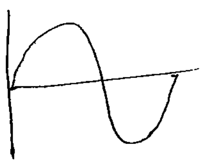
DC voltmeter
D i/p = Vdc
= Vm

Vrms = Vm

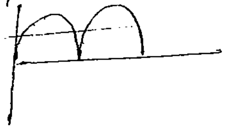
objective = 1 X response

scale calibration fator is 1

FWR i/p



o/p of FWR



$V_{dc} = \frac{2V_m}{\pi}$

$= \frac{2}{\pi}$ ($\because V_m = 1V$)

$V_{rms} = 1 \times V_{dc}$

$= 1 \times \frac{2}{\pi} = \frac{2}{\pi}$ V

Essential statement

* A FWR voltmeter reads the true rms value of i/p waveform

reason - The FWR voltmeter (AC) has a rectifier unit first which feeds its o/p to PMMC indicating instrument.

Essential is wrong, reason is true

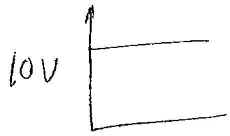
* A symmetrical square wave voltage is read by avg response electronic voltmeter whose scale is calibrated in terms of rms value of a sinusoidal wave. The error in reading is ------

① −3.9% (b) +3.9% (c) −11% [✓ (d) 11%]

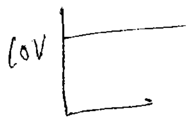
Error $= \frac{1.11 - 1}{1} = 0.11$ or +11%

Que:- An avg response rectifier type electronic voltmeter as dc voltage of 10v applied to ~~its~~ @ it what is meter readins

FWR i/p



FWR o/p



$V_{dc} = 10V$
$= 10 \times 1.11$
$= 11.1$

Que:* What is the advantag electronic voltmeter over non electronic voltmez

(a) ~~High i/p impedance~~ Low power consuption (b) low i/p impedance

(c) The ability to measure wide ranges of voltage & resistance

(d) Large portability

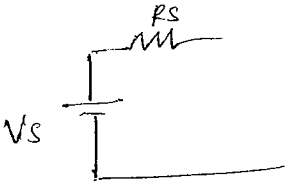
Que:- For measurement of the voltage of the order of mV the voltmeter used is

(1) Rectifier amplifier VTVM
✓ (2) Amplifier rectifier type VTVM
(3) Diode peak VTVM
(4) Slight wire (VTVM)

Que... PMMC voltmeter has a sensitivity of 20kΩ/Volt. A Reading of 4.5 Ω is obtained when measuring a voltage source with the internal resistance on it 5 volts scale. When the scale is change to 10volts a reading 6 volts is obtained. The value of the voltage source & its internal resistance are ....

(a) 10 V, 100 kΩ (b) 9V, 100 kΩ

(c) 10 V, 200 kΩ (d) 9 V, 200 kΩ.



soln:- $S = 20 k\Omega/volt$

* 5V scale

$\rightarrow R_V = 20 \frac{k\Omega}{V} \times 5V$

$R_V = 100 k\Omega$

$\rightarrow$ Reading $= V_S \times \frac{100 k\Omega}{R_S + 100 k\Omega}$

$$4.5 = V_s \times \frac{100 k\Omega}{R_s + 100 k\Omega}$$

$$V_S = \frac{4.5V}{100k\Omega}\left[R_s + 100 k\Omega\right] - ①$$

* 10 V scale

$$R_V = 20 \frac{k\Omega}{V} \times 10 V = 200 k\Omega$$

$$rdg = V_S \times \frac{200 k\Omega}{R_S + 200 k\Omega}$$

$$6V = V_S \times \frac{200 k\Omega}{R_S + 200 k\Omega}$$

$$V_S = \frac{6V}{200k\Omega}\left[R_S + 200 k\Omega\right] - ②$$

equating eqn ① with eqn ②

$$\frac{4.5 V}{100k\Omega}\left(R_S + 100k\Omega\right] = \frac{6V}{200k\Omega}\left[R_S + 200 k\Omega\right)$$

$\Rightarrow \quad R_S = 100 k\Omega$

Putting Rs in eqn ①

$V_S = \frac{4.5}{\cancel{100k\Omega}} \left[\cancel{100k\Omega} \parallel \overset{2}{\cancel{100k\Omega}} \right]$

$\boxed{V_S = 9 \text{ volt}}$

Q meter

*Principle of operation

- * Direction connection ckt diagram
- * elements in the connection
- * Working
- * Mention error, % error & correction factor

} Done previous

Que- Explain with the help of ckt diagram the principle of wor of Q meter.

Que :- Describe a method of measuring the disiputive capacitance of coil derive a necessary expression.

Soln:- * Q meter in direct connection can be used for measur of Cd of coil

- * Direction connection of ckt diagram
- * elements in connection
- * 2 steps of resonant state
  Mention reading of each step
- * Derivation for Cd
- * Ex

$$\left.\begin{array}{l} f \longrightarrow 2f \\ C_1 \longrightarrow C_2 \end{array}\right\} C_d = \frac{C_1 - 4C_2}{3}$$

Que :- A coil was tested using a Q meter ~~and~~ the following result was obtained

Oscillator frequency	3 MHz	6 MHz
Tunning Capacitance setting	251PF	50PF

Find self capacitance of coil

Soln :- $n = \frac{6MHz}{3MHz} = 2$

$$Cd = \frac{251PF - 4 \times 50PF}{3} = 17 PF$$

Que :- (a) Describe the method of measuring the value of Q factor of an unknown inductance in the range 1µH - 1mH with high accuracy

(b) An unknown inductance resonant at frequency of 1MHz with an external capacitance of 210 PF (Tuning capacitance) & has a Q of 100. If the frequency of the source is doubled it is found that the tunning capacitor required for resonant is 45 PF. Determine the value of unknown inductance & other component associated with it in the equivalent ckt

Que :- In a Q meter measurement to determine the self capacitance of a coil the 1st resonant occured at f_1 with $C_1 = 300PF$ the 2nd resonance occureed at $f_2 = 2f_1$ with $C_2 = 60PF$ The self capacitance of Cs - - - -

$$= \frac{300 - 2^2 \times 60}{3} = 20PF$$

2003

Que - Assertion → The Qmeter measures the Q factor of a coil when the ckt is at resonance (True)

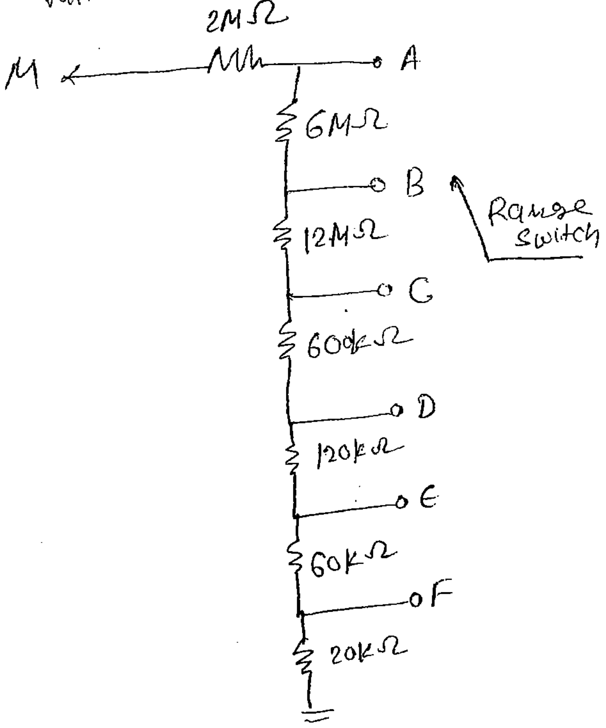
Reason → The Q factor of coil depends only on its inductance & not on it resistance (False)

2000

Que - Assertion ⇒ The basic principle of operation of a Q meter is based on the property of series resonance ckt (True)

Reason ⇒ If a fixed voltage is appled to a series resonant ckt the Voltage developed accross it capacitor is Q time the applied voltage (True)

Que:- The figure shows i/p attenuation of multimeter the meter read full scale with 12V at M & range s/w at B what is the required voltage at M to obtain full scale deflection with the range s/w position at D



(a) 1.2V

(b) 150V

(c) 120 V

(d) 147 V

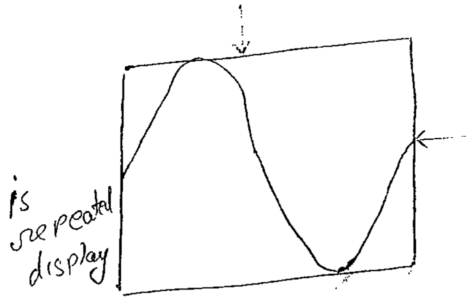
n ite
12/04/2012

Que:- An analog single channel CRO is used to measure a time varying signal $2 \sin 100\pi t$ Ω Identify the image of signal displayed on screen for the following relation betwn signal frequency & sweep frequency

① $\frac{f_{signal}}{\cancel{f_{sweep}}} = f_{sweep}$ ② $f_{signal} = \frac{3}{4} f_{sweep}$

(3) $f_{signal} = 1.5\ f_{sweep}$

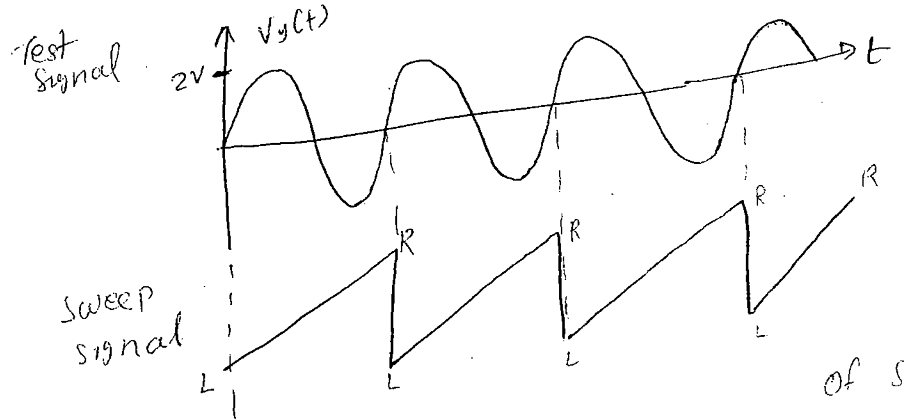
(4) $f_{signal} = 2\ f_{sweep}$



~~Assume~~ ~~in terms~~

Soln ⇒ (1) $f_{signal} = f_{sweep}$

i.e $T_{signal} = T_{sweep}$



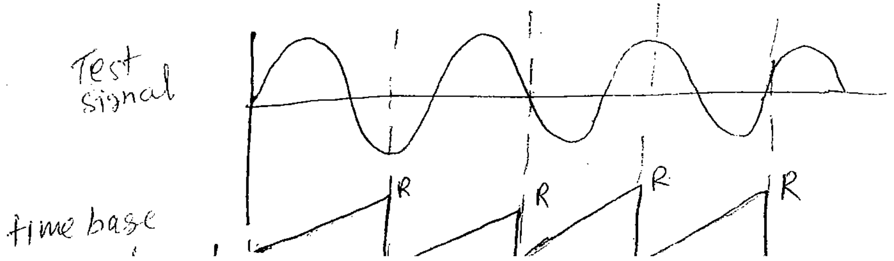
of signal
→ 1 cycle Displayed

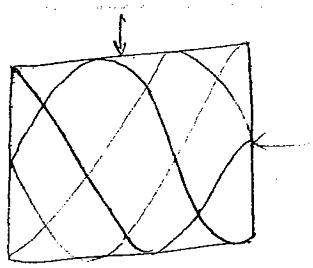
$\left(\because \frac{f_{signal}}{f_{sweep}} = 1\right)$

→ steady display (∵ Same Portion of 1 cycle)

(2) $f_{signal} = \frac{3}{4} f_{sweep}$

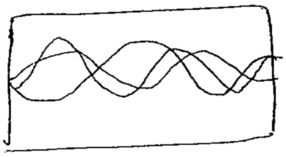
$T_{signal} = \frac{3}{4} T_{signal}$ (75% of signal Portion)





Jumble (∵ different position of displayed)

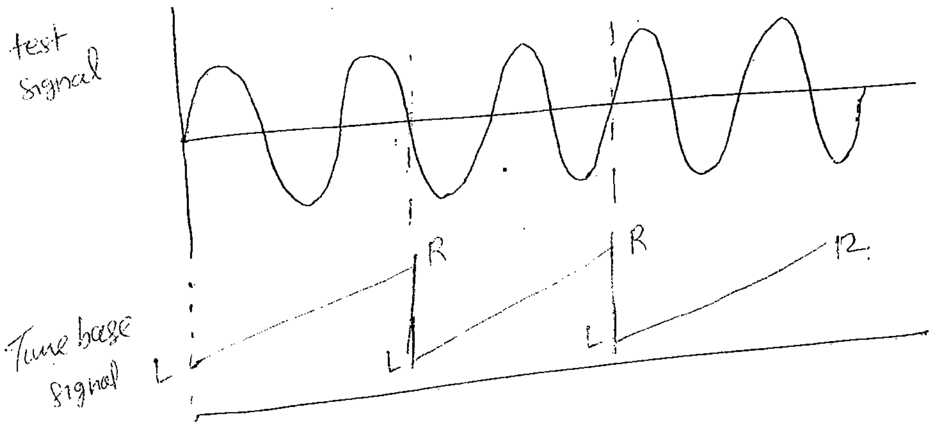
Ex :-

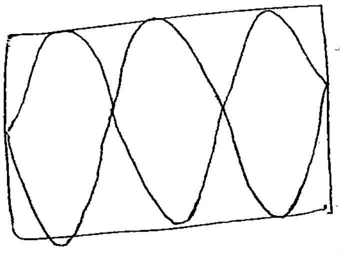


Note ⇒ To avoid such Jumble i-e to get a steady display of image the user has to either Synchronised by adjusting Time/div or select proper triggering point

③ $f_{signal} = 1.5 f_{sweep}$

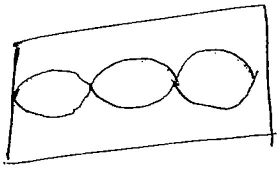
$T_{signal} = 1.5 T_{sweep}$





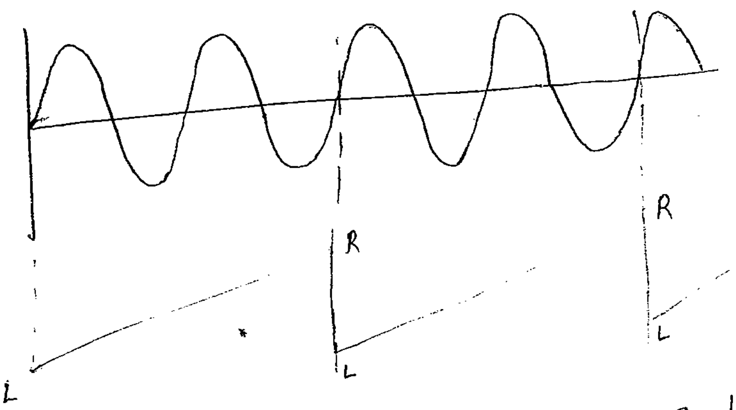
Jumble (Different 1.5 cycle of signal displayed)

Ex :-



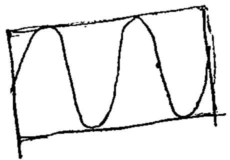
④ $f_{signal} = 2 f_{sweep}$

$T_{signal} = 2 T_{sweep}$



⇒ 2 Cycles of signal displayed

$(\because \frac{f_{signal}}{f_{sweep}} = 2)$



> steady display
(∵ Same 2 cycles are repeatedly displayed)

Que - A single channel analog CRO is used to measure a time varying signal $2 \sin 100\pi t$. Internal trigger source is choosen Draw the image displayed on the screen for the following case

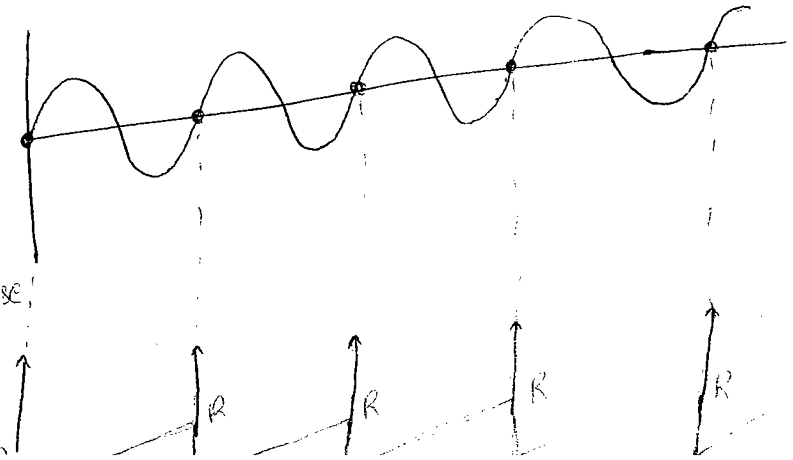
1) $f_{signal} = f_{sweep}$ & trigger point 0V, +ve
2) $f_{signal} = f_{sweep}$ & trigger point 0V, -ve
3) $f_{signal} = 1.5 f_{sweep}$ & trigger point 0V, +ve
4) $f_{signal} = 3/4 f_{sweep}$ & trigger point 0V, +ve

Sol^n

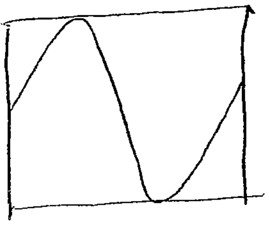
$f_{signal} = f_{sweep}$ & (0V, +ve)

$T_{sweep} = T_{signal}$, t.V.L = 0V, t-S = +ve

Test signal as triggering signal (0V, +ve)



trigger Pulse



→ 1 cycle of steady image of signal

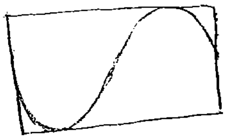
(∵ $\frac{f_{signal}}{f_{sweep}} = 1$) (Proper triggering)

② $f_{signal} = f_{sweep}$ & (0V, -ve)

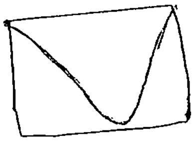
$T_{signal} = T_{sweep}$

→ 1 cycle of signal displayed since $\frac{f_{signal}}{f_{sweep}} = 1$

& it will shown from 0V & falling side

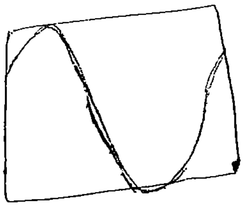


Note ⇒ For 1:1 ratio & (2V, -ve) ⇒

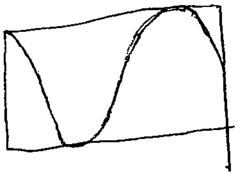


③ $f_{signal} =$ ~~1.5 f_{sweep} & (0V, +ve)~~

→ For 1:1 ratio & (+1V, +ve) ⇒

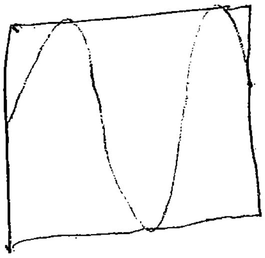


⇒ For 1:1 ratio & (+1V, -ve)



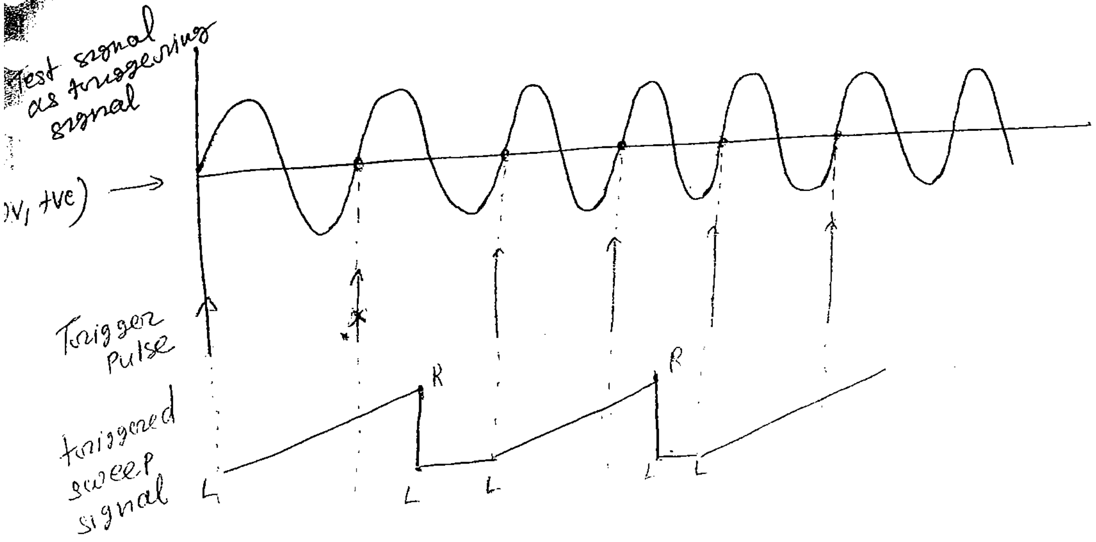
③ $f_{signal} = 1.5\ f_{sweep}$ & (0V, +ve)

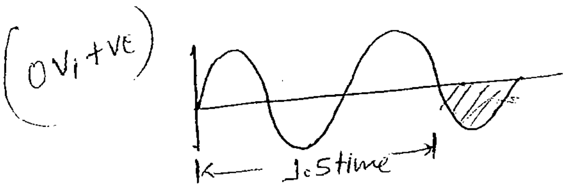
$T_{sweep} = 1.5\ T_{signal}$ i.e. V.L – 0V t_s = +ve



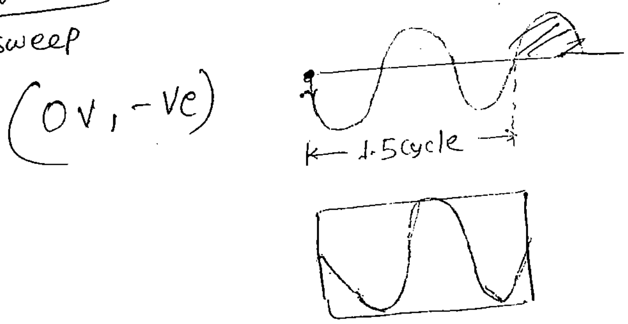
→ 1.5 cycle of signal steady image of.

(∵ $\frac{f_{signal}}{f_{sweep}} = 1.5$) (∵ Proper triggering)





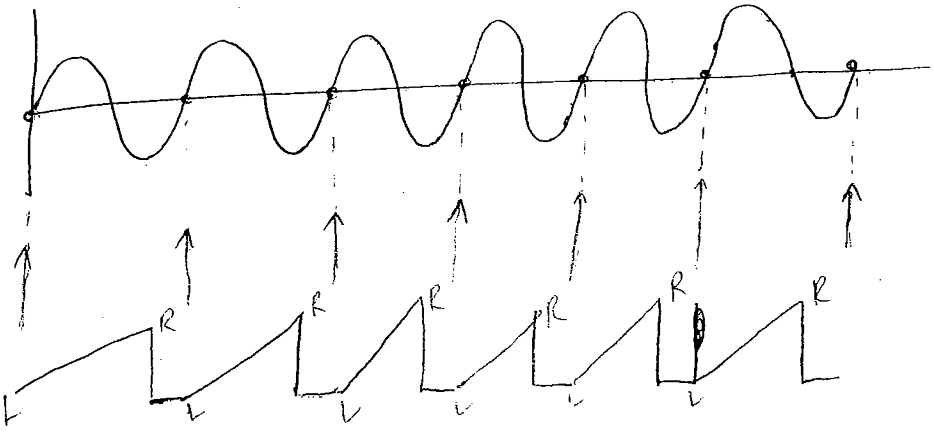
Note:- $\frac{f_{signal}}{f_{sweep}}$ = ~~1.5~~ 1.5 & 0V, -ve

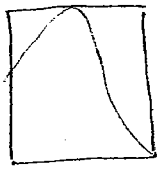


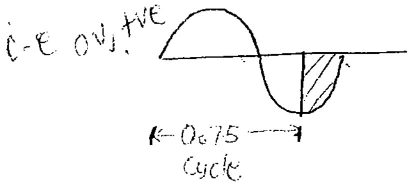
④ $f_{signal} = \frac{3}{4} f_{sweep}$ (0V, +ve)

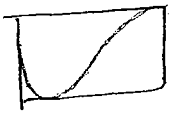
→ $T_{sweep} = 3/4\ T_{signal}$

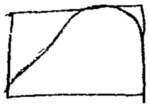
t.V.L = 0V , t.s. - +ve

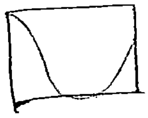






Note - ⇒ 3/4 & (0V, -ve) ⇒ 

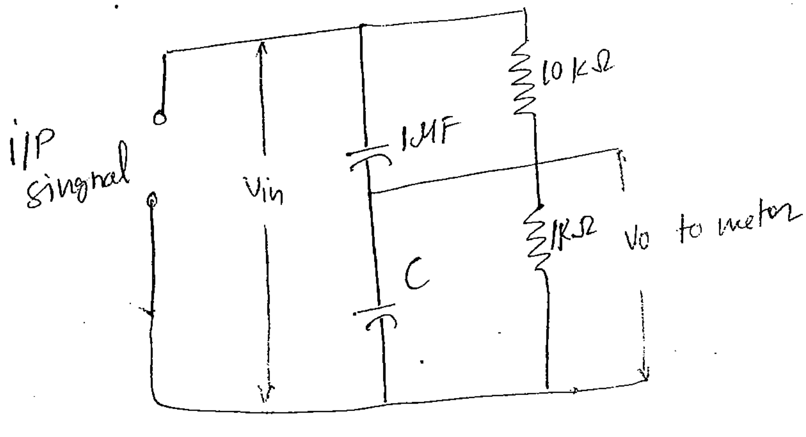
⇒ 3/4 & (-2V, +ve) ⇒ 

⇒ 3/4 & (+2V, -ve) ⇒ 

Not ⇒ Improper triggering always need to rumble where as prope triggering produces steady image of signal on screen,

(

Que ⇒ The arrangement shown in the given figure represents a RC potentiometer for measuring ac voltage what should be the value of C so that Vo/Vin is independent of frequency of the i/p signal



(a) 10 μF
(b) 11 μF
(C) 0.1 μF
(D) 0.09 μF

* $R_1C_1 = R_2C_2$ to make $\frac{V_o}{V_{in}}$ independent of frequen

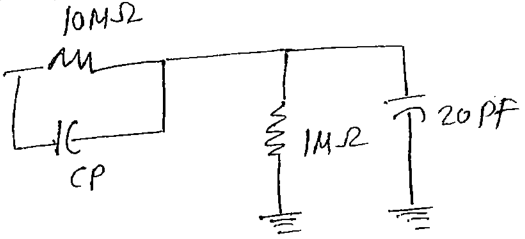
$10K\Omega \times 1\mu F = 1K\Omega \times C$

$\therefore C = 10\mu F$

Que :- An oscilloscope has i/p impedance consisting of 1MΩ & 2 PF in parallel a high impedance + connected to i/p of 10 MΩ Resistance. Thus of this oscilloscope ~~ba.~~ 10 MΩ resistance - - -

1 MΩ || 20PF
10MΩ || - - - -

(a) Need not to be shunted
(b) should be shunted by 20 PF
(c) should be shunted by 200 PF
(d) should be shunted by 2 PF



$R_1 C_1 = R_P C_P$

$1M\Omega \times 20PF = 10M\Omega \times C_P$

$\therefore C_P = 2 PF$

Or $\frac{V_i}{V_s} = \frac{R_i}{R_p + R_i} = \frac{1 M\Omega}{10M\Omega + 1M\Omega}$

$= \frac{1}{11}$

Now $\frac{V_i}{V_S} = \frac{C_P}{C_P + C_i} \Rightarrow \frac{1}{11} = \frac{C_P}{C_P + 20PF}$

$C_P + 200pF = 11 C_P \Rightarrow C_P = 2 PF$

Or $\frac{V_i}{V_s} = \frac{1}{11}$

i.e 11:1 Probe
- → Vs ↓ by 11 lines
- → $R_P = 10 R_i$ &
  $C_P = \frac{C_i}{10}$ . . . . > $C_P = \frac{20PF}{10} = 2 PF$
- → ↑ $R_{eff} = 11 R_i$
  ↓ $C_{eff} = \frac{C_i}{11}$

Que ⇒ The oscilloscope has an i/p capacitance of 50 PF under resistance of 2MΩ & voltage divider ratio (K) of 10 what are the parameter a high probe.

$C_i = 50PF$ $\qquad R_i = 2M\Omega$

$K = 10 \; .\;.\;.\;.\;. \; = \frac{V_s}{V_i}$

i.e $\quad V_i = \frac{1}{10} V_s$

→ 10 time attenuation

$R_P = (10-1) R_i \Rightarrow \quad R_P = 9R_i$

$R_P = 9 \times 2 M\Omega \quad \Rightarrow \quad \underline{R_P = 18 M\Omega}$

$C_P = \frac{C_i}{(10-1)} = \frac{C_i}{9}$

$= \frac{50}{9} P.F. = 5.55 PF$

Que The bandwidth of CRO is from 0 to 20MHz. The fastest rise time which a square wave have in order that it is accuratly reproduced by the CRO is -----

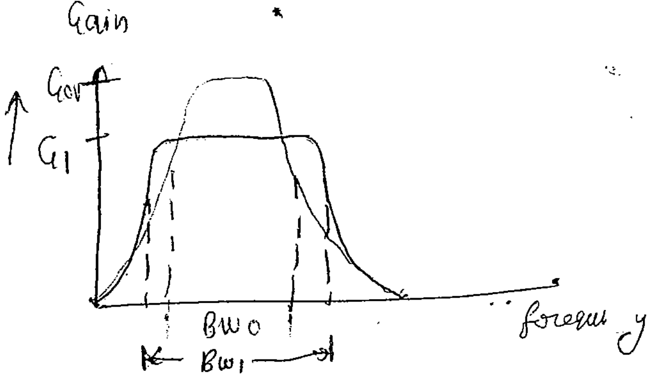
$t_r \times B.W = 0.35$

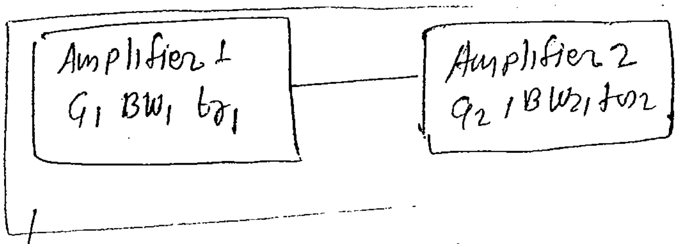
$t_r = \frac{0.35}{20 MHz} = \frac{0.035}{2} \mu s$

$= 17.5 \mu sec$

Que - A CRO with a rise time of 150 nsec measures the rise time of signal as 20 nsec. what is the actual rise time of the signal

[Pre-requisite





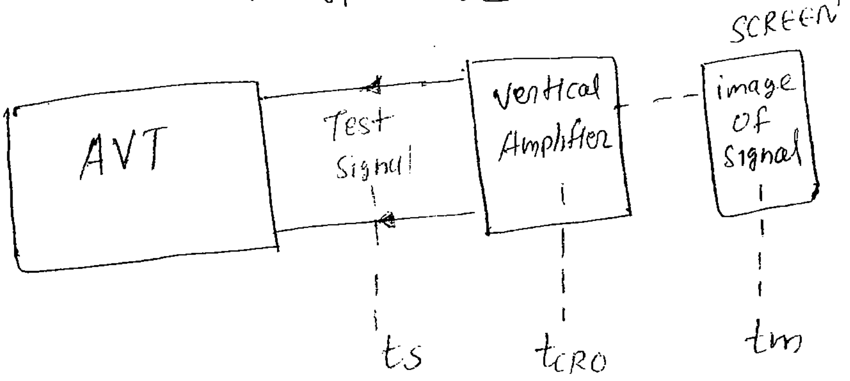
$\uparrow G \times BW \downarrow \sim K$

$t_r \times BW = 0.35$

$G_{ov} = G_1 \times G_2$

$t_{r} = \sqrt{t_{r_1}^2 + t_{r_2}^2}$

→



t_s = Actual or true rise time of signal

t_{CRO} = CRO rise time (i.e Vertical Amp rise time)

t_m = measured rise time is overall rise time

$$t_m = \sqrt{t_s^2 + t_{CRO}^2}$$

Soln :-

T_{CRO} = 15 nsec

t_m = 20 nsec

$$20\,ns = \sqrt{t_s^2 + (15ns)^2}$$

$$t_s = \sqrt{(20ns)^2 - (15ns)^2}$$

$$= \underline{\underline{13.23\ ns}}$$

Que ⇒ A CRO has a rise time ~~was~~ of 20 ns. The rise time of a signal measured by this CRO is 25 ns. Find the true rise time of signal.

Solⁿ

$$t_m = \sqrt{t_s^2 + t_{CRO}^2}$$

$$25 = \sqrt{t_s^2 + (20)^2}$$

$$t_s = \sqrt{(25ns)^2 - (20ns)^2}$$

$$t_s = 15\,ns$$

Que ⇒ A CRO is operated with the x & y settings of 0.5 msec / cm & 100 mV/cm The screen of CRO is 10cm×8cm. the cycle of frequency 200Hz & RMS amplitude of 300 mvolts is applied to the twice the screen will shows - - - -

(a) 1 Cycle of Undistorted sine wave.

(b) 2 Cycles of undistorted sine wave

(c) 1 cycle of the sine wave with clipped amplitude

(d) 2 cycle of the sine wave with clipped amplitude.

Given here 0.5 ms/cm 100 mV/cm

10cm × 8cm screen

1 cycle or 2 cycle

$$n = \frac{f_{signal}}{f_{sweep}} = f_{signal} \times T_{sweep}$$

$$= 200Hz \times \left[10cm \times 0.5\,\frac{ms}{cm}\right]$$

$$= 200 \times 5\,msec$$

$$= 1\ \text{cycle}$$

∴ option (b) & (d) are eleminated

Ans eithe A or C

$$V_{rms} = \frac{V_{P-P}}{2\sqrt{2}} = \frac{NV \times volt/div}{2\sqrt{2}}$$

$$\therefore NV = 2\sqrt{2} \times \frac{V_{rms}}{Volt/div}$$

$$= 2\sqrt{2} \times \frac{300mV}{100\ \frac{mV}{cm}}$$

$$= \underline{\underline{8.48\ cm}} > \text{Available ventical scale of 8cm}$$

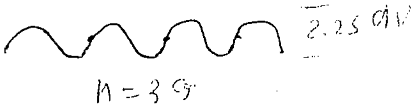
∴ Peak points will be applied

So Ans ⇒ C

<u>Que</u> ⇒ A CRO is calibrated for 20 V/div & its sweep ckt is set for 6 msec. 3 complete sine waves with a distance 2.25 divisions between there upper & lower extremnts appear on the screen. Find Rms voltage & frequency of signal

⇒ Given data 20 volt/div

T_{sweep} = 6 ms



$$V_{rms} = \frac{V_{P-P}}{2\sqrt{2}}$$

$$= \frac{2.25 \times 20\ Volt/div}{2\sqrt{2}}$$

$$= \frac{22.5}{\sqrt{2}}\ V$$

$$= 15.9\ V$$

→ $f_{signal} = n\ f_{sweep}$

$$= 3 \times \frac{1}{6ms}$$

$$= \frac{1}{2ms}$$

$$= 0.5\ KHz$$

$$= 500\ Hz$$

Que — A pulse having rise time of 40 ns is displayed on CRO of 12 MHz Bandwidth the rise time of the pulse observed on CRO would be approximatly equal to

- - - - -

(a) 40 ns (b) 83.3 ns

(c) 80 ns (d) 50 ns

⇒ BW = 12 MHz t_s = 40 ns

t_m = ?

$$t_{CRO} = \frac{0.35}{12 MHz} = 30 ns$$

$$t_m = \sqrt{t_s^2 + t_{CRO}^2}$$

$$= \sqrt{(40 ns)^2 + (30 ns)^2}$$

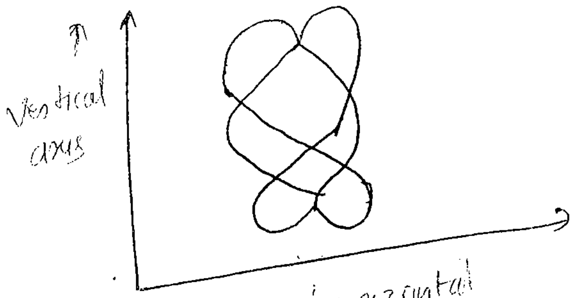
$$= 50 ns$$

Que : A sine wave voltage is displayed on a CRO its vertical amplifier sensitivity is set at 5 V/cm & time base selector switch is set at a swee speed of ~~1~~50 μsec/cm. The display of sine wave has peak to peak amplitude of 5.4 cm & its two complete cycle on accomodated over 8.1 of horizontal axis. determine the rms Value ~~of~~ & frequency of o/p voltage.

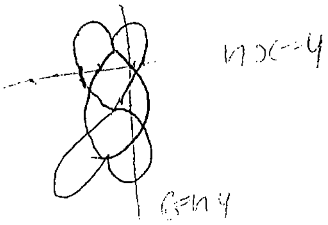
(2)

Qu.- A scrren pattern oscillogram shown in the given figure is obtained when a sine wave of unknown frequency is connected to vertical i/p terminals & same time 600x sinewave voltage is connected to the horizontal i/p terminal of on oscilloscope. What is the value of unknown freequny

a) 300x
b) 400x ✓
c) 600x
d) 900x



Interaction ~~Tangential~~ Technique



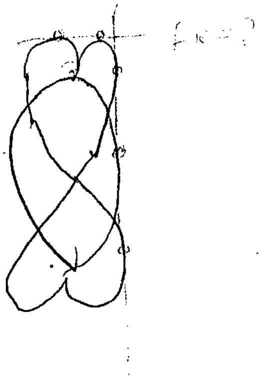
$$\Rightarrow f_y n_y = f_x n_x$$

$$f_y = \frac{f_x n_x}{n_y}$$

$$= \frac{4}{6} \times 600\,Hz$$

$$\boxed{f_y = 400\,Hz}$$

Tangential Technique



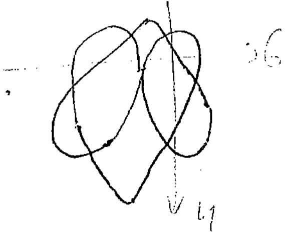
$$f_y = \frac{n_x}{n_y} f_y$$

$$= \frac{2}{3} \times 600$$

$$f_y = 400\,Hz$$

Que In a oscillioscope 2 lyssajious figure X & Y are observed this indicates the ratio of vertical i/p signal frequency to that of horizontal i/p signal frequency are ....

X

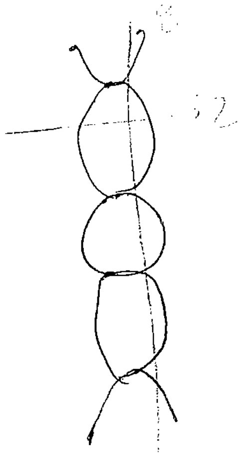


Y

3:2
for X

3:2
for Y

Que. When a CRO is operated in X-y display w the below given lessajous figure is displayed the screen what is the Horizontal to Vertr



$$\frac{f_y}{f_x} = \frac{n_x}{n_y}$$

$$= \frac{2}{8}$$

$$f_y/f_x = 1/4$$

$f_y : f_x = 1:4$ Vertical to Horizontal frequency

$f_x : f_y = 4:1$ Horizonta to vertical frequency

Que ⇒ When a sinusoidal signal of 220V, 50Hz Pro. on CRO a vertical deflection 2Cm at a particular setting of the vertical gain control what would be the value of voltage to b applied to produce a deflection of 3Cm w 3 vertical gain

* $\frac{Volt}{div}$ → Difflection factor Df (Voltage gain)

$S = \frac{div}{volt}$ $S = \frac{d}{V_d}$

$D_F = \frac{V_d}{d}$ 220V → 2cm

$D_F = \frac{220}{2}$

$= 110v/cm$

for 3 cm deflection

$V_d = 3cm \times 110V/cm = 330V$

Que: A CRT has deflection factor of 18 v/cm the amount of deflection seen on the screen for deflecting voltage ~~18V~~ 54 V

$D_F = 18 V/m$ $V_d = 54V$

$d = \frac{54}{18 V/cm} = 3 cm$

Que – ECE 2005

Which of the following measurement can be made using lissagiase figure

1) frequency (2) phase difference

× 3) Time interval betwen pulse × 4) Pulse width

✓5) fundamental & higher harmonic component

Ans → 1 & 2

Que: Beam of electronics in CRT eleminates because of

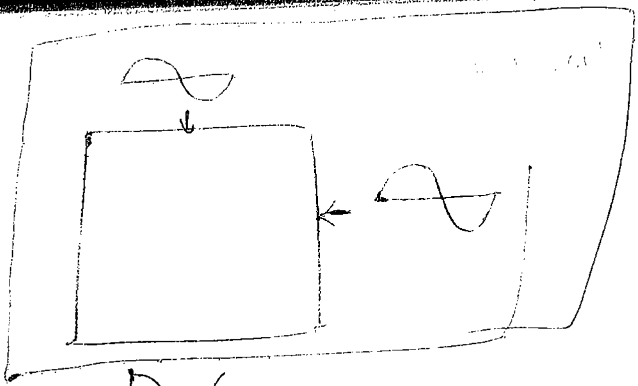
(a) 2nd emmision

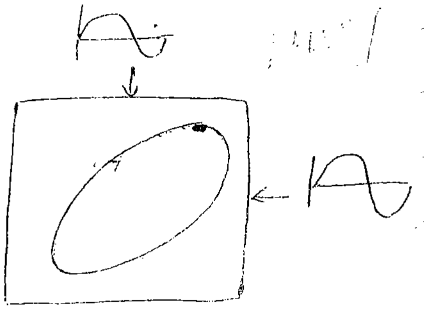
✓(b) Thermionic emmision

(c) deffusion

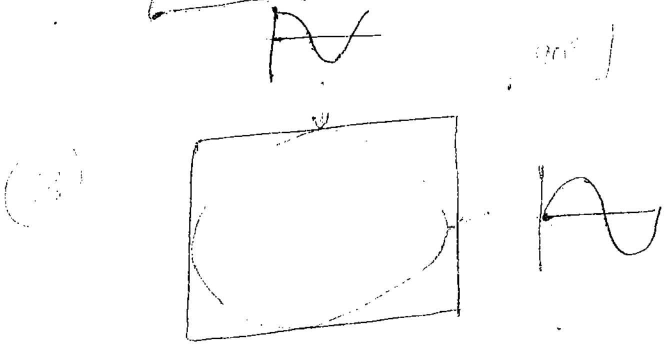
(d) post accelaration

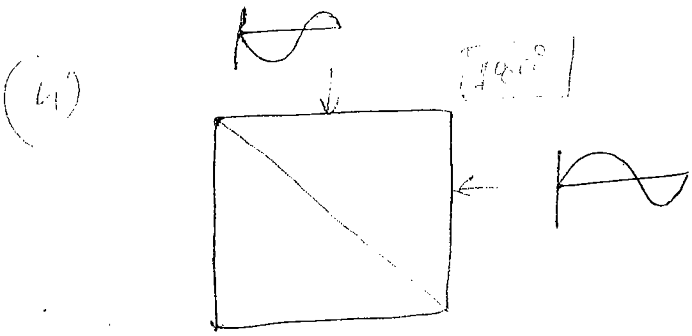
Que: 1000 Hz sinusoidal voltage is connected to both X & Y on CRO which of the following waveform is ~~shown~~ seen on screen of CRO

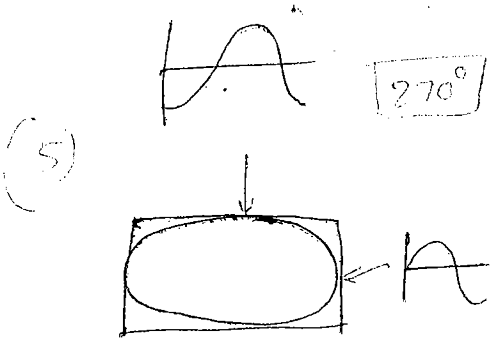


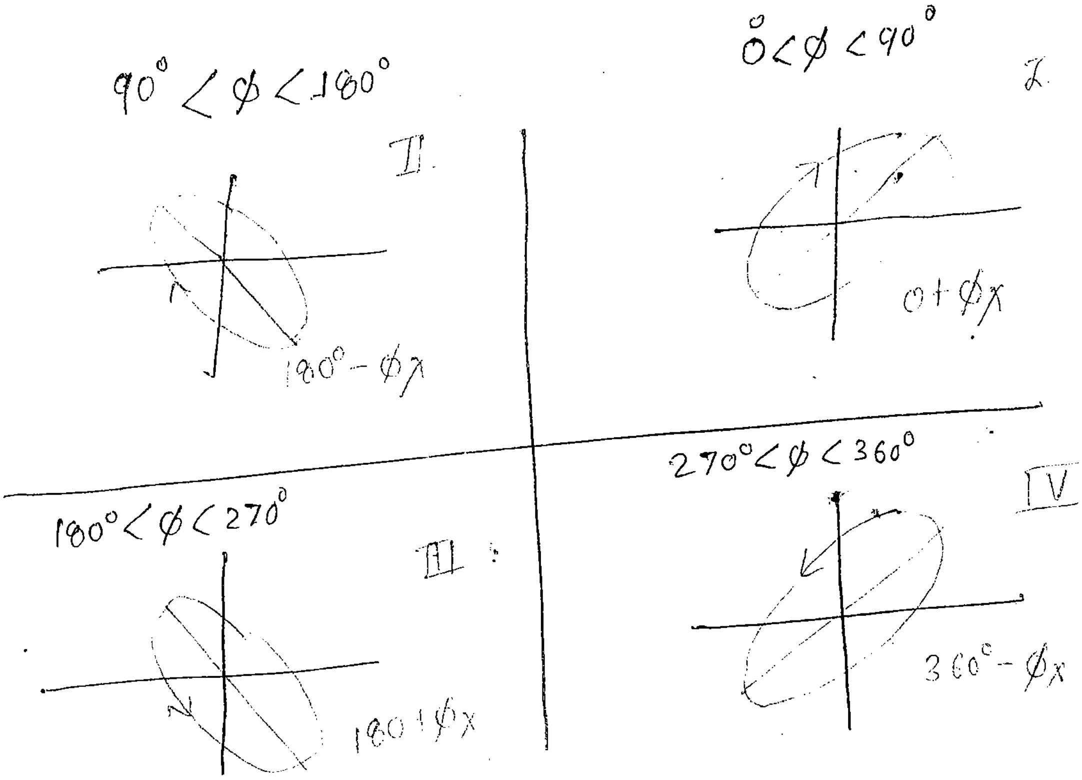


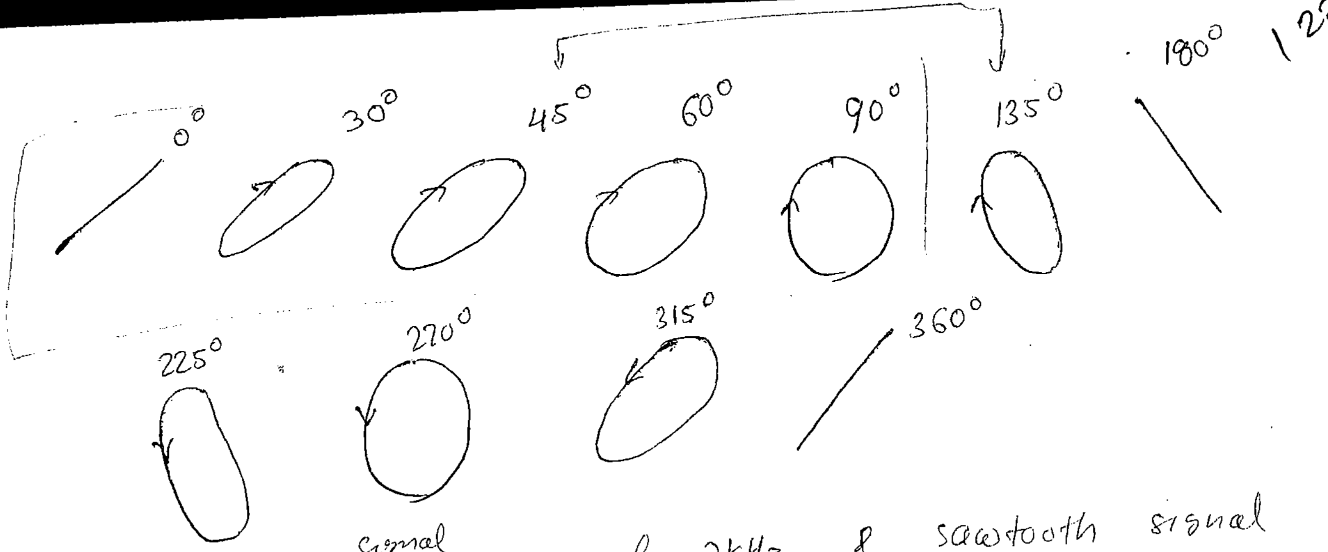
$\phi = \sin^{-1}\frac{y_{int}}{y_{max}}$





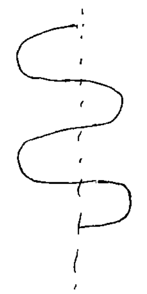




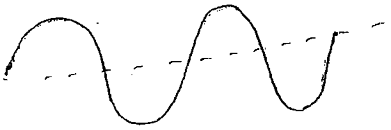


Que.- A sinsouidal signal frequncy of 2KHz & sawtooth signal of frequncy 1KHz applied to Horizontal & Vertical i/p of a CRO the waveform display on the screen will be.

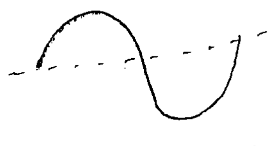
(a)



(b)



(c)



(d)