

Electrical and Electronics Measurement & Instrumentation

Error Analysis : The deviation of the measured quantity from the true value / actual value is called 'error'. It is denoted by ' ϵ '.

It is defined as :

$$\epsilon = A_m - A_t$$

A_m = measured value.

A_t = true value.

It is of two types,

(i) Static error : The errors which are independent of time are called static error.

(ii) Dynamic error : The errors which are depend on time are called dynamic error. It is possible in real time practical.

So, the static error = $A_m - A_t$.

$\epsilon = +ve$; $A_m > A_t$, & $\epsilon = -ve$; $A_m < A_t$.

Correction factor : The value which we are added or subtracted from the measured quantity in order to get true value is called correction factor.

C.F. = +ve ; $\epsilon = -ve$.

C.F. = -ve ; $\epsilon = +ve$.

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

Relative static Error :

The error taken over the true value is relative static error.

Electronics : 30V 11KV

frequency { KHz 33KV
 MHz :
 GHz 1000KV

$$R.S.E. = \frac{A_m - A_t}{A_t} = \frac{e}{A_t}$$

$$\% R.S.E. = \frac{A_m - A_t}{A_t} \times 100$$

% RSE determines the quantity of an instrument.

A	B
$A_t = 2A$	$100A$
$e = 1A$	$10A$
$\% RSE = 50\%$	1%

B is the best as compare to A.

Limiting Error :- (tolerance/uncertainty)

The limiting error specified by the manufacturer of it'll give the range of op. The error is always w.r.t. true value.

** The %LE is not zero at all.

10
 $(0-10)A ; \% LE = \pm 1\%$

$$\left. \begin{array}{l} 2A ; 2 \times \frac{\pm 1}{100} = (2 \pm 0.2) = (1.98 - 2.02) \\ 10A ; 10 \times \frac{\pm 1}{100} = (10 \pm 0.1) = 9.9 - 10 \end{array} \right\} \begin{array}{l} \text{measured} \\ \text{value}(A_m) \end{array}$$

[$9.9-10.1 \rightarrow$ is the wrong one bcoz the meter it-self range from $(0-10)A$].

A meter ranges from $(0-10)A$.
 $\hookrightarrow$ full scale value.

Basic characteristic of Instruments :-

A = Accuracy

P = Precision

L = Linearity

S = Sensitivity

Dead time

of zone

eg:

of

with

Linearity :-

Whatever the reading = o/p.

Here the o/p of all the ang elec.

Instrument is 'o'.

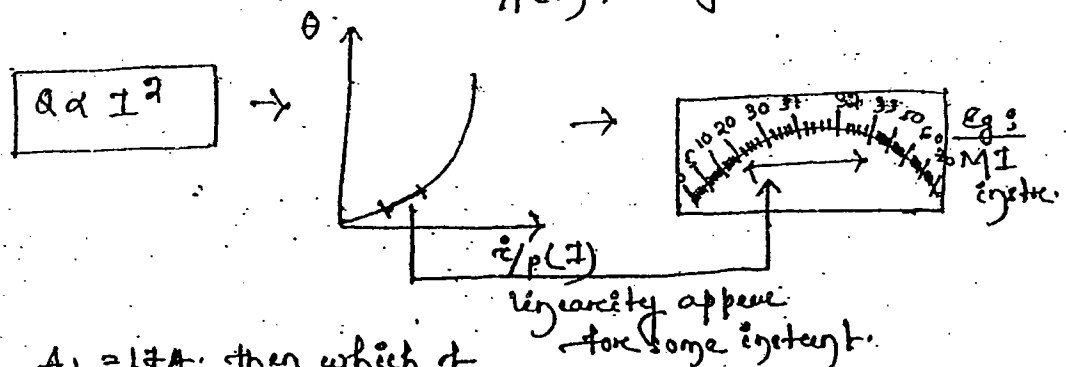
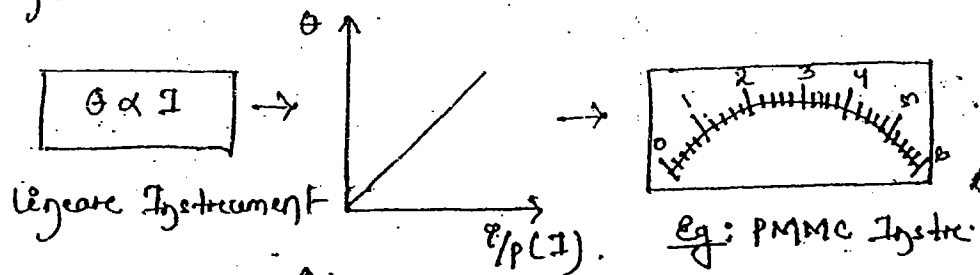
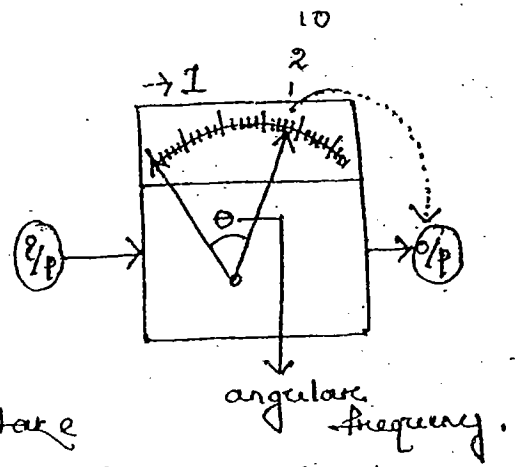
Whatever the parameter is given as i/p to the instrument

but the instrument always take

current as i/p. And the current is proportional to

angular frequency 'o'. And this relation b/w o and I

shows whether the instrument is linear or non-linear one.



Q: $A_L = 174$. Then which of the following will give more accuracy:

(i) (0-100) A note: Even an instrument is a non-linear one, but we have to choose a

(ii) (0-20) A

(iii) (0-30) A point that the pointer chooses enters into the non-linear region.

The o/p follows the i/p with linear relation linear eqn is known as linearity. It is a desirable condⁿ, but it is necessary, but (not compulsory)."

→ we select the meters always in such a way that the pointers should enter into linear region. so that we may not lose the accuracy.

Sensitivity :-

→ we have to choose always high sensitive instruments.

If in an instrument : for $2.1 \text{ (i/p)} = 2 \text{ (o/p)}$
and $2.0 \text{ (i/p)} = 2 \text{ (o/p)}$ } low sensitive instrument.

High sensitive = wide response = more accuracy.

Low sensitive = Less response = Less accuracy.

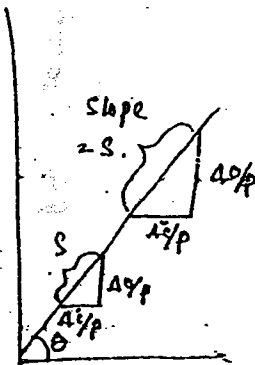
$$S = \frac{\text{change in \%p}}{\text{unit change in i/p}} = \frac{4\%p}{\Delta \text{i/p}} = \text{slope.}$$

How the sensitivity place in Linear scale :-

→ For the linear scale sensitivity is always const.

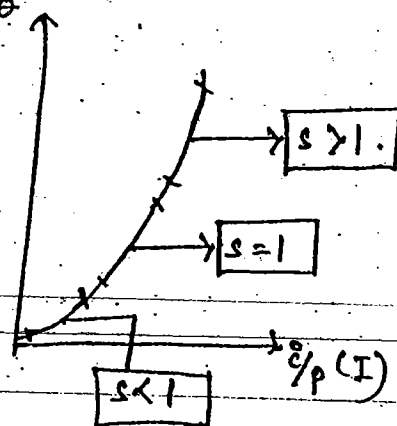
→ For linear scale / instruments :

$$S = \tan \theta = 1 \quad (\theta = 45^\circ)$$



What about the sensitivity in non-linear scale :-

→ Sensitivity is vary throughout the scale in non-linear instr.



Mean

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note :-

becoz

Dead time :-

In this instr. we have to measure the voltage.

After measuring $V = 3V$.

Initially the pointer placed at '0'. Due to some force 'F' the pointer moves from '0' to '3'.

In voltage measurement system :

$$\theta \propto F \propto I \propto V.$$

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

In current measurement system :

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

In any electrical instrument, ^{always} the current is the ^{or} i/p ~~meter~~. In current measurement system the connection should be in series.

↳ In all electrical instrument the responsible quantity is current.

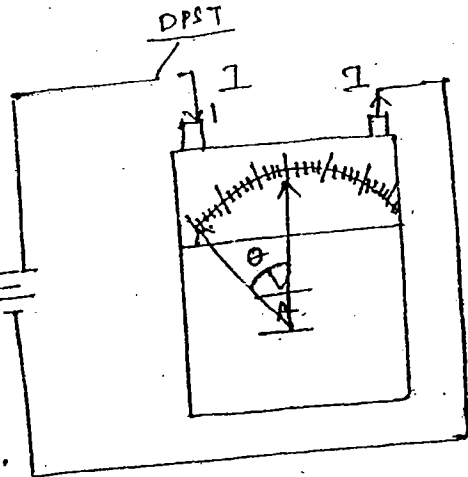
$$\hookrightarrow \text{If } \theta \propto I^2 \propto V^2 \text{ or } \theta \propto I^{2/3} \propto V^{2/3}.$$

Note: In electronic instrument the responsible quantity is voltage and in electrical instrument the responsible quantity is current.

beacz: In electronic instr. the o/p is in pulse, and pulse = voltage mode. (pulse concept)

In electrical instr. the pointer is rotating due to some force. This force is due to the current inside it. Inside the electrical instr. there is energy conversion is occurs, that convert I to F by the relation

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



B/w electronic or electrical instrument, the electronic instrument is fast one. and more accuracy becoz the counter is fast, there is no energy conversion. and the electrical instrument have less loss also.

↳ All electrical instrument are energy converter i.e. convert the electrical energy to mechanical energy.

↳ "The time taken by the instrument to the pointer from its initial position is known "dead time"

↳ The main reason for 'dead time' is 'inertia'.

↳ we can't avoid the dead time in an instruments. becoz we can't avoid the inertia i.e. we can't avoid the pointer in an instruments.

↳ we can't prepare/get a 100% accuracy instrument, becoz we can't prepare a '0' weight pointer **.

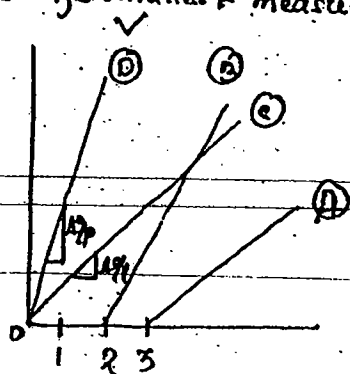
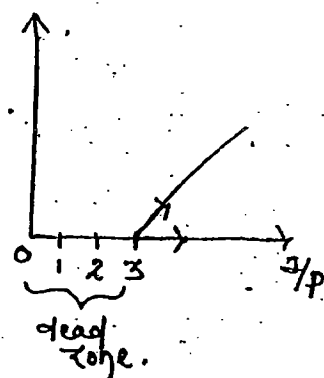
** All the instrument will subjected to both transient and steady state stability **.

Dead zone :-

↳ The min^m i/p beyond which the response will come is known as Dead zone.

↳ It is also known as threshold.

↳ It defines the smallest measurable i/p.



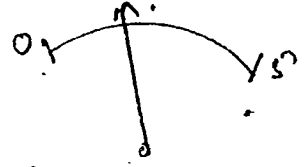
Among 4 of them '1' is the best one. It is linear as well as ^{high} sensitive one also. Here is no dead zone also.

(iii)
error
Range
range

Resolution :- (R).

we prefer always high resolution.

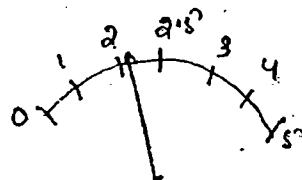
high resolution $\Rightarrow$ more clarity $\Rightarrow$ more accurate.



- a) 2.5
 - b) 2.2
 - c) 1.9
 - d) 1.7
- because the scale has only 10 resolution. so less accuracy is there.



- a) 2.1
 - b) 2.2
 - c) 2
 - d) 2.5
- The clarity is much better than previous one, but still we aren't accurate.



- a) 2.1
 - b) 2.2
 - c) 2
 - d) 2.5
- here also the clarity is much better than previous two, but still we are unable to give accurate value.

Statement : The smallest o/p that we can detect with certainty or clarity is called resolution.

$\hookrightarrow$ When there is an smallest change in i/p, then only we can detect smallest o/p.

$$\text{resolution} = \frac{\text{fullscale reading}}{\text{total no. of division}}$$

$\hookrightarrow$ **no. of division increases = Resolution increases**

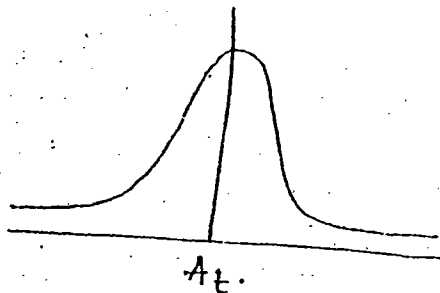
Types of Errors :-

- (i) Gross Error (It is due to only human negligence)
- (ii) Systematic error
 - $\rightarrow$ Instrumental (manufacturing error, inst. aging error)
 - $\rightarrow$ Environmental error
 - $\rightarrow$ observational error (parallax error)
- (iii) Random Error :- There is no particular reason for random error. Sometimes error will come and eliminate automatically. Random error may be +ve or -ve. All the instruments are having random error. It can be solve by using mathematical tool 'statistics'.

** parallel error $\Rightarrow$ Gross error, but it enters goes in systematic error. becoz it is common for all human being (parallel error = due to eye defect)

** common for all $\Rightarrow$ systematic error.

** n't common for all $\Rightarrow$ Gross error.



This shape of curve is available for all type of error.

Random Error Analysis :-

100 times
(0-150) V, $A.E. = 100$ V.

99.7 V	$\rightarrow$ 1
99.8 V	$\rightarrow$ 4
99.9 V	$\rightarrow$ 12
100 V	$\rightarrow$ 19
100.1 V	$\rightarrow$ 10
100.2 V	$\rightarrow$ 3
100.3 V	$\rightarrow$ 1

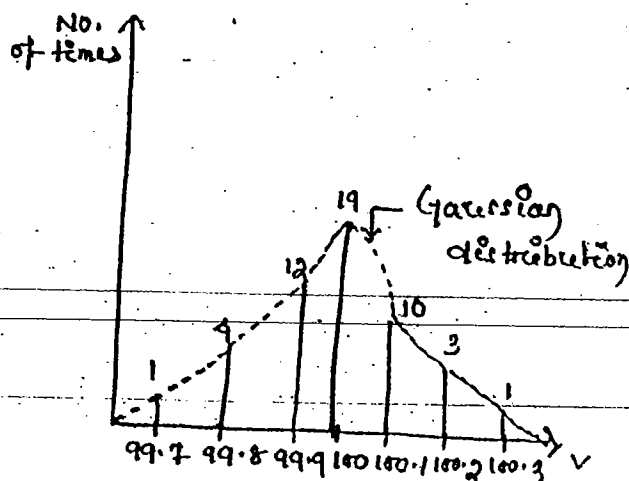
Here we get 100 V 19 times.

so it is accurate as well as precise one.

Here ± 1 deviation = 22 times.

± 2	"	= 7.	} Probab le, error
± 3	"	= 2.	

** (no. of small deviation is more probable than large deviation) **



If we integrate the samples from 99.7 to 100.3
 then we get the total area betⁿ the two point. In
 side this we'll get all the 50 samples.

$$\boxed{\text{Probable error } (\pm k) = 0.6745 \sigma.}$$

$$\text{standard deviation } (\sigma) = \sqrt{\frac{d_1^2 + d_2^2 + \dots + d_n^2}{n-1}} ; n \leq 20.$$

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + \dots + d_n^2}{n}} ; n \geq 20.$$

Small deviations are more probable compare to large deviation.

Ex: $A_t = 230$ Find the range of error?

$$\begin{array}{l} 230.1 \\ 229.8 \pm 0.2 \\ 230.2 = \pm 0.2 \\ 230.1 = \pm 0.1 \end{array} \quad \frac{229.8 + 230.2 + 230.1 + 230 + 229.9 + 230 + 230}{7}$$

$$230.2 = \pm 0.2$$

$$230.1 = \pm 0.1 = 230 = A_t.$$

$$230 = 0$$

$$229.9 = \pm 0.1$$

$$230 = 0$$

$$230 = 0$$

$$V_{\max} - V_{\min} = 230.2 - 230 = \pm 0.2.$$

$$V_{\max} - V_{\min} = 230.2 - 229.8 = 0.2.$$

$$\frac{0.2 + 0.2}{2} = 0.2.$$

$$(230 \pm 0.2) = (229.8 - 230.2).$$

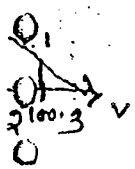
Find the probable error.

$$\text{deviation} = \left(\frac{0.04 + 0.04 + 0.01 + 0.01}{6} \right)^{1/2}$$

$$= 0.129.$$

$$\pm k = 0.6745 \times 0.129.$$

Distribution



note: $R_1 = 100 \pm 4$
 $R_2 = 50 \pm 2$
 $R_1 + R_2 = 150 \pm 6$

$R_1 = 100 \pm 4$
 $R_2 = 50 \pm 2$
 $R_1 - R_2 = 50 \pm 6$

In case of addition and subtraction the absolute error

$R_1 \times R_2 = 5000 \pm 6\%$, $R_1/R_2 = 2 \pm 6\%$

In the case of mul and div the % error should be added.

$R_2^2 R_1 = 250000 \pm 8\%$

Ex: The i/p of the machine is $6500 \pm 3\%$ and the o/p of the machine is $5000 \pm 2\%$. Find the losses in the machine.

Solⁿ: $5000 \pm 2\% - 6500 \pm 3\% = 1500 \pm 5\%$

$6500 \pm 3\% = 6500 + \frac{3}{100} = 195$

$5000 \pm 2\% = 5000 + \frac{2}{100} = 100$
 295

$1500 \pm \frac{x}{100} = 295$

$x = 19.6\%$

Ans: $1500 \pm 19.6\%$

$\eta = \frac{65000 \pm 3\%}{6500 \pm 3\%} = 0.76 \pm 5\%$

The supply volt = $(230 \pm 10)^v$, supply current = $(100 \pm 10)^A$

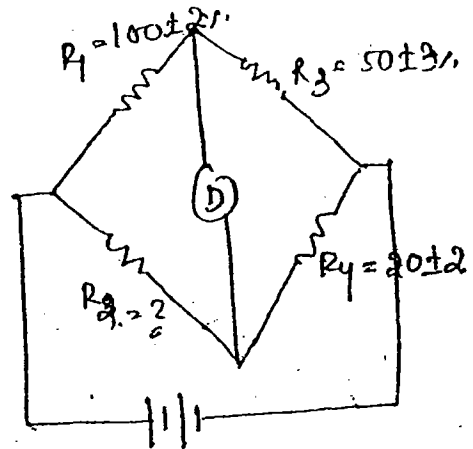
$\frac{230 \pm 10}{100 \pm 5} \Rightarrow 230 \times \frac{x}{100} = 10 \Rightarrow x = 4.3$
 $100 \times \frac{x}{100} = 5 \Rightarrow x = 5$

$P = 2.3 \pm 9.3\%$

solⁿ:

$$R_2 = \frac{R_1 \times R_4}{R_3}$$

$$= \frac{100 \pm 2\% \times 20 \pm 2}{50 \pm 3\%}$$



Qb: A three phase power is measured by using a wattmeter method. One of the wattmeter reading is 50 watt with an accuracy error $\pm 1.5\%$ reading, and the 2nd wattmeter is 125 wattmeter with an accuracy error $\pm 1.5\%$, both the wattmeters are having a $\pm 1.5\%$ is 150 watt. The total power in the 3-phase circuit is:

$$50 \times \frac{\%}{100} = 1.5$$

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

$$\Rightarrow \% = \frac{1.5 \times 100}{50} = 3$$

$$\% = 0.4$$

$$50 \pm 3$$

$$125 \pm 4$$

$$\text{Total power} = 125 \pm 3 + 50 \pm 4$$

$$= 175 \pm 7$$

$$175 \times \frac{\%}{100} = 7, \quad 175 \pm 7$$

$$\% = 4\%$$

$$50 \times \frac{\%}{100}$$

$$\Rightarrow 1^{\text{st}} \text{ wattmeter} = 50 \pm 1.5\%$$

$$2^{\text{nd}} \text{ "}$$

$$= 125 \pm 1.5\%$$

$$= 175 \pm 1.5 \times \frac{5}{100} = 0.75\%$$

now, 2^{nd} wattmeter = 125 ± 0.75 .

1^{st} wattmeter = $50 \pm 1.5\%$.

$$= 50 \times \frac{1.5}{100}$$

$$= 50 \pm 0.75.$$

$$125 \pm 0.75 + 50 \pm 0.75 = 175 \pm 1.5.$$

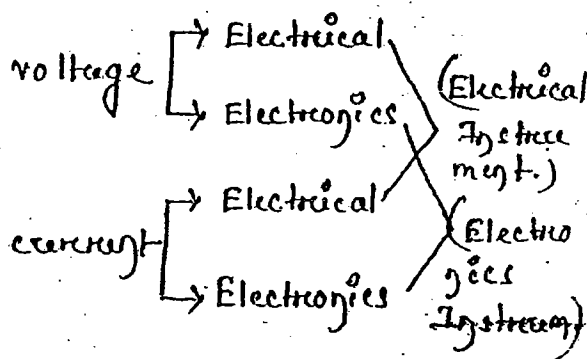
$$\Rightarrow 175 \times \frac{\%}{100} = 1.5$$

$$\Rightarrow \% = 0.857.$$

$$= W = W_1 + W_2 = 175 \pm 0.857\%.$$

Basic Instruments :-

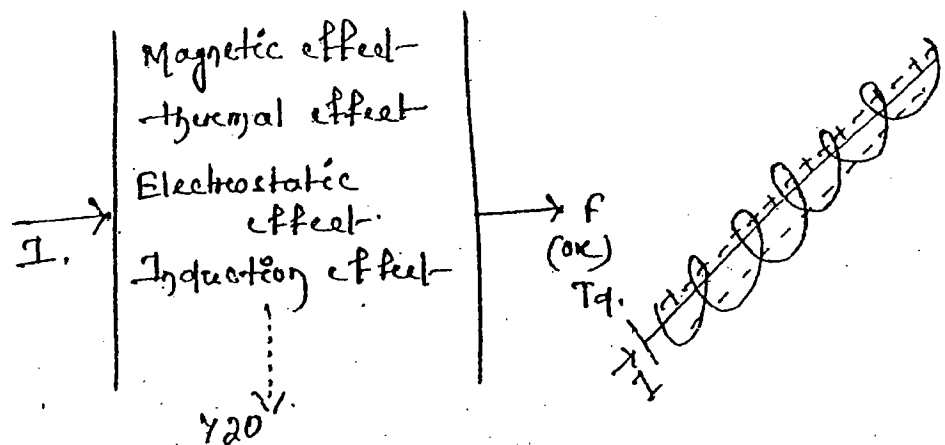
Basic parameters :



Electrical Instruments :

due to the current I the force is generated. Somewhat the force is converted into deflection Torque. (Tq-mechanical parameter)

If we allow to pass the current through a path there is many effect can be obtained.



In Electrical Instruments basically there are three forces are developed. deflection force/ deflection path.

Deflection Torque : This is the force required to move the pointer from its initial position to any one of ^{the} ~~effect~~ ^{is called} deflection torque.

Whenever we give whatever i/p if we may give to the meter.

Beoz of the deflection torque always the pointer will move to the final posⁿ which is undesirable. we required a proportional o/p to the i/p. For this we required control force or control torque. (T_c)

Control Torque : This is the force opposite to the deflection torque. Beoz of the control torque we can stop the pointer at various level.

by when $T_d = T_c$ then the pointer will come to steady state.

(Electrical Instrument.)

(Electro gears Instrument)

a path

Funcⁿ of control torque :-

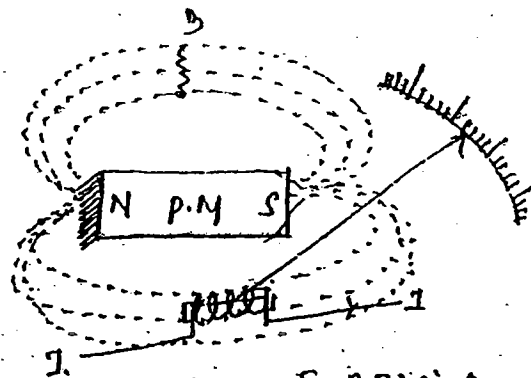
- (i) control torqueⁿ will provide a proportional o/p to the i/p.
- (ii) It will remove the i/p and make the pointer to come back to the initial posⁿ. ($I=0$, $F=0$, $T_q=0$).
- (iii) when $T_q = T_c$ there is occurrence of oscillation at steady state.

Damping force: This is the force which will reduce the no. of oscillation at final posⁿ ($T_q = T_c$).

∴ The damping force will make to reduce the speed of the pointer so that the no. of oscillation can be reduced at final position.

Mechanism for producing deflection torque :- (magnetic effect)

- (i) force betⁿ permanent magnet and current carrying coil.

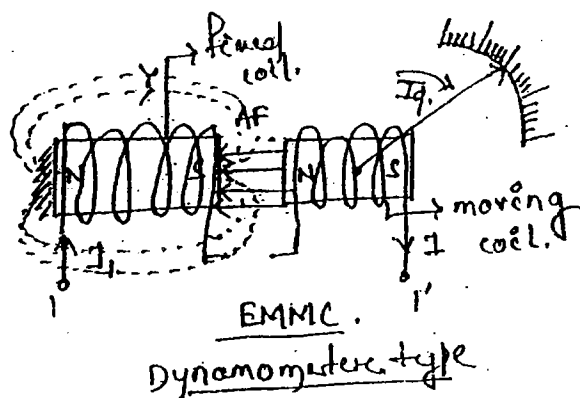


$$F = BIL \sin \theta$$

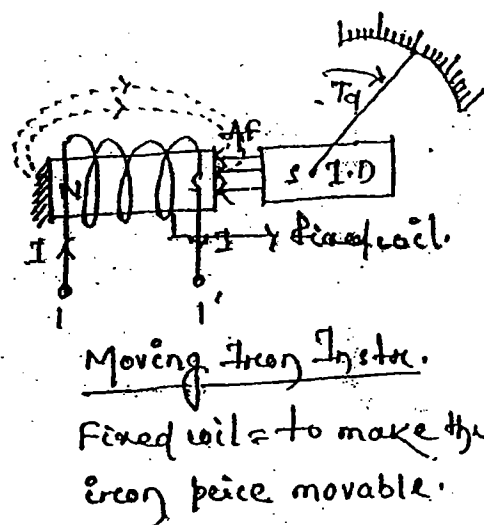
tempⁿ = ΔT
copper = true temp.
coefficient

Force betⁿ two current-carrying coil :

↳ when



Force betⁿ current-carrying coil and soft iron disc :

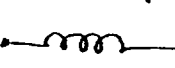


Mechanism for producing control torque : (T_c)

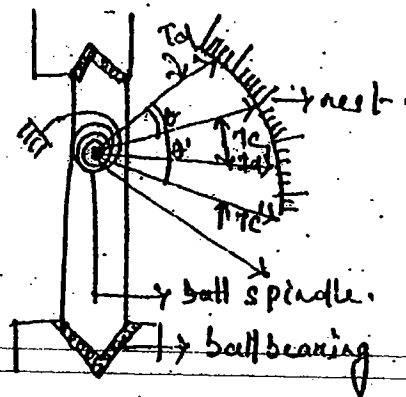
(i) Spring control = Springs having property of restoring the energy. (elasticity property). - When we give a current then a force will generated, and this force on the spring generate a deflection force, due to this deflection force the spring itself generate a controlling opposition force (i.e. controlling torque)

which oppose the deflection force. When the deflection force and control torque will equal then only the spring come under a steady state. When there is no current, then no deflection force is there and ~~no~~ ^{the} control torque ^{that} is generated inside the spring make the spring to come back to its initial position.

There are two types of springs (made up of phosphor bronze)

- (i) Helical spring  (Here compression will occur)
- (ii) Spherical spring  → this can be used in measuring devices (in place of pointer).

Here in spherical spring angular movement'll occur that why here exactly known as deflection torque. When more deflection torque is there then more control torque will generated and the spring will tight more and more in order to store more energy. Due to this control torque the pointer will move to the various levels when there is no T_c then the pointer will move towards the initial position.



$$T_c \propto \theta$$

$T_c = K\theta$; K = spring const.

$$K_c = \frac{T_c}{\theta}$$

Advantages :

(i) $T_c \propto \theta$ $\rightarrow$ having linearity property.

(ii) The spring control instrument we can use both horizontally as well as vertically.

(iii) Disadvantages :

(i) The springs are having ageing effect (As age passes the springs may loose elasticity property)

(ii) Temp error ($\text{temp} \uparrow = \text{stiffness} \downarrow = T_c \downarrow = T_c \propto \theta \uparrow = \theta$).

if $\text{temp} \uparrow = \mu \downarrow = T_c \downarrow = \theta \downarrow$. ($F = 321 \sin \theta$).

so the total deflection is depend upon temp not on current).

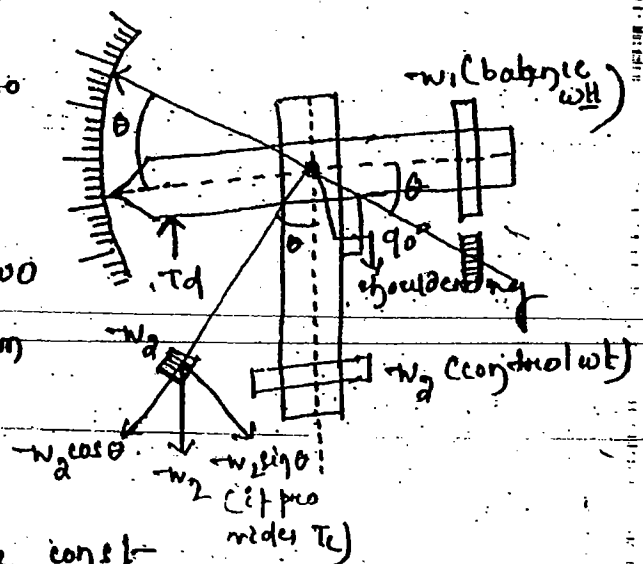
To overcome these above technique we are preferring the following technique. i.e.

(iii) Gravity Control :

$\rightarrow$ Here the balance wt is to reduce the oscillation.

$\rightarrow$ Here two spindle are present. out of these two one will acts as a beam pointer by itself.

$\rightarrow$ Here the shouldering is made in order to make const. like a beam of steel.



Once current will flow through it, the deflection torque will generate. This deflection torque produce a control torque which always try to bring the one of the beam spindle to its original position.

Here $w_g \sin \theta$ acts as a control torque.

$$T_c \propto \sin \theta$$

Advantages :

- (i) No aging effect is here.
- (ii) No temperature error is there.

Disadvantages :

- (i) It provides non-linear operation.
- (ii) It works / operate only in vertical direcⁿ.

Mechanism for producing damping force :

underdamped oscillⁿ

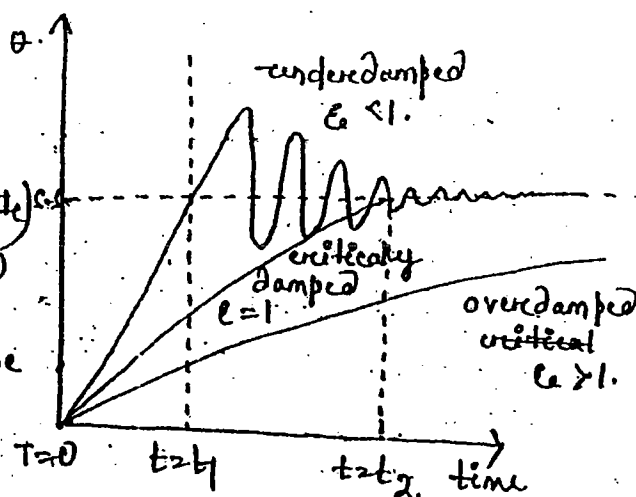
↳ no. less time gap

↳ more no. of oscillation. ($T_d = T_n$)

critical damped oscillⁿ

↳ moderate time period.

↳ no. oscillat.



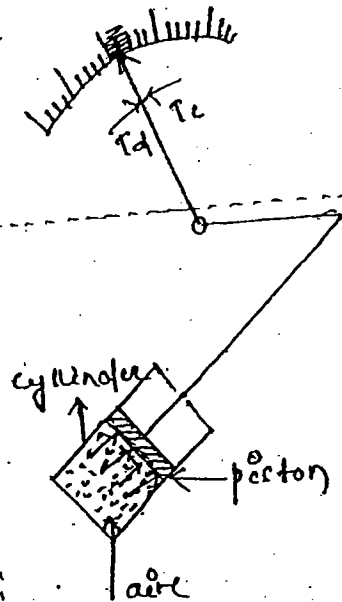
** The best instrument is that one for which having a little bit less than "under damped oscillation".

friction

are
try to
regional(i) Air friction damping :

Here the pointer will move when the piston will go inside, but inside the cylinder air is filled

so this air make an opposition force which oppose the piston to come inside, thus the speed of the pointer will slow down, hence the no. of oscillation will reduced.



→ this arrangement is done specifically for reducing the no. of oscillation.

(ii) Fluid friction damping :

Fluid friction damping is more effective damping compared to air friction damping since the fluid is having a property of viscosity.

fluid > air

air > fluid

preference of effectiveness • preference of

In fluid friction damping we have to maintain some angle to keep the instrument (there'll be more chance to come out the fluid).

Here the maintenance cost we is also more.

(iii) Eddy current damping :

Eddy current > Fluid friction > Air friction
(order of effectiveness)

Eddy current > Air friction > Fluid friction

Eddy current damping is useful when there will be a permanent magnet & available.

Eg: PMMC instrument.

16/09/10

Here the spindle is strictly bounded under the ball bearing.

Whenever any force applied to it the spindle will rotate. (Due to deflection torque the spindle will rotate).

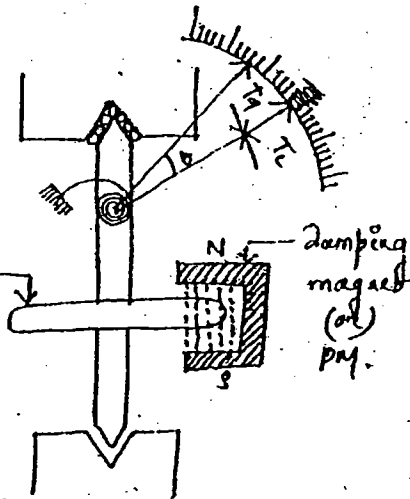
Here our motto is to reduce the speed by reducing no. of oscillation.

For this we use here an aluminium disc and a permanent magnet. When the spindle is rotates the (attached) aluminium disc is also rotating and there also a permanent magnet is present.

In this PM the magnetic field flows from N to S. When the Al disc rotate continuously through this magnetic field the magnetic induced e.m.f. will enter through the 'Al' disc.

The 'Al' disc has its own resistance and due to this induced e.m.f. it produce a current. (we can collect current a current will generate)

(we can collect current only on 'cu' wire)



constant
bearing
the
a
coil

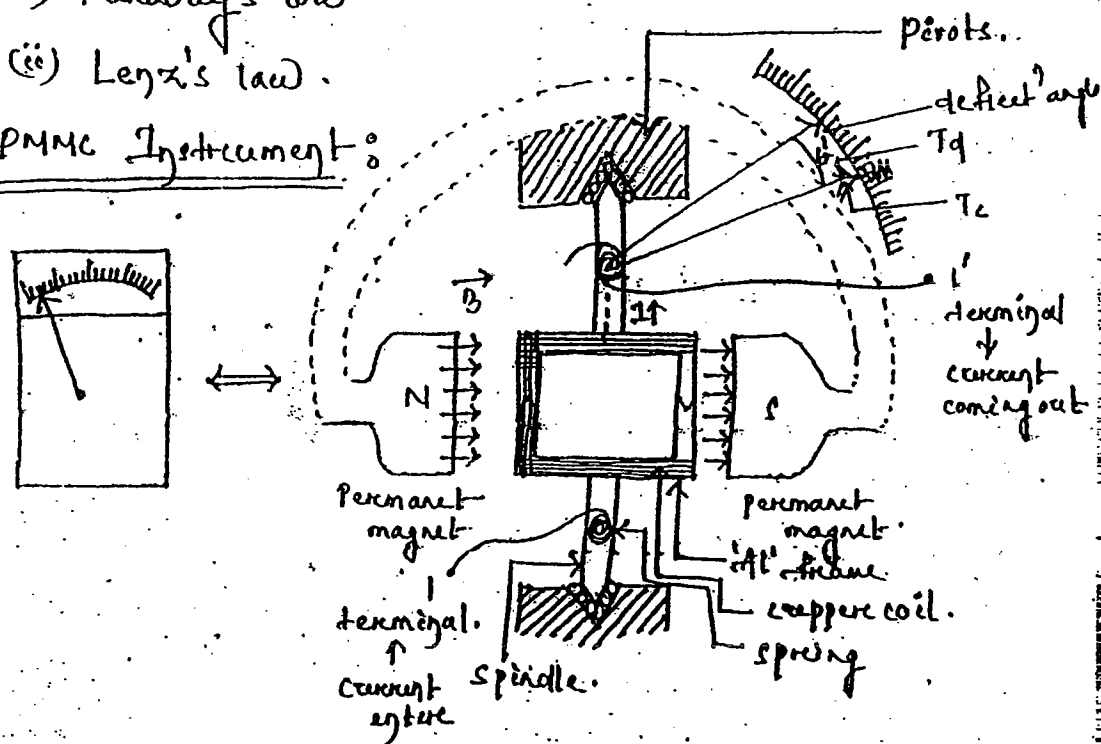
Here we can't collect current that's why it is known as eddy current. This eddy current reduce the no. of oscillation and thus speed will also decrease. Here we use spring control mechanism.

Here we can use only permanent magnet instead of using electric magnet (because permanent magnet gives const magnetic field and electric magnet will give variable magnetic field).

(i) Faraday's law

(ii) Lenz's law.

PMMC Instrument:



construction →

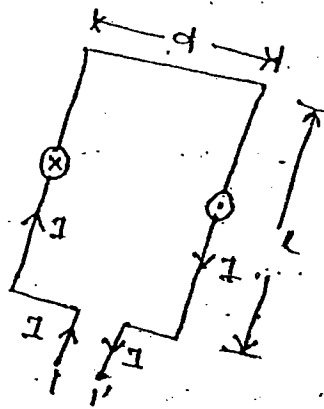
Here a spindle is under the force of jewel bearing. Two permanent magnet is also there. At the center of both spindle and permanent magnet a 'al' frame is placed. This is wound by 'cu' coil. There are two terminal 'I' (current enter)

and I' (current comes out).

operation $\rightarrow$ once the switch is closed due to the permanent magnet a magnetic field is passed through the 'cc' wire (Al frame) and due to the induced e.m.f. current is flowing through the 'cc' coil. Once the switch is closed the current enters to the terminal 'I'. Due to this current the pointer will rotate.

Here three of the following mechanism occur.

- deflecting torque $= b/w$
- damping force $=$ eddy current
- control torque $=$ spring control mechanism



In PMMC instrument it's over

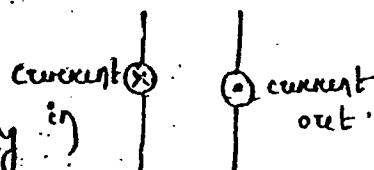
responsibility to develop radial flux density. $\therefore$ i.e. the angle b/w magnetic field and current must be 90°

$$F = BIL \sin \theta$$

$$\theta = 90^\circ$$

$$F = BIL$$

Basic working in principle of PMMC (Lorentz's eqn)



Deflection torque, $T_d = \text{Force} \times I^{\text{rd}} \text{ distance}$.

$$T_d = BIL \times d$$

$$\therefore T_d = BIL \times d \times n \quad (\text{for } n \text{ turns})$$

$$T_d = BINA \quad (\because L \times d = A)$$

Relationship b/w $i/p(I)$ and $o/p(T_d)$:-

Here the relation b/w $i/p(I)$ and $o/p(\text{deflection torque})$ is linear. And the scale that are used in this instrument is linear one. beoz

$$T_d \propto I$$

Deflection angle :

$$T_c = K_c \theta$$

$$T_c = T_d \text{ (at steady state).}$$

$$K_c \theta = B I N A$$

$$\theta = \frac{B I N A}{K_c}$$

$$\theta \propto I$$

In case of voltage measurement the two terminals are connected across the supply. $(\theta \propto I \propto V) = (\theta \propto V)$.

Motor principle $\rightarrow$ Fleming's left hand Rule.

Generator principle $\rightarrow$ Fleming's right hand Rule.

Here the idea about the direction of current and magnetic field are known. To know the direction of force we have to apply 'Fleming's left hand rule'.

When current $\uparrow$ (upward) $\rightarrow$ force $\downarrow$ downward.
current $\downarrow \rightarrow$ force $\uparrow$.

Advantages :-

(i) Scale is linear.

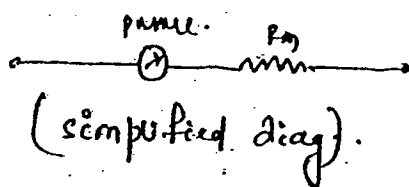
(ii) It is a high accurate and high sensitive instrument ($\because$ powerful eddy current damping is used).

Disadvantages :

- (i) If by using basic PMMC instrument we can't measure high ^{current} since the spring and one being used as current carrying conductor (Here the coil and spring are connected in series).

(The max^m allowable current in PMMC is I_m)

- (ii) By using PMMC we can't measure A/c.



Here we show only resistance becoz it is a dc current instrument.

$$\theta \propto I_m$$

I_m = meter current.

$$\theta \propto I_m = \frac{V_m}{R_m} \quad (R_m = \text{const.})$$

$$I_m \propto V_m$$

$$\theta \propto I_m \propto V_m$$

$$\boxed{\theta \propto V_m}$$

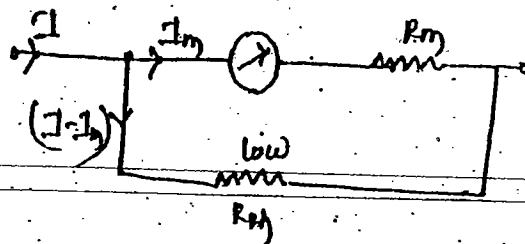
Here we can't measure 'I' and capital 'V'. becoz due to high current and high voltage the spindles will damage.

Instrument : It has no specific application. It can be used for various purpose.

Meter : It has a specific/particular application.

Extension Ranges of basic PMMC instrument :-

Here to bypass the high current a shunt resistance connected in parallel.



As the range of 'I' increases, the ' R_{sh} ' value is going to decrease.

- we can

R*

PMMC

- when

the

when

then

conge

V

R*

V

V

V

V

Here

I del

it

$$\theta \propto I_m \left(\frac{1}{I_m} \right) \leftarrow \text{multiplication factor.}$$

$$\theta \propto 1.$$

we know that

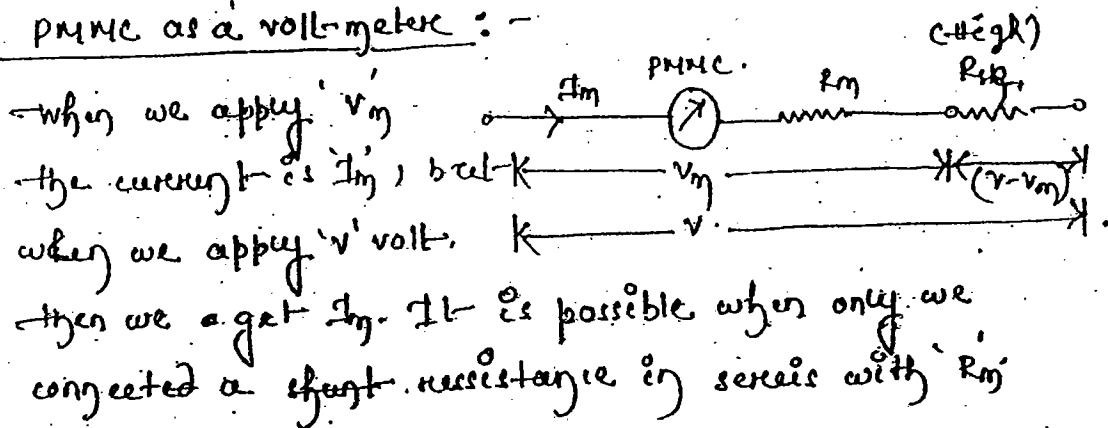
$$I_m R_m = (1 - I_m) R_{sh}.$$

$$\boxed{\frac{1}{I_m} = 1 + \frac{R_m}{R_{sh}}} \text{ multiplication factor.}$$

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

$R_m = \text{moving coil resistance.}$

PMMC as a voltmeter :-



$$\theta \propto I_m \propto V_m.$$

$$\theta \propto V_m.$$

$$\theta \propto V_m \left(\frac{V}{V_m} \right) \leftarrow \text{multiplication factor.}$$

$$\frac{V_m}{I_m} = \frac{V - V_m}{R_{se}}.$$

$$\boxed{\frac{V}{V_m} = 1 + \frac{R_{se}}{R_m}} = m.$$

$$\boxed{R_{se} = R_m (m-1)}$$

Ammeter

Here R_{se} should be high.

Ideal internal resistance of voltmeter $\rightarrow \infty$

" " " " " Ammeter $\rightarrow 0$.

In order to measure high current (1kA, 10kA)
the prime instrument is not at all a suitable one.
For this we have to choose current transformer.

In prime max^m extendable current (I) = 100mA.

max^m " voltage (V) = 1000V.

In case of max^m voltage, the resistance is 10 times
high than ammeter. due to high resistance
the very less current will flow through it. Here
the meter / scale can't detect such a small current
beoz the spring deflection is so high.

In both cases the $R_{th} = R_{se} = \text{multiplier}$.

The multipliers are made up of const. temp. co-efficient
material.

There are four types of temp. - co-efficient

- (i) +ve = $I \uparrow = R \uparrow$ eg: Cu, all metals.
- (ii) -ve = $I \uparrow = R \downarrow$ eg: semiconductors, insulators.
- (iii) const. = $I \uparrow = R \leftarrow (\text{const})$ eg: Mn, constantan.
- (iv) zero = at $0^\circ K$ temp resistance is exactly 0.
eg: Pt-Ir (at $37^\circ K \rightarrow R=0$).

All electrolyte are undergo in -ve temp. co-efficient.
(H_2SO_4 , HCl).

For manufacturing multiplier
we always prefer for 'Mn' beoz constantan is more
brittle and expensive than 'Mn'.

For high sensitive temp. we go for constantan.

'constantan' gives 100% accuracy.

In case of the instrument the multiplier is made up of constant, but in the instrument the multiplier is made up of 'm'.

Error in PMMC :-

(i) Frictional Error :

From the bearing we get frictional energy.
In PMMC we get the electrical energy at spring.
In PMMC when the spindle starts rotating at that instant the electrical energy is converted to mechanical energy. In an instrument the frictional error can be defined by the (more/less) torque/weight ratio. If the weight is more then the friction will be more.

Always we prefer high torque/weight ratio bcoz in this case the frictional ratio is small.

We can reduce the / minimize the frictional error we should minimize the area of contact, and to reduce we should use grease inside the bearing. (to avoid the bearing to bearing friction).

*(The electronic device has more accurate than electrical instruments bcoz there is no such rotating part so no frictional error.)

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(ii) Temperature Error :

There are four types of temp. coefficient
 +ve $\rightarrow I \uparrow \rightarrow R \downarrow$ eg: Cu, all metals
 -ve $\rightarrow I \uparrow \rightarrow R \downarrow$ eg: semiconductor and insulator.
 const $\rightarrow I \uparrow \rightarrow R$ (const) eg: Mn, constantan.
 zero $\rightarrow$ at 0°K it is the resistance is exactly zero.

✓ We are using a metal that is the combination of Mn and Cu (30:1). Here 'Cu' is used in order to increase the strength of the 'Mn' resistor.

✓ The temp. error can be

reduced by providing swamping resistor in an basic meter.

$$\frac{m + Cu}{\text{swamping resistor}}$$

(iii) Frequency Error :

The frequency error is absent in PMMC instrument, becoz we measure ac only here, not a/c.

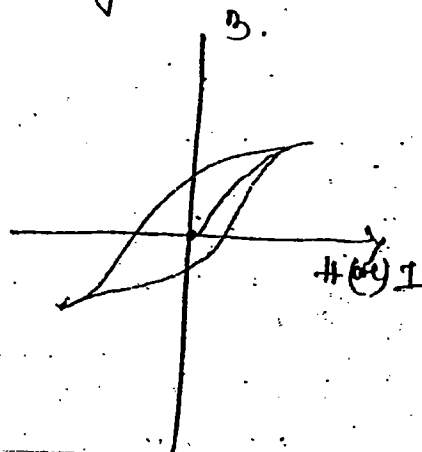
(iv) Hysteresis Error :

$$\oint \vec{B} \cdot d\vec{l} = \mu I_{\text{enclosed}}$$

$$\oint \vec{H} \cdot d\vec{l} = I_{\text{enclosed}}$$

$$\oint \vec{H} \cdot d\vec{l} = N \cdot I_{\text{enclosed}}$$

$$\vec{H} \cdot \vec{l} = NI$$



(v) S-
 ing
 But
 is k
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 size
 the
 %
 so
 Draw
 y B
 curve
 volt

If we take any point in loop neither H and B will be zero simultaneously except origin. In this loop always ' B ' lags to ' H '. So it is known as 'B-H curve'. Due to this hysteresis loop, hysteresis error will be there. In order to reduce the hysteresis error we have to decrease the thickness of the hysteresis loop. For this we are using Aluminium frame, since 'Al' is having a thin hysteresis loop. So the difference b/w two magnetic field can be neglected.

(v) Stray magnetic field error:

The magnetic field that is present inside the instrument is known as pet magnetic field (stronger). But the error due to external magnetic field is known as stray magnetic field.

The stray magnetic field error is less in PMMC. Since a strong magnetic field is available inside the micrometre.

- All the errors are very less (min^m) in PMMC instr. so that it is high accurate or high sensitive instrument.

Drawback:

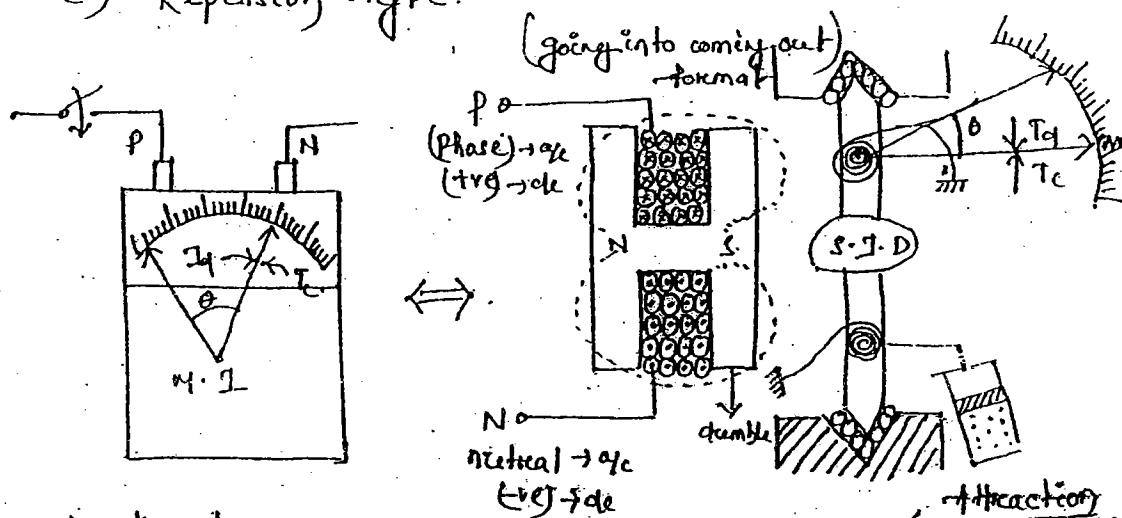
- By using PMMC instrument we can measure dc current / dc voltage and can't measure ac current / volt. or power.

✓ PMMC always read avg value / dc value.

Moving Iron Instrument : (self inductance of fixed coil)

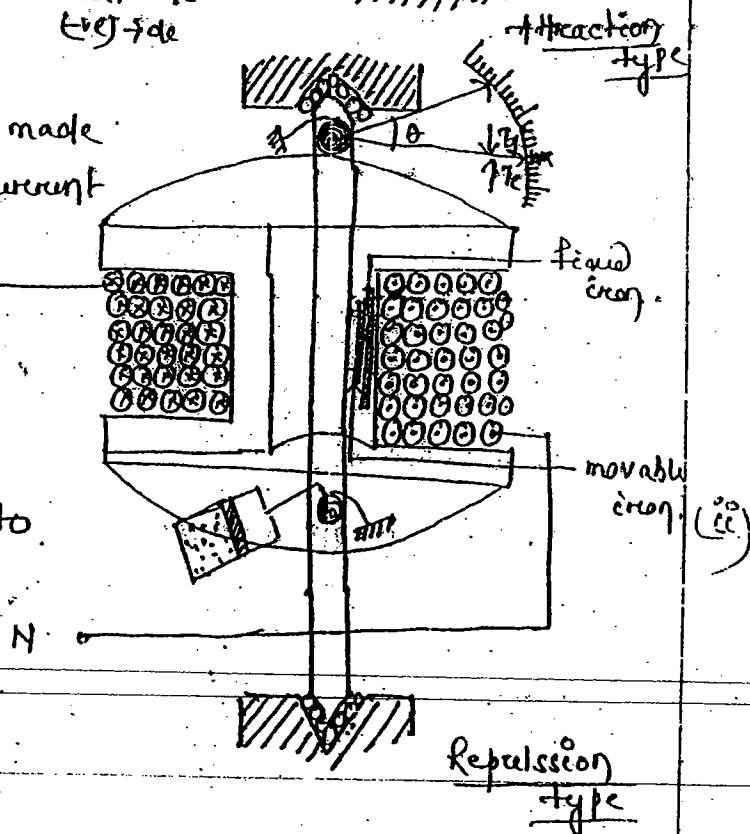
In this we can measure both ac and dc and we can't use the spring force as a current-carrying conductor. It is of two types

- (i) Attraction type
- (ii) Repulsion type

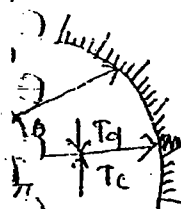


$N = \text{thumb}$

Here the dumb is made up of iron. The current passing through the iron make it into a magnetic material. As the current goes into and coming out then the polarity are changes respectively.



of fixed
(coil)
and we
are trying



Attraction
type



fixed
iron.



movable
iron.

Recession
type

due to the opposite polarity magnetic field will generate from N to S. Again due to this magnetic field, attraction force will generate. This attraction force will attract the soft iron disc (S.I.D). Later this attraction force will convert into rotating force. As the S.I.D starts rotating the corresponding spindle will also start rotating and finally as a result deflection torque/force will generate which help the pointer to move to the final position. Finally electric current convert into mechanical force (T_d).

In case of A/C the polarity of the magnetic field will change alternatively, but it has no effect on the attraction force/direct (but in PMMC the change in current direct effect the force direct.)

As the spindle rotate the springs will start tightening.

Here air friction damping is used (beoz it is a E.M not PM).

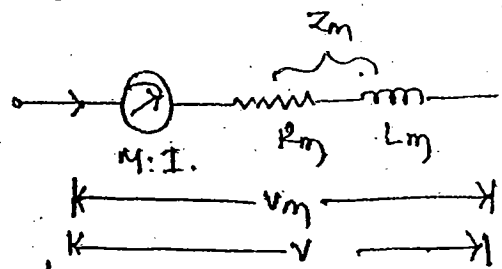
(ii) Repulsion type:

If we make a 90° shift to the attraction type meter instrument then it will become a repulsion type moving iron instrument. Here the handle is totally round/hollow. Inside this handle we place a

spindle and this spindle is kept by jewel bearing. This spindle is attached to the adhere of the wall of the handle through two iron metal. One is fixed iron and another is movable iron. Here when the current is passing through the coil, the two iron metal having same polarity. Due to same polarity the two iron piece start repulsing. When the moving iron start repulsing to some distance, the spindle starts rotating and as soon as it will generate. And finally the electrical element will convert into mechanical force and pointer will start rotating.

Fixed coil
 P_m = moving iron
 Resistor.

L_m = self fixed coil
 self inductance.



The inductance ^{which} will not allow a sudden change in current until one unless the flux linkage will close is nothing but self inductance.

L_m
 $\downarrow$

$$L = \frac{N\Phi}{I}$$

I - high current

$$\frac{d(LI)}{dt} = \frac{d}{dt}(N\Phi)$$

$$L \frac{dI}{dt} + I \frac{dL}{dt} = N \frac{d\Phi}{dt}$$

$$L \frac{dI}{dt} + I \frac{dL}{dt} = e \times I \times dt$$

$$2) I \times dt = e \times I \times dt$$

3) $I \times dt = d\omega$ $\rightarrow$ The total amt. of energy drawn from the source at time dt sec.

$$2) \boxed{LI dI + I^2 dL = d\omega} \quad \text{--- (1)}$$

This total amt. of energy is converted into mechanical energy (i.e. spin the rotation)

$$\text{--- work done} = T_d \cdot d\theta \quad \text{--- (2)}$$

$\rightarrow$ this much electrical energy will convert into mechanical energy in dt sec. ^{displacement}

Energy stored in the fixed coil in dt sec. is:

Energy stored in $t+dt$ sec - energy stored in t sec

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

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

$$= \frac{1}{2} I^2 + LI \cdot dI + \frac{1}{2} I^2 \cdot dL +$$

$$\text{eqn } 1 = \text{eqn } 2 + \text{eqn } 3$$

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

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

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

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

$T_d \propto I^2 \propto v^2 \rightarrow$ non-linear org.

Again,

Spring control $T_c = \theta K_c$

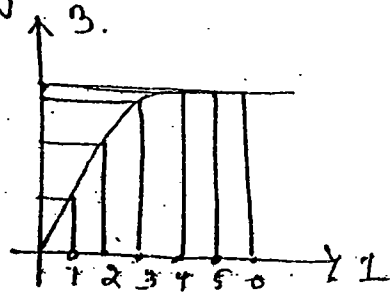
at steady state $T_c = T_d$

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

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

$\theta \propto I^2 \propto V^2 \rightarrow$ non-linear.

Though the high current is pass through the spring in m.i. it's not able to measure the high current becoz of magnetic saturation.



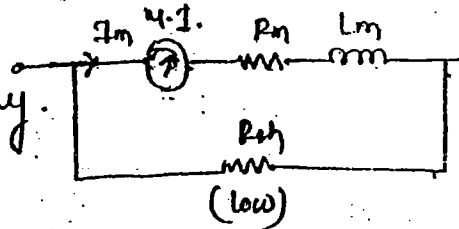
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Extension ranges of m.i. instruments :-

m.i. instrument as an ammeter (to measure I)

All the instrument is independent of frequency.

In p.m.c. instrument in order to measure the current I we connect a shunt resistance ($R_{sh} = \text{low}$).



$$L_m = X_m = 2\pi f I_m$$

self inductive reactance

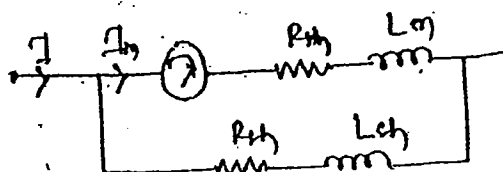
but in m.i. although we are connecting a R_{sh} then the magnetic saturation error is can be minimized, but the another pb is arise i.e.

In order to make an instrument we have to connect L_m in series with R_{sh} . but this is also not sufficient.

$$\begin{aligned} \text{So } \frac{I_m}{I_{sh}} &= \frac{\sqrt{(R_{sh})^2 + (\omega L_m)^2}}{\sqrt{R_m^2 + (\omega L_m)^2}} \\ &= \frac{R_{sh} \sqrt{1 + \left(\frac{\omega L_m}{R_{sh}}\right)^2}}{R_m \sqrt{1 + \left(\frac{\omega L_m}{R_m}\right)^2}} \end{aligned}$$

$$\frac{\omega L_m}{R_{sh}} = \frac{\omega L_m}{R_m}$$

$$\boxed{\frac{L_m}{L_m} = \frac{R_{sh}}{R_m}}$$



$$\frac{L_m}{L_m} = \tau = \text{time const. of shunt resistance}$$

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

In case of A.C ammeter we have to connect a shunt coil in basic instrument in such way that the time const. of basic meter = time const. of shunt. Then the meter is independent of frequency.

$$\begin{aligned} \tau &= \text{sec?} \quad \tau = R-L \Rightarrow \tau = \frac{L}{R} = H/\Omega \\ R-C &\Rightarrow \tau = RC. \end{aligned}$$

$$V_L = L \frac{dI}{dt}$$

$$\begin{aligned} L &= \frac{V \times dt}{dI} \\ &= \frac{IR \times \text{sec}}{dI} \end{aligned}$$

$$= R \times \sec.$$

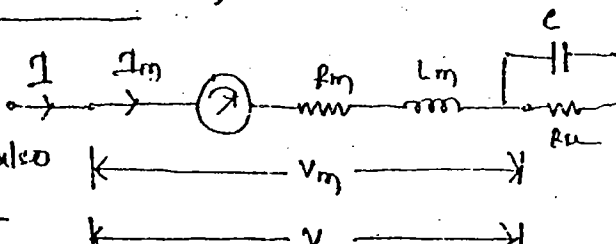
$$Z = \frac{L}{R}$$

$$= \frac{R \cdot \sec}{R}$$

$$Z = \sec.$$

up. I instrument as voltmeter :

The moment we give high voltage 'v' then also we get maxⁿ current 'I_m' instead of getting 'I'.



In this case if we connect a 'R_{se}' in series with 'L_m'. Then also the pb. is n't completely eliminated.

(pb: If reactance 'X_m' change then the inductance 'L_m' then current 'I_m' is also varies and the corresponding frequency is also varying).

so we have to connect a capacitor in parallel with 'R_{se}'. Then the inductance reactance is cancelled by the capacitive reactance. and the meter is independent of frequency.

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

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

$$Z = (R_m + j\omega L_m) + \left(\frac{R_{se} - j\omega R_{se}^2 C}{1 + j\omega^2 R_{se}^2 C^2} \right)$$

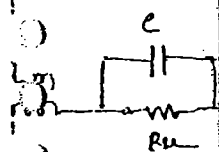
$$Z \approx (R_m + R_{se}) + j\omega (L_m - R_{se}^2 C)$$

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

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

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

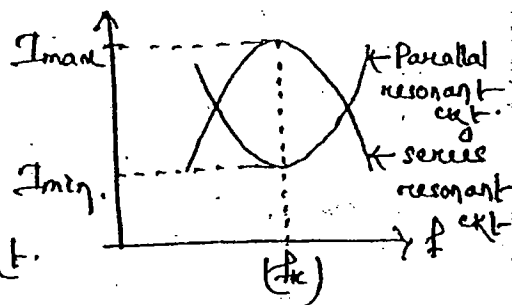
$$C = 0.41 \frac{L_m}{R_{se}^2}$$



Why we connect the 'C' in parallel instead of series?

If we connect a capacitor in series with the ckt then it will become a series

RLC ckt i.e. resonant ckt.



We know there are two types of resonant ckt

- (i) Parallel resonant ckt
- (ii) Series resonant ckt

In series resonant ckt the current is max^m so again magnetic saturation pb. is there, but in parallel resonant ckt the current is min^m and we can reduce the magnetic saturation pb.
 The ckt is

Errors in Moving Iron Instrument :-

- (i) Frictional error :

The frictional errors are more compare to PMMC since a weak magnetic field is available inside the meter. And also the torque/weight ratio is less in less M.I. instrument compare to PMMC instrument. So the frictional errors are

more compare to μmV .

(i) Temperature error:

The temp. error is more compare to μmV instrument. we can reduce the error by connecting a swamping resistance.

(ii) Frequency error:

The frequency error is more compare to μmV since a/c measurement. we can't avoid the frequency error. we can reduce it only becoz the exact time const or the exact value of capacitance.

(iv) Hysteresis Error:

The hysteresis error is more in M.T. instrument compare to μmV since directly iron related material is being used in the moving system. For iron related material the hysteresis loop is thick. we can't avoid the hysteresis error as well as we can't reduce. because we can't replace the Iron as 'Al' becoz if we in case of 'Al' there is no repulsion and attraction force.

v) Stray magnetic field Error:

Stray magnetic field error is more compare to μmV since a weak magnetic field is inside the M.T. instrument.

Conclusion: All the error is more compare to PMMC. So it is less accurate and less sensitive.

PMMC & M.I (order of sensitivity and accuracy)

Note:

↳ By using M.I instrument we can measure ac/dc current or voltage, but not power.

↳ In case of a/c the meter will read r.m.s. value, but in case of dc the meter will read avg. value.

↳ By using M.I. instrument we can measure ac/dc current/volt, but we shouldn't measure dc becoz it is less accurate and less sensitive for a/c.

Electro magnet moving coil Instrument :-

↳ we can measure I , (ac/dc), V (ac/dc), P (ac/dc) and power factor also.

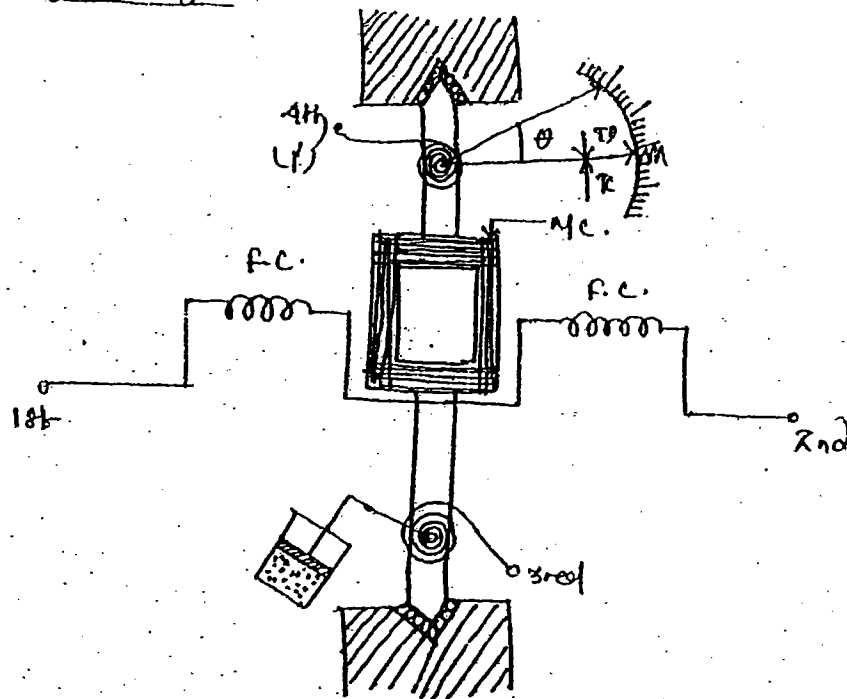
↳ EMMC instrument is nothing but the comb' of PMMC + M.I.

↳ It is the only instrument which is having two coil one is fixed coil (in order to provide EM)

another is moving coil (in order to provide torque)

that's why it is known as dynamometer type instrument.

4 The working principle of EMMC is mutual inductance.



- 4 The moment when we short cut the 2nd and 3rd terminal then it has 2 terminals. The current that enters into the instrument is responsible for producing a magnetic force as well as torque.
- 4 In EMMC we use air friction damping force.
- 4 It has a non-linear or linear characteristic that can be decided by the i/p - o/p relationship.
- 4 Again here current flows through the spring.
- 4 Both the current is connected in series.

Q. In SMC instrument if small current is passing through the instrument then the spring will damage but the sufficient magnetic field will not produce to rotate the coil. again if we increase the current then the spring will damage. so to overcome this pb. we have to increase the no. of turns. i.e.,

$$\phi = \frac{m\mu I}{l}$$

$$\phi \propto NI$$

Q we know that,

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

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

$$\text{Now, } T_d = \frac{1}{2} I^2 \frac{d(L_1 + L_2 + 2M)}{d\theta}$$

When the coil is rotating then there is no change in L_1 and L_2 only M is affected.

$$\begin{aligned} \text{So } T_d &= \frac{1}{2} I^2 \frac{d(2M)}{d\theta} \\ &= \frac{1}{2} I^2 2 \frac{dM}{d\theta} \end{aligned}$$

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

$$T_d \propto I^2$$

$$T_d \propto I^2 \propto v^2$$

$$T_d \propto v^2$$

we know that,

$$T_c = K_c \theta$$

at steady-state, $T_c = T_d$.

$$K_c \theta = I^2 \frac{dm}{d\theta}$$

$$\theta = \frac{I^2}{K_c} \frac{dm}{d\theta}$$

$$\theta \propto I^2$$

$$\theta \propto I^2 \propto V^2$$

$$\theta \propto V^2$$

note: ~~the current~~ of the coil if we want to make it

In order to measure the current and voltage the coils are connected in series. and in order to measure power the connection should be made parallel.

$$T_d = I^2 \frac{dm}{d\theta}$$

$$= I_1 \cdot I_2 \frac{dm}{d\theta} \quad (\text{Here we can separate the current due to two diff coils})$$

But in N.I. instrument we can't separate I^2 as $I_1 \cdot I_2$ becoz there is only one coil.

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

$$I = I_m \sin \omega t$$

$$I = I_m \sin(\omega t - \phi)$$

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

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

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

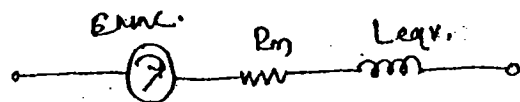
$$= \frac{1}{2\pi} \frac{I_{m1} I_{m2}}{2} \frac{d\theta}{d\phi} \int_0^{2\pi} 2 \sin (\omega t - \phi) \cdot \sin \omega t \cdot d(\omega t)$$

$$\boxed{I_q = I_1 I_2 \cos \phi \frac{d\theta}{d\phi}} \rightarrow \text{(this is the required eqn to design a wattmeter)}$$

$$= I_1 \frac{V_{in}}{R} \cos \phi \frac{d\theta}{d\phi}$$

$$= \frac{1}{R} V_{in} I \cos \phi \frac{d\theta}{d\phi}$$

not simplified dig:



In order to measure the high current we have to connect the R_m and L_m in series to each other. but across parallel to the ckt. The extension range is same as μ instrument.

In order to measure voltage we have connect a series resistor across it to capacitor.

Errors in ENMC Instrument:

(i) Fractional error:

Fractional error is more than compare

to PMMC and M.I instrument. Since a very very weak $\Rightarrow$ magnetic field is there.

EMMC γ M.I γ PMMC.

(ii) Temperature Error :

Temp. error is more compare to PMMC & M.I becoz more no. of coils are there. We can reduce the temp. error by swamping resistor.

EMMC γ M.I γ PMMC.

(ii) Frequency error :

Frequency error is more compare to PMMC and M.I. We can reduce the frequency error by doing below arrangement.

EMMC γ M.I γ PMMC.

(ii) Hysteresis error :

Hysteresis loss is almost all absent in EMMC. In PMMC it is there due to eddy current damping force. But here no iron related material in moving system and we are using here air ^{friction} damping force.

M.I γ PMMC γ EMMC.

(ii) Stray Magnetic field error :

The stray magnetic field is zero becoz very very weak magnetic field inside.

very

$$\text{order of accuracy} = \text{PMMC} \times \text{M.T} \times \text{EMMC}$$

Since it is less accurate compare to PMMC and M.T. that's why it isn't used in laboratory. Only in order to measure the power we are using EMMC instrument.

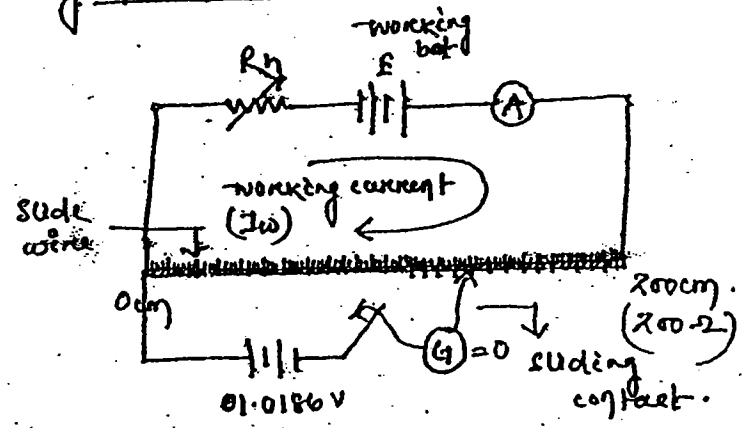
$$\text{Power (W)} = V \cdot I$$

15 11
29/10/10

Potentiometer :-

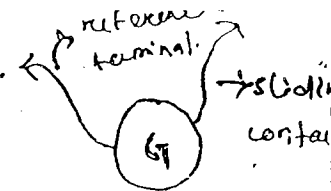
To measure a very low voltage with accuracy we are preferring potentiometer.

$$I_w = \frac{E}{R_h + 200}$$



Here our purpose is to check whether actual long current I_w is flowing through the meter or not. But we have no faith on ammeter, that's why for cross checking we have to connect a standard cell of cell having potential 1.0186 V across the potentiometer. In this standard cell we are connecting a galvanometer for checking of accuracy. The

galvanometer is having two terminal. one is reference terminal i.e. connected to the one terminal of galvanometer stand and cell and another terminal is connected to the slide wire i.e. known as sliding contact.



In order to check the exact 10mA current we have to make the galvanometer reading into 'zero'. When the potential across the sliding wire and the standard cell is same then only the galvanometer shows zero reading.

$$\begin{aligned} \text{So } 10\text{mA} \times R &= 1.0186\text{V} \\ R &= 101.86\ \Omega \quad (1\ \Omega = 1\text{cm}) \\ &= 101.86\text{cm.} \end{aligned}$$

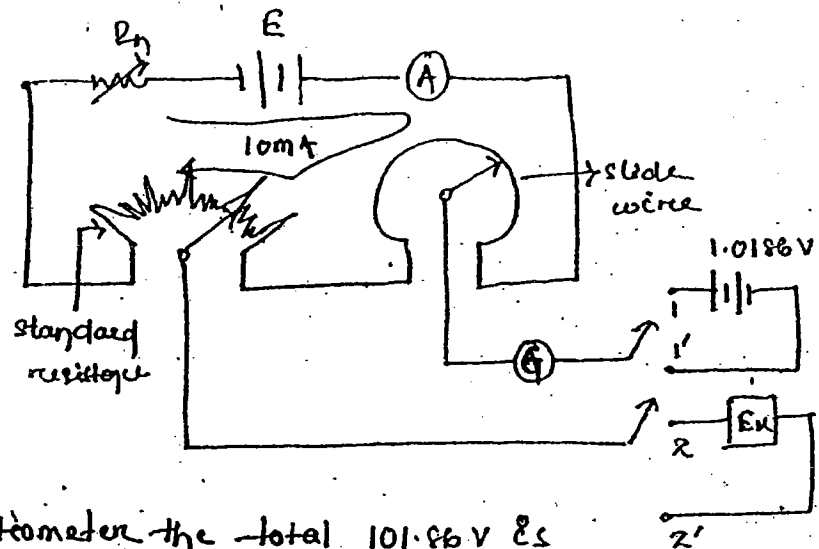
At scale reading 101.86cm the galvanometer shows zero reading. and from that we can assure that there is exact 10mA amount of current is flowing through the potentiometer.

Again if the drop / p.d. is same, but still 10mA current isn't flowing there then there must be some fault in ammeter.

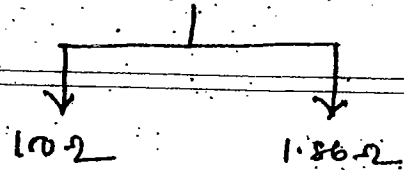
Sliding contact is made up of Cu-gold-silver.
Slide wire is made up of platinum-gold-silver.

$$R = \frac{V}{cm} = \frac{IR}{cm} = \frac{10mA \times 200\Omega}{200cm} = 0.01V/cm$$

Crompton Potentiometer :-



In potentiometer the total $101.86V$ is completely contributed by slide wire. So we are using a long filament like slide wire. But in order to reduce/compact the potentiometer size we are splitting it (slide wire) in to two parts by putting a standard resistance across it. and instead of using a long slide wire we are using a small scale cylindrical scale having resistance 1.86 i.e. the 100Ω is offered 101.86Ω and by standard resistance



Pb: A mag swamp resistance is connected in series with moving ammeter connected with constant current with a suitable shunt in order to

- minimize the effect of temp variation.
- obtain the large deflecting torque.

Pb: The effect of stray magnetic field on the deflecting torque of a portable instrument is max.

when the operating field of instrument and stray magnetic fields are

a) perpendicular

deflecting torque = inside mag. field.

b) parallel

stray torque = outside mag. field.

c) Inclined at 60°

d) Inclined at 30°

when inside mag. field is added with outside then only it'll be max.

Pb: The inductance of a certain moving iron ammeter is expressed as

$$L = 10 + 3\theta - \left(\frac{\theta^2}{4}\right) \mu H.$$

where θ = deflection of radian from zero pos.

the control spring torque is $20 \times 10^{-6} \text{ Nm/rad}$.

The deflection of the pointer is radian. The meter carries a current of 5 amp.

a) 2.4 rad c) 1.2 rad.

b) 2.0 rad d) 1.0 rad.

center
rest of

$$T_c = 25 \times 10^{-6} \text{ Nm/rad.}$$

$$I = 5 \text{ amp.}$$

we know that, $T_c = T_d$

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

$$25 \times 10^{-6} \times \theta = \frac{1}{2} (5)^2 (3 - \frac{\theta}{2}) \times 10^{-6}$$

$$\frac{25 \times 10^{-6}}{\frac{1}{2} \times (5)^2} = \frac{(3 - \frac{\theta}{2}) \times 10^{-6}}{\theta}$$

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

$$2 \times 10^{-6} =$$

$$\theta = 1.2 \text{ rad.}$$

accuracy
max
and

side mag.
field.

side mag.
field.
added
to the main?

meter

0.1

0.1

0.1

0.1

Pr: The potentiometer is designed to measure up to 2 volt with slide wire of 800 mm. If standard cell emf of 1.18 volt obtained balanced at 600 mm. A test cell is being to obtained balance at 680 mm then the emf of the test cell is

- a) 1.0 volt $1 \text{ cm} = 1 \Omega$ $V = IR$
 - b) 1.34 volt $10^{-1} \text{ mm} = 1 \Omega$ $I = \frac{2}{8000} =$
 - c) 1.50 volt $\frac{1}{10} \text{ mm} = 1 \Omega$
 - d) 1.70 volt $1 \text{ mm} = 10 \Omega$
- $800 = 8000 \Omega$

$$10^{-1} \text{ mm} = 1 \text{ cm}$$

$$1 \text{ mm} = 10 \text{ cm}$$

$$I_w \times 600 \text{ mm} = 1.18 \text{ volt}$$

$$I_w = 1.96 \times 10^{-3} \times 680$$

$$I_w = 1.33 \text{ mV}$$

52
 Pb: A galvanometer with full scale current of 10 mA has a $r = 1000 \Omega$. The multiplying power of 100Ω shunt with this galvanometer is _____.

$$m = 1 + \frac{R_m}{R_{sh}} \\ = 1 + \frac{1000}{100} = 11$$

Pb: A moving coil of meter has 100 turns and a length and depth of $10 \text{ mm} \times 20 \text{ mm}$ respectively. It is positioned in a uniform radial flux density of 200 mT . The coil carries a current of 50 mA . Then the torque on the coil is:

solⁿ:

$$N = 100 \text{ turns} \\ l \times d = 10 \text{ mm} \times 20 \text{ mm} \\ \phi = 200 \text{ mT} = B \\ T_d = 32 \text{ N} \cdot \text{m} \\ T = \frac{T_d}{N} \\ T_d = 200 \text{ mT} \times 10 \times 10^{-3} \times 20 \times 10^{-3} \times 100 \\ = 200 \text{ mN} \cdot \text{m}$$

Pb: A moving iron ammeter produces a full scale torque of $240 \text{ mN} \cdot \text{m}$ with a deflection of 120° at a current of 10 amp . The rate of change of self inductance at full scale is:

$$T = 240 \text{ mN} \cdot \text{m} \quad T_c = T_d \\ I = 10 \text{ amp} \\ = \frac{1}{2} I^2 \frac{dL}{d\theta}$$

10 mV
100 Ω

$$2) 240 = \frac{1}{2} \times 10^2 \frac{dL}{d\theta}$$

$$2) \frac{240}{2 \times 100} = d\gamma/d\theta$$

$$2) 4.8 \text{ mH/deg.} = d\gamma/d\theta$$

Prob: A prime volt-meter is connected across a series combination of a dc voltage source of 2V and ac voltage source $3 \sin 4t$. Then the meter reads

- a) 2V
- b) 5V
- c) $(2 + \sqrt{3}/2)V$
- d) $\sqrt{17}/2 V$

Prob: A dc ammeter has a resistance of 0.1Ω and its current range is 0-100 amp. If the range is to be extended 0-500 amp. then the meter requires the following shunt resistance.

Sol: $R = 0.1$
 $I = 100 \text{ A}$

$$R_{sh} = \frac{R_m}{\frac{I_{fsd}}{I_{mfsd}} - 1}$$

$$= \frac{0.1}{\frac{100}{500} - 1}$$

$$= 0.25$$

Pb: A current of $(-8 + 6\sqrt{2} \sin \omega t + 30^\circ)$ Amp. is passing through 3 meters. There a centre '0' p.m.c meter, a true r.m.s. meter and m.i. instrument. The respective readings will be

$$I = -8 \text{ (p.m.c.)}$$

$$I = \sqrt{(-8)^2 + (6\sqrt{2}/\sqrt{2})^2} \text{ (r.m.s. meter)}$$

$$= 10$$

$$I = 10 \text{ (m.i.)}$$

Pb: A variable 'w' is related to 3 other variables (x, y, z) as $w = \frac{xy}{z}$. The variables are measured with the meters accuracy of $\pm 0.5\%$ reading, $\pm 1\%$ of full scale value, $\pm 1.5\%$ reading respectively. The actual reading of 3ms are 80, 20, & 50 with a 100 is being full scale value of 3 meter. Then the total uncertainty in the 'w' will be.

$$\Delta x = 100$$

$$\Delta x = 0.5\% \times 80 =$$

$$\Delta y = \pm 1\% \times 20 = 20 \pm 1 = 20 \times \frac{1}{100} = 1 = 5\%$$

$$\Delta z = \pm 1.5\% \times 50$$

$$5 + 1.5 + 1.5 = 7\%$$

Accession: comparison methods of direct measmt are most widely used in electrical engg.

Reason: comparison methods of direct measmt gives high accuracy.

passing

there,

The

a) Both 'P' & 'Q' individually true & 'R' is the correct explanation of 'P'

b) Both 'P' and 'Q' individually true & 'R' is not the correct explanation of 'P'.

c) 'P' is true & 'Q' is false.

d) 'P' is false & 'Q' is true.

Ex: A 0-250 volt voltmeter has a guaranteed accuracy error of 2% of its full scale value. The voltage measured by this voltmeter is 150 volt, then the percentage limiting error is:

$$\begin{aligned} \text{Sol: } \text{gal} &= 2\% \\ &= \frac{2}{100} \times 250 = 5 \\ \therefore \text{L.E} &= 100 \times \frac{5}{150} = 3.33\% \\ n &= 3.33\% \end{aligned}$$

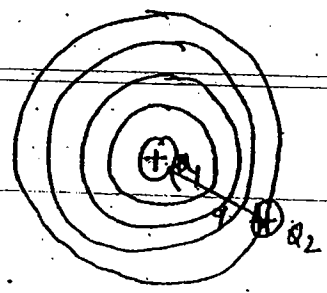
Electrostatic Effect:-

Coulomb's Law:

$$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$$

This is Coulomb's law:

Again, if we place two charge in an electric field then only we experience a force at Q_2



variable

measured

g, $\pm 1\%$

g. The

g a

g the

g 1 = 5%

g are

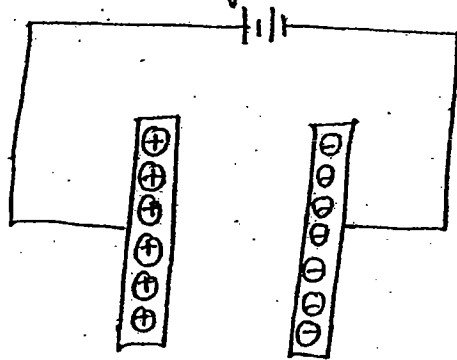
gives

If another charge q_3 is placed outside of the electric field ~~then~~ then we are unable to experience the force at q_3 .

This electric field is given by Faraday law of electromagnetic induction.

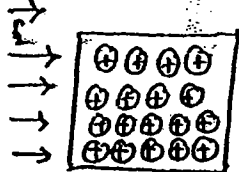
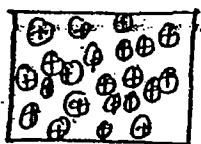
$$E = F/q \rightarrow \text{this force is nothing but Coulomb's law.}$$

Coulomb's law is an empirical law. we experience the force practically, but there is no such derivation.

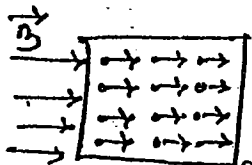
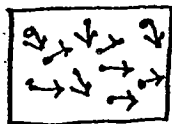


In Electrostatic field we can only measure voltage becoz

$$Q \propto V$$



when a current carrying conductor placed in an electric field then it experiences an electrostatic effect i.e. known as polarization.



magnetostat?

- ↳ Inductor stores energy in form of magnetic field.
- ↳ Capacitor stores energy in form of electric field.
- ↳ Although the capacitor is an o.c device, but due to polarization the current pass through it.

that In electrostatic field we can only measure voltage. So in electrostatic field we are using the electrostatic voltmeter in order to measure high voltage.

Here $\boxed{Q \propto V}$

If we apply high voltage then more charge will develop. This high amount of charge cause to develop high force that result in movement of metallic plate.

In electrostatic voltmeter we are always applying the high voltage in order of KV. If we apply high volt then only it is possible to move the plate. For the high resultant high voltage. The max^m 500KV we can measure by the help of electrostatic voltmeter. The relation b/w force and voltage.

Whether this electrostatic voltmeter is linear or non-linear that depends upon the relation b/w force and voltage.

If $\boxed{F \propto V}$ $\rightarrow$ then it is linear one

If $\boxed{F \propto V^2}$ $\rightarrow$ then it is non-linear one.

dipole:

voltage

measuring
in an electric
circuit a
D.C. known

field.

D field

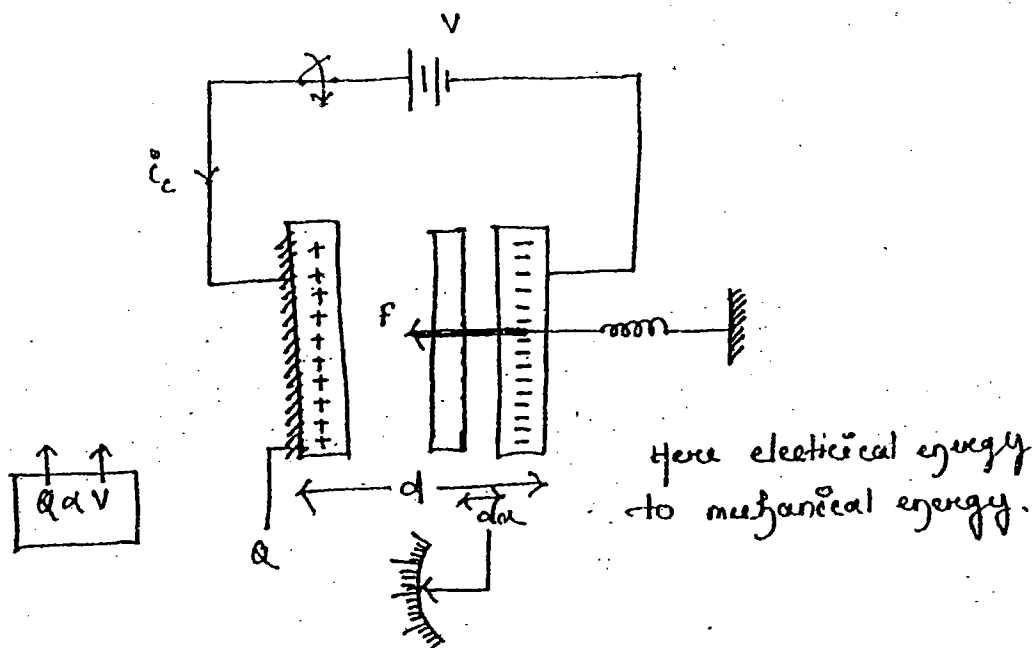
D due

D

0

0

14/11/10

Electrostatic Voltmeter :-Relation b/w i/p (applied volt) & o/p (force) :- i_c = charging current - (it depends upon time)

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

In this case b/w two plates 2 variables are there i.e. Q, V, F, d & C . All these variables are depend upon charge.

we know that $C = \frac{\epsilon A}{d}$ (net b/w displacement and capacitance)

Here both charge (Q) and capacitance (C) both are varies w.r.t time 't'.

$$C \frac{dV}{dt} + V \frac{dC}{dt} = i_c$$

In order to calculate the power,

$$V \left[C \frac{dV}{dt} + V \frac{dC}{dt} \right] = i_c V$$

But all the electrical instruments are energy converter not power converter.

Hence the total electrical energy is taking 'dt' sec to convert into mechanical energy

$$\text{So } q \times v \left[c \frac{dv}{dt} + v \frac{dc}{dt} \right] = i_c \times v \times dt$$

$$\Rightarrow cv \frac{dv}{dt} + v^2 \frac{dc}{dt} = i_c \times v \times dt$$

$$\Rightarrow \boxed{cv \frac{dv}{dt} + v^2 \frac{dc}{dt} = dw} \quad \text{--- (1)}$$

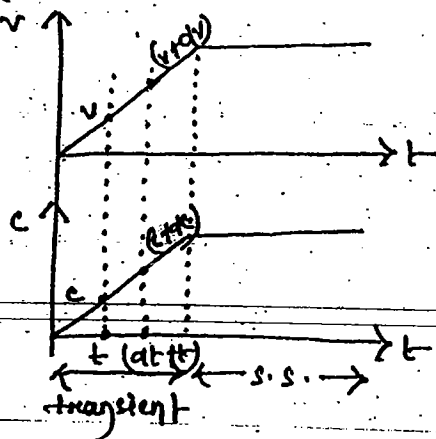
dw = total electrical energy drawn by capacitance in 'dt' sec

This much electrical energy converted into mechanical energy that will do some useful work done. Therefore mechanical work done in 'dt' sec. = $F \times du$ --- (2)

Energy stored in the capacitance in 'dt' sec. :- Linear displacement

Beac of charge (q) there are two variables are there

i.e. c & v .



Energy stored in capacitance in 'dt' sec = E.s. in '(t+dt)' sec
 + E.s. in 't' sec

$$\begin{aligned}
&= \frac{1}{2} (c + dc) (v + dv)^2 - \frac{1}{2} cv^2 \\
&= \frac{1}{2} (c + dc) (v^2 + 2v \cdot dv + dv^2) - \frac{1}{2} cv^2 \\
&= \frac{1}{2} [cv^2 + 2v \cdot c \cdot dv + dc v^2 + 2v \cdot dv \cdot dc] - \frac{1}{2} cv^2 \\
&= \frac{1}{2} cv^2 + cv \, dv + \frac{1}{2} v^2 dc - \frac{1}{2} cv^2 \\
&= cv \, dv + \frac{1}{2} v^2 dc \quad \text{--- (3)}
\end{aligned}$$

n/w according to law of conservation of energy:

$$\textcircled{1} = \textcircled{2} + \textcircled{3}$$

$$cv \, dv + v^2 dc = F \, dx + cv \, dv + \frac{1}{2} v^2 dc$$

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

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

this is the required relation b/w F & v .

$\therefore$ Hence the scale is non-linear.

$$\text{Hence } \boxed{F \propto v^2}$$

we know that $F \propto v^2 \propto I^2$

$F \propto I^2$ (but we it's impossible)

$\hookrightarrow$ becoz in electrostatic volt-meter we can measure only voltage n't current.

$\hookrightarrow$ Inductor and capacitor is a mirror image of each other. Both are storing (energy) element, but we use capacitor widely becoz inductor reverse it's polarity by it's own, but capacitor doesn't change it's polarity until or unless

- ↳ Inductor can reverse its polarity by its own that means after it storing energy fully it will delivered it to source.
- ↳ Again when it stores energy its size becomes 10 times more than capacitance
- ↳ capacitance storing energy very slowly that no noise can be interrupted. At the same time inductor make a big noise. becoz of inductance current inside it there is a physically change in polarity.
- ↳ we never open circuit the inductor and never s.c. the capacitance.

Measurement of Resistance :

It can be classified into 3 categories

(i) Low resistance ($< 1 \Omega$) Eg: Ammeter shunt, diode F.B.

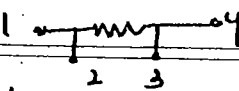
(ii) Medium resistance ($1 \Omega \Rightarrow 100 K \Omega$) ^{ammeter winding, series field winding} resistance.

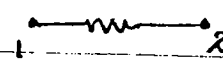
(iii) High resistance ($R > 100 K \Omega$)

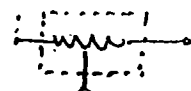
Eg: shunt field winding, potentiometer slide wire

Eg: Diode R_B, all insulation resistance etc.

leakage resistance, op-amp i/p impedance,

~~Low resistance having '4' terminals~~ 

medium resistance having '2' terminals 

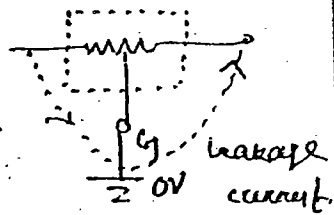
High resistance having '3' terminals 

(ground terminal)

The purpose of guard terminal:

↳ In order to measure the high resistance we have to make the third terminal ground & to avoid leakage current. Once we make it grid then the leakage current will bypass through the ground.

↳ So the purpose of guard terminal is to avoid leakage current.



↳ we can measure the low resistance by using Kelvin's double bridge.

↳ we can measure the med^m resistance by following 4 methods.

(i) - whistone bridge method (It is an accurate one)

(ii) $\left. \begin{matrix} V-I \\ I-V \end{matrix} \right\}$ method ($R_m = \frac{\text{Volt}}{\text{Amm.}}$)

(iii) Substitution method.

(iv) ohm meter (worst-one)

↳ we can measure the high resistance by following 4 methods

(i) Megger

(ii) Loss of charge method (accurate one)

(iii) Direct deflection method

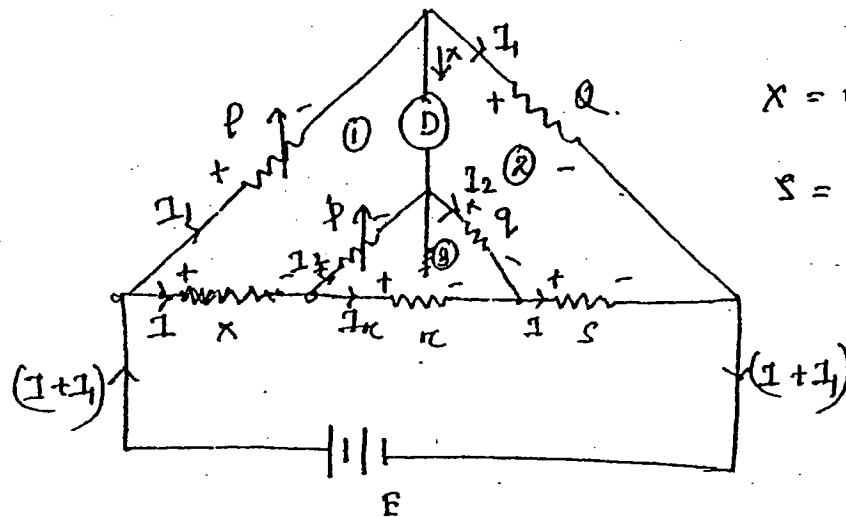
(iv) Mega ohm bridge (worst one)

Kelvin's double bridge :-

$P, Q, p, q = \text{known resistances / bridge resist.}$

$X = \text{unknown low resist.}$

$S = \text{Stand. resist.}$



$\kappa = \text{contact / lead resistance.}$

under bias current condⁿ there is no current through 'g'.

By KVL;

$$-I_1 P + I_2 P + I X = 0 \quad \text{--- (1)}$$

$$I_1 P = I_2 P + I X \quad \text{--- (1)}$$

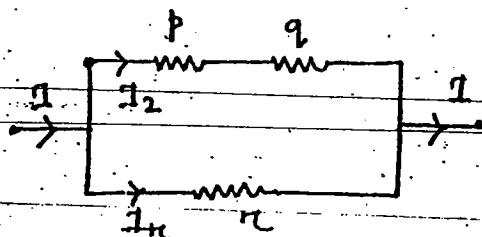
By KVL;

$$-I_1 Q + I S + I_2 q = 0$$

$$I_1 Q = I_2 q + I S \quad \text{--- (2)}$$

Again by KVL,

$$-I_2 P - I_2 q + I \kappa = 0$$



$$I_2 = \frac{I \kappa}{P + q + \kappa} \quad \text{--- (3)}$$

now, $I_1 P = \frac{I_R}{P+q+r} P + I_X$

$$= I \left[\frac{Pr}{P+q+r} + X \right] \quad \text{--- (4)}$$

similarly, $I_1 Q = \frac{I_R}{P+q+r} q + I_S$

$$= I \left[\frac{qr}{P+q+r} + S \right] \quad \text{--- (5)}$$

now divide equⁿ (4) by (5)

$$\frac{I_1 P}{I_1 Q} = \frac{\frac{Pr}{P+q+r} + X}{\frac{qr}{P+q+r} + S}$$

$$\Rightarrow \frac{P}{Q} = \frac{\frac{Pr}{P+q+r} + X}{\frac{qr}{P+q+r} + S}$$

$$\Rightarrow \frac{P}{Q} \left[\frac{qr}{P+q+r} + S \right] = \frac{Pr}{P+q+r} + X$$

$$\Rightarrow X = \frac{P}{Q} S + \frac{P}{Q} \frac{qr}{P+q+r} - \frac{Pr}{P+q+r}$$

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

↳ It is known as double bridge becoz it has two ratio arms i.e. $\frac{P}{Q}$ & $\frac{P}{q}$.

↳ Its purpose is to measure low resistance.

By using Kelvin double bridge we can measure medium resistance also but the condⁿ is

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

$$\therefore X = \frac{P}{Q} \epsilon + \left[\frac{\pi q}{P+q+\pi} \left[\frac{P}{Q} - \frac{P}{q} \right] \right]$$

$$\boxed{X = \frac{P}{Q} \epsilon}$$

Hence it is the eqn of wheatstone bridge.

Wheat stone bridge :-

R = unknown resistance

S = standard resistance

$$I_1 P = I_2 R$$

$$\frac{I_1}{I_2} = \frac{R}{P} \quad \text{--- (1)}$$

drop across BC =

drop across DC .

$$I_3 Q = I_4 S$$

$$\frac{I_3}{I_4} = \frac{S}{Q} \quad \text{--- (2)}$$

$$\text{But } I_1 = I_3 \text{ \& } I_2 = I_4$$

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

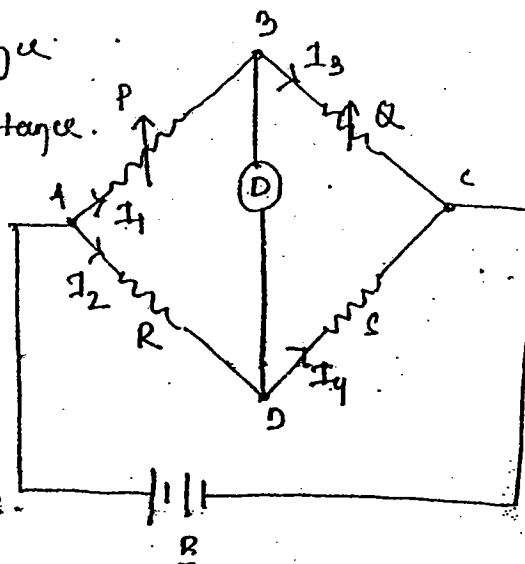
$$\boxed{R = \left(\frac{P}{Q} \right) S}$$

Hence we get only one ratio i.e. P/Q .

Sensitivity :

(i) Detector Sensitivity : $(S_D)_2$

$$S_D = \frac{\text{change in deflection}}{\text{change in P.D.}} = \frac{40}{\epsilon}$$



(ii) Bridge sensitivity (S_B) :

$$S_B = \frac{\text{change in resistance deflection}}{\text{unit change in Res.}} = \frac{\Delta \theta}{\Delta R/R}$$

from deflection sensitivity,

$$\Delta \theta = S_D e$$

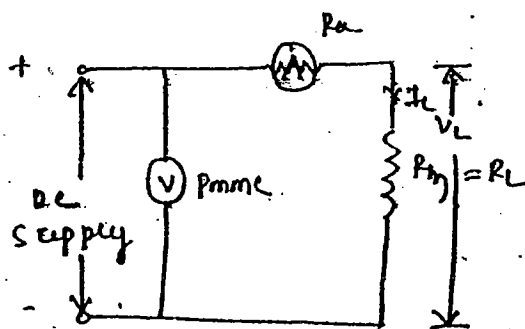
now

$$S_B = \frac{\Delta \theta}{\Delta R/R}$$

$$\checkmark \uparrow S_B = \frac{\uparrow S_D e}{(\Delta R/R)}$$

The sensitivity of detector depends upon bridge sensitivity. So always take / choose a high sensitive detector.

voltmeter - Ammeter method :-



$$\begin{aligned} (P_m)_m &= \frac{\text{volt-}}{\text{Ammeters}} \\ &= \frac{V_L + V_a}{I_L} \\ &= \frac{V_L}{I_L} + \frac{V_a}{I_L} \end{aligned}$$

$$(P_m)_m = (P_m)_L + P_a$$

(i) $P_m \gg P_a$

(ii) In the v-a the error is lesser of ammeter.

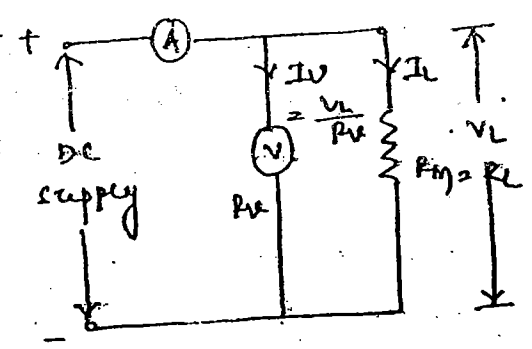
(iii) % error = $\frac{I_m - I_L}{I_L} \times 100$

% error = $\frac{R_a}{R_m(\text{or}) R_L} \times 100$

∴ in order to reduce the % error we have to increase the load resistance value. we can't change internal range.

∴ so this measure high resistance in medium range

Ammeter-voltmeter method :-



$(P_m) = \frac{\text{volt}}{\text{Ampere}}$

$(P_m)_m = \frac{V_L}{I_L + I_m}$

$(P_m)_m = \frac{V_L}{\frac{V_L}{R_L} + \frac{V_L}{R_V}}$

$$\begin{aligned} (P_m)_m &= \frac{1}{\frac{1}{R_L} + \frac{1}{R_V}} \\ &= \frac{1}{\frac{1}{R_L} \left(1 + \frac{R_L}{R_V}\right)} \\ &= \frac{R_L}{\left(1 + \frac{R_L}{R_V}\right)} \end{aligned}$$

$(P_m)_m \approx \left[1 + \frac{R_L}{R_V}\right] \approx R_L$

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

Ammeter

$$\% \text{ error} = \frac{(R_m)_m - R_L}{R_L} \times 100 = \frac{-(R_m)_m}{R_L} \times 100$$

(i) Here $-(R_m)_m$ becoz $R_m < R_L$.

(ii) In A-V the error is becoz of voltmeter.

(iii) The % error can be reduce only when the load resistance is having low value.

$\therefore$ So that this method is suitable only for "Low resistance in medium range value".

Pb: For what value of resistance both the case the % error is same?

Ans:

$$\frac{R_A}{R_L} = \frac{R_L}{R_V}$$

$$R_L^2 = R_A \cdot R_V$$

$$R_L = \sqrt{R_A \cdot R_V}$$

$$\therefore \text{medium resistance} = \sqrt{\text{ammeter} \times \text{load resist.}}$$

Note:

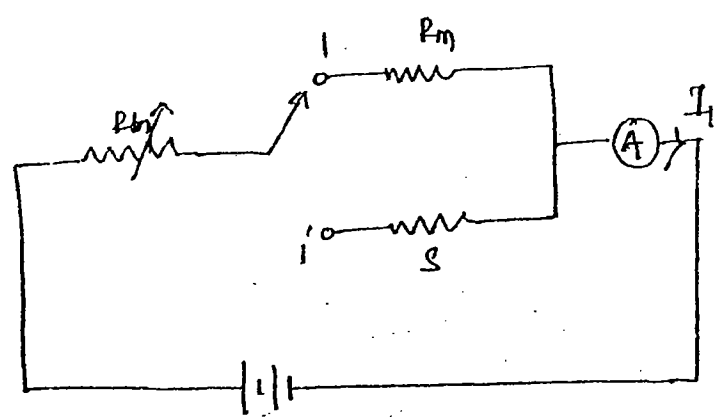
Always the error becoz of always load side of the instrument.

Substitution Method :-

R_m = unknown med. resistance.

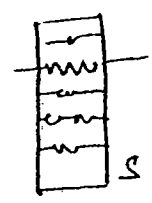
S = standard resistance.

$$I = \frac{E}{R_h + R_m}$$



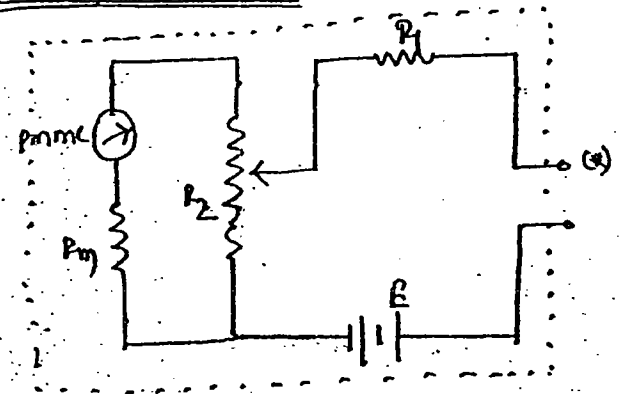
now it switched to 1' ;

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



Instead of changing rheostat we have to substitute the different resistance in the standard resistance box that we are will getting 'Rm' for a particular resistance.

Ohm meter :-



$R_m, R_1, R_2 = \text{known resistance / internal resistance.}$

In order to measure the current I_1 we have to 1st s.c. the terminal (a). then the total current flow through the meter.

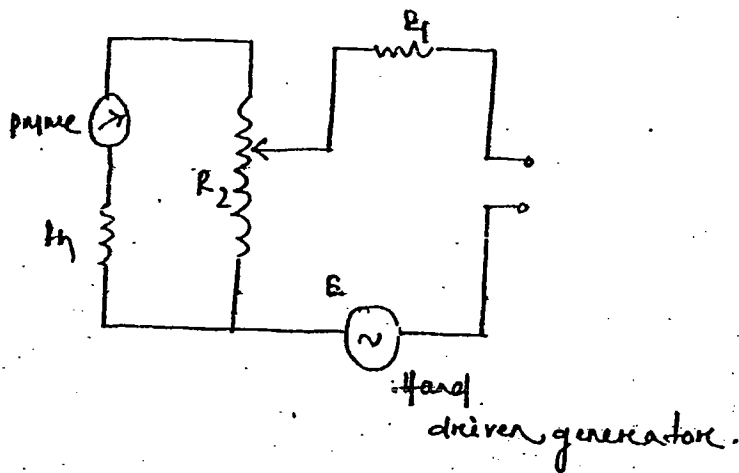
$$I_1 = \frac{E}{(R_1 + R_2) + R_m}$$

Again to find out ' I_2 ' remove the s.c. terminal

$$I_2 = \frac{E}{(R_1 \parallel R_2) + R_1 + R_2}$$

Megger :-

The megger is best suitable to check the continuity in the underground cable.



Note :-

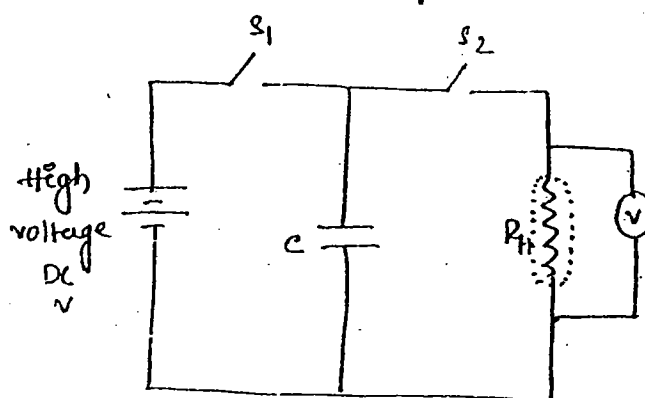
C.R.

cycle

capo

2 mms

rearranging

17/11/10 Loss of charge method :-

Here R_t is high that's why we apply here E.S.V High voltage.

Due to this high voltage we are using E.S.V.

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

at 't' $\leftarrow$ supply volt.
see the amt. of voltage pass through resis.

$$\text{now } \frac{V}{V} = e^{-t/RC}$$

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

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

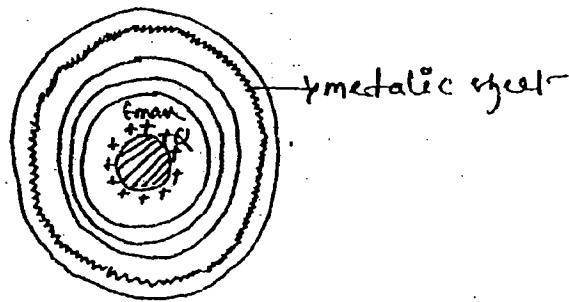
$$R_m = \frac{t}{C \ln\left(\frac{V}{V}\right)} = R = \frac{0.434t}{C \ln\left(\frac{V}{V}\right)}$$

It is known as Loss of charge method becoz by the help of capacitor we are derive the high resistance value.

Note:- here measured value is always less than true value

(R_t); since the electrostatic voltmeter will have some internal capacitance i.e. being parallel with actual capacitance. Then the capacitance value will increase & measured value is decrease.

Loss of charge method is best suitable for the mmt of insulation resistance in case of cables. becoz the capacitors that are used in cable that only use in ^{directly} as the capacitors in loss of charge method. Hence it is less expensive.



$$\oint \vec{E} \cdot d\vec{a} = \frac{1}{\epsilon_0} Q_{\text{enclosed}} \quad (\text{Gauss law})$$

$$\vec{E} \cdot 4\pi r^2 = \frac{1}{\epsilon_0} \times 0 \Rightarrow \boxed{\vec{E} = 0}$$

surface charge $\rightarrow$ Electric field is max^m on the surface of the conductor.

$$\vec{E} \cdot 4\pi r^2 = \frac{1}{\epsilon_0} Q \quad \text{surface of the conductor.}$$

$$\vec{E} = \frac{Q}{4\pi\epsilon_0 r^2}$$

$$\boxed{\vec{E} \propto \frac{1}{r^2}}$$

$$\text{parallel plate capacitance} = \frac{\epsilon_0 A}{d} \quad \text{---||---}$$

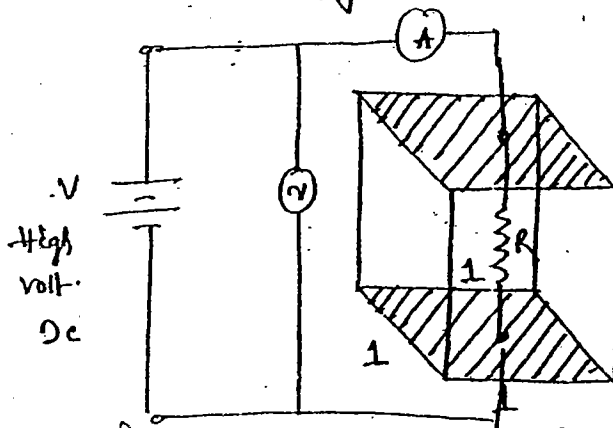
$$\text{cylindrical plate capacitance} = \frac{2\pi\epsilon_0}{\ln(b/a)}$$

$$\text{spherical capacitance} = \frac{4\pi\epsilon_0 ab}{(b-a)}$$

Since the cable is offering same capacitance that can be used directly in this test.

Direct Deflection method :-

Direct deflection method is the best method for measurement of resistivity rather than resistance. The property of resistance is nothing but resistivity. It is the only method to measure resistivity (ρ).



If we measure the resistance b/w two opposite surface then we directly get the value of ' ρ '.

because

$$\rho = \frac{RA}{L}$$

$$\boxed{\rho = R}$$

that's why it is known as direct deflection method.

now how to measure this resistance ' R '?

For this we have to connect a high voltage DC supply to this resistance, now gradually increase the supply volt, at some point we will get a small amount of current, then find the resistance at that particular point by the following

Formula:

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

Mega ohm bridge :-

$R = \text{med}^n$ resistance.

we know that

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

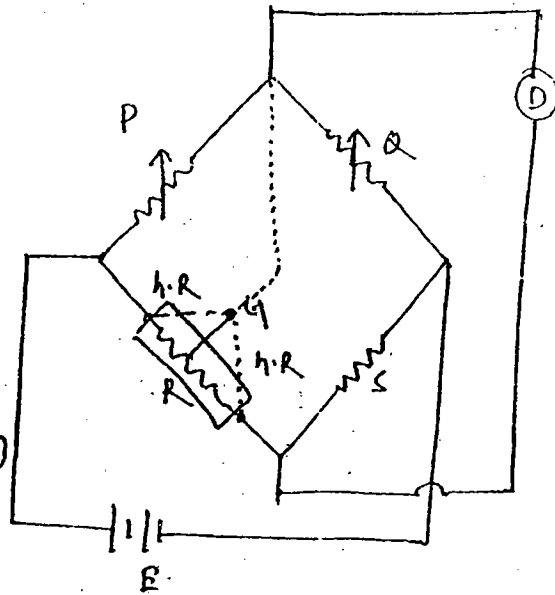
But we want to measure high resistance. Then we have to connect a high resistance

in place of med^n resistance. But in high resistance in order to avoid the leakage resistance we are connecting the guard terminal in b/w the corner of 'P' and 'Q'.

→ In this guard resistance the leakage current is split into two part on both side of guard terminal as a high resistance.

→ one side high resistance is connected parallel across the 'P' terminal and another is parallel connected to the 'Q' (i.e. nothing but internal resistance).

→ But both 'P' and 'Q' are very small. so as a result the high resistance is cancelled out and a very small amount of resistance eqv. to 'P' and 'Q' are getting.



Measurement of Inductance / A.C bridge :-

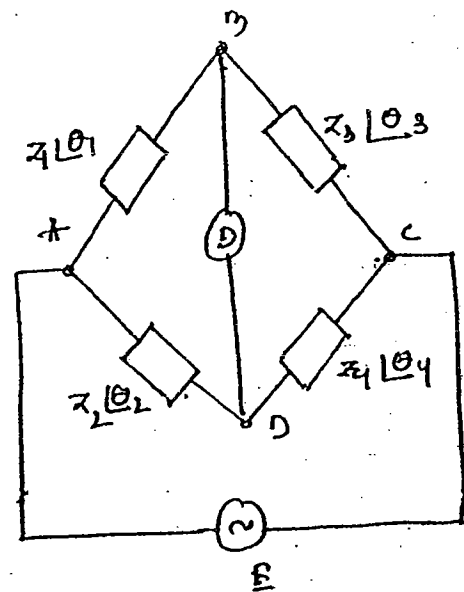
- (i) Maxwell's inductance bridge.
- (ii) Maxwell's inductance-capacitance bridge.
- (iii) Hay's bridge.
- (iv) Owen's bridge.
- (v) Anderson's bridge.

A.C bridge :-

Balancing condⁿ

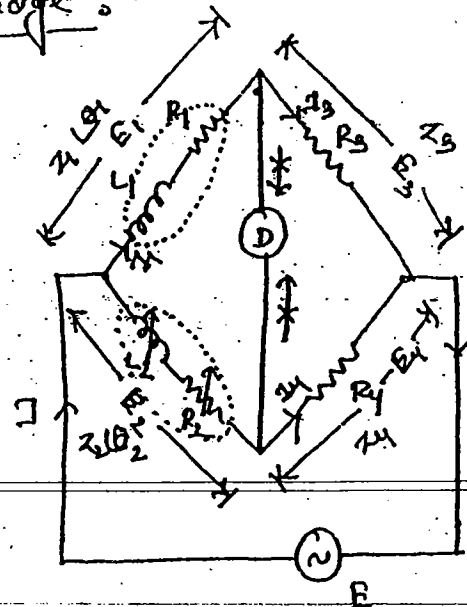
$$Z_1 Z_4 = Z_2 Z_3$$

$$L\theta_1 + L\theta_4 = L\theta_2 + L\theta_3$$



(i) Maxwell's inductance bridge :-

L_1 = unknown inductance.
 L_2 = known inductance.
 Under balance condⁿ:
 there is no current across detector.



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

$$Z_1 Z_4 = Z_2 Z_3$$

$$(R_1 + j\omega L_1) R_4 = (R_2 + j\omega L_2) R_3$$

$$R_1 R_4 + R_4 j\omega L_1 = R_2 R_3 + R_3 j\omega L_2$$

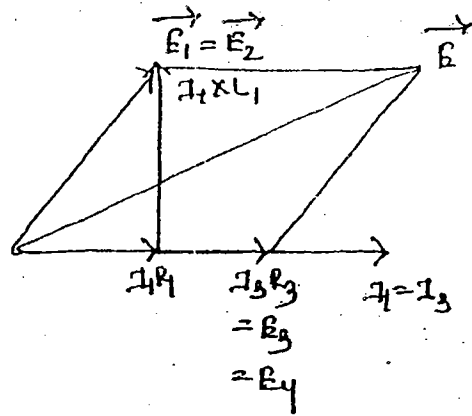
now,

$$R_1 R_4 = R_2 R_3$$

$$L_1 R_4 = L_2 R_3$$

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

$$L_1 = \frac{L_2 R_3}{R_4}$$



In this above the uncommon terms are variable i.e. R_2 and L_2

In the quality factor Q indicates the quality of an inductor.

$Q = 100\%$ $\rightarrow$ It indicates 100% of inductive nature

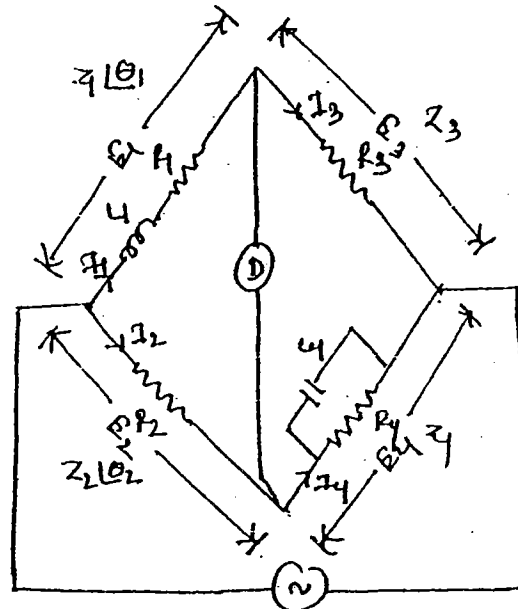
$Q = 60\%$ $\rightarrow$ It indicates 60% of inductive nature and 40% of resistive.

Generally,

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

But in we can only measure the quality factor (Q) in resonance and (i.e. $X_L = X_C$). For that we required an capacitor in theckt. But in this above in bridge there is no capacitor. Hence we can't find out the quality factor.

Maxwell inductance cap-capacitance bridge :-



$$Z_1 Z_3 = Z_2 Z_4$$

$$(R_1 + j\omega L_1) (R_3 + j\omega L_3) = R_2 R_4$$

$$\Rightarrow (R_1 + j\omega L_1) \frac{R_3 \cdot \frac{1}{j\omega C_4}}{R_4 + j\omega L_4} = R_2 R_3$$

$$\Rightarrow \boxed{R_1 = \frac{R_2 R_3}{R_4}} \quad \boxed{L_1 = R_2 R_3 C_4}$$

quality factor : $Q = \frac{\omega L_1}{R_1} = \omega C_4 R_4$

$$\boxed{Q = \omega C_4 R_4}$$

$$\boxed{Q \propto C_4}$$

(i) Resistance $\begin{cases} \rightarrow \text{variable (easy to manufacture)} \\ \rightarrow \text{fixed (n't so easy)} \end{cases}$

(ii) Capacitance $\begin{cases} \rightarrow \text{variable (n't so easy)} \\ \rightarrow \text{fixed (easy to manufacture)} \end{cases}$

$$\text{beac } C = \frac{\epsilon A}{d}$$

(iii) Inductance $\begin{cases} \rightarrow \text{variable} \\ \rightarrow \text{fixed} \end{cases} \left\{ \begin{array}{l} \text{n't at all easy to manufacture} \\ \text{due to no. of turns.} \end{array} \right.$

these turns are affected by reluctance and mag. field.

↳ In this we can't measure high quality factor.
 Because in order to measure high quality factor we
 have to design a high & variable capacitor,
 but design of variable capacitor is not so easy.
 that's why in this case quality factor (Q) is
 restricted to a condⁿ: $Q < 10$

Hay's bridge :-

$$Z_1 Z_4 = Z_2 Z_3$$

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

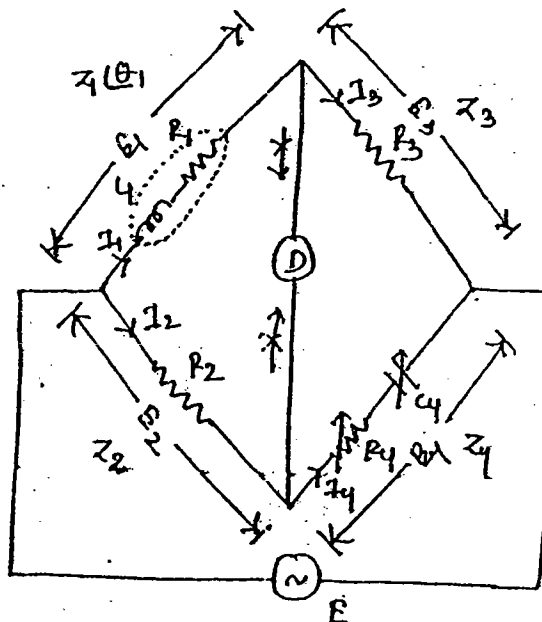
$$1) R_1 R_4 + \frac{R_1}{j\omega C_4} + R_4 j\omega L_1 + \frac{j\omega L_1}{j\omega C_4} = R_2 R_3$$

$$2) R_1 R_4 = R_2 R_3$$

3)

$$\Rightarrow \frac{R_1}{j\omega C_4} + R_4 j\omega L_1 + \frac{j\omega L_1}{C_4} = 0$$

3)



$$R_1 = \frac{\omega^2 C_4^2 R_2 R_3 R_4}{1 + \omega^2 C_4^2 R_4^2}$$

$$L_1 = \frac{R_2 R_3 C_4}{1 + \omega^2 C_4^2 R_4^2}$$

fore.
or we
fore,
so easy.

$$\text{quality factor } (Q) = \frac{\omega L_1}{R_1} = \frac{1}{\omega C_1 R_1}$$

$$Q \propto \frac{1}{C_1} \quad (Q > 10)$$

High quality factor can be measured accurately by Hey's bridge.

Owen's Bridge :-

$$\begin{aligned} Z_1 Z_4 &= Z_2 Z_3 \\ (R_1 + j\omega L_1) j\omega C_1 &= (R_2 + \frac{1}{j\omega C_2}) R_3 \\ R_1 j\omega C_1 + j\omega L_1 j\omega C_1 &= R_2 R_3 + \frac{R_3}{j\omega C_2} \\ &= R_2 R_3 + \frac{R_3}{j\omega C_2} \end{aligned}$$

$$R_1 = \frac{R_2 R_3 C_1}{C_2}$$

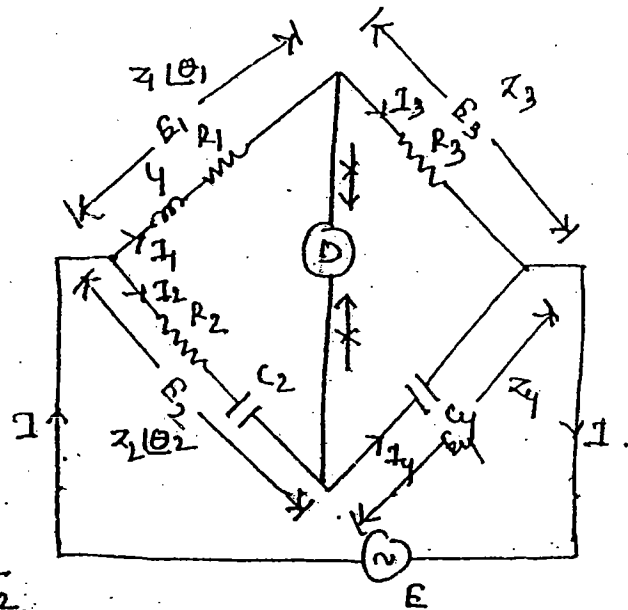
$$\Rightarrow L_1 = R_2 R_3 C_1$$

quality factor: $Q = \frac{\omega L_1}{R_1}$

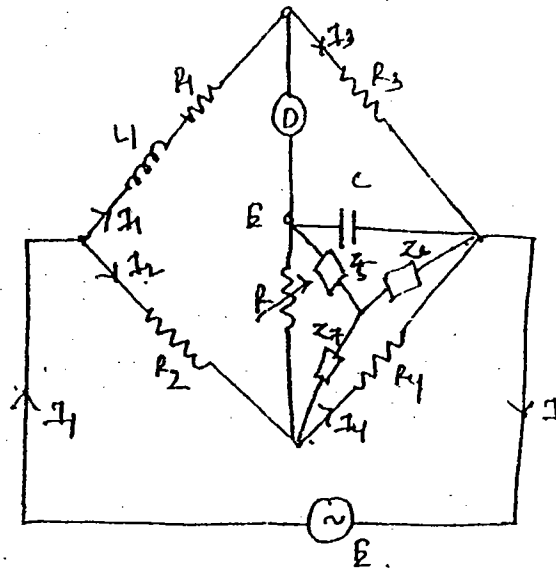
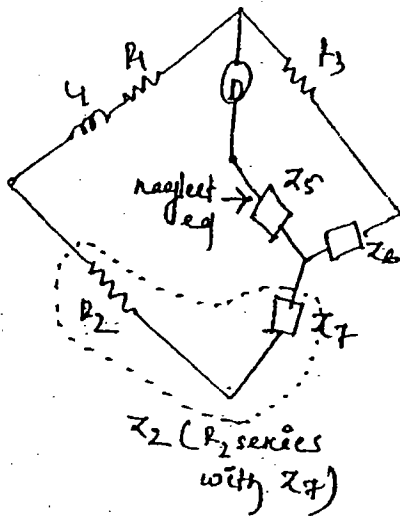
$$Q = \omega R_2 C_2$$

$$Q \propto C_2$$

$$(Q < 10)$$



Anderson's bridge :-



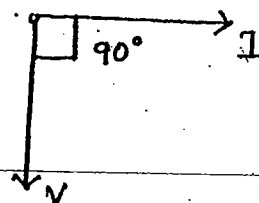
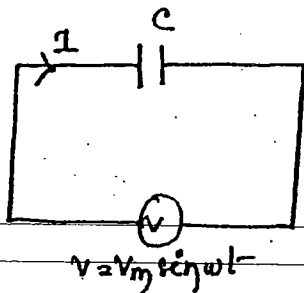
$$R_1 = \frac{R_2 R_3}{R_4}$$

$$L_1 = \frac{CR_3}{R_4} [R R_2 + R R_4 + R_2 R_4]$$

Here we can't measure Q -factor because we are connecting here a fixed capacitor.

Measurement of capacitance bridges :-

- (i) Deauty bridge
- (ii) Modified deauty bridge.
- (iii) Schering bridge. (Highly accurate bridge)



(iii)

C

Bal

Z1 Z2

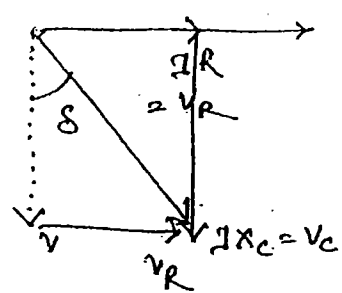
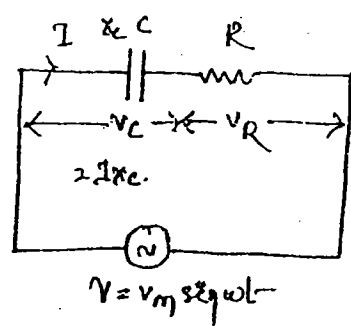
$$\left(\frac{1}{j\omega C} \right)$$

$$= \frac{R}{\omega^2 C}$$

$$= \frac{R}{\omega^2 C}$$

C

R



δ = loss angle (It is available only in capacitor)

If it is a pure capacitor then $\delta = 0$

$$\begin{aligned} \tan \delta &= \frac{V_R}{V_C} \\ &= \frac{IR}{I/j\omega C} \\ &= \frac{R}{1/j\omega C} = \omega CR \end{aligned}$$

$\tan \delta = \omega CR \Rightarrow$ D-factor (that determines the quality of capacitor)

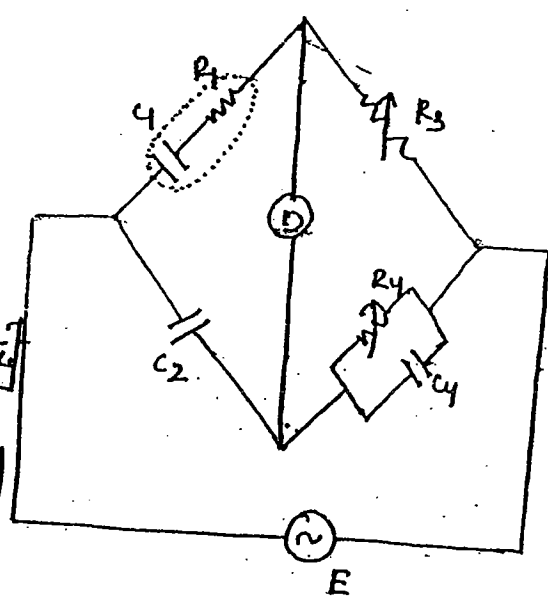
(iii) Schering bridge :-

C_1 = unknown capacitor.

Balancing condⁿ:

$$Z_1 Z_4 = Z_2 Z_3$$

$$\begin{aligned} \left(\frac{1}{j\omega C_1} R_1 \right) \frac{1}{j\omega C_2} &= \frac{R_3 \left[R_4 + \frac{1}{j\omega C_4} \right]}{R_4 + \frac{1}{j\omega C_4}} \\ \Rightarrow \frac{-R_1}{\omega^2 C_1 C_2} &= R_3 \left[\frac{R_4 \cdot \frac{1}{j\omega C_4}}{R_4 + \frac{1}{j\omega C_4}} \right] \\ \Rightarrow \frac{-R_1}{\omega^2 C_1 C_2} &= R_3 \left[\frac{R_4/j\omega C_4}{R_4/j\omega C_4 + 1} \right] \end{aligned}$$



$$\begin{aligned} C_1 &= \frac{C_4 R_4}{R_3}, & \text{D-factor} &= \omega C_1 R_1 \\ R_1 &= \frac{R_3 C_4}{\omega C_1} & &= \omega C_4 R_4 \end{aligned}$$

Measurement of frequency :-

(i) Wien's bridge :

Balancing cond :

$$Z_1 Z_4 = Z_2 Z_3$$

$$2) \left(\frac{R_1}{j\omega C_1} \right) = \left(R_2 \parallel \frac{1}{j\omega C_2} \right)$$

$$= R_3 R_4$$

$$2) \frac{R_1}{j\omega C_1} \left[\frac{R_2 \cdot \frac{1}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}} \right] = R_3 R_4$$

$$2) \frac{R_1}{j\omega C_1} \left[\frac{R_2}{R_2 j\omega C_2 + 1} \right] = R_3 R_4$$

$$2) \frac{R_1 R_2}{-R_2 \omega^2 C_1 C_2 + 1} = R_3 R_4$$

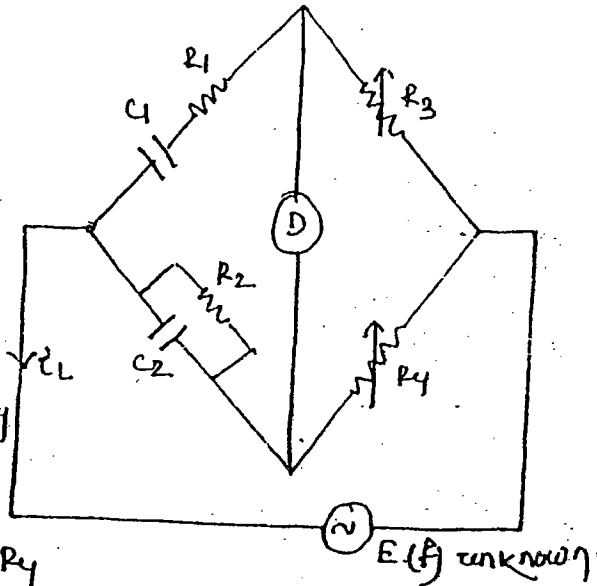
$$2) R_1 R_2 = -R_3 R_4 R_2 \omega^2 C_1 C_2 + R_3 R_4$$

2)

$$\Rightarrow \omega^2 = \frac{1}{C_1 C_2 R_1 R_2}$$

$$\omega = \frac{1}{\sqrt{C_1 C_2 R_1 R_2}}$$

$$f = \frac{1}{2\pi \sqrt{C_1 C_2 R_1 R_2}}$$



(i)

2)

2)

2)

2)

2)

2)

2)

2)

2)

2)

2)

2)

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2)

2)

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2)

2)

2)

Measurement of power :-

(i) Dc power ($P = VI$) — $\left. \begin{array}{l} \rightarrow V-I \\ \rightarrow I-V \end{array} \right\} \text{method}$

$$P_m = \text{Volt} \times \text{Amp.}$$

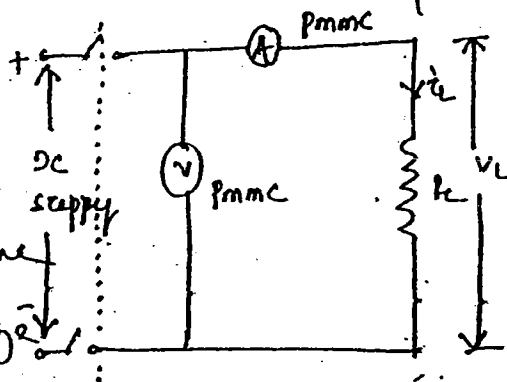
(ii) A/c power ($P = VI \cos \phi$)

↳ (dynamometer type wattmeter)

(iii) A/c power measurement :-

In order to measure ^{dc} power the supply must be a dc source and load must be a resistive load.

At the moment of connect the d.c. switch the load 'R_L' will drop some 'I_L' amt of current and again some 'V_L' amount of volt across the load 'R_L'.



Now for the msmt of 'V_L' and 'I_L' we are using voltmeter-meter-ammeter method. for this we are connecting two pmmc instrument across the circuit. Again we know that

$$P_L = V_L I_L$$

Again $P_m = \text{volt} \times \text{Ammeter}$

$$= (V_L + V_A) I_L = V_L I_L + V_A I_L$$

nothing but product of $V-I$

condition :-

(i) $P_m \neq P_L$

$$P_m = P_L + I_L^2 R_A$$

↳ loss due to ammeter.

(ii) Power loss is due to ammeter.

(iii) Power loss can't be eliminated, but it is minimised by using high load resistance.

∴ So V-I method is best suitable for measurement of high resistive load and low load current.

Ammeter-volt-meter method :-

→ true power.

$$P_T = V_L I_L$$

P_m = volt-meter $\times$ ammeter

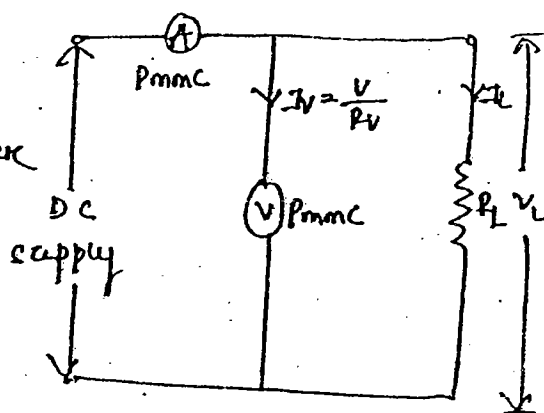
$$= V_L (I_L + I_V)$$

$$= V_L I_L + V_L I_V$$

$$P_m = P_T + \frac{V_L^2}{R_V}$$

↓
measured power.

↓ power loss
due to volt-meter.



and:

(i) $P_m > P_T$.

(ii) Error is due to voltmeter.

(iii) This error/loss can be minimize by increasing the load resistance or increasing the load current.

conclusion:

Hence ammeter-voltmeter method is best suitable for measurement of low load resistance and high load current.

AC power measurement :-

In order to measure AC power the supply must be v-phase of supply. (single phase)

Resistive load $\Rightarrow V_L = I_L$

inductive load $\Rightarrow I_L$ lags V_L

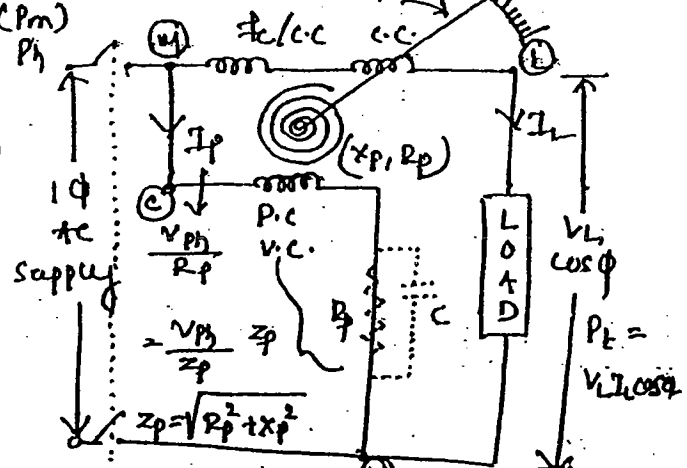
capacitive load $\Rightarrow I_L$ leads V_L

In order to measure the power across the load we are connecting a watt-meter (dynamometer type wattmeter / same)

The moment we close the d.p.s switch the load draws V_L and I_L amt of power from the source i.e. nothing but true power.

1) To measure the power we are connect a wattmeter. Initially the pointer shows zero reading, but after some power drawn whatever the pointer deflection shows it is the measured pow. (Pm)

2) The coil which is connected series with load it is known as current coil. and coil which is connected parallel across the supply i.e. known as moving coil / pressure coil. or volt. coil.



3) Both the coils are connected in parallel. So that 2 different current will flow through the coils i.e. I_L and I_p .

In order to measure the power we have to consider two assumptions:

Assumption - (1): the supply voltage = load voltage.
(But this isn't possible. It is possible only when the drop across current coil is neglected)

$$V_{\text{phase}} = V_L$$

Assumption - (2): Pressure coil is purely a highly resistive. (But it isn't practically possible)

→ Pressure coil having both X_p (pressure coil reactance) and R_p (pressure coil resistance).

→ The above assumption is true when $X_p = 0$.

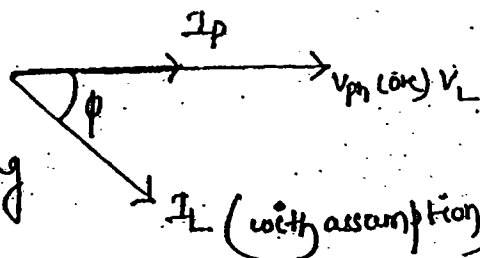
$$I_p = ?$$

$$I_p \text{ (pressure coil current)} = \frac{V_{ph}}{R_p}$$

→ Let us consider, the load is lagging load (i.e. inductive load) = I_L lags V_L at angle ϕ

→ Here two voltage and two current are there.

Phasor diag:



when two currents are moving with a phase angle ϕ .

$$\text{then } T_d = I_1 I_2 \cos(\theta_1 \& \theta_2) \frac{d\theta}{d\theta}$$

initial $\beta = 0$
due to purely resistive

$I_1 =$ current across C.C. = I_L

$I_2 =$ current across m.c./p.c. = I_p

Note

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

Ex

consider

so

$$T_d = I_L I_p \cos(\phi) \frac{d\eta}{d\theta}$$

$$= I_L \frac{V_{ph}}{P_p} \cos \phi \frac{d\eta}{d\theta}$$

$$T_d = I_L \frac{V_L}{P_p} \cos \phi \frac{d\eta}{d\theta} \Rightarrow P_L \text{ --- (1)}$$

(with assumption)

$$T_d \propto \text{Ac power}$$

Note

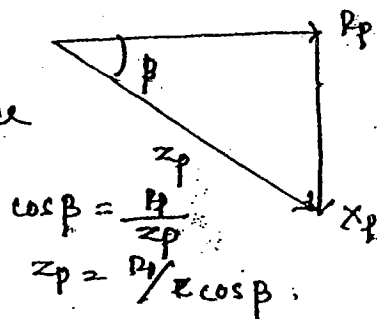
Error due to pressure coil inductance:

Earlier pressure coil assumed to be purely resistive, but practically $x_p \neq 0$ so that we'll get some errors in the reading.

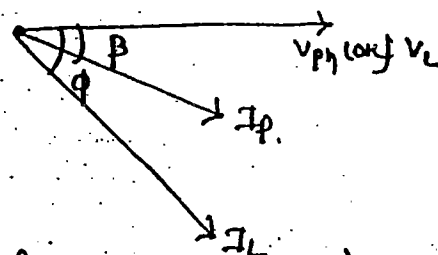
Impedance triangle:

z_p = pressure coil impedance

β = Impedance angle of pressure coil.



$$T_d = I_L \frac{V_L}{z_p} \cos(\phi + \beta) \frac{d\eta}{d\theta} = P_m$$



(i) $P_m > P_L$

$$= I_L \frac{V_L}{P_p} \cos \beta (\cos(\phi + \beta)) \frac{d\eta}{d\theta} = P_m \text{ (without assumption)}$$

(2)

(ii) $P_m \times C.F. = P_L$

$$C.F. = \frac{P_L}{P_m} \quad (C.F. < 1)$$

$$C.F. = \frac{\cos \phi}{\cos \beta \cos(\phi + \beta)}$$

$$P_m \times \frac{\cos \phi}{\cos \beta \cos(\phi + \beta)} = P_t$$

$$(ii) \% \text{ error} = \frac{P_m - P_t}{P_t} \times 100$$

$$= \left(\frac{P_m}{P_t} - 1 \right) \times 100$$

$$\% \text{ error} = \pm \left(\frac{1}{\text{C.F.}} - 1 \right) \times 100$$

(i) dynamometer type wattmeter

$$(iv) \% \text{ error} = \pm (\tan \phi \cdot \tan \beta) \times 100$$

∴ All the above power is due to reactance of pressure coil. (beoz. $X_p \neq 0$ practically)

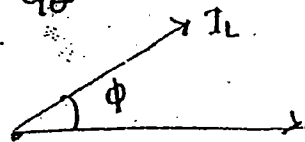
All the above formulae are valid only for lagging load.

In case of leading:

$$T_q = I_L \frac{V_L}{Z_p} [\cos(\phi + \beta)] \frac{d\theta}{d\phi} = P_m$$

$$P_m < P_t$$

$$\text{C.F.} = \frac{\cos \phi}{\cos \beta \cos(\phi + \beta)}$$



$$P_m \times \frac{\cos \phi}{\cos \beta \cos(\phi + \beta)} = P_t$$

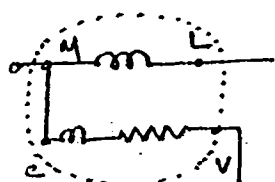
$$\% \text{ error} = \pm \left(\frac{1}{\text{C.F.}} - 1 \right) \times 100$$

$$\% \text{ error} = - (\tan \phi \tan \beta) \times 100$$

✓ If we $X_p = 0$ then (by connect a capacitor in parallel to R_p) then capacitor reactance is cancelled out by inductor reactance of pressure coil. Then the pressure coil is purely resistive.

The value of $C = 0.41 \frac{L_p}{R_p^2}$

L_p = Pressure coil inductance.

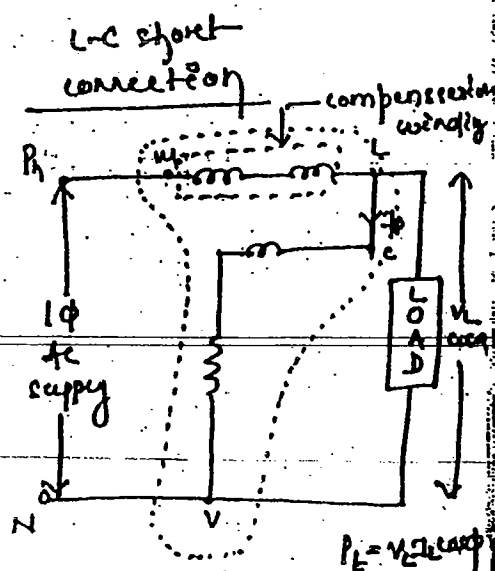
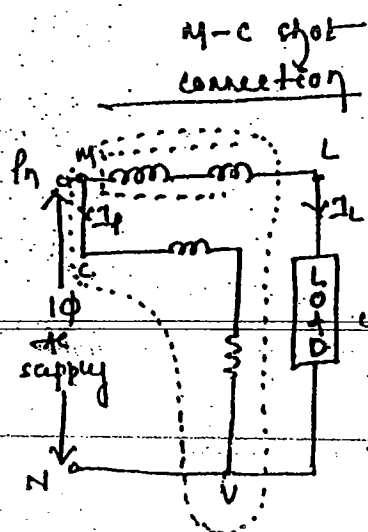


M = main terminal
L = load terminal
C = common terminal
V = voltage terminal.

✓ M-C short wattmeter = connection before pressure coil.
before C.C.

✓ L-C short connection wattmeter = connection of pressure coil after C.C.

Error due to coil connection :-



$$P = I_{L.C} I_{P.C} \cos(\angle) \frac{d\eta}{d\theta}$$

m-c shot connection :-

$$P = I_L I_P \cos(\angle) \frac{d\eta}{d\theta}$$

L-c shot connection :

$$P = (I_L + I_P) I_P \cos(\angle) \frac{d\eta}{d\theta}$$

compensation winding is required only in L-c shot connection. It is not present in m-c shot (becoz only one current is flowing through winding).

in m-c :

$$P_m = P_t + P.L \text{ in c.c.}$$

$$P_m > P_t$$

$$P_m = P_t + I_L R_{c.c.}$$

in L-c :

$$P_m = P_t + P.L \text{ in P.C.}$$

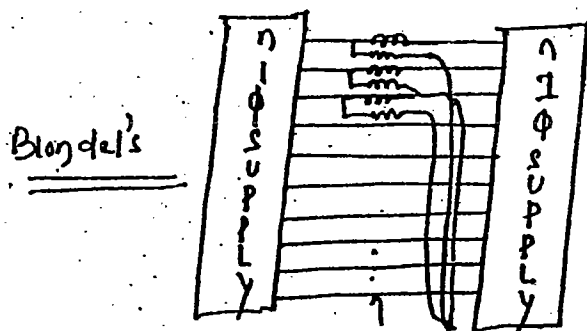
$$P_m = P_t + \frac{V^2}{R_{P.C.}}$$

In m-c shot connection error becoz of c.c. becoz it is nearer to load.

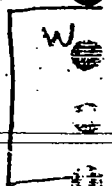
$$P_m < P_t$$

error is due to P.C. becoz it is nearer to load.

Measurement of polyphase (n phase) power :-



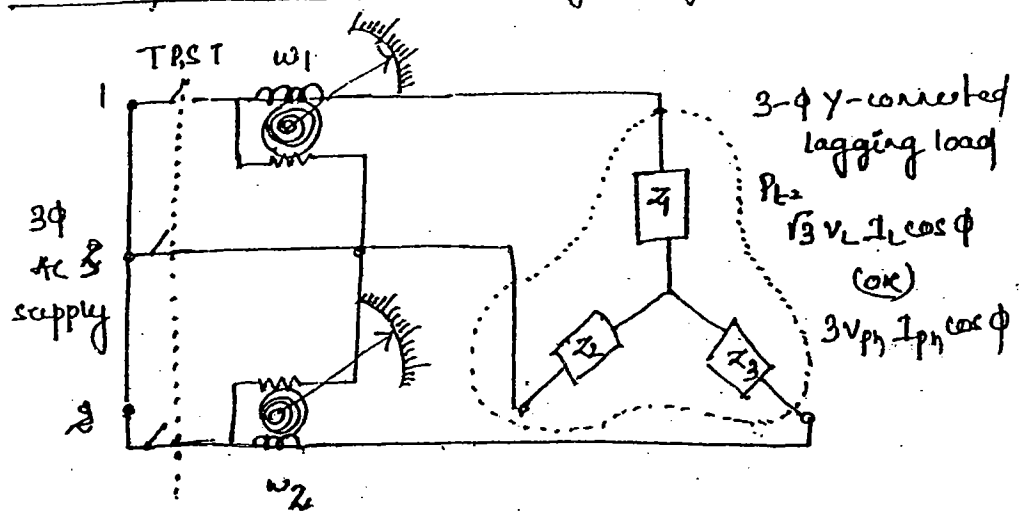
To measure power in this case how many wattmeter are required that can depend upon neutral point. if there is a common neutral point then 'n'



wattmeter is needed, if several neutral points are there then 'n-1' wattmeter is needed. (According to Blondel's theorem).

4 If the neutral point is not available then one of the line act as common line.

Measurement of 3- ϕ power by using 2 wattmeter :-



$$P = I_{L.C.} V_{P.C.} \cos(\theta_{L.C.} \angle V_{P.C.})$$

Phasor diag :

$$W_1 = \vec{I}_1 V_{13} \cos(\theta_1 \angle V_{13})$$

$\downarrow$
 $V_{13} = V_1 - V_3$
 $V_1 + (-V_3)$

$$\vec{I}_1 = \vec{I}_2 = \vec{I}_3 = \vec{I}_{ph}$$

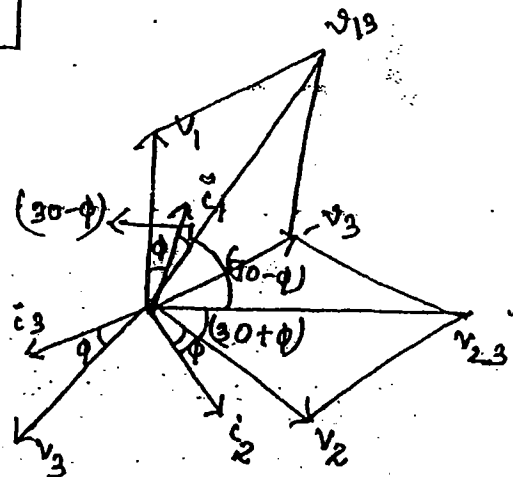
$$V_1 = V_2 = V_3 = V_{ph}$$

$$W_1 = I_{ph} \sqrt{3} V_{ph} \cos(30^\circ - \phi)$$

$$= V_L I_L \cos(30^\circ - \phi)$$

$$W_2 = \vec{I}_2 V_{23} \cos(\theta_2 \angle V_{23})$$

$\downarrow$
 $V_{23} = V_2 - V_3$



$$W_2 = -I_{ph} \sqrt{3} V_{ph} \cos(30 + \phi)$$

$$\begin{aligned} W_2 &= \sqrt{3} V_{ph} I_{ph} \cos(30 + \phi) \\ &= V_L I_L \cos(30 + \phi) \end{aligned}$$

total power :

$$W = W_1 + W_2$$

$$= \sqrt{3} V_{ph} I_{ph} [\cos(30 - \phi) + \cos(30 + \phi)]$$

$$= \sqrt{3} V_{ph} I_{ph} [2 \cos 30 \cos \phi]$$

$$W = 3 V_{ph} I_{ph} \cos \phi \quad \text{--- (1)}$$

Again $W_1 - W_2$

$$= \sqrt{3} V_{ph} I_{ph} [2 \sin 30 \sin \phi]$$

$$\Rightarrow W_1 - W_2 = \sqrt{3} V_{ph} I_{ph} \sin \phi$$

$$\Rightarrow \sqrt{3} (W_1 - W_2) = (\sqrt{3} V_{ph} I_{ph} \sin \phi) \sqrt{3}$$

$$\Rightarrow \sqrt{3} (W_1 - W_2) = 3 V_{ph} I_{ph} \sin \phi \quad \text{--- (2)}$$

$$\sqrt{3} (W_1 - W_2) = Q$$

$$Q = 3 V_{ph} I_{ph} \sin \phi$$

now equate equ (1) & (2)

phase angle $\rightarrow \tan \phi = \frac{\sqrt{3} (W_1 - W_2)}{W_1 + W_2}$

$$P.f. = \cos \phi = \cos \left[\tan^{-1} \left(\frac{\sqrt{3} (W_1 - W_2)}{W_1 + W_2} \right) \right]$$

In case of leading :

$$\begin{aligned} -W_1 &= \sqrt{3} V_{ph} I_{ph} \cos(30 + \phi) \\ &= V_L I_L \cos(30 + \phi) \end{aligned}$$

$$\begin{aligned} -W_2 &= \sqrt{3} V_{ph} I_{ph} \cos(30 - \phi) \\ &= V_L I_L \cos(30 - \phi) \end{aligned}$$

If we remove one wattmeter and connect the only wattmeter across the supply and again the pressure & coil supply terminals are connected across 2 & 3 terminal then -

The total power =

$$P = I_{ec} V_{pc} \cos(\angle I_{ec} \angle V_{pc})$$

$$= I_1 V_{23} \cos(\angle I_1 \angle V_{23})$$

$$= I_{ph} V_{ph} \sqrt{3} \cos(90 - \phi)$$

$$\sqrt{3} W = 3 I_{ph} V_{ph} \cos(90 - \phi)$$

∴ Hence the total power across a 3-φ circuit can be measured by using only wattmeter. (Only the connection is different).

Measurement of Energy :

Relⁿ b/w power and time :

$$\begin{aligned} \text{Energy} &= \text{Power} \times \text{time} \\ &= \int (\text{power}) dt \end{aligned}$$

that's why we are using integrated type (energy meter) instrument.

Instead of a deflection pointer there is a disc inside the energy meter.

The working principle of energy meter is inductive effect.

$$T_d = T_{d1} \sim T_{d2}$$

→ driving torque.

Aluminium disc is almost purely resistive, but a small amt of it is inductive

$$T_d = T_{d1} \sim T_{d2}$$

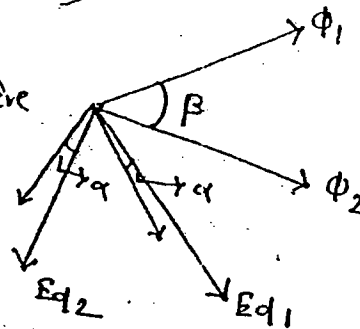
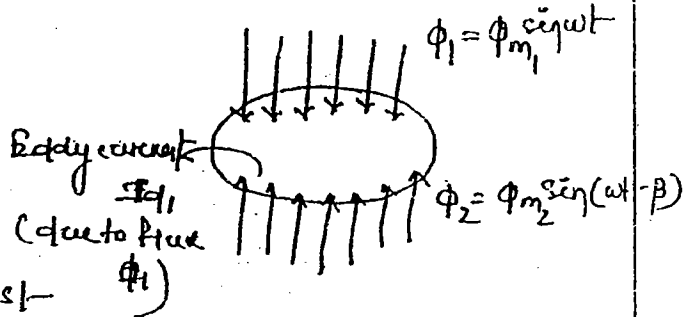
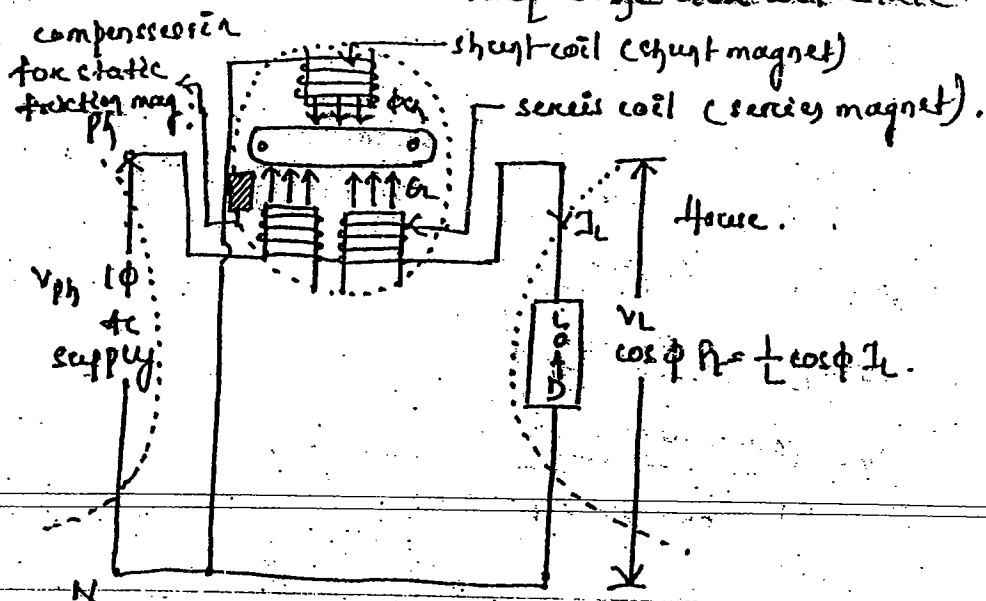
$$T_d = \phi_1 \phi_2 \sin \beta \cos \alpha$$

→ driving torque.

But, $\alpha \approx 0$

$$T_d = \phi_1 \phi_2 \sin \beta$$

With this deflecting torque the disc will rotate.



For $\sin \delta$

relative

$\sin \omega t$

$\sin(\omega t + \beta)$

The coil which is connected in series with load are called series coil and that magnet is called series magnet.

The coil which is connected across the supply that is called shunt coil and that magnet is coil is shunt magnet.

$$\phi_L \propto I_L$$

$$\phi_{sh} \propto I_{sh}$$

$$\phi_{sh} \propto I_{sh} \propto V_{sh}$$

$$\phi_{sh} \propto V_{sh}$$

In order to measure energy we have to consider two assumption.

Assumption (1): supply voltage = load voltage.

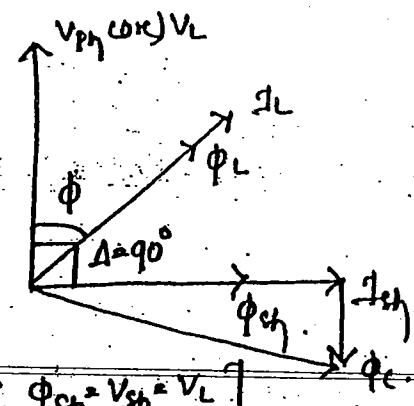
Assumption (2): shunt coil is assumed to be purely inductive.

Phasor diagram: (Here the load is assumed to be lagging load)

$$T_d = \phi_1 \phi_2 \sin(\phi_1 \pm \phi_2)$$

$$\phi_1 = \phi_L, \phi_2 = \phi_{sh}$$

$$T_d = \phi_L \phi_{sh} \sin(\Delta - \phi)$$



$$T_d = \phi_L V_L \sin(\Delta - \phi) \quad [\because \phi_{sh} = V_{sh} = V_L]$$

→ driving torque.

$$T_d = \phi_L V_L \cos \phi \quad (\text{when } \Delta = 90^\circ) \quad \text{--- (1)}$$

$T_d \propto AC \text{ power}$

The energy meter is nothing but the ^{integration of} wattmeter
o/p which is present inside it. So energy meter
indicates the power consumption.

Here $\Delta = 90^\circ$ when the current coil is purely
inductive in nature.

Inside the energy meter the control coil is there
to make $\Delta = 90^\circ$. That's why it is named as
lag adjustment device.

Inside the energy meter there is a permanent magnet
this is known as braking torque. The purpose
of braking torque is to see the disc to
rotate at const. speed by producing braking
torque.

Braking torque (T_B) $\propto$ speed of disc.

$$T_B \propto N \quad \text{--- (2)}$$

At steady state,

$$T_D \propto T_B$$

$$\int (\text{power}) dt \propto \int (N) dt$$

$$\boxed{\text{Energy} \propto \text{no. of revolution}}$$

Although the load is totally disconnected from the
main supply then also the disc will rotate, bcoz
Although $I_L = 0$, $\Rightarrow \phi_L = 0$, but still ϕ_m is there
to make the disc rotate.

creeping effect : Under no load condⁿ there is a slow rotation of disc is called creeping effect.

✓ The creeping effect can be reduced by drilling two holes diametrically opposite on the aluminium disc.

✓ How much amt of inertia is produced by the disc that will be compensated by the magnet.

Meter const. : The no. of revolution made by disc in order to indicate 1 kWh energy consumption is called meter const.

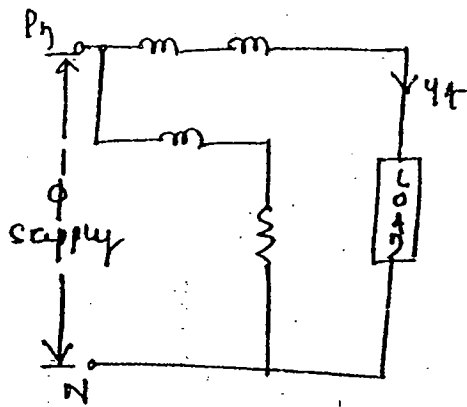
The units of meter const = $\frac{\text{revolution}}{\text{kWh hour}}$.

The main reason for creeping is overcompensation for static friction.

overcompensation :- Instead of reduce the speed it will speed up the disc.

Pb: A 250 volt electrodynamic type wattmeter has a resistance of current and potential coil 0.5Ω and $12.5 \text{ k}\Omega$ respectively. The % error due to each of two methods (m-c short & L-c short) of connection with unity p.f. load at 250 volt with a load current of 4 A is:

M-C short



$$\cos \phi = 1$$

$$P_L = V_L I_L \cos \phi$$

$$= 250 \times 4 \times 1$$

$$= 1000 \text{ watts}$$

$$P_m = P_L + I_L^2 R$$

$$= 1000 + 4^2 \times 0.5$$

$$= 1000 + 16 \times \frac{5}{10}$$

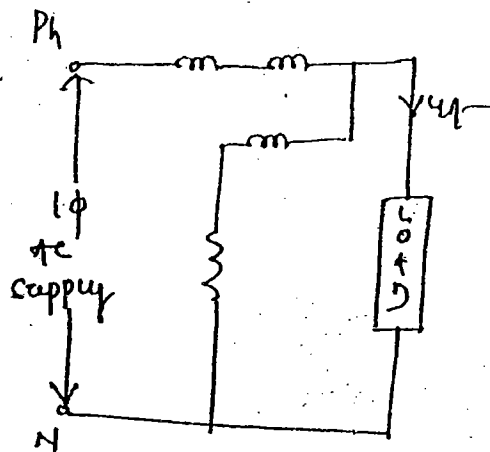
$$= 1008 \text{ watt.}$$

$$\% \text{ error} = \frac{P_m - P_L}{P_m} \times 100$$

$$= \frac{1008 - 1000}{1008} \times 100$$

$$= 0.8\%$$

L-C short



$$\cos \phi = 1$$

$$P_L = V_L I_L \cos \phi$$

$$= 250 \times 4 \times 1$$

$$= 1000 \text{ watt.}$$

$$P_m = P_L + \frac{V_L^2}{R}$$

$$= 1000 + \frac{250^2 \times 5}{1000}$$

$$= 1005 \text{ watt.}$$

$$\% \text{ error} = \frac{P_m - P_L}{P_m} \times 100$$

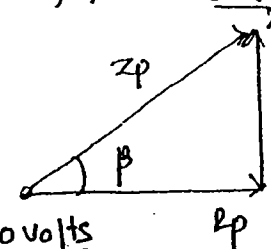
$$= 0.5\%$$

Pb: The reactance of pressure coil of a wattmeter is 1% of its resistance. The percentage error due to this cause at a p.f. of 0.5 lagging is —

$$\% \text{ error} = 2(\tan \phi \cdot \tan \beta) \times 100 \quad (\text{lagging} = +ve)$$

$$= + (3\%)$$

$\gamma. \text{ error} = \left(\frac{1}{\text{C.F.}} - 1 \right) \times 100$ (it should less than 1 becoz lagging)
 $\tan \beta = \frac{x_p}{P_p} = \frac{0.8 P_p}{P_p} = 0.8$
 $\text{C.F.} = \frac{\cos \phi}{\cos \phi \cos (\phi - \beta)}$



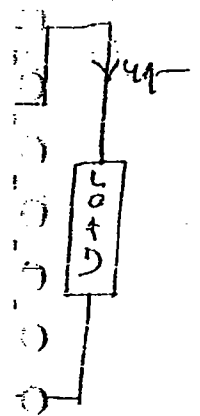
Pb: The meter const. of a 5 amp wattmeter has 3275 revolution/kwhr. The meter is subjected to full load for 1 hr. The speed of the disc is.

Ans: Energy consumption = kWh.
 $= \frac{220 \times 5}{1000} \times 1$
 $= 1.1 \text{ kWh.}$

meter const. = 3275 rev./kwh.

no. of revolution = E.C x m.c
 $= 1.1 \times 3275$
 $= 3602.5 \text{ rev.}$

speed = $\frac{\text{revolution}}{\text{sec}}$
 $= \frac{3602.5}{3600} \approx 1 \text{ rev.}$



$\frac{250 \times 250}{15 \times 1875}$
 $\frac{25}{25 \times 8}$
 $\frac{25 \times 1000}{1000} \times 100$

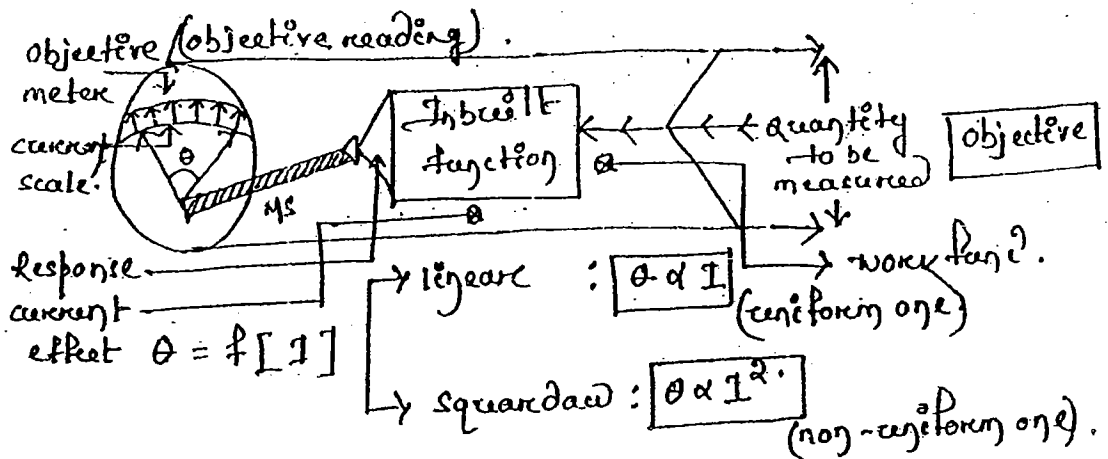
- 0 %
- 0
- 0
- 0
- 0 wattmeter
- 0 error
- 0

lag is —
 Ave)

- 0
- 0
- 0

4/09/10

Any Analog measuring unit is a current measuring unit, since current is an analog quantity which is measurable. And it is always the current effect that produces deflection.



work function : (Types)

- ↳ meters only works for D.C. i/p.s. eg: PMMC.
- ↳ meters only working for a/c. i/p.s. eg: Induction type.
- ↳ meters which works for both a/c and d.c i/p.s.

eg: thermocouple,
moving iron,
Electrodynamometer,
Electrostatic,
Rectifiers etc.

Types of current effects :

↳ Electromagnetic effect (when a current carrying conduct placed acts as a electromagnet when it carrying current).

↳ Electrostatic effect

Eg: Electrostatic voltmeters
capacitors pick up voltage.

↳ Electrothermic effect / Heating effect.

Eg: thermocouple, hot wire.

↳ Induction type

Eg: I Energy meter.

↳ Hall effect

Eg: Flux meter.

The response produced by the instrument fitted to the objective scale is nothing but measurement.

Types of Response : (types of measurement)

↳ Average response (DC) current

Eg: PMMC.

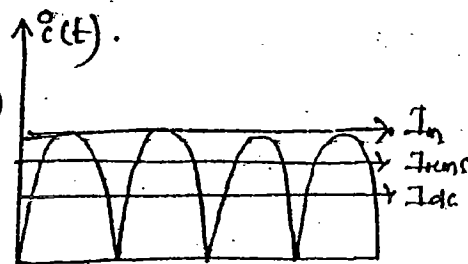
↳ RMS response

Eg: thermocouple
moving iron.
Electrodynamometer

↳ Peak response

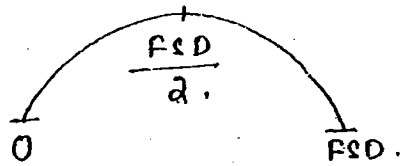
Eg: CRO

Peak responding voltmeter.



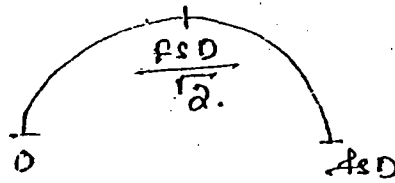
Types of Indicator :

1) Linear scale / uniform scale. $\theta \propto I$



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

2) Squared scale / non-uniform / non-linear



$$\theta \propto I^2$$

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

DC meter

(i) works only for d.c. i/p.s.

(ii) D.C. meter always measures avg. value or produces dc response or avg. response.

(iii) It follows linear relⁿ ($\theta \propto I$).

(iv) It indicates measured avg. value via linear scale.

A/c meter

(i) It works both for a/c and d.c. i/p.s.

(ii) measures rms value. (produce rms response)

(iii) It follows squared relⁿ. ($\theta \propto I^2$).

(iv) It indicates measured rms value via a non-linear scale.

DC meter : "An average measuring/responding and avg. indicating/reading meter with linear scale which only works for d.c. i/p.s."

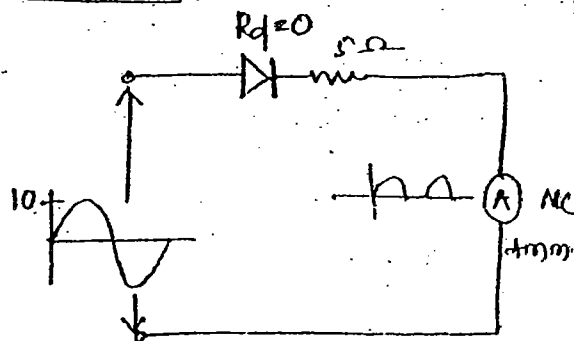
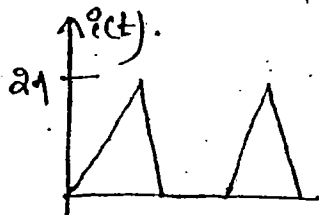
Eg: PMMC.

A/c meter: "A rms measuring and rms indicating meter squaddaw scale which works for both a/c and d.c. i/p.s."

Eg: Thermocouple, moving iron type.

Pb: In a ckt shown in below fig. the reading of moving coil ammeter is _____. If the moving coil ammeter is replaced with an ideal moving iron ammeter, then its reading would be _____.

Sol: $\frac{10}{5} = 2A = I_m$



∴ Mc ammeter readg = I_{dc}

$$= \frac{I_m}{\pi} \text{ or } 0.318 I_m$$

$$= \frac{2}{\pi} A$$

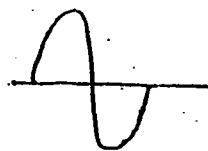
Here $I_m = \frac{V}{R_d + R + R_t}$

∴ Mc ammeter readg = I_{rms} (In halfwave cycle rms value)

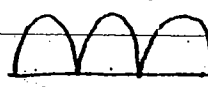
$$= \frac{I_m}{2} \text{ never be } I_m/\sqrt{2} = \text{rms}/2$$

$$= \frac{2}{2} = 1A$$

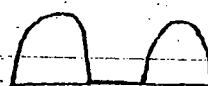
Ans: $\left(\frac{2}{\pi} A, 1A\right)$



$$\frac{I_{rms}}{I_m/\sqrt{2}} = \frac{I_{dc}}{0}$$



$$\frac{I_m}{\sqrt{2}} = \frac{2I_m}{\pi}$$



$$\frac{I_m}{2} = \frac{I_m}{\pi}$$

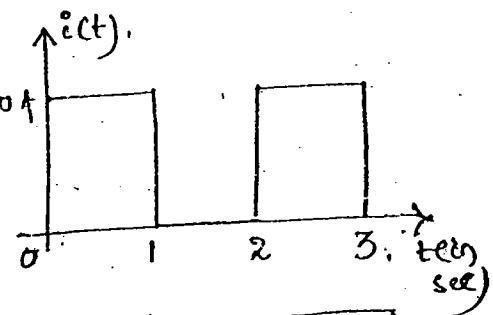
165-2006

Rating

Pb: A time-varying current $i(t)$ passing through a series combination of a dc ammeter and a thermocouple ammeter has a waveform shown in below fig. The reading of both the ammeters _____ respectively.

Sol: The alternating current

for rms value = $\frac{I_m}{\sqrt{2}}$
 $= \frac{100}{\sqrt{2}}$



$I_{dc} = \frac{1}{T_0} \int_0^{T_0} i(t) \cdot dt$ (mean).

$I_{rms} = \left[\frac{1}{T_0} \int_0^{T_0} i^2(t) \cdot dt \right]^{1/2}$

$$I_{rms} = I_m \sqrt{d}$$

$$I_{dc} = I_m d$$

$d = \text{duty cycle}$
 (only for half-wave rectifier)
 $T_0 = 2$ (ON-OFF condition)

Sol: $i(t) = 100A, 0 < t < 1$
 $0, 1 < t < 2$

Mc ammeter rdg = I_{dc}
 $= \frac{1}{2} \int_0^1 100 dt$
 $= 50A$

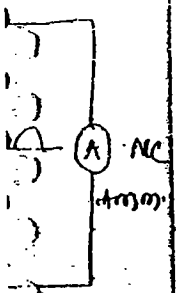
Tc ammeter rdg = I_{rms}
 $= \frac{1}{2} \int_0^1 100^2 dt$
 $= \frac{100}{\sqrt{2}} A$

Another method:

Here $d = \frac{T_{ON}}{T_{ON} + T_{OFF}} = \frac{1}{1+1} = \frac{1}{2}$

$I_{dc} = I_m d = 100 \times \frac{1}{2} = 50A$

$I_{rms} = I_m \sqrt{d} = 100 \times \frac{1}{\sqrt{2}} = \frac{100}{\sqrt{2}} A$



Rating

Value

100/2

100

0

27m

1

100

100

Pb: An ideal electrodynamo ammeter is used to measure a time-varying current, which is a clipped saw-tooth superimposed at 1 amp. dc. as shown in below fig. Then the ammeter reading _____

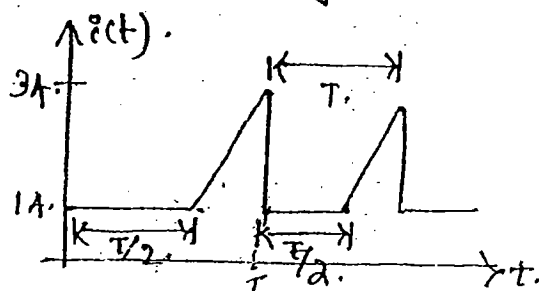
solⁿ:

$$I_{dc} = \frac{2}{2} \cdot \frac{T}{T}$$

$$= 2A$$

$$I_{rms} = 2 \left(\frac{T}{T} \right)^{1/2}$$

$$= 2(1)^{1/2} = 2A$$



$$I_{rms} = \sqrt{\frac{1}{T} \int_0^{T/2} 1^2 dt + \int_{T/2}^T (?)^2 dt}$$

Now,

$$y - y_1 = m(x_2 - x_1)$$

$$i(t) - 1A = \left(\frac{3-1}{T-T/2} \right) (t - T/2) \quad (T/2, 1A)$$

$$i(t) = \frac{4t}{T} - 2 + 1$$

$$= \frac{4}{T}t - 1$$

$$= \frac{1}{T} [4t - T]$$

$$\therefore i(t) = 1A, \quad 0 < t < T/2$$

$$= \frac{1}{T} [4t - T], \quad T/2 < t < T$$

$$I_{rms} = \sqrt{\frac{1}{T} \int_0^{T/2} (1A)^2 dt + \frac{1}{T} \int_{T/2}^T \left[\frac{1}{T} (4t - T) \right]^2 dt}$$

measured

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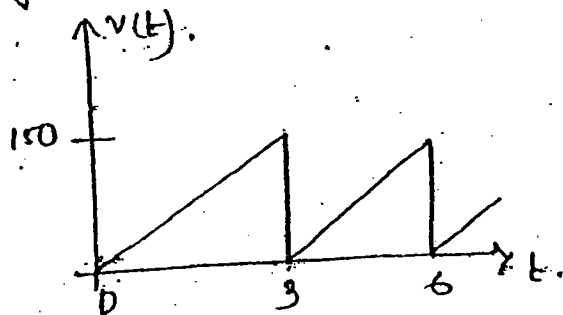
—

$$\begin{aligned}
 &= \sqrt{\frac{1}{T} \times \frac{T}{2} + \frac{1}{T^3} \left[\frac{(4T-T)^3}{3 \times 4} \right] T} \\
 &= \sqrt{\frac{1}{2} + \frac{1}{12T^3} \times (27T^3 - T^3)} \\
 &= \sqrt{\frac{1}{2} + \frac{26T^3}{12T^3}} \\
 &= \sqrt{\frac{32}{12}} \\
 &= 1.63 A.
 \end{aligned}$$

Qb: If thermocouple voltmeter is used to measure a time varying voltage whose waveform is shown below. then the reading of the voltmeter is _____.

solⁿ:

$$\begin{aligned}
 I_{rms} &= \sqrt{\frac{1}{3} \int_0^3 v^2(t) \cdot dt} \\
 &= \sqrt{\frac{1}{3} \int_0^3 (50t)^2 \cdot dt}
 \end{aligned}$$



$$\begin{aligned}
 v(t) &= \frac{150}{3} \times t \quad (\text{Here } y = mx) \\
 v(t) &= 50t \quad 0 < t < 3 \quad (0,0) \quad (3,150)
 \end{aligned}$$

$$\begin{aligned}
 &= \sqrt{\frac{1}{3} 50^2 \left[\frac{t^3}{3} \right]_0^3} \\
 &= \sqrt{\frac{50^2}{3 \times 3} [3^3 - 0]} \\
 &= \sqrt{50^2 \times 3} \\
 &= 50\sqrt{3} = 86.6 V.
 \end{aligned}$$

Pb:

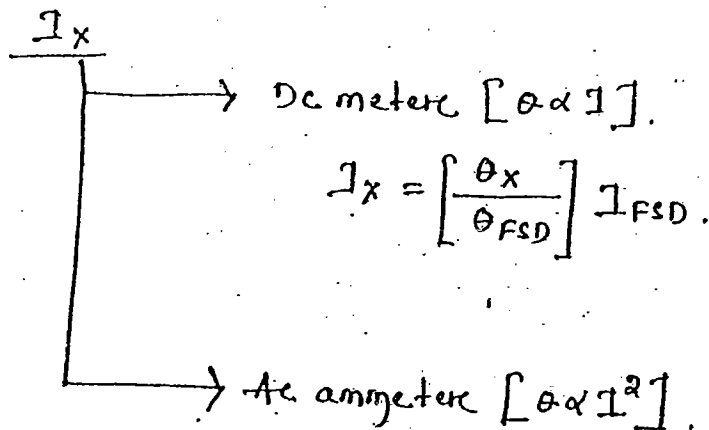
A thermocouple ammeter produces fullscale deflection for a current of 10 A . Then $\frac{1}{4}$ th of fullscale deflection is produced by a current of _____ amp.

Sol:

$$\text{If } \theta_{\text{FSD}} = I_{\text{FSD}}$$

$$\theta_x = I_x = ?$$

Now,



$$I_x^2 = I_{\text{FSD}}^2 \frac{\theta_x}{\theta_{\text{FSD}}}$$

$$I_x = I_{\text{FSD}} \sqrt{\frac{\theta_x}{\theta_{\text{FSD}}}}$$

Note: If AC ammeter produces FSD for 10 A .
then,

$$\begin{aligned} \rightarrow 20\% \text{ FSD is produced by } &= 10 \sqrt{\frac{0.2 \theta_{\text{FSD}}}{\theta_{\text{FSD}}}} \\ &= 10 \sqrt{0.2} = 4.47 \end{aligned}$$

$$\begin{aligned} \rightarrow 50\% \text{ of FSD is produced by } &= 10 \sqrt{\frac{0.5 \theta_{\text{FSD}}}{\theta_{\text{FSD}}}} \\ &= 10 \sqrt{0.5} = 7.07 \text{ A} \end{aligned}$$

$\frac{1}{4}$ th of FSD produced by

Pb:

as

then

across

App:

I_aV_{dc}

=

=

=

=

=

=

Pb:

ac

ac

Set:

=

=

=

Eq:

=

=

=

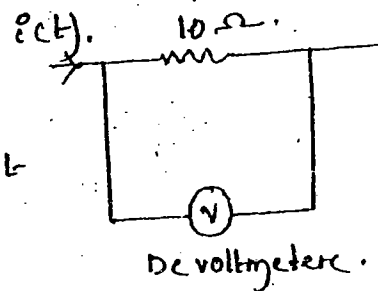
=

Direction
Defec-

Prob: A current $i(t)$ passing through a $10\ \Omega$ resistor as shown in fig-1, has a waveform shown in fig-2. then the reading of dc voltmeter connected across $10\ \Omega$ resistor is _____.

Another method:

$$I_{dc} = \frac{1}{2} \left[\int_0^T 12 \cdot dt + \int_T^{2T} 5 \cdot dt \right]$$



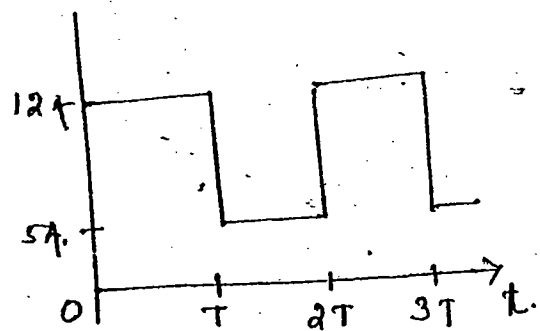
$$V_{dc} = I_{dc} \times 10\ \Omega$$

$$= \left(\frac{12+5}{2} \right) \times 10$$

$$= \frac{17}{2} \times 10$$

$$= 8.5 \times 10$$

$$= \frac{85}{10} \times 10 = 85\ \text{V}$$



Prob: The current $i(t)$ passing through an ac ammeter is $1 + \sqrt{2} \sin(314t + 30^\circ) + 2 \sin(100t + 15^\circ)$ amps. The ac ammeter indicates _____.

Sol: $I_{dc} = 1\ \text{A}$

$$I_{rms} = \sqrt{1^2 + \left(\frac{\sqrt{2}}{\sqrt{2}}\right)^2 + \left(\frac{2}{\sqrt{2}}\right)^2}$$

$$= 2\ \text{A}$$

eg: $i(t) = 5 + 10 \sin 314t$

$$I_{dc} = 5\ \text{A}$$

$$I_{rms} = \sqrt{5^2 + \left(\frac{10}{\sqrt{2}}\right)^2} = \sqrt{25 + \frac{100}{2}} = \sqrt{75} = 5\sqrt{3}\ \text{A}$$

0.20 FSD

0.0 FSD

0.47

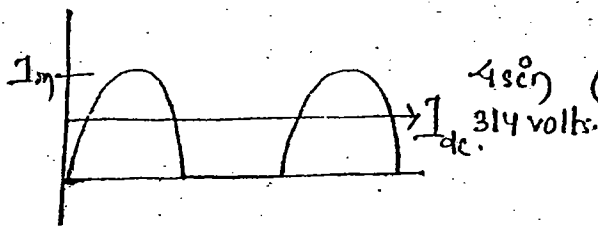
0.50 FSD

0.0 FSD

0.7 A

Pb: In the ckt shown in below fig the ammeter is an avg. indicating ammeter with zero internal resistance and both the diodes are ideal. Then the reading of ammeter is _____.

sol: Avg. ind. amtr = I_{dc} .



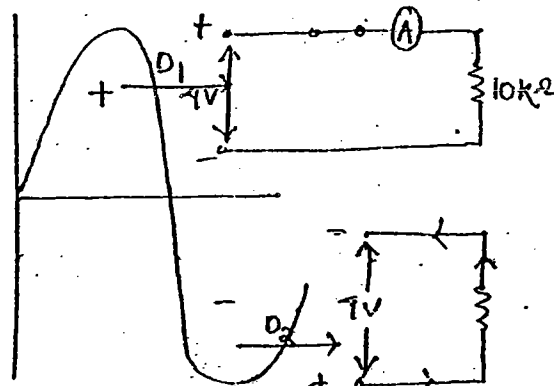
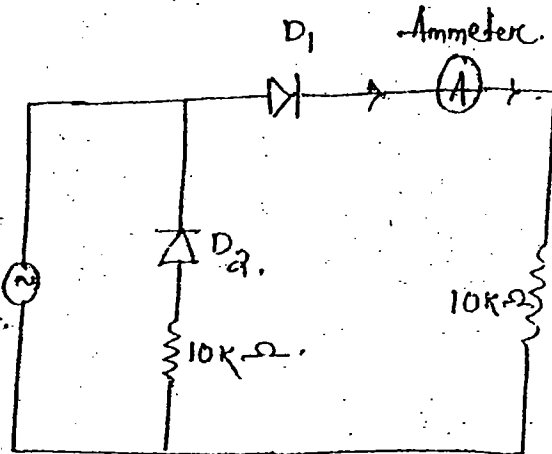
$$I_{dc} = \frac{I_m}{\pi}$$

$$= \frac{4/10 \times 10^3}{\pi}$$

$$= \frac{0.4}{\pi} \text{ mA}$$

$$I_{rms} = \frac{I_m}{2}$$

$$= \frac{0.4}{2} \text{ A}$$

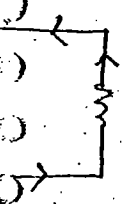
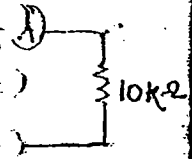
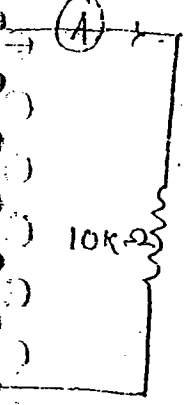


PMMC Instrument :- [utilization,

A PMMC instrument consist of a cylindrical iron core inserted into a rectangular magnet frame. Around which a thin wire coil of N -turns is wound. A free rotating spindle attached to it and fine pointers deflected over a

meter
integral
in the

Ammeter



0

0

0

Real

Frame.

0

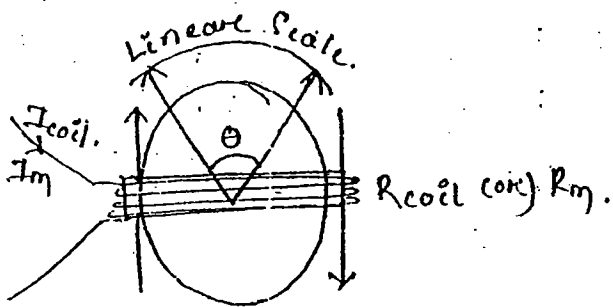
0

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calibrated scale attached to attached to spindle. The entire arrangement is placed inside the permanent magnet.



PMMC → It is an EM instruments.

EM → Electromechanical.

It doesn't contain any electronic device in; but at the i/p side we used to give electronic device as a i/p.

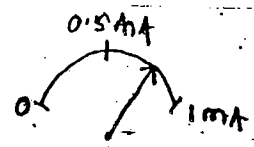
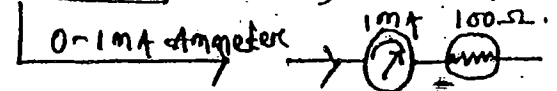
PMMC rating (specification).

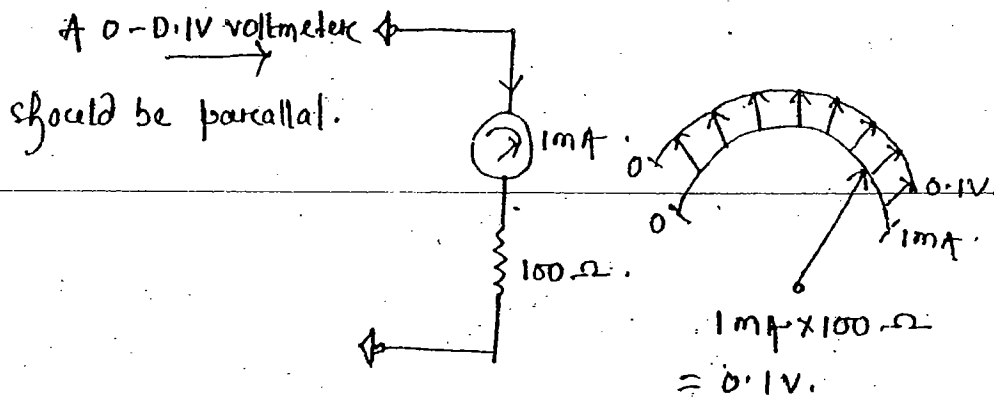
(i) $I_{coil max}$ = max allowable current without damping coil.
 $= I_m(max) = I_m(FSD)$ } $0 < I_m \leq I_m(FSD)$
range.

(ii) R_{coil} = coil Ω
 $=$ meter's internal Ω
 $= R_m$.

→ Utilization : [only current measurement].

eg: 0-1mA, 100Ω PMMC instrument.





Here volt. rating cap is low, becoz the current sensing capacity is low becoz here we are using a thin coil (current-carrying).

For all practical measurement of either current or voltage suitable extensions must be used.

There are two extension namely

a) shunt

b) multiplier. (series)

↳ A low valued shunt resistance is connected in parallel in PMMC for extending current range.

↳ A high value multiplier resistance is connected in series with PMMC to extend the voltage range.

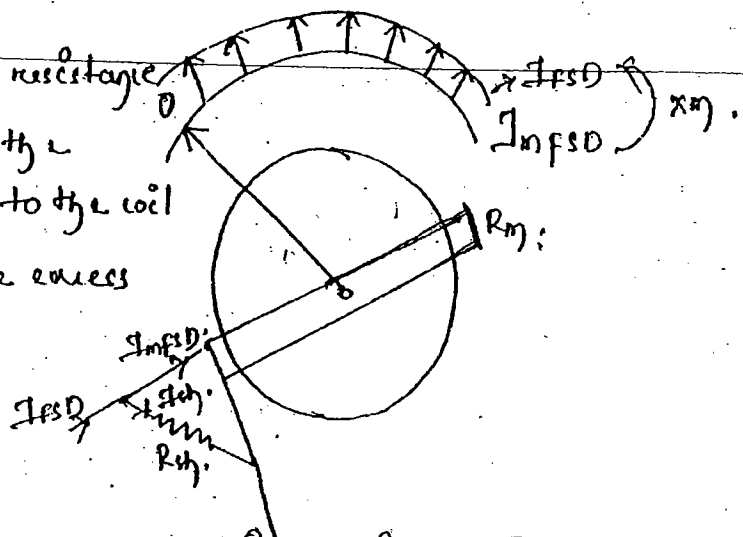
Extending current range :-

The available range of current $[I_{\text{mfsd}} \xrightarrow{x_m} I_{\text{fsd}}]$

$x_m = \text{to be extended}$

↳ multiplying factor.

R_{sh} = shunt resistance
 place inside the
 coil/parallel to the coil
 to bypass the excess
 current.



4 A low value shunt resistor is placed parallel to the coil to bypass the excess amt. of current.

$$I_{sh} = I_{FSD} - I_{mfSD}$$

$$m = \frac{I_{FSD}}{I_{mfSD}} = \text{multiplying power.}$$

4 Since R_m and R_{sh} are in parallel,

$$V_{sh} = V_m$$

$$I_{sh} \times R_{sh} = I_{mfSD} \times R_m$$

(R_m = meter coil resistance)

$$(I_{FSD} - I_{mfSD}) R_{sh} = I_{mfSD} \times R_m$$

$$R_{sh} = \frac{R_m}{\frac{I_{FSD} - I_{mfSD}}{I_{mfSD}}}$$

$$R_{sh} = \frac{R_m}{\left(\frac{I_{FSD}}{I_{mfSD}} - 1\right)}$$

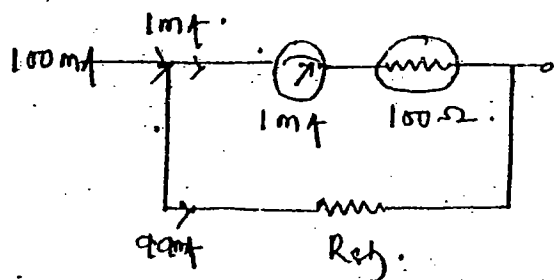
$$R_{sh} = \frac{R_m}{m - 1}$$

Q: A PMMC meter which produces deflection for a current of 1 mA is to be converted into 100 mA ampere. If the internal resistance of PMMC is $100\ \Omega$. Then the value of required shunt resistance is _____.

solⁿ:

$$1\text{ mA}, 100\ \Omega \xrightarrow{\times 100} 100\text{ mA}$$

$$R_{sh} = \frac{100}{99} = 0.01\ \Omega$$

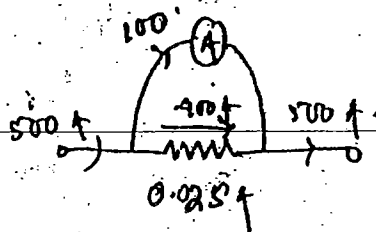
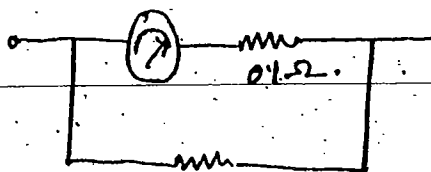


Q: A $0-1\text{ mA}$ DC ammeter is used in 100 mA DC current range.

eg: If the DC ammeter has a resistance of $0.1\ \Omega$ and its current range is $(0-100)\ \mu\text{A}$. If this range is to be extended to $500\ \mu\text{A}$, then the value of required shunt resistance is _____.

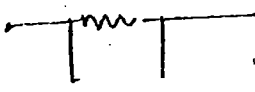
solⁿ:

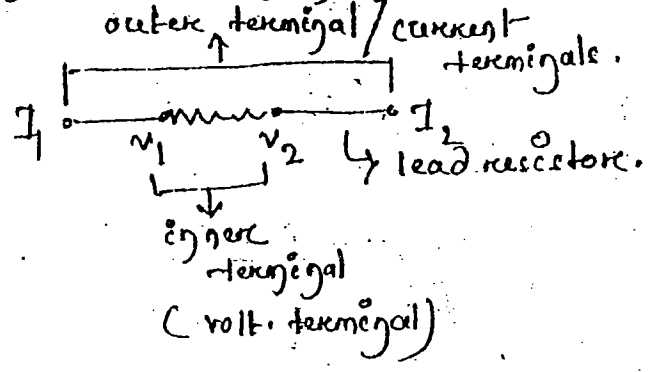
$$R_i = 0.1\ \Omega$$



for a
100 mA
40 is
1/2 resist-

Among four of these below which one is too one.

- a) 
- b) 
- c) 
- d) none.



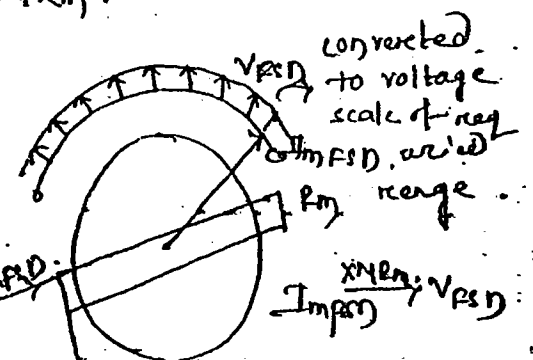
Extending voltage range :-

$$I_{mfsd} \times R_m = V_{mfsd} \xrightarrow{\times M} V_{fsd}$$

$M = \text{multiplying factor} \times M R_m$

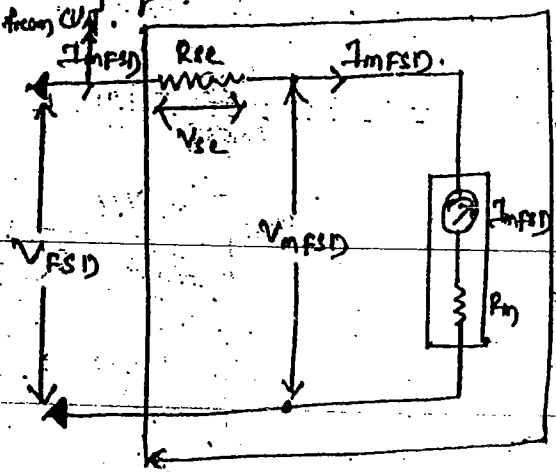
A high valued resistor is placed in series with prime instrument to limit the i/p current up to I_{mfsd} .

(Dropping excess applied voltage)

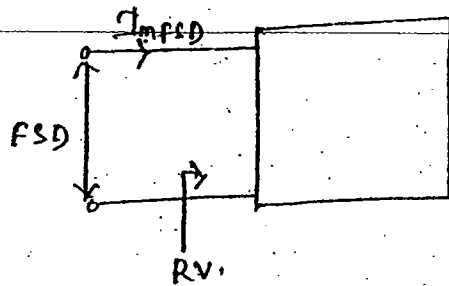


$R_{se} = \text{series current limiting resistor.}$

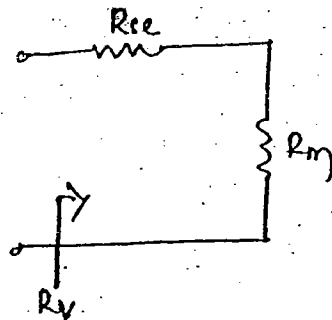
The value of R_{se} :



I/p resistance of voltmeter :



$$\rightarrow R_V = \frac{V_{FSD}}{I_{m FSD}}$$



$$R_V = R_{se} + R_m$$

$$\begin{aligned} R_V &= R_m \cdot [M-1] + R_m \\ &= M R_m - R_m + R_m \\ &= M R_m \end{aligned}$$

Again, $R_V = \text{Sensitivity} \times \text{range}$

Series circuit limiting :

$$R_{se} = R_V - R_m$$

$$= \frac{V_{FSD}}{I_{m FSD}} - R_m$$

$$= R_m \left[\frac{V_{FSD}}{I_{m FSD} \times R_m} \right]$$

$$= R_m \left[\frac{V_{FSD}}{V_{m FSD}} - 1 \right]$$

$$R_{se} = R_m [M-1]$$

Sensitivity of volt-meter :-

$S_v = \text{Resistance per volt-meter rating of a volt-meter.}$

$= \text{Sensitivity of volt-meter.}$

$= \text{Fig. of merit of volt-meter.}$

units : ohms/volt.

$$S_{DC} = \frac{R_v}{V_{FSN}}$$

$$= \frac{V_{PSN} / I_{MFSN}}{V_{FSN}}$$

$$S_{DC} = \frac{1}{I_{MFSN}}$$

Activity x range.

A dc ammeter is nothing but a

the sensitivity of a 200 μ A meter movement when it is used as a dc voltmeter is _____.

a) 500 Ω /mv. solⁿ: $S_v \text{ or } S_{dc} = \frac{1}{I_{mfsd}}$

b) 5 Ω /v.

c) 0.5 Ω /mv.

d) 5 Ω /mv.

$$= \frac{1}{200 \times 10^{-6}}$$

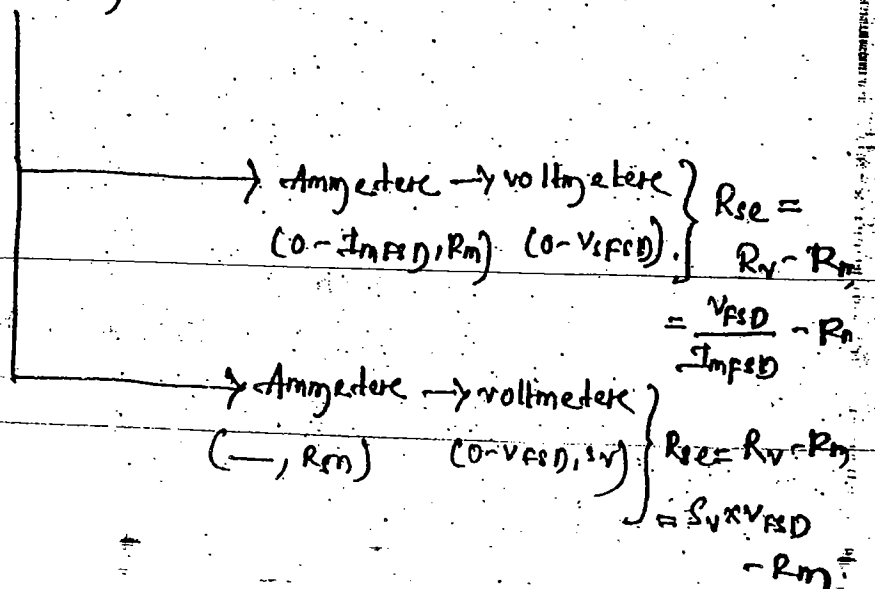
$$= 0.5 \times 10^{-2} \times 10^6$$

$$= 5 \text{ K}\Omega/\text{v}.$$

$$5 \text{ K}\Omega/\text{v} = 5 \Omega/\text{mv}$$

Pb: The value of the multiplier resistance for a dc voltmeter having 50 v range with 5 $\text{K}\Omega/\text{v}$ sensitivity, employing a 200 μ A meter movement and having internal resistance of 100 Ω is given by, _____.

Ammeter to voltmeter
(0 - I_{mfsd} , R_m)



(or)

A 200 μ A DC ammeter with internal resistance of 100Ω is to be converted into 0-50V DC voltmeter. The required series limiting resistance is _____?

(or)

A 50V DC voltmeter with figure of merit of $5 \text{ k}\Omega/\text{V}$ is constructed using dc ammeter whose internal resistance is $100 \text{ k}\Omega$. Then value of R_{se} is _____?

solⁿ: $R_{se} = R_v - R_m$
 $= S_v \times V_{fsd} - R_m$
 $= \frac{5 \text{ k}\Omega}{\text{V}} \times 50\text{V} - 100 \Omega$
 $= \frac{5 \times 10^3 \Omega}{\text{V}} \times 50 - 100 \Omega$
 $= 249.4 \text{ k}\Omega$

Pb: A 0-1mA meter movement with an internal resistance of 100Ω is to be converted into 0-100mA. To achieve this value of shunt resistance is given by _____?

solⁿ: $R_{sh} = \frac{R_m}{m-1}$
 $= \frac{100}{100-1} = \frac{100}{99} = 1.01 \Omega$

Pb: A moving coil ammeter having a resistance of 1Ω gives full scale deflection when a current of 10 mA is passed through it. The instrument can be used for the measurement of volt. up to 10 volt.

a) connecting a resistance of 999Ω in parallel to the load, ammeter

b) " " " 999Ω " " to the load.

c) " " " 1000Ω in series with the ammeter.

d) " " " 999Ω " with the load.

solⁿ: $10mA, 1\Omega \longrightarrow 10V.$

$$R_{se} = \frac{10V}{10mA} - 1\Omega.$$

$$= 1K\Omega - 1\Omega$$

$= 999\Omega$ in series with ammeter.

(or)

$$R_{se} = R_m(m-1)$$

$$= 1\Omega \left(\frac{10V}{10mA \times 1\Omega} - 1 \right) = 999\Omega.$$

2702009
EEE.

Pb: An analog dc ammeter of full scale rating of $1mA$ is obtained by connecting a shunt resistance of 11Ω in parallel with a galvanometer having a full scale current rating of $100\mu A$. The value of shunt resistance needed for obtaining an ammeter of $10mA$ used in the same galvanometer is _____.

$$I_{msd} = 1mA \quad 11\Omega, 1mA \longrightarrow 10mA.$$

$$R_{sh} = 11\Omega$$

Can be

Colt.

U

$$100 \mu A \rightarrow 1 mA$$

$$R_{m1} = 11 \Omega$$

$$\frac{R_m}{9} = 11 \Omega$$

$$R_m = 99 \Omega$$

$$100 \mu A \rightarrow 10 mA$$

$$R_{m2} = \frac{R_m}{m_2 - 1}$$

$$= \frac{R_m}{99}$$

$$= \frac{99 \Omega}{99}$$

$$= 1.0 \Omega$$

GATE
EEE

Pb: A dc voltmeter having a fig of merit of $20 K \Omega / V$ is used to measure half full scale voltage in 10V range. Then the current through the meter is _____?

$$* \begin{cases} V_{FSD} = 10V. \\ S.R. = 20 K \Omega / V. \end{cases}$$

$$\frac{V_{MFS}}{R} = \frac{10}{2 \times 10^3} = 5 \times 10^{-3}$$

$$\frac{1}{I_{MFS}} = 5 \times 10^{-3}$$

$$V_{MFS} = \frac{1}{2} \times FSD = \frac{1}{2} \times 10 = 5V.$$

$$R_v = 20 K \Omega / V \times 10V$$

$$= 200 K \Omega$$

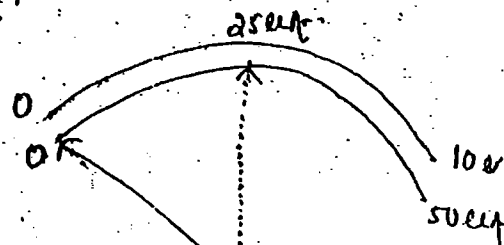
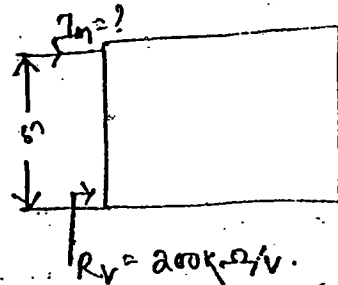
$$I_m = \frac{5V}{200 K \Omega}$$

$$= 2.5 \times 10^{-5} A = 25 \mu A$$

(OR)

$$I_{MFS} = \frac{1}{20 K \Omega}$$

$$= 50 \mu A$$



Pb: $\frac{1}{4}$ of FSD is measured in 50V range. Then current through the meter is $\frac{1}{4} \times 50 \mu A$.

Qb: 80% of FSD is measured in 30V range, then

$$I_m = 0.8 \times 50 \mu A$$

Qb: A galvanometer (dc ammeter) with full scale current rating of 10mA has a resistance of 1000Ω . The multiplying power of a 100Ω shunt resistance with this galvanometer is _____

sol: $20K \Omega$ $50V$ $I_{FSD} = 10mA$, $R_m = 1000 \Omega$ $21K \Omega$.
 $R_{sh} = 100 \Omega$.

$$m = \frac{I_{FSD}}{I_{mFSD}} = \frac{R_m}{R_{sh}} + 1$$

$m = \text{multiplying power}$

$$m = \frac{1000}{100} + 1 = 11$$

$$10mA \xrightarrow{\times 11} 110mA$$

Again,

$$M = \frac{V_{FSD}}{V_{mFSD}} = \frac{R_{se}}{R_m} + 1$$

Qb: To triple the current range of an ammeter, the ratio of ammeter to shunt resistance is _____

sol: $m = \frac{R_m}{R_{sh}} + 1$

$$3 = \frac{R_m}{R_{sh}} \Rightarrow \frac{R_m}{R_{sh}} = 2$$

Qb: ~~200V~~ dc voltmeter two 100 volt dc voltmeter

with figure of merit of $10K \Omega/V$ and $20K \Omega/V$ are connected in series. Then the max^m volt. that can be measured using this series combination is _____. The reading of both the voltmeter

sol: $V_{FSD} = 100$ is _____ respectively.

a) 200V, 100V, 100V.

b) 150V, 50V, 50V,

c) 150V, 50, 100V.

d) voltmeter can never be parallel.

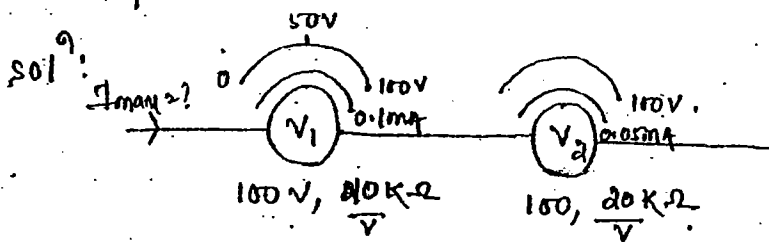
(voltage source of different rating we can connect in '||' and a current source in series.)

solⁿ:

$$\text{sol}^n: V_{FSD} = 100V$$

When three of the coil is connected in series. Having different current rating we can't must be that the max^m allowable current is the least value of the current rating among of the three coil. and sensitivity must be high.

The same rule / word² can be applicable when two voltmeter of different rating connected in parallel.



$I_{max} = \text{Lowest FSD current rating.}$

$= \text{FSD current rating of voltmeter with high sensitivity.}$

$$= 0.05mA$$

$$V_{max} = I_{max} [R_1 + R_2]$$

$$= 0.05mA [100K\Omega + 200K\Omega]$$

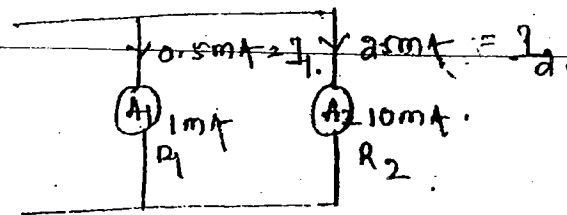
$$= 150V.$$

Phy: 1 one mA ammeter and a 10mA ammeter are connected in parallel. If there is readings of 0.5mA and 5mA then the ratio of

Differe
nt in '11'
ence in

their internal resistances is _____

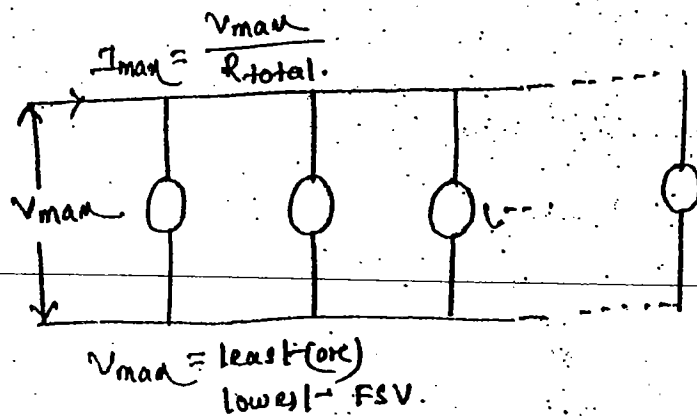
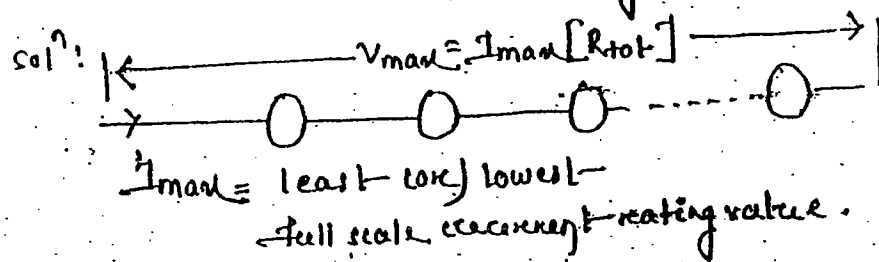
solⁿ:



$$\frac{\frac{V}{R_1}}{\frac{V}{R_2}} = \frac{I_1}{I_2} \Rightarrow \frac{R_2}{R_1} = \frac{0.5 \text{ mA}}{2.5 \text{ mA}} = \frac{1}{5}$$

$$\Rightarrow \frac{R_1}{R_2} = \frac{5}{1}$$

Q: Two different dc ammeters with full scale current rating of 1mA and 10mA are connected in parallel. Their internal resistance are 100Ω and 25Ω respectively. The max^m current which can be measured by this parallel combination is _____. The reading of both the ammeters is _____ respectively.



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it be

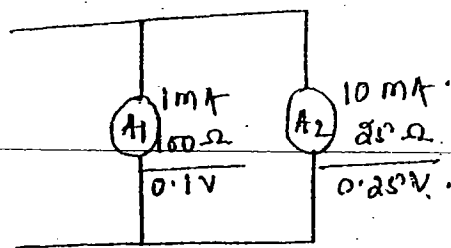
least-
the three

pplicable
connected

with
vity.

meter
readings

of



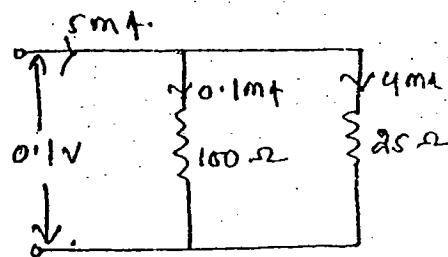
$$0.1V \sim 0.25V.$$

$$V_{max} = 0.1V.$$

$$I_{max} = \frac{0.1V}{R_L}$$

$$R_L = \frac{100\Omega}{25} = 20\Omega.$$

$$I_{max} = \frac{0.1V}{20\Omega} = 5mA.$$



$$5mA, 4mA, 0.1mA.$$

voltmeter

Pb: In the ckt shown in below fig. The ammeter used has full scale deflection current rating of $1mA$ with internal resistance of 100Ω . The values of ' R_1 ' and ' R_2 ' for $10V$, $50V$, ranges resp.

sol:

$$I_{FSD} = 1mA.$$

$$R_m = 100\Omega.$$

For $10V$ range

$$R + 100\Omega = \frac{V}{I} = \frac{10}{1mA} + 100\Omega$$

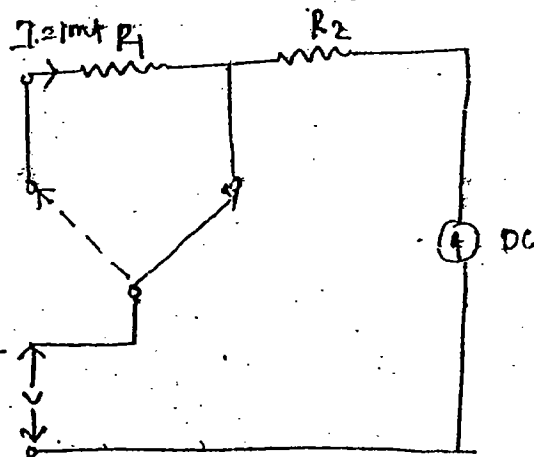
$$= \frac{10}{1 \times 10^{-3}} + 100$$

$$= 10 \times 10^3 + 100$$

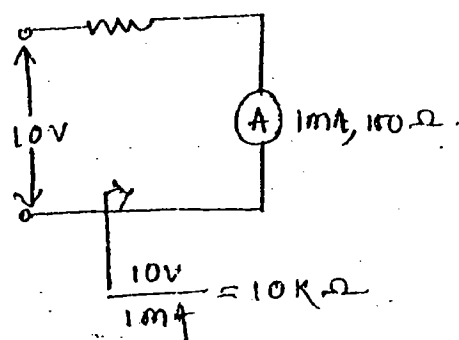
$$R + 100 = 10000 + 100$$

$$R = 10000 - 100$$

$$= 9900$$

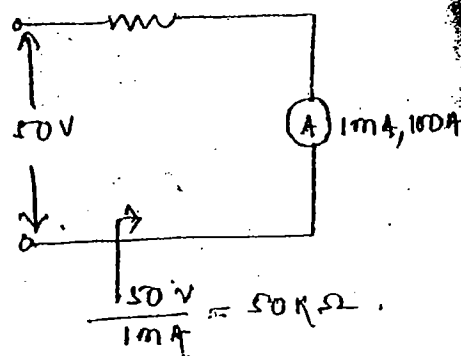


sw (A)



$$R_1 = 10K\Omega - 100\Omega = 9.9K\Omega$$

sw (B)



$$R_2 + R_1 = 50K\Omega - 100\Omega = 49.9 - 9.9$$

$$= 40K\Omega$$

Pb: A 35 volt dc source is connected to series combination of 600Ω and R_x . A voltmeter is connected across 600Ω indicates 5 volts. If the i/p resistance is $1.2K\Omega$ then the value of R_x is _____.

solⁿ: $V_{PSD} = 35 \text{ volt}$

$$I = \frac{V}{R} = \frac{5}{600} = \frac{1}{120} = \frac{1}{120} \text{ mA}$$

$$\frac{1}{120} \times 35 = \frac{1}{120} (600 + R_x + 1.2 \times 10^3)$$

$$35 = \frac{1}{120} (600 + R_x + 1.2 \times 10^3)$$

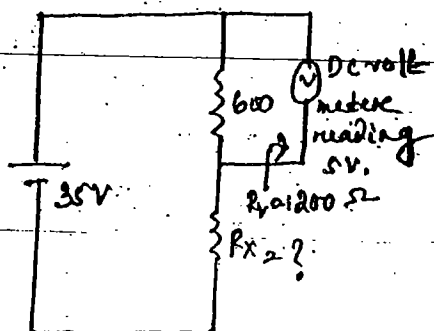
$$35 = \frac{1}{120} (601.2 \times 10^3 + R_x)$$

$$35 \times 120 = 601.2 \times 10^3 + R_x$$

$$\Rightarrow (35 \times 120) - 601.2 \times 10^3 = R_x$$

$$I = \frac{5V}{120}$$

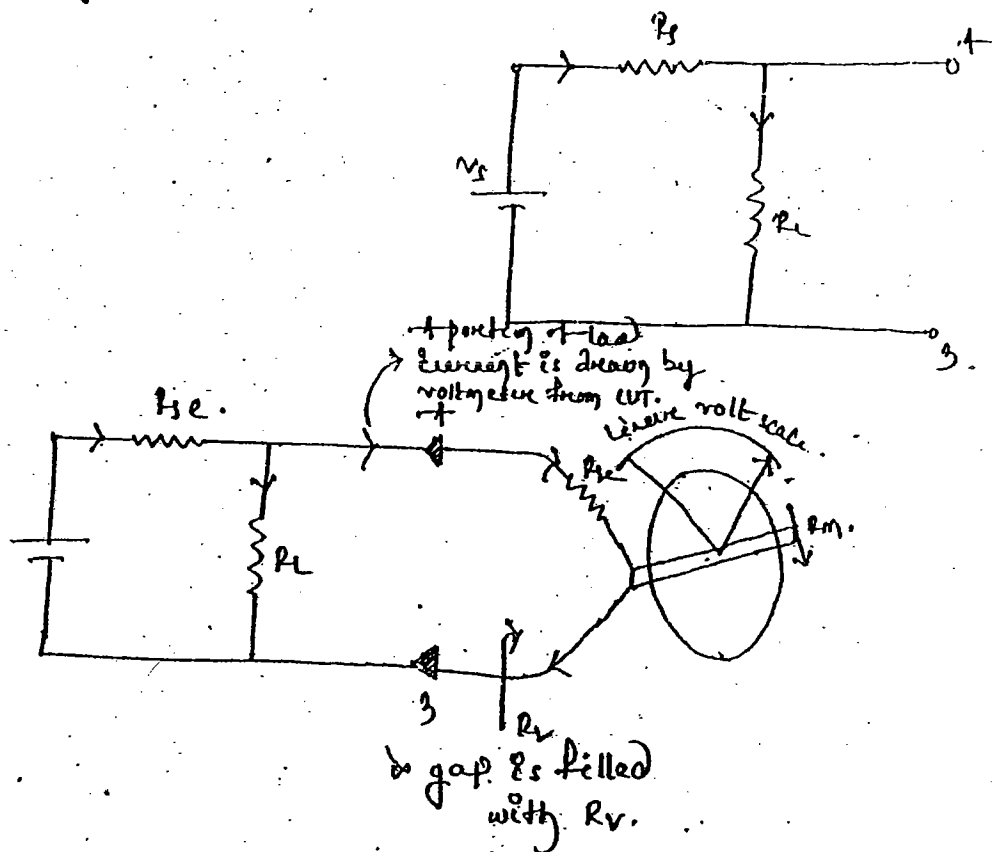
$$V_x = 35 - 5 = 30V$$



$$R_x = \frac{300 \times 400}{5} = 2400 \Omega = 2.4 \text{ k}\Omega.$$

$$V_x = 35 \times \frac{2.4 \times 10^3}{2.4 \times 10^3 + 400}$$

Loading effect due to voltmeter Resistance :-



without voltmeter

$$R_L(\text{true}) = R_L \parallel \infty = R_L$$

$$V_L(\text{true}) = \frac{V_s}{R_s + R_L} \times R_L$$

↑
true/actual
value.

with voltmeter

$$R_L(\text{eff}) = R_L \parallel R_v \quad \left. \begin{array}{l} \text{Loading} \\ \text{effect} \end{array} \right\}$$

$$V_L(\text{eff}) = \frac{V_s}{R_s + R_{\text{eff}}} \times R_{\text{eff}} \quad \left. \begin{array}{l} \text{Loading} \\ \text{effect} \end{array} \right\}$$

↑
measured/indicated
volt.

loading
error

✱✱ An ideal voltmeter with ∞ resistance is a non-st meter, when there is ∞ resistance, there is no current there is no deflection. But if it can stand with a ckt then only it is the best ckt. ✱✱.

Definition :-
"Introduction of voltmeter in parallel with R_L changes the value of loading resistance and in terms of voltage across it this is known as loading effect due to voltmeter resistance."

$$\text{Loading effect} = V_{ind} - V_{true} = (-ve)$$

$$\% \text{ Loading error in reading due to voltmeter} = \frac{V_{ind} - V_{true}}{V_{true}} \times 100$$

✓ Error is zero if voltmeter resistance is ∞ .

Eg: Ideal voltmeter with ∞ resistance = ∞ .

Best with a ckt.
Non-st measurement.

✓ Loading error never be eliminate. It can be reduced.

✓ To reduce the loading error, A voltmeter should have very high ∞ resistance. ($R_v \gg R_L$).

$$R_{v \min} = 10 R_L \quad (\text{For } 90\% \text{ accuracy})$$

$$R_v = 100 R_L \quad (\text{For } 99\% \text{ accuracy})$$

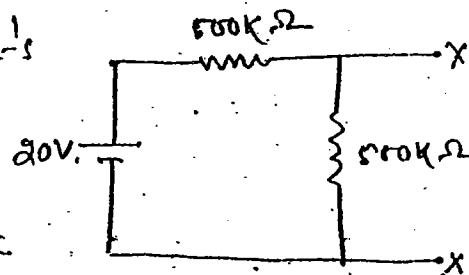
$$R_{v \min} > 10 R_L$$

i/p resistance		Ideal		Practical
voltmeter	—	∞	—	High
current source	—	∞	—	High
Ammeter	—	0	—	Low
voltage source	—	0	—	Low

(In case of voltage source the i/p res. is zero in order to reduce the drop error.)

Qb: The ckt shown in below fig. a voltmeter with a fig of merit of $20k\Omega/V$ is connected across load terminals 'x' and 'y'.

(i) then the reading on it's 50 volts range scale is _____.



(ii) The percentage error introduced into the reading error indicating into voltage measurement is _____?

solⁿ: $S_V = 20k\Omega/V$
 $V = 50 \text{ volts}$

$$S_V = \frac{V}{R_m}$$

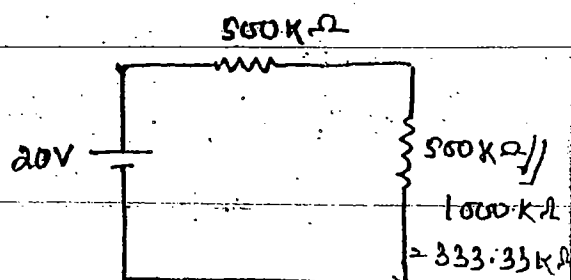
$$R_m = 20 \times 10^3 \times 50V = 1000k\Omega$$

without voltmeter.

$$V_{500k\Omega} = 10V$$

with voltmeter:

$$V_{333.3k} = 20 \times \frac{333.3}{833.3} = 8V = V_{ind}$$



$$(ii) \text{ Percentage error} = \frac{8V - 10}{10} \times 100$$

$$= \frac{-2}{10} \times 100$$

$$= -20\% \quad (\text{Here the } V_E = +2V \text{ i.e. -ve sign})$$

($\uparrow$ $\rightarrow$ high indication in voltage)

(negative in voltage)
-ve sign.

1b: In the circuit shown in below fig the voltmeter with a fig of meter of $2000 \Omega/V$ is connected across $200k\Omega$. The range of voltmeter is $100V$. The % error in the reading is _____.

sol: $R_v = 2000 \Omega/V$

$$V = 100V$$

$$R_v = 2000 \times 100 = 200k\Omega$$

$$V_{ind} = 100 \times \frac{200 || 200}{200 || 200 + 400}$$

$$= 100 \times \frac{100}{600}$$

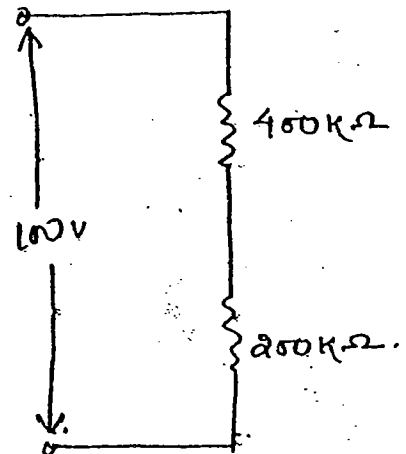
$$= 33.33V$$

$$V_{true} = 100 \times \frac{200}{200 + 400}$$

$$= 100 \times \frac{200}{600} = 33.33V$$

$$\% \text{ Error} = \frac{100 - 33.3}{33.3} \times 100$$

$$= -40\%$$

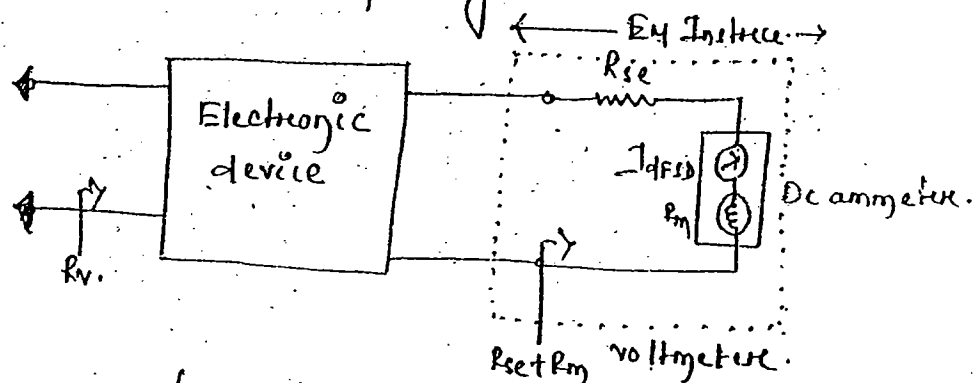


500kΩ //
100kΩ
= 333.33kΩ

19/09/10

Electronic Voltmeter :-

An Electronic voltmeter is nothing but a DC voltmeter with an electronic device at the i/p side. And the scale drop only calibrated.



(Analog, Electronic voltmeter)

- pt
- ↳ If this electronic device is a half wave rectifier full wave rectifier then it is a rectifier.
 - ↳ If it will a transistor, FET, op-amp then the device act as a Amplifier type voltmeter.
 - ↳ If it will a peak detector, then the device acts as a peak responding voltmeter.
 - ↳ If it will a thermocouple (rms detector) then the device acts as thermocouple voltmeter / True rms voltmeter.
 - ↳ Here the interface is a Electronic interface.
 - ↳ Dc ammeter is a dc deflection meter. Those are primary sensing element.

A

voltage

And

(i) Rectifier type A/C voltmeter :

Statement : A rectifier voltmeter is nothing but a dc voltmeter with a rectifying device with the $\frac{\pi}{p}$ side and the scale calibrated to read true rms value of sinusoidal $\frac{\pi}{p}$.

$\hookrightarrow$ M.I. instrument are A/C voltmeter, but they are going to measure the true rms value.

$\hookrightarrow$ If $\theta \propto I^2$.

$$\theta = K I^2$$

$\hookrightarrow$ const. then only the device is a true square law device / instrument.

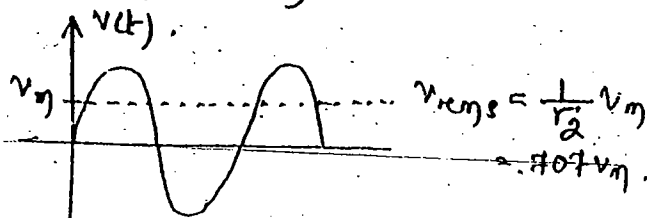
$\hookrightarrow$ But in M.I. instrument: $\theta = \frac{1}{2} I^2 \frac{dL}{d\theta}$.

It is a perfect rms instrument.

Here $K = \frac{1}{2} \frac{dL}{d\theta}$, but this is not const. It seems to be perfect square instrument, but exactly they are not.

$\hookrightarrow$

$\hookrightarrow$ In perfect square instrument.



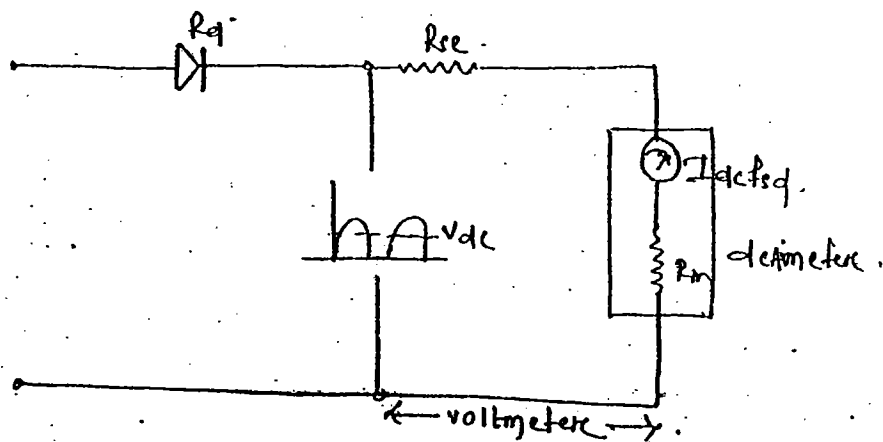
But m.I. and E.M.F. never going to give accurate

Objective of the design:

The available electromechanical AC voltmeters are not true rms meter since they don't follow perfect square law. As such rectifier type are design (in order to measure the true rms).

↳ Either a half wave rectifier or full wave rectifier is used.

① Half wave rectifier voltmeter →



Half wave rectifier voltmeter is nothing but a h.w rect, but here the half wave rectifier is replaced by a dc voltmeter.

R. ↳ This dc voltmeter doesn't respond for AC i/p. That's why we put here a rectifier in order to convert the alternating i/p into unidirectional one.

↳ Here our objective is to measure V_{rms} , but the instrument responds to I_{dc} . In h.w

$$I_{dc} = \frac{I_m}{\pi}$$

AC voltmeter range requires HWR

↳ I_{dc}

4) So we have to find out the relatⁿ b/w 'I_{dc}' and 'V_{rms}' i.e. do calibration in order to get exact objective.

objective $\Rightarrow V_{rms} = \frac{V_m}{\sqrt{2}}$

Ammeter respond $\Rightarrow I_{dc} = \frac{I_m}{\pi}$

$\Rightarrow$ So the relatⁿ b/w objective and respond (Form Factor)

$$\begin{aligned} V_{rms} &= \frac{1}{\sqrt{2}} V_m \\ &= \frac{1}{\sqrt{2}} (R_d + R_{se} + R_m) I_m \\ &= \frac{1}{\sqrt{2}} (R_{se} + R_m) I_{dc} \cdot \pi \end{aligned}$$

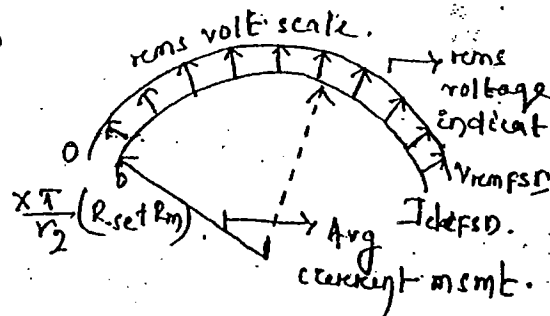
$$V_{rms} = \frac{\pi}{\sqrt{2}} (R_{se} + R_m) I_{dc}$$

R_{se} = Series limiting resistor

$\rightarrow$ const. factor that we have to multiply after reading the dc current.

(It is required to convert the dc ammeter value to HWR value)

$$V_{rms\ fsd} = \frac{\pi}{\sqrt{2}} (R_{se} + R_m) I_{afsd}$$



A volt. range of required. HWR volt.

dc current range (or) calibration factor Available dc ammeter.

(ZRP = zero resting position)

$\Rightarrow$ If the HWR is used for alternating sinusoidal wave form then there is no error, but in other waveform it will give error.

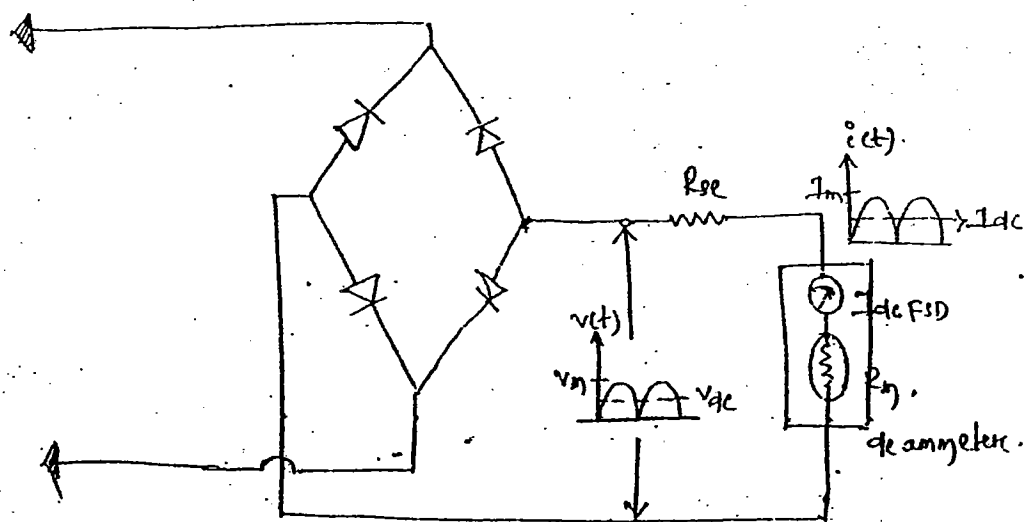
✓ If we are going to connect a dc voltmeter, then the relⁿ b/w objective and response is

$$V_{rmsFD} = \frac{2.22}{\gamma} V_{dcFD}$$

✓ Form factor.

⑤ Full wave rectifier voltmeter:

In this case we can also use a bridge rectifier.



The available electronic electromechanical meters are n't going to measure true rms value.

objective of design:

objective of FWR voltmeter $\Rightarrow V_{rms} = \frac{V_m}{\gamma}$

Response of dc ammeter $\Rightarrow I_{dc} = \frac{2.17}{\gamma} I_m$

$$V_{rmsFD} = \frac{\gamma}{2\sqrt{2}} \cdot (R_{se} + R_m) I_{dcFD}$$

Here,

$$V_{rms, PSD} = 1.11 (R_{se} + R_m) I_{dc, PSD}$$

(This is useful for construction point of view)

dc ammeter into FWR voltmeter

$$V_{rms, PSD} = 1.11 V_{dc, PSD}$$

(This is use for utilization point of view)

dc voltmeter into FWR voltmeter.

→ It is useful for calculation of 'R_{se}', 'R_{di}' or sensitivity.

→ If we apply dc i/p (pure dc voltage) then also it will be response. (there the rectifier action won't be there)

→ It will not give true

Important note about Rectifier voltmeter :

- (i) A rectifier voltmeter works for both ac & dc i/p.
- (ii) A rectifier voltmeter is an electronic voltmeter.
- (iii) Inbuilt funcⁿ : PMMC instrument.

measurement (or) response → Avg value

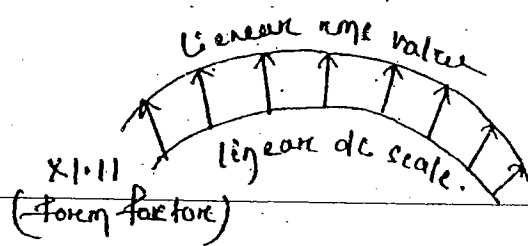
indication (or) reading → rms value.

It is a rectifier type voltmeter. is an avg measuring and rms indicating voltmeter.

(iv) The rms scale of rectifier voltmeter is linear.

(It is said to be non-linear in perfect square law instrument).

beac^z : It is not designed for square law, it is



i_p = alternating current
 i_p

∴ It is also a derived rms meter.

Therefore an Error will be introduced into voltage measurement / indication when used for non-sinusoidal waveform.

✓ Alternating sinusoidal
 ✓ Full wave bridge rectifier } For these two i_p the full wave rectifier is not going to give any error.

2b

Full wave rectifier
 A/C voltmeter

$$V_{rms} = 1.11 (R_{se} + R_m) I_{dc}$$

$$V_{rms} = 1.11 \text{ Volts (cyclic)}$$

$$V_{rms} = 2.22 (R_{se} + R_m) I_{dc}$$

$$V_{rms} = 2.22 \text{ Volts (cyclic)}$$

$$V_{rms} - V_{rms} \text{ (cyclic)} = \pm [1.11 V_{dc} - k_f V_{dc}] \times 100$$

$$= \pm \frac{[1.11 V_{dc} - k_f V_{dc}] \times 100}{k_f V_{dc}} \text{ (or)}$$

$$= \pm \left[\frac{1.11 - k_f}{k_f} \right] \times 100$$

① valⁿ b/w reading & response
 ② Reading for any i_p rectify $\rightarrow$ rms multiply $\rightarrow$

③ Error in reading for sinusoidal i_p

④ Error in reading for non-sinusoidal i_p

⑤ % error in non-sinusoidal i_p

$$= \pm \left[\frac{2.22 - k_f}{k_f} \right] \times 100$$

conversion
p/p

Age
single
the
Q₁⁺
Derive.

$$= \frac{1.11 V_{dc} - k_h V_{dc}}{k_h V_{dc}} \times 100$$

$$= \frac{1.11 V_{dc} - k_h V_{dc}}{k_h V_{dc}} \times 100$$

$$= \frac{1}{k_h} [1.11 - k_h] \times 100$$

$$= \frac{1}{k_h} [1.11 - k_h] \times 100$$

iteration for congtu.

1 p m for
rectifier volt
meter (assuming
ideal diode)

$$R_v = R_{se} + R_m$$

$$= \frac{1}{2.22} \frac{V_{rms FSD}}{I_{dc FSD}}$$

$$R_v = 0.45 \frac{V_{rms FSD}}{I_{dc FSD}}$$

$$R_v = R_{se} + R_m$$

$$= \frac{1}{1.11} \frac{V_{rms FSD}}{I_{dc FSD}}$$

$$R_v = 0.9 \frac{V_{rms FSD}}{I_{dc FSD}}$$

$$R_v = \frac{S_{dc}}{C_{H.W}} \times V_{rms FSD}$$

$$R_v = \frac{S_{dc}}{C_{F.W}} \times V_{rms FSD}$$

$$R_{se} = R_v - R_m$$

$$R_{se} = R_v - R_m$$

series multi
like resistor
for conversion
of DC ammeter
to rectifier
to ammeter

Q: If dc volt of 10 volt is applied by a rectifier volt meter then the reading of voltmeter is _____

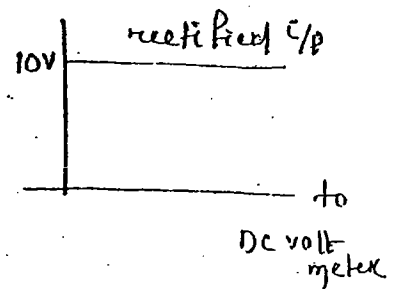
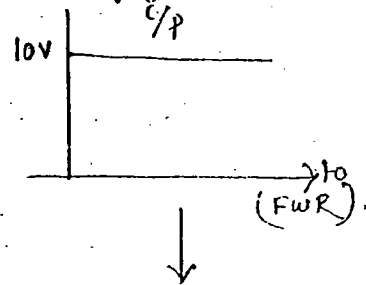
sol: reading of voltmeter is _____

$$S_{AC} = \frac{R_v (FW)}{V_{rms} FSD} = 0.45 \frac{V_{rms} FSD}{I_{dc} FSD} = 0.45 SDC$$

Pb.

$$S_{AC} = \frac{R_v (FW)}{V_{rms} FSD} = 0.9 \frac{V_{rms} FSD}{I_{dc} FSD} = 0.9 SDC$$

(9) Ac sensitivity of rectifier volt meter.



$$DC \text{ voltmeter measr} = V_{dc} = 10V$$

$$\text{reading} = 1.11 \times V_{dc}$$

$$= \frac{\pi}{2\sqrt{2}} \times 10$$

$$= 11.1V \text{ or } \frac{5\sqrt{2}}{2}$$

$$\text{Error} = V_{rms} - V_{true} \quad (\text{indi}) \quad (\text{true})$$

$$= 11.1 - 10$$

$$= +1.1V$$

$$\% \text{ error} = \frac{11.1 - 10}{10} \times 100$$

$$= +11\%$$

(ii)

It is

Kern volt
adding it

meter is

(FWR).

of 1/2

to
De volt
metermembr = V_{dc}
= 10V.

xVdc

x10

0 or $\frac{5V}{\sqrt{2}}$ - V_{rms}
(true)

-10

V.

-100
x 100

0.

subjective type

Q: A 0-1mA dc ammeter having internal resistance of 100Ω is to be used in the following volt. ranges.

(i) 0-10V dc range (ii) 0-10V ac range using a FWR

(iii) 0-10V ac range using a HWR.

Calculate the i/p resistance; series multiplied resistor and sensitivity of each volt-meter.

(i) A 0-10V dc volt-meter

using a 1mA dc ammeter $\Rightarrow$

$$\hookrightarrow R_v = \frac{10V}{1mA} = 10K\Omega.$$

$$\hookrightarrow R_{se} = 10K\Omega - 100\Omega = 9.9K\Omega.$$

$$\hookrightarrow S_v \text{ or } S_{dc} = \frac{1}{1mA} = 1K\Omega/V.$$

(or)

$$S_{dc} = \frac{10K\Omega}{10V} = 1K\Omega/V.$$

(ii) 0-10V ac range using a FWR

$$\hookrightarrow R_v = 0.9 \times \frac{10V}{1mA} = 0.9 \times 10K\Omega = 9K\Omega.$$

$$\hookrightarrow R_{se} = 9K\Omega - 100\Omega = 8.9K\Omega.$$

$$\hookrightarrow S_{ac} = \frac{9K\Omega}{10V} = 0.9K\Omega.$$

$$\hookrightarrow S_{dc} = \frac{1}{1mA} = 1K\Omega/V.$$

(iii) 0-10V ac range using HWR

$$R_v = 0.45 \times 10K\Omega.$$

$$\rightarrow R_{se} = 4.5 \text{ k}\Omega - 100 \Omega = 4.4 \text{ k}\Omega. \quad (\text{loading error is less in dc measure. \& more in ac msmt.})$$

$$\rightarrow S_{ac} = \frac{4.5 \text{ k}\Omega}{10} = .45 \text{ k}\Omega.$$

$$S_{dc} = \frac{1}{1 \text{ mA}} = 1 \text{ k}\Omega/\text{V}.$$

(\& sensitivity is high in dc msmt compare to ac msmt.)

Comparison :

$$(i) \quad R_v > R_{v(FWR)} > R_{v(HWR)}.$$

$$S_{dc} > S_{ac(FWR)} > S_{ac(HWR)}.$$

$$(ii) \quad R_{v(FWR)} = 0.9 R_v \\ = 2 R_{v(HWR)}.$$

$$S_{ac(FWR)} = 0.9 S_{dc} \\ = 2 S_{ac(HWR)}$$

$$(iii) \quad R_{v(HWR)} = 0.45 R_v \\ = \frac{1}{2} R_{v(FWR)}.$$

$$S_{ac(HWR)} = 0.45 S_{dc} \\ = \frac{1}{2} S_{ac(FWR)}.$$

(iv) Loading error in a crt is less in dc measurement. A dc voltmeter (EM type) offers i/p — \& high sensitivity than a rectifier voltmeter.

(v) Conventional rectifier ac voltmeter is FWR type voltmeter. A FWR voltmeter offers high i/p — \& high ac sensitivity than a HWR sensitivity voltmeter.

Sol:

Q: A
It's

Sol:

cores

measur.

etc

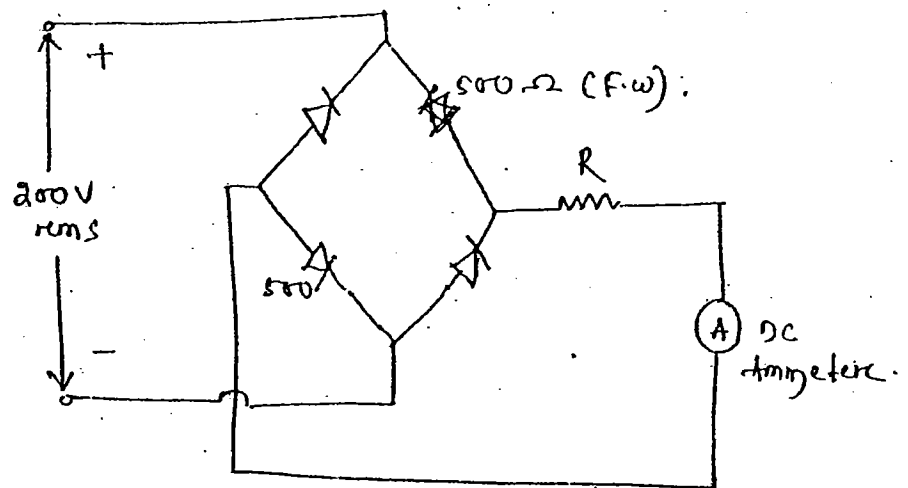
is high

impair

GATE

Q: In the rectifier voltmeter shown in below fig. the ammeter used produces full scale deflection for 25 mA. The internal resistance of ammeter is 100Ω . Each diode has forward resistance of 500Ω and an 'infinite' reverse resistance. The value of 'R' is _____.

sol:



Here $R_s = R_{se}$.

It is a constant current based ckt.

$I_{deflection} = 25 \text{ mA}$.

$R = 100 \Omega$.

$$R_{se} = 0.9 \times \frac{200}{25 \times 10^{-3}} - R_m \quad (\text{Assuming ideal diodes})$$

$$= 0.9 \times \frac{200}{25 \times 10^{-3}} - R_m - 2R_d$$

$$= 0.9 \times \frac{200}{25 \times 10^{-3}} - 100 - 2 \times 500$$

$$= 6.1 \text{ K}\Omega$$

Q: A rectifier voltmeter has a dc sensitivity of $20 \text{ K}\Omega/\text{V}$. Its i/p resistance is _____ in 50 V AC range.

sol:

$$S_d = 20 \text{ K}\Omega/\text{V}$$

Correct

Or high

0

0

type

Op m

Directly voltm sol:

$$\begin{aligned}
 S_{dc} &= \frac{R_v}{V_{rmsFS}} \\
 \times \left\{ \begin{aligned} 20 \times 10^3 &= \frac{R_v}{50} \\ 1000 \times 10^3 &= R_v \end{aligned} \right. \\
 R_v &= 1000 \text{ K}\Omega
 \end{aligned}
 \qquad
 \begin{aligned}
 S_{ac} &= 0.9 \cdot S_{dc} \\
 &= 0.9 \times 20 \text{ K}\Omega \\
 &= \frac{9}{10} \times 20 \text{ K}\Omega \\
 &= 18 \text{ K}\Omega
 \end{aligned}$$

2) i/p resistance = $18 \text{ K}\Omega \times 50$

3) i/p resistance = $900 \text{ K}\Omega$

Q: A fullwave rectifier has $S_{ac} = 1 \text{ K}\Omega/\text{V}$, then it's i/p Ω is _____ in 10V a/c range.

solⁿ: $S_{a/c} = 0.9 \times 1 \text{ K}\Omega$
 $= 0.9 \text{ K}\Omega$

2) i/p resistance = $0.9 \text{ K}\Omega \times 10$
 $= \frac{9}{10} \times 10 = 9 \text{ K}\Omega$

Q: A 1mA dc ammeter is to be used in 10 volt range used in FWR. It's i/p Ω in 10V range is _____

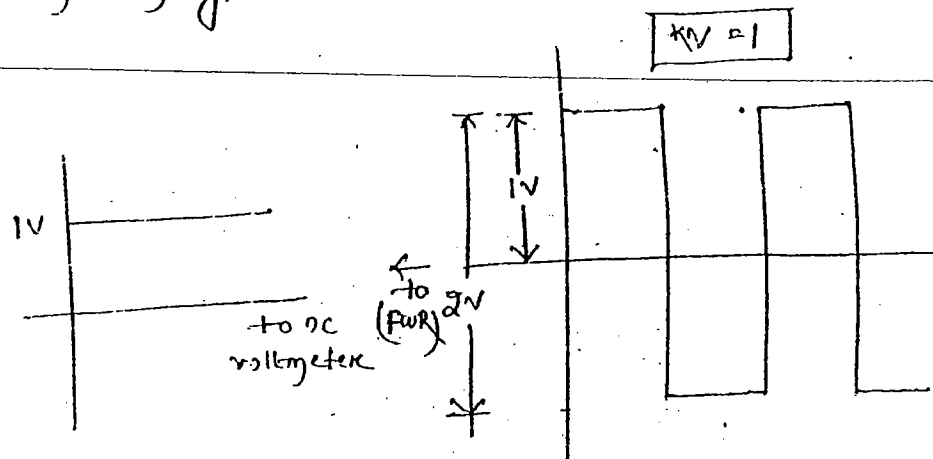
solⁿ: i/p resistance = $0.9 \times \frac{10}{1\text{mA}}$
 $= 0.9 \times 10 = 9 \text{ K}\Omega$

R. GATE

Q: A rectifier type a/c voltmeter is used to measure a symmetrical square wave a/c voltage with peak to peak amplitude of 2 volts to stop. Then the reading of voltmeter and amt of % error introduced into voltage measurement is _____, respect

solⁿ:

when nothing is



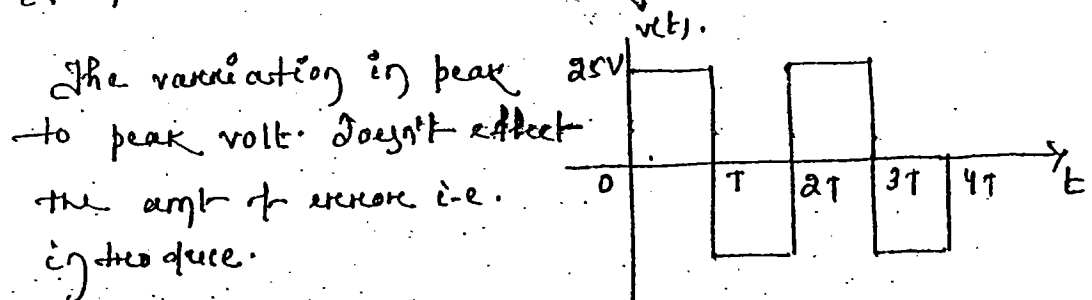
A symmetric square wave follows a full wave rect.

$$\hookrightarrow \text{DC measmt} = 1V = V_{dc}$$

$$\text{reading} = 1.11 \times V_{dc} = 1.11V.$$

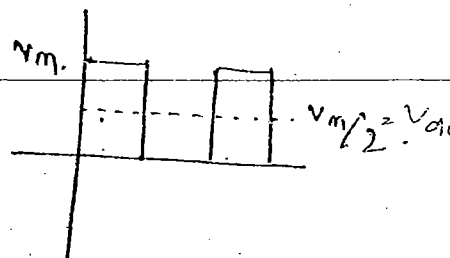
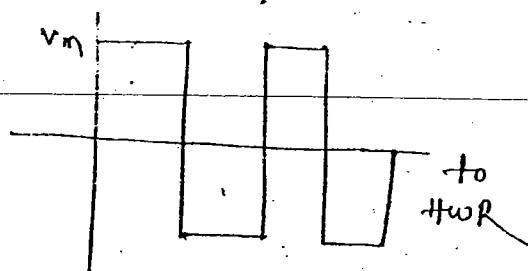
$$\hookrightarrow \% \text{ error} = \frac{1.11V - 1V}{1V} \times 100 = +11\%.$$

Q: An Electronic A/C voltmeter which uses a full wave rectifier is used to measure a time-varying voltage whose measurement is given below. Then % error in the reading is +11%.



Q: An Electronic Avg. measuring and rms reading voltmeter has a scale calibrated in terms of rms of sine wave and uses a half-wave rectifier. It indicates 24 volts when used to measure a symmetrical square wave volt. with 0 mean. Then actual rms of the i/p is _____

solⁿ: $V_{rmsfsd} = 24V$



V_m (actual) is nothing but peak-to-peak voltage.

4) Dc volt-meter msmt = $V_{dc} = \frac{V_m}{2}$

4) reading = $2.22 \cdot V_{dc}$

= $2.22 V_{dc} = \frac{\pi}{\pi^2} V_{dc}$

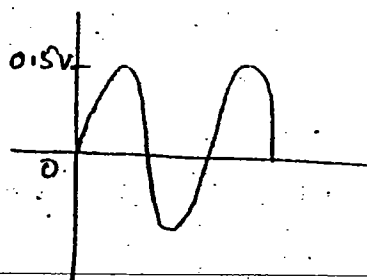
Pb

$24V = \frac{\pi}{\pi^2} \times \frac{V_m}{2}$

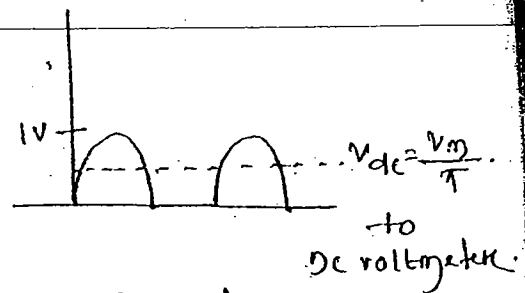
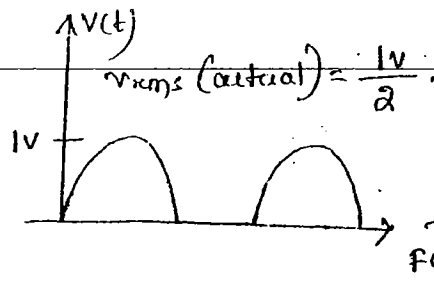
$\Rightarrow \frac{48\pi^2}{\pi} = V_m$ (actual rms)

Q: A full wave rectifier A/c volt-meter is used to measure full wave rectified sinusoidal volt, with a peak value of 1V. then the reading of volt-meter and % error in the reading are $\frac{1}{2}V$, 0% respectively.

P solⁿ:



Q: A HWR A/c volt-meter is used to measure a half wave rectified sinusoidal volt., then reading of volt-meter is $\frac{1}{2}$ and % error in volt-meter is (consider peak volt = 1V.)



DC voltmeter ment = v_{dc}

$$= \frac{v_m}{\pi} V$$

$$= \frac{1}{\pi} V$$

reading of FWR

$$= \frac{\pi}{2r_2} \times \frac{1}{\pi} V$$

$$= \frac{1}{2r_2} V$$

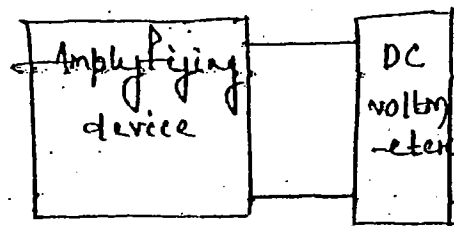
$$\therefore \text{error} = \frac{\frac{1}{2r_2} - \frac{1}{2} V}{\frac{1}{2} V} \times 100$$

$$= \left(\frac{1}{r_2} - 1V \right) \times 100$$

$$= (0.707 - 1V) \times 100$$

$$= -30.2\%$$

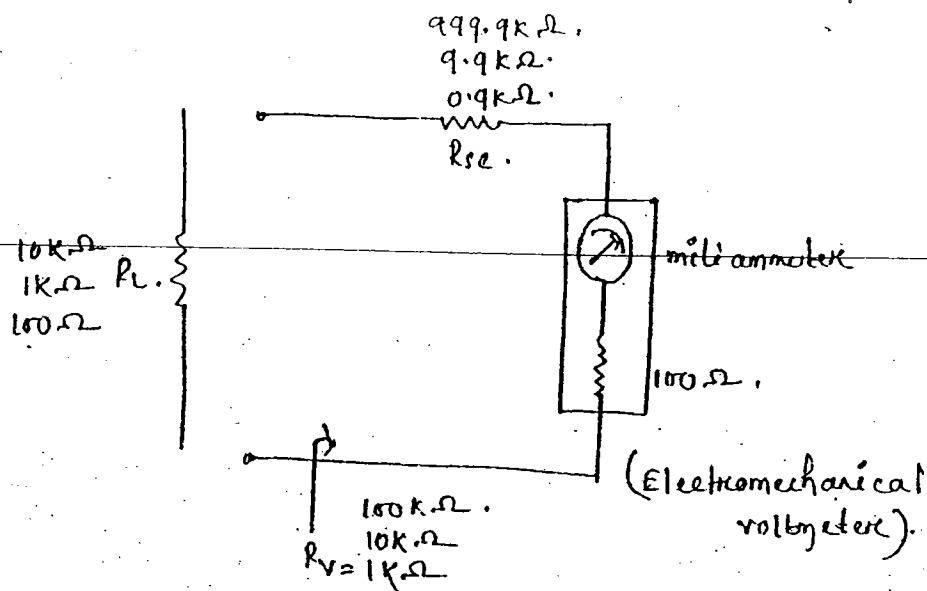
07/10/10



objective of design :

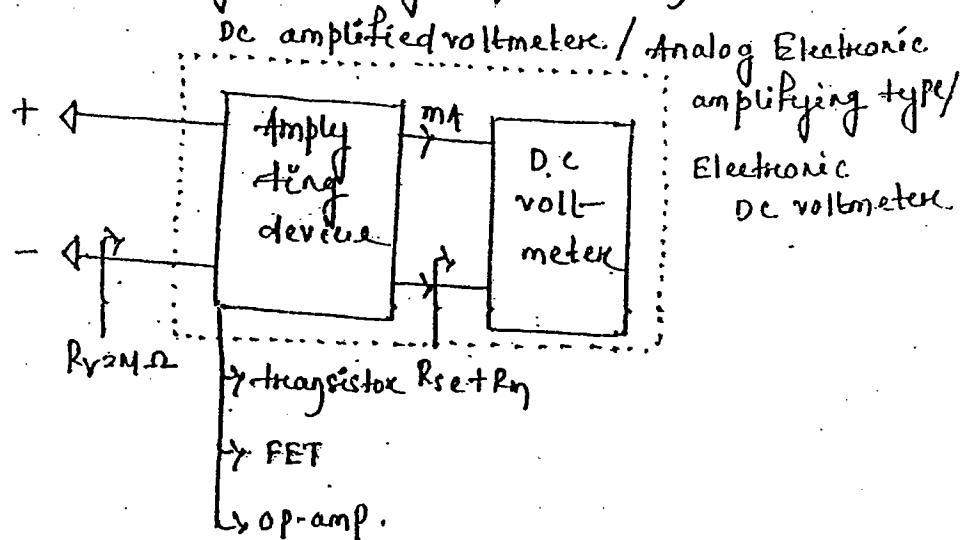
The prime instrument has a following limitations when used a very high resistive ext as given below

- (i) The prime instrument are having very high $\%$ resistance
- (ii) This instrument can't sense a very small $\%$ resistance (even in ext).



↳ PMMC has low sensitivity as such amplifier type voltmeter are designed to achieve the objectives of high sensitivity and high Ω resistance.

↳



↳ Here when we give a μA current to the device it'll amplified into 100 times and pass to the voltmeter.

A zero-1 mA PMMC milliammeter is to be converted into the following voltmeter.

- (i) A 0-10 volt electromechanical dc voltmeter.
- (ii) A 0-10 volt electronic voltmeter using a transistor with a current gain of 100.

The internal resistance of PMMC is 100Ω . Calculate required R_{ac} , i/p resistance, sensitivity of both voltmeters.

$$V_{in} = 0-10V.$$

$$I = 0-1mA.$$

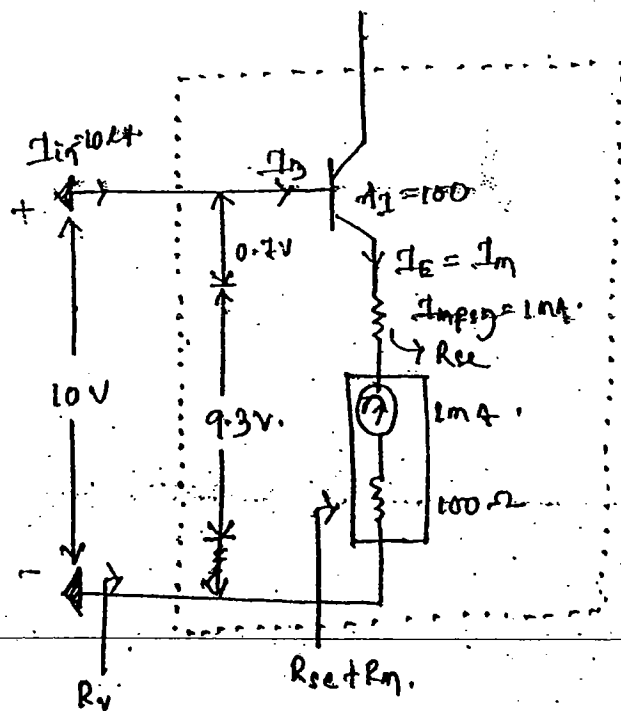
$$R = \frac{10}{1 \times 10^{-3}} = 10k\Omega.$$

$$R_{ac} = 9.9k\Omega.$$

$$(ii) S_{DC} = \frac{10k\Omega}{10V} = 1k\Omega/V$$

$$S_{DC} = \frac{1}{1mA} = 1k\Omega/V$$

(2) (b) $V = 0-10$ volt electronic voltmeter



$$A_1 = \frac{I_E}{I_B}$$

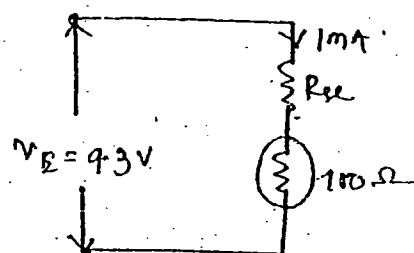
$$A_1 = \frac{I_m}{I_{in}} \Rightarrow 100 = \frac{1mA}{I_{in}} \Rightarrow I_{in} = \frac{1}{100} mA$$

$$\therefore R_V = \frac{10V}{10\mu} = 1M\Omega = 1000K\Omega.$$

Here the total 10V is not appear across the voltmeter.
due to transistor. there is a volt. drop across
this transistor

$$(R_{SE} + 1000) \cdot 1mA = 9.3V$$

$$R_{SE} = \frac{9.3}{1mA} = 9.3K\Omega \\ \approx 9.2K\Omega.$$



Here we calibrate in terms of 10V (but exactly
it is 9.3V). if we remove this transistor then
the total i/p voltage available across the voltmeter,
but we may loose the i/p resistance and sensitivity.
and the error can be eliminated.

$$\therefore S_{DC} = \frac{1000K\Omega}{10V} = 100K\Omega/V.$$

so

$$S_{DC} = \frac{1}{1\mu A} = 0.1m\Omega/V = \frac{100K\Omega}{V}.$$

$\therefore$ Error in scale calibration:

0V $\rightarrow$ 10V but 9.3V must required.
 $\therefore$ External supply of 15V is required.

$\therefore I_{EO}$ & V_{BE}

$$\frac{dV_{BE}}{dT} = -2.5mV/^\circ C$$

double in every

10 $^\circ$ C rise in temp. (there are very temp. sensitivity
parameter)

Advantages of Electronic Voltmeter :

- ↳ Conventional Electromechanical voltmeter.
- ↳ Electronic amplifier voltmeter offer very high i/p resistance in the range of $M\Omega$.
- ↳ An electronic amplifier voltmeter offer very high sensitivity in the range of $M\Omega/volt$.
- ↳ High i/p Electronic amplifier voltmeter causes min^m loading when used in very high resistive loads.
- ↳ Electronic amplifier voltmeter can sense very low level electronic i/p signals. (current in the range of μA , volt. in order of mV).
- ↳ Frequency range of operation is widened and accuracy increases.

Disadvantages of

- ↳ It is used for external source for their operaⁿ.
- ↳ Transistor parameters like I_{CS} and V_{BE} or temp. sensitive as such entire measuring unit become sensitive to temp.

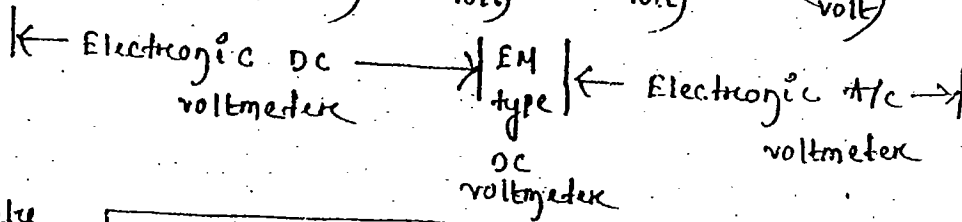
Eq. of Electronic Dc voltmeter

- ↳ Transistor voltmeter
- ↳ Emitter follower voltmeter
- ↳ Differential voltmeter
- ↳ FET i/p voltmeter.
- ↳ op-amp voltmeter.

$$R_{V \text{ cop-volt}} > R_V > R_V > R_V > R_V > R_V$$

(FET volt) (FET volt) (FET volt) (FET volt) (H.W volt)

$$S_{DC \text{ cop-volt}} > S_{DC \text{ (FET volt)}} > S_{DC \text{ (FET volt)}} > S_{AC \text{ (F.W volt)}} > S_{AC \text{ (H.W volt)}}$$



conclusion:

Sensitivity $\propto$ i/p resistance

Differential voltmeter is the integral part of FET i/p voltmeter.

FET i/p voltmeter :-

$$\begin{aligned} V_m &= V_{E1} - V_{E2} \\ &= V_{D1} - 0.7 - (V_{D2} - 0.7) \\ &= V_s - 0.7 - (V_p - 0.7) \\ &= V_{gs} - V_{gs} - 0.7 - (V_p - 0.7) \\ &= V - V_{gs} - 0.7 - V_p + 0.7 \end{aligned}$$

$V_m = V - V_{gs} - V_p$

$V_{gs} = -V_E$ for FET (n-channel)

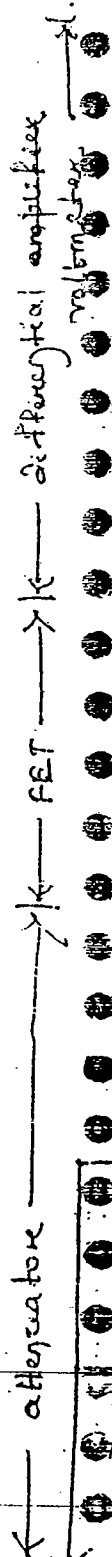
$V = V_{in}$ in selected range

if sw - (A) $\Rightarrow V = V_{in}$

if sw - (B) $\Rightarrow V = V_{in}; \frac{R_D + R_L + R_g}{\Sigma R}$

if sw - (C) $\Rightarrow V = V_{in}; \frac{R_D + R_L}{\Sigma R}$

if sw - (D) $\Rightarrow V = V_{in}; \frac{R_g}{\Sigma R}$



∴ Prior to any practical measurement of voltage zero adjustment must be carried out where ' R_s ' is varied to get/achieve $|V_p| = |V_{qs}|$. Such that $V_m = V$. (This is done with zero i/p)

Eg: $V_{qs} = -3V$

$V = 10V = V_q$

∴ $V_s = 10V - (-3V) = 13V$

∴ $V_{E1} = 13V - 0.7V = 12.3V$

$V_{B2} = V_p = 3V$ (fixed during zap)

∴ $V_{E2} = 3V - 0.7V = 2.3V$

∴ $V_m = 12.3 - 2.3 = 10V$
(OK)

$V_m = V$ (after zap)

15/10/10

Q-METER :-

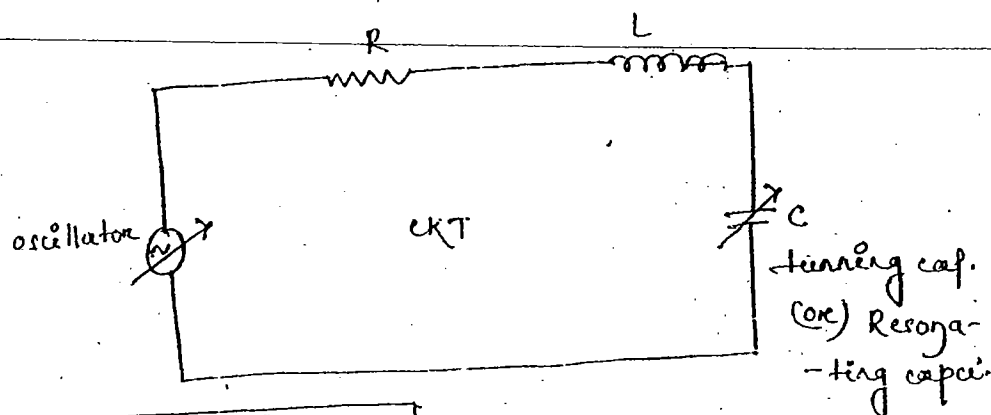
∴ A q-meter (quality factor meter) is basically used for the measurement of following property of a given test

- (i) True Q-coil. measl- (Endo true measl)
- (ii) Self capacitance (or) distributed capacitance measl
- (iii) Self inductance of coil (L).

In q-meter there are actually 3-connections →

Basic Principle of operation:

Q-meter is ~~not~~ having a series resonance point of view
since Q-meter is ~~not~~ having but series R-L-C circuit



Resonance condⁿ: $X_L = X_C$

But initially, $\omega \neq \frac{1}{2\pi f_c}$

Now set the freq. = f_n

Here we are not going to vary the ω . we are varying the capacitance i.e.

$\omega \neq \frac{1}{2\pi f_n}$

But at $\omega = \omega_n$ $\omega \neq \frac{1}{2\pi f_n}$

Properties of series R-L-C ckt at Resonance:

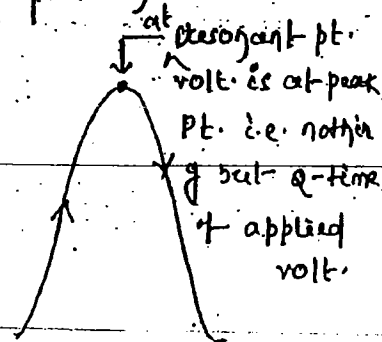
(i) Impedance of ckt (Z) is nothing but purely resistive (i.e. $Z = R$).

(ii) Resonance frequency, $f_n = \frac{1}{2\pi\sqrt{LC}}$

(iii) Volt. at capacitance 'C' when the capacitance value is C_n

i.e. $V_{Cn} = V_{max}$

$V_{Cn} = Q \cdot V$ — Applied volt.
 ↑ ↑
 max^m volt. Quality factor
 across cap. at res.



** Series R-L-C ckt is act-as voltage magnifier.

** parallel R-L-C ckt is act as 'current magnifier'

In series R-L-C ckt 1st fixed the i/p and vary the capacitance value, then a volt. at the i/p side ω that we can track is nothing but applied volt. and the volt. developd at capacitance is the max voltage that we can track.

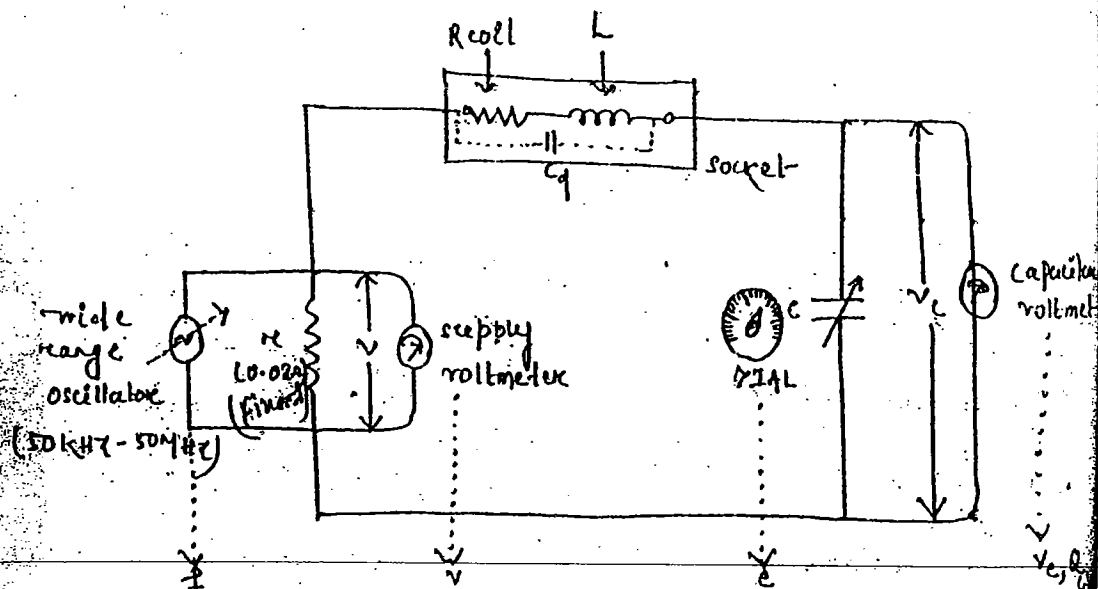
$$Q = \frac{\text{Reactance}}{\text{Resistance}}$$

$$Q_{\text{true}} = \frac{X_L}{R}$$

$$= \frac{\omega L}{R}$$

Again $Q_{\text{true}} = \frac{X_C}{R} (\text{or}) = \frac{1}{\omega CR}$

Direct connection of Q-meter (or) Direct msmt mode



the scale is not in terms of Q , but in terms of capacitance.

not true
of coil

Tuning Process :

- 1. Introduce the given test coil into socket.
- 2. Q-meter resembles series R-L-C ckt.
- 3. Tune Q-meter into resonance by fixing the frequency and i/p volt. and adjust (vary) resonating capacitor, till max^m steady deflection is provided by capacitor volt-meter.
- 4. Note down readings.

Then Q value = $\frac{\text{capacitor voltmeter rdg}}{\text{supply voltmeter rdg.}}$

$$Q = \frac{V_{cmax}}{V}$$

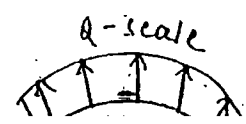
- 5. Here on paper we are showing one capacitor, but exactly there are two capacitors i.e. the capacitance of coil ^{capacitance} i.e. introduce into the ckt has a it's own capacitance.

- 6. In this case the inductive capacitance

- 7. Here the error is due to two parameters i.e.
 - a) C_d
 - b) R

- 8. To overcome such calculation of 'Q' the manufacturer provides a scale calibrated in terms of 'Q' from voltage scale of capacitor voltmeter.

$$Q = \frac{V_c}{V} \times \frac{1}{V}$$



∴ capacitor volt-meter is known as 'p-volt-meter'.

∴ The Q-voltmeter indicate doesn't indicate true Q of coil, it indicates ckt 'Q' only. becoz of 2 errors

- injection resistance (r)
- distributing capacitance (C_d).

Q-voltmeter is also called as "ckt-Q-meter".

Measured - Q vs True-Q :-

$$\frac{Q_{ckt}}{\omega L} < \frac{Q_{coil}}{\omega L}$$

$$\frac{\omega L}{R_{coil} + r} < \frac{\omega L}{R_{coil}}$$

$$\frac{1}{\omega(L+C_d)(R_{coil}+r)} < \frac{1}{\omega L R_{coil}}$$

Measured - Q
(or)

observed - Q
(or)

Indicated - Q
(or)

circuit - Q

True Q of coil.
(or)

Actual Q of coil
(or)

coil - Q.

(a) Error in Q-measmt due to r (0.02Ω):

$$\text{Error} = Q_{msmt} - Q_{true}$$

$$= Q_{ckt} - Q_{coil}$$

$$= \frac{\omega L}{R_{coil} + r} - \frac{\omega L}{R_{coil}}$$

$$\% \text{ Error} = \frac{\frac{\omega L}{R_{coil} + r} - \frac{\omega L}{R_{coil}}}{\frac{\omega L}{R_{coil}}} \times 100\%$$

meter.

true

+ 2

$$\left. \begin{array}{l} \% \text{ Error in } Q_{\text{meas}} \\ \text{due to } r \end{array} \right\} = \frac{-r}{r + R_{\text{coil}}} \times 100\%$$

Correction factor to be applied on Q -measured :

$$\frac{Q_{\text{true}}}{Q_{\text{measured}}} = \frac{\frac{WL}{R_{\text{coil}}}}{\frac{WL}{R_{\text{coil}} + r}}$$

$$\frac{Q_{\text{true}}}{Q_{\text{measured}}} = \frac{R_{\text{coil}} + r}{R_{\text{coil}}}$$

$$Q_{\text{true}} = \left(1 + \frac{r}{R_{\text{coil}}} \right) Q_{\text{meas.}}$$

indication of Q -voltage.
 correction factor

case-I :-
 if $r = 0$,
 (Ideal)

$$Q_{\text{true}} = Q_{\text{measured}} \quad (\text{Ideal case})$$

and % Error is NIL

case-II : if $r \neq R_{\text{coil}}$,
 (Rare)

$$Q_{\text{true}} = 2 Q_{\text{measured}}$$

$$Q_{\text{true}} \gg Q_{\text{measured}}$$

Again,

$$Q_{\text{measured}} \ll Q_{\text{true}}$$

$$Q_{\text{measured}} = \frac{1}{2} Q_{\text{true}}$$

$\Rightarrow$ % Error is high.

case-III : if $r \ll R_{\text{coil}}$, $Q_{\text{measured}} \approx Q_{\text{true}}$
 (usual)

% Error is very small i.e. it can be neglected.

4 In general insertion resistance is very low compared to coil resistance. As such error introduced into Q-mst due to 'r' can be neglected.

b) Error in Q-mst due to 'c':

$$\text{Error} = Q_{\text{measured}} - Q_{\text{true}}$$

$$= Q_{\text{ext}} - Q_{\text{coil}}$$

$$= \frac{1}{\omega(L+c)(R+r)} - \frac{1}{\omega L R_{\text{coil}}}$$

$$\approx \frac{1}{\omega(L+c)R_{\text{coil}}} - \frac{1}{\omega L R_{\text{coil}}} \quad (\because r \ll R_{\text{coil}}) \quad \text{Case-iii}$$

$$\% \text{ Error in Q-mst due to } c = \frac{\frac{1}{\omega(L+c)R_{\text{coil}}} - \frac{1}{\omega L R_{\text{coil}}}}{\frac{1}{\omega L R_{\text{coil}}}} \times 100\%$$

$$\% \text{ Error in Q-mst due to } c = \frac{-c}{L+c} \times 100\%$$

Correction Factor:

$$\frac{Q_{\text{true}}}{Q_{\text{measured}}} = \frac{\frac{1}{\omega L R_{\text{coil}}}}{\frac{1}{\omega(L+c)R_{\text{coil}}}}$$

$$\frac{Q_{\text{true}}}{Q_{\text{measured}}} = \frac{L+c}{L} \quad \text{Ratio of } Q's$$

$$Q_{\text{true}} = \left[1 + \frac{c}{L}\right] Q_{\text{measured}}$$

(w) compared

ed gto

we can't compare 'c' and 'c_d', although 'c_d' is fixed but 'c' isn't fixed. it is varying within the experiment itself.

↳ To apply the correction factor the value of 'c_d' must be known as each the 1st mmt is carried out using Q-measured will always be mmt of 'c_d'

16/10/10

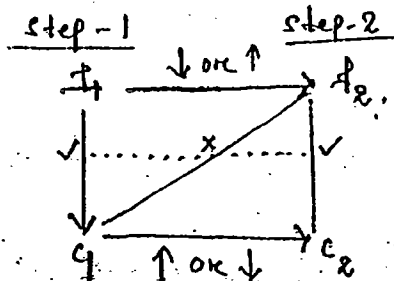
Measurement of 'c_d' of coil using direct connection of

tuning process:

Q-meter:-

↳ Introduce given test-coil into socket and resonate twice at f_1 and f_2 where $f_2 = n f_1$

↳ 1st set the frequency 'f₁' with the corresponding value of 'c₁'. at 'c₁' we are getting the value of resonance.



$$f_1 = \frac{1}{2\pi\sqrt{L(c_1 + c_d)}} \quad (1)$$

edges of step-1 →

$f_1, v, c_1, v_{c_1}, Q_1$ ✓ ckt 'a'

$$\text{Again, } f_2 = \frac{1}{2\pi\sqrt{L(c_2 + c_d)}} \quad (2)$$

edges of step-2 →

$f_2, v, c_2, v_{c_2}, Q_2$ ✓ ckt 'a'

* coil 'a' is not going to change, but ckt 'a' is changing frequently.

$$f_1 + f_2 = \frac{1}{2\pi\sqrt{L(c_1 + c_d)}} + \frac{1}{2\pi\sqrt{L(c_2 + c_d)}}$$

The ratio of $\frac{V_{c2}}{V} = Q_2$ o/p volt. / i/p volt. = Q

$\frac{V_{c1}}{V} = Q_1$

Now divide eqn '1' and eqn '2'.

$$\frac{I_1}{I_2} = \frac{\frac{1}{2\pi\sqrt{L(c_1+c_d)}}}{\frac{1}{2\pi\sqrt{L(c_2+c_d)}}}$$

$$\frac{I_1}{I_2} = \frac{1}{\frac{\sqrt{L(c_1+c_d)}}{\sqrt{L(c_2+c_d)}}}$$

$$\frac{I_1}{I_2} = \frac{\sqrt{L(c_2+c_d)}}{\sqrt{L(c_1+c_d)}}$$

$$\frac{I_1}{I_2} = \frac{c_2+c_d}{c_1+c_d}$$

$$\frac{1}{I_2} = \frac{c_2+c_d}{c_1+c_d} \cdot \frac{1}{I_1}$$

$$\eta^2 c_2 + \eta^2 c_d = c_1 + c_d$$

$$c_d = \frac{c_1 - \eta^2 c_2}{\eta^2 - 1}$$

Measurement of true Q of coil using direct method of Q-meter:

- ✓ First measure 'cd' of coil by resonating twice.
- ✓ Use the reading of 'cd' to get Q-coil.

$$Q_{\text{coil}} = \left[1 + \frac{c_d}{c}\right] Q_{\text{ckt}}$$

$$\Rightarrow Q_{\text{coil}} = \left(1 + \frac{c_d}{c_1}\right) Q_1, \text{ (or)} Q_{\text{coil}} = \left(1 + \frac{c_d}{c_2}\right) Q_2$$

Measurement of 'L' of coil using direct connection of Q-meter :

(either for msmt of 'Q' or msmt of 'L' first measure the value of capacitance)

- ↳ 1st measure 'C₁' of coil by resonating twice.
- ↳ Use readings of 'C₁' to measure 'L'.

$$Q = \frac{1}{2\pi\sqrt{L(C_1 + C_2)}}$$

$$L = \frac{1}{4\pi^2 Q^2 (C_1 + C_2)}$$

$$L = \frac{1}{4\pi^2 Q^2 (C_1 + C_2)}$$

(or)

$$L = \frac{1}{4\pi^2 Q^2 (C_1 + C_2)}$$

Pb : Assertion : The Q-meter measures the Q-factor of coil when the ckt is in resonance. (False).

Reason : The Q-factor of a coil depends only on its inductance and not on its resistance.

Ans-2003

msmt m
value :
vice.

Pb: A reading of 120 is obtained when a standard inductor was connected in the ckt of a Q-meter when the variable capacitor is adjusted to a value 500 pF. A lossless capacitor 'C₂' is then connected in parallel with the variable capacitor and the same reading was obtained when the variable capacitor readjusted to 200 pF. Then the value of C₂ is



$$C_1 = 500 \text{ pF}, \quad Q = 120$$

$$C_2 = 200 \text{ pF}$$

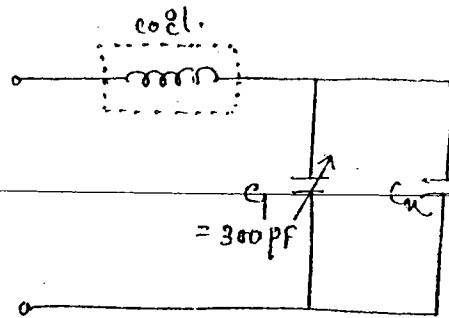
$$Q_1 = Q_2 = 120$$

$$\frac{1}{\omega L R} = \frac{1}{\omega (C_2 + C_u) R}$$

$$2) C_1 = C_2 + C_u$$

$$2) 300 = 200 + C_u$$

$$2) C_u = 100 \text{ pF.}$$



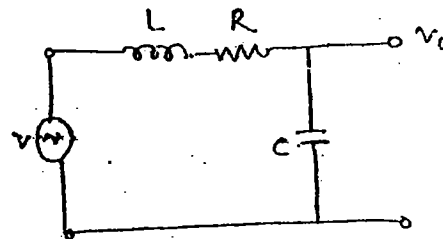
Q: Q-meter works on the principle of _____

Ans: series resonance.

Q: A Q-meter with cu is supplied with an oscillator having 500 mV o/p volt. while testing an unknown coil the reading of Q-volt-meter is 10 volt. Then the Q-factor of coil is _____.

solⁿ:

$$\frac{V_0}{V} = Q = \frac{10}{500 \text{ mV}} = 20.$$



Pb: A coil is tested with a Q-meter and the self capacitance of coil is found to be 820 pF. The resonance has occurred at a frequency of 10^6 rad/sec. with a capacitance of 9.818 nF . Then the inductance of coil is _____.

$$L = \frac{1}{4\pi^2 f^2 C} \quad \omega = 10^6 \text{ rad/sec.}$$

$$f = \frac{1}{2\pi \sqrt{L(C + C_0)}}$$

$$10^6 = \frac{1}{2\pi \sqrt{L(820 \times 10^{-12} + 9.818 \times 10^{-9})}}$$

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$$2) 10^6 \times 2 \times \pi = \frac{1}{\sqrt{L(820 \times 10^{-12} + 9.18 \times 10^{-9})}}$$

$$3) L = \frac{1}{4\pi^2 f^2 (C + C_d)}$$

$$4) L = \frac{1}{4\pi^2 (10^6)^2 (820 \times 10^{-12} + 9.18 \times 10^{-9})}$$

$$5) L = \frac{1}{(10^6)^2 (820 \times 10^{-12} + 9.18 \times 10^{-9})}$$

$$6) L = 100 \mu\text{H}$$

Pb: A coil is tuned to resonance at 500 kHz with a resonating capacitance. A frequency is raised to 1 MHz. The resonance is obtained at 72 pF. The self capacitance of coil is _____.

Pb: A coil is tuned to resonance with a resonating capacitance of 36 pF. At 250 kHz the resonance is obtained with a capacitance of 160 pF. What is the distributed capacitance of coil?

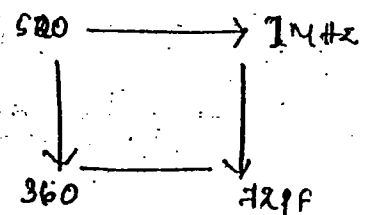
sol:

$$L = \frac{1}{4\pi^2 f^2 (C + C_d)}$$

$$C_d = \frac{360 - 2^2 \times 72}{2^2 - 1}$$

$$= \frac{360 - 4 \times 72}{4 - 1} = \frac{360 - 288}{3}$$

$$= \frac{72}{3} = 24 \text{ pF}$$



5V
met

note: After deriving C_d , value of L also can be carried out.

$$L = \frac{1}{4\pi^2 (500 \times 10^3)^2 [360 + 24]}$$

$$L = \frac{1}{4\pi^2 (1000 \times 10^3)^2 [72 + 24]}$$

Pb: 2

$$f_1 = 500 \text{ kHz} \quad C_1 = 36 \text{ pF}$$

$$f_2 = 250 \text{ kHz} \quad C_2 = 160 \text{ pF}$$

$$\eta = \frac{1}{2} = 0.5$$

$$C_d = \frac{36 - (0.5)^2 160}{(0.5)^2 - 1} = 5.33 \text{ pF}$$

Pb: A coil with a resistance of 10Ω is connected in direct mmt-mode of Q-meter. Resonance occurs when the oscillator frequency is 1 MHz and the resonating capacitance is set as 65 pF . Then the magnitude of % error introduced in Q-mmt due to insertion resistance value 0.02Ω is _____

solⁿ:

$$R = 10 \Omega$$

$$f = 1 \text{ MHz}$$

$$r = 0.02 \Omega$$

$$Q_{true} = \frac{1}{\omega CR}$$

$$= \frac{1}{2\pi (C+C_d) (R+r)}$$

this is not required.

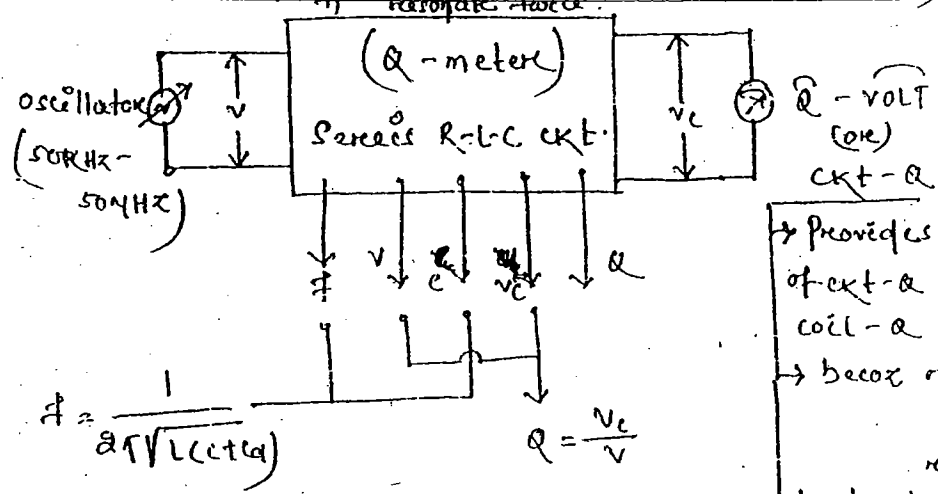
$$= \frac{-r}{r + R_{coil}} \times 100$$

$$= \frac{-0.02}{10.02} \times 100$$

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$$C_d = \frac{4 - n^2 c_2}{n^2 - 1} \quad Q_{true} = \left(1 + \frac{C_d}{C}\right) Q \quad L = \frac{1}{4\pi^2 f^2 (C + C_d)}$$

↑
resistor twice



→ Provides indication
of ext-a but n't
coil-a

→ becoz of 2 error

$r = 0.02 \text{ cm}$

due to:

$$\rightarrow C_{fe} = 1 + \frac{\mu}{R_{coil}}$$

$$\% \text{ error} = \frac{-R}{R + R_{\text{coil}}} \times 100$$

→ die to eq:

$$C_{fq} = 1 + \frac{C_q}{C}$$

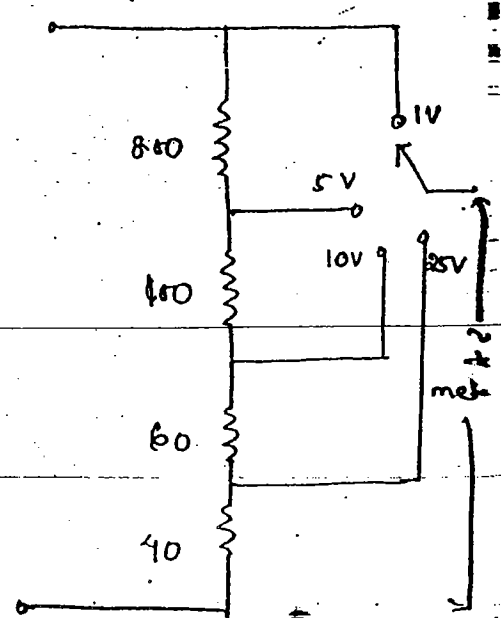
$$\eta_{\text{схем}} = \frac{-C_q}{C + C_q} \times 100$$

Digital volt-meter :-

↳ A digital measuring unit is a volt measuring unit.

The attenuator shown in below fig is the $\frac{1}{10}$ stage of a FET $\frac{1}{10}$ voltmeter. The FET instrument use has a I_{SD} of 1mA and resistance of $1\text{k}\Omega$. It used to measure 7.5V in 10V DC range then the current through the meter is _____.

The diagram shows a voltage divider circuit. The input voltage is 10V . The divider consists of three resistors in series: 800Ω , 100Ω , and 60Ω . The output voltage is measured across the 100Ω resistor, which is labeled as 5V . The 60Ω resistor is connected to ground.



$$v_{gs} = 2.5 = |v_p|.$$

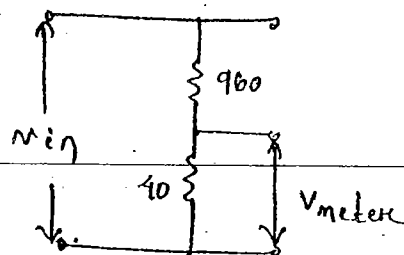
$R = 1 \text{ k}\Omega$

At $25V$:

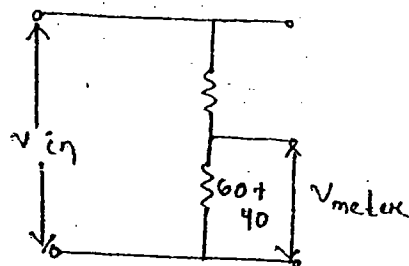
$$V = \frac{1}{25} \times V_{in}$$

$$= \frac{40k\Omega}{100k\Omega} \times V_{in}$$

$$= \frac{1}{25} \times V_{in}$$

at $10V$:

$$V = \frac{V_{in}}{10}$$



At the i/p side we'll get max^m 1 volt, but in o/p side we'll never get more than 1 volt range more than (0-1)V.

$$I_m = \frac{10}{0.4 \times 10^3} \times \frac{7.5}{1 \times 10^3} = \frac{75}{10 \times 10^3} = 0.75 \times \frac{7.5}{10} = 7.5$$

This can be possible only by zero adjustment

$$I_m = \frac{V_m}{R_m} = \frac{0.75}{1 \times 10^3} = 0.75 mA$$

Pb: The below fig shows i/p attenuation of an analog multimeter. The meter reads full scale with 12V at 'A' with the range switch at position 'D'. What is the required voltage at 'A' to obtain 1A with the range switch posⁿ at 'D'.

Pb: Identify the decreasing order of voltmeters in terms of their i/p resistance.

- (i) A $10,000 \frac{\Omega}{V}$ moving coil voltmeter.
 - (ii) Bridge rectifier type voltmeter.
 - (iii) Differential type voltmeter.
- 3, 1, 2

Pb: Loading effect is primarily due to instrument having _____.

- (i) High i/p resistance
- (ii) High sensitivity
- (iii) Low sensitivity
- (iv) Low full scale voltage.

Pb: The i/p stage of an electronic voltmeter primarily consist of _____.

- (i) UJT
 - (ii) SCR
 - (iii) BJT
 - (iv) none.
- (if FET, then $\checkmark$ FET).

Pb: Identify the voltmeter that required external supply for its operation

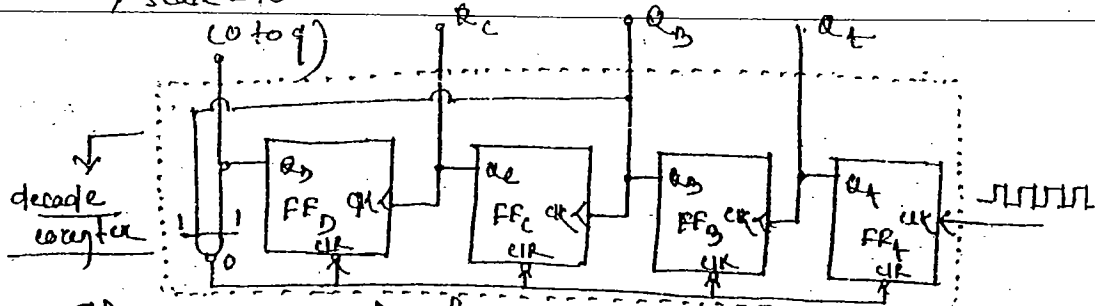
- (i) Electronic Dc voltmeter.
- (ii) Electronic a/c voltmeter.
- (iii) Electrodynamic meter.
- (iv) moving coil meter

24/10/20

Decade Counter :

There are four flip flop in decade counter.

→ scale = 10



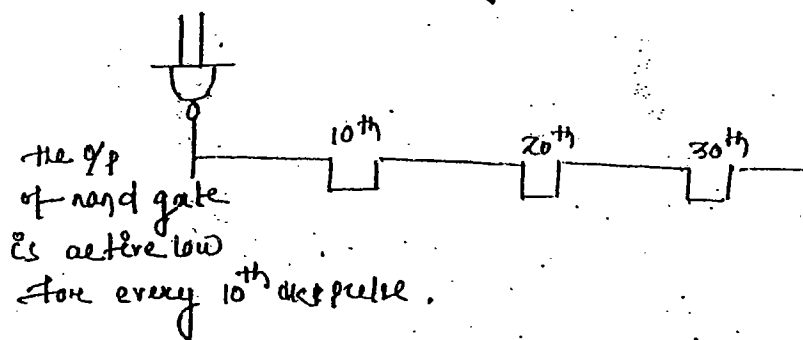
The o/p of the flip flop are based on the pulses that are given to the flip flop.

At p/p →

	Q ₀	Q ₁	Q ₂	Q ₃
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	0	0	0	0

In this total system, we get logic zero only at 10th state / clk. pulse i.e. we get decade counter for every 10th pulse.

At o/p → (o/p of nand gate)



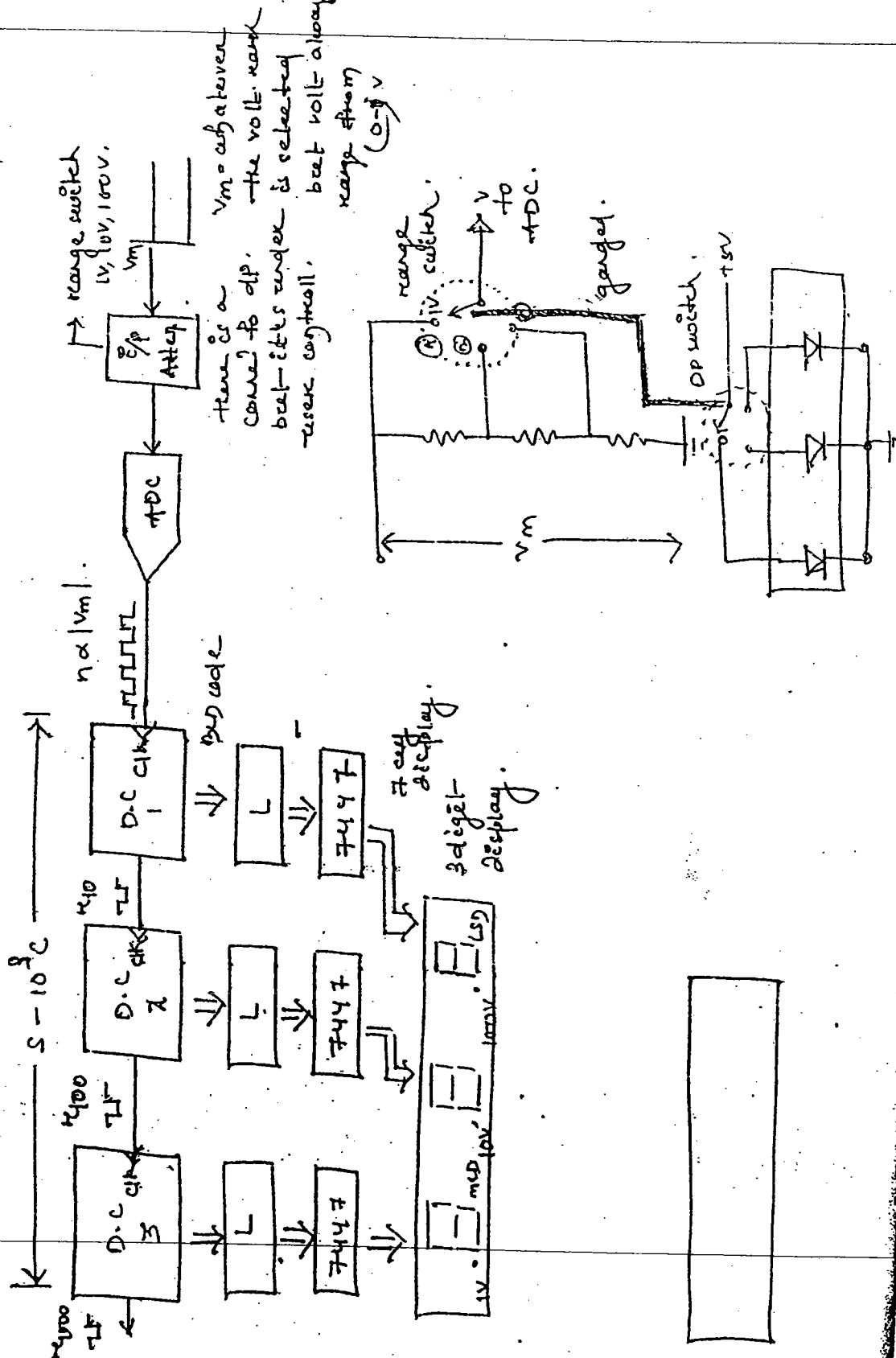
The o/p of nand gate is active low for every 10th clock pulse.

If we cascade one decade counter to another decade counter then the o/p are not based on the o/p of f.f. it is depend upon the nand gate o/p.

state (or) counts

$$= 10^3 \text{ state} = \text{total states}$$

Here no dr^0 pulse for dr .



controlled

segment

is very

range

(1)

(2)

(3)

trip

Wign.

(4)

(5)

other

don't

because

only

(6)

not for

(7)

(8)

(9)

(10)

(11)

(12)

(13)

(14)

(15)

0 to 1.

(16)

(17)

(18)

(19)

(20)

(21)

(22)

(23)

$\frac{3}{4}$ digit : -

Digit	
Full digit	$\square \rightarrow 0, 1, \dots, 9$
$\frac{1}{2}$ digit	$FSR=1 \Rightarrow 0, 1 \Rightarrow \square$ scale = 2
$\frac{3}{4}$ digit	$FSR=3 \Rightarrow 0, 1, \dots, 9 \Rightarrow \square$ not p scale = 4 $\leftarrow 4 \rightarrow$
$\frac{5}{6}$ digit	$FSR=5 \Rightarrow 0, 1, \dots, 5 \Rightarrow \square$ not p scale = 6 $\leftarrow 6 \rightarrow$

Note: The $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{6}$ digits are used for extending count range of a N -digit DVM.

Resolution of a DVM = $\frac{1}{10^N}$ $N = \text{no. of Full Digits}$

Sensitivity of DVM = Resolution $\times$ Range
(S = $\frac{1}{R}$) $\rightarrow 1V, 10V, 100V$

3-digit DVM : -

Roll over : -

0 0 0	] D_1
0 0 1	
...	
0 0 9	] D_2
0 1 0	
0 1 1	
...	
0 9 9	] D_3
1 0 0	
1 0 1	

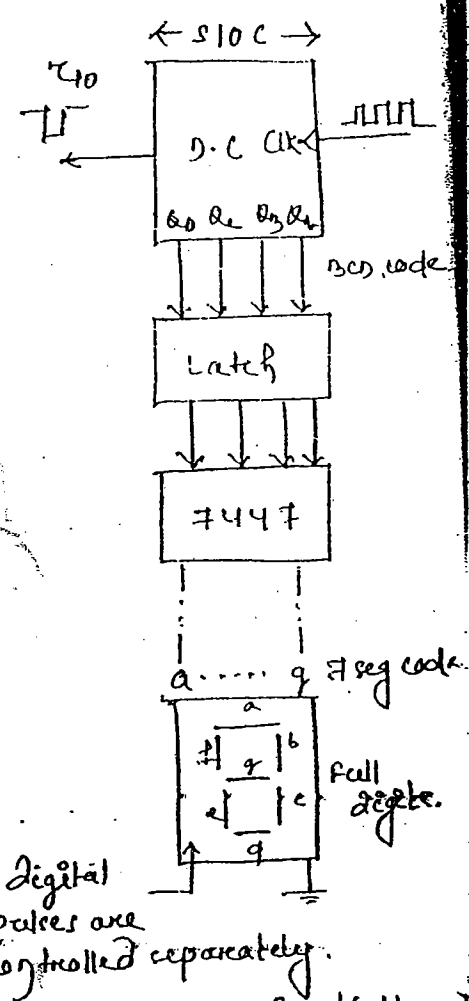
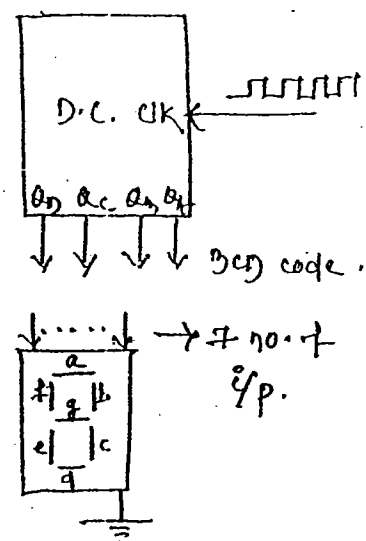
000 = reset
001 = min
...

999 = FSR

4 counter range of a 3 digit dvm is = 0 to 999.
scale = 001 to 999 = 1000 state readings
1000 can be display only in $\frac{3}{2}$ digit

bytes.

A full digit is externally driven within decade counter.



Roll over : i.e. the status of decade counter is displayed by the full digit.

state (or) counts $\left[\begin{matrix} 0 \\ \vdots \\ q \end{matrix} \right]$ when the decade counter is reset the full digit is also reset.

counter range of full digit } = 0 to 9.

0 = reset state

1 = min^m state

9 = max^m state / Full scale

$$\text{Total no. of state} = \text{min}^m + \text{FSR}$$

$$= 1 + 9$$

$$= 10 = \text{scale}$$

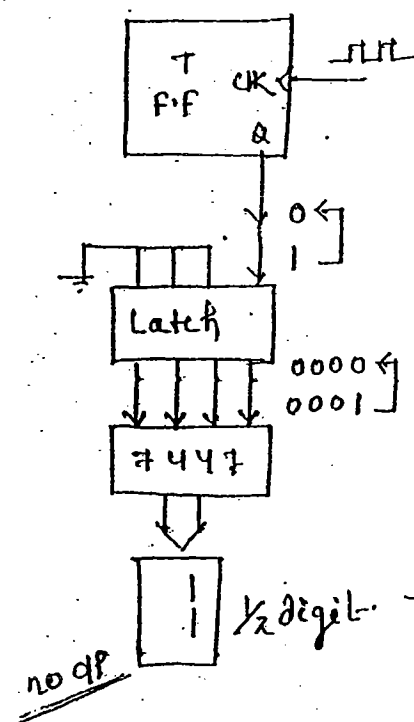
(beoz it can't show any no. more than '9').

This 7 segment display is displayed/controlled by turning it on by some of these 7 segment.

For specification of 7 segment the roll over is very useful. This specification means min^m or max^m range of full digit value.

1/2 digit :-

↳ A 1/2 digit is internally driven with a toggler flip flop. It is nothing but showing the state of '1' design.



↳ For display the digit '1' we have to ground all other terminal. Here we didn't get any decimal pt. (because we getting decimal pt. only at full digit)

↳ There is no decimal point for 1/2 digit.

Roll over : 0 ←
1

↳ reset state = 0
min^m state = 1
max^m state = 1

count range of 1/2 digit = 0 to 1.
Scale = 1 + 1 = 2.

Full scale reading
1/2 digit

↳ scale / scale of two counter

3-digit dvm	sw-a	sw-b	sw-c
Minimum (001)	0.001V	0.01V	0.1V
FSR (999)	0.999V	9.99V	99.9V
	0-1V range	0-10V range	0-100V range

Resolution of 3-digit dvm $\Rightarrow R_{3d} = \frac{1}{10^3}$

$$= \frac{1}{1000}$$

= 1 part in 1000 parts

$$= 1:1000$$

$$= 0.001$$

$$= 0.1\%$$

Sensitivity $\Rightarrow S = \frac{R}{R}$

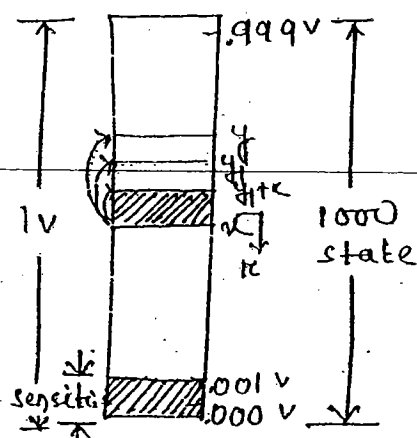
$$\frac{1}{10^3} \rightarrow 1V \times \frac{1}{10^3} = 0.001V (S_{1V})$$

$$\frac{1}{10^3} \rightarrow 10V \times \frac{1}{10^3} = 0.01V (S_{10V})$$

$$\frac{1}{10^3} \rightarrow 100V \times \frac{1}{10^3} = 0.1V (S_{100V})$$

∴ Sensitivity of a DVM is the min^m reading that can display by the ^{dvm} design. It is the min^m volt. that it can measure.

Thus "the min^m i/p volt. that can be sensed and displayed by the DVM is called as its sensitivity" (The 1st i/p that the DVM can sense is known as sensitivity.)

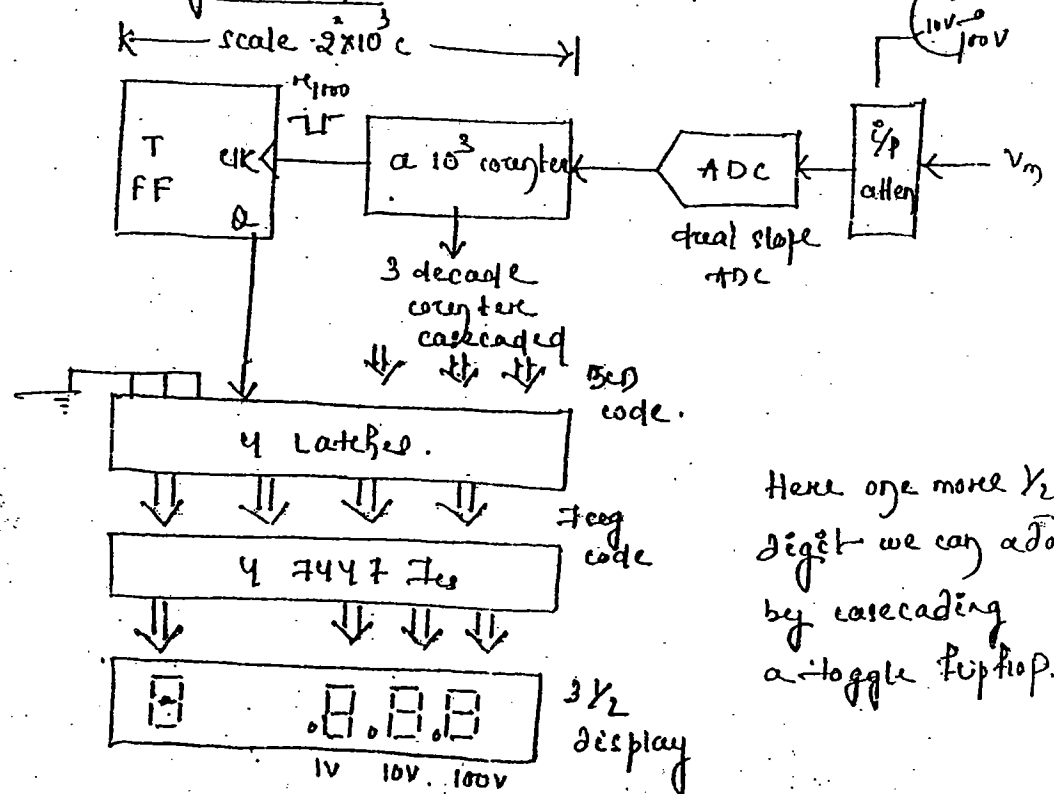


The min^m difference beyond which we can't detect is known as resolution.

The smallest possible incremental change allowed at i/p is known as resolution.

Its sensitivity and resolution are going to be same at 1V range.

3 $\frac{1}{2}$ digit DVM :-



Here one more $\frac{1}{2}$ digit we can add by cascading a toggle flip flop.

$\leftarrow \frac{1}{2} \text{ digit} \rightarrow \leftarrow 3 \text{ digits} \rightarrow$

Roll over :

Basic range
+ 3 digit
DVM
 $\frac{1}{2}$ digit
is turned on

0 000 $\rightarrow$ reset
0 001 $\rightarrow$ min^m
...
0 999
1 000
1 999 $\rightarrow$ FSR

counter range of

3 $\frac{1}{2}$ digit DVM =
0 to 1999

Scale = 0001 + 1999

= 2000 states

= 2×10^3 states

90

and which

↓
(coarser range is extended)

↳ (0-1) V range :

msd			
-----	--	--	--

 $\frac{1}{2} \leftarrow 3 \rightarrow$
 digits

$$\text{min}^m = 0.001 \text{ V}$$

$$\text{FSR} = 1.999 \text{ V} \Rightarrow 2 \text{ V range.}$$

Overranging $\Rightarrow$ when it is 2V i.e. 1.999 V.

↳ (0-100) V range :

		.	
--	--	---	--

$$\text{MIN} = 00.01 \text{ V}$$

$$\text{FSR} = 19.99 \text{ V} \Rightarrow 20 \text{ V range.}$$

↳ (0-1000) V range

			.
--	--	--	---

$$\text{MIN} = 000.1 \text{ V}$$

$$\text{FSR} = 199.9 \text{ V} \Rightarrow 200 \text{ V range}$$

↳ Overranging : measuring 1.999V in 1V range.
 measuring 19.99V in 10V range.
 measuring 199.9V in 100V range.

*** Overranging is due to $\frac{1}{2}$ digit switch ^{switched} ~~turned~~ on.

$$\hookrightarrow \text{Resolution} \Rightarrow R_{\frac{1}{2}d} = \frac{1}{10^3}$$

$$= \frac{1}{1000}$$

$$= 0.001$$

$$= 0.1\%$$

$$= 0.1\%$$

$$= 0.1\%$$

$$= 0.1\%$$

$$= 0.1\%$$

$$= 0.1\%$$

$$= 0.1\%$$

$$= 0.1\%$$

$$= 0.1\%$$

$$\hookrightarrow \text{Sensitivity} \Rightarrow S_{1V} = \frac{1}{10^3} \times 1 \text{ V} = 0.001 \text{ V}$$

$$S_{10V} = \frac{1}{10^3} \times 10 \text{ V} = 0.01 \text{ V}$$

$$S_{100V} = \frac{1}{10^3} \times 100 \text{ V} = 0.1 \text{ V}$$

$$\boxed{R_3 = R_{\frac{1}{2}d}}$$

So

$$S_{3\frac{1}{2}} = S_3 \text{ in a selected range of } 0V$$

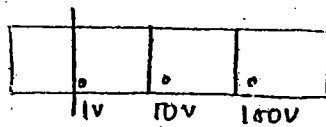
$$r_{N-n} = r_N$$

$$S_{N-n} = S_N \text{ in same range}$$

$$\text{counter range}_{N-n} \neq \text{counter range}_N$$

In every $\frac{1}{2}$ digit dvm the denominator represent the multiplying factor.

$3\frac{3}{4}$ digit dvm :-



3 digit
 $\frac{3}{4}$ digit

It's having a counter to count upto 3 digit.

Roll over :

0 0 0 0 $\rightarrow$ Reset
0 0 0 1 $\rightarrow$ min
...

counter near 9

+ 3 9 9 9 $\rightarrow$ FSR

scale
4 0 0 0
 4×10^3

1V range

min^m volt.

sensitivity

0.001 V

0.001 V

10V range

00.01 V

0.01 V

100V range

000.1 V

0.1 V

1V range

max^m volt.

sensitivity

3.999 V

3.999 V

10V range

39.99 V

39.99 V

100V range

399.9 V

400 V

over ranging

volt to time converter

Electronic timer/counter

91

4 In ADC the FSR = $2^N - 1$

4 But in Electronic counter/timer = $10^N - 1$ (for any DMC)

The i/p comparator compares V_{ramp} with V_m , whereas the ground comparator compares V_{ramp} with ground.

4 At t_1 ramp volt. coincides

4 the 1st crossover detected by i/p comparator.

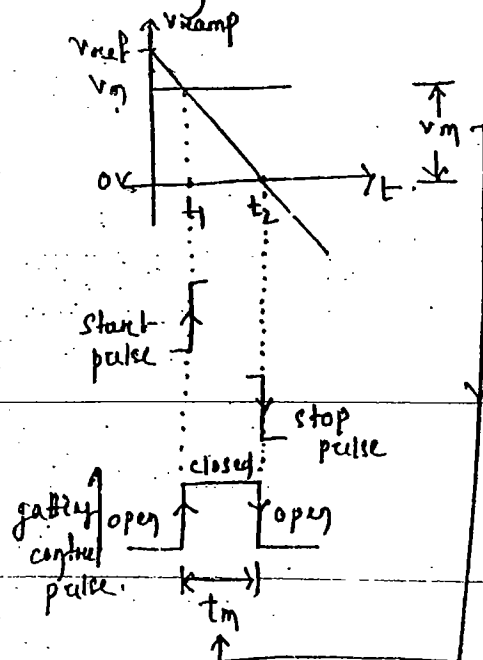
the 2nd crossover detected by ground comparator.

4 At t_1 , the i/p comparator generates start pulse which closes the switch & gating and indexing counter starts.

4 counting is continued till t_2 , where the ZCD produces a stop pulse, which opens the switch & gating.

voltage to time conversion :-

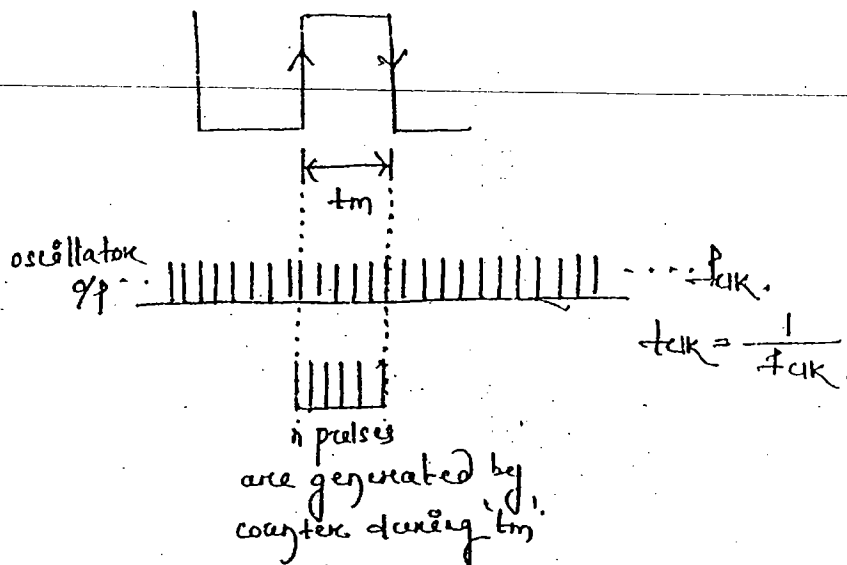
Here the magnitude of voltage is converted into time interval.



$$V_m = \frac{V_{\text{ref}}}{t_m} \times t_m \quad (1)$$

v to time
conversion
 $t_m \propto |V_m|$

Time period measurement :



$$t_m = n \times t_{clk} \quad \text{--- (2)}$$

Substituting eqn (2) in (1)

$$V_m = \frac{V_{ref}}{t_r} \times n \times t_{clk} \quad \left[\frac{V_{ref}}{t_r} = \text{slope} \right]$$

unknown volt.
analog voltage
to be measured

= slope $\times$ signal width $\times$ CLK width.

$$V_m = \frac{V_{ref}}{t_r} \times n \times t_{clk}$$

(if this is changed then it is going to introduce a large error)

$\boxed{\text{fixed}}$

$\boxed{\text{fixed}}$

variable $n \propto |V_m|$

$\boxed{\text{fixed}}$

(ii) conversion time :

$$t_{conv} = \text{start to stop}$$

$$t_1 \text{ to } t_2$$

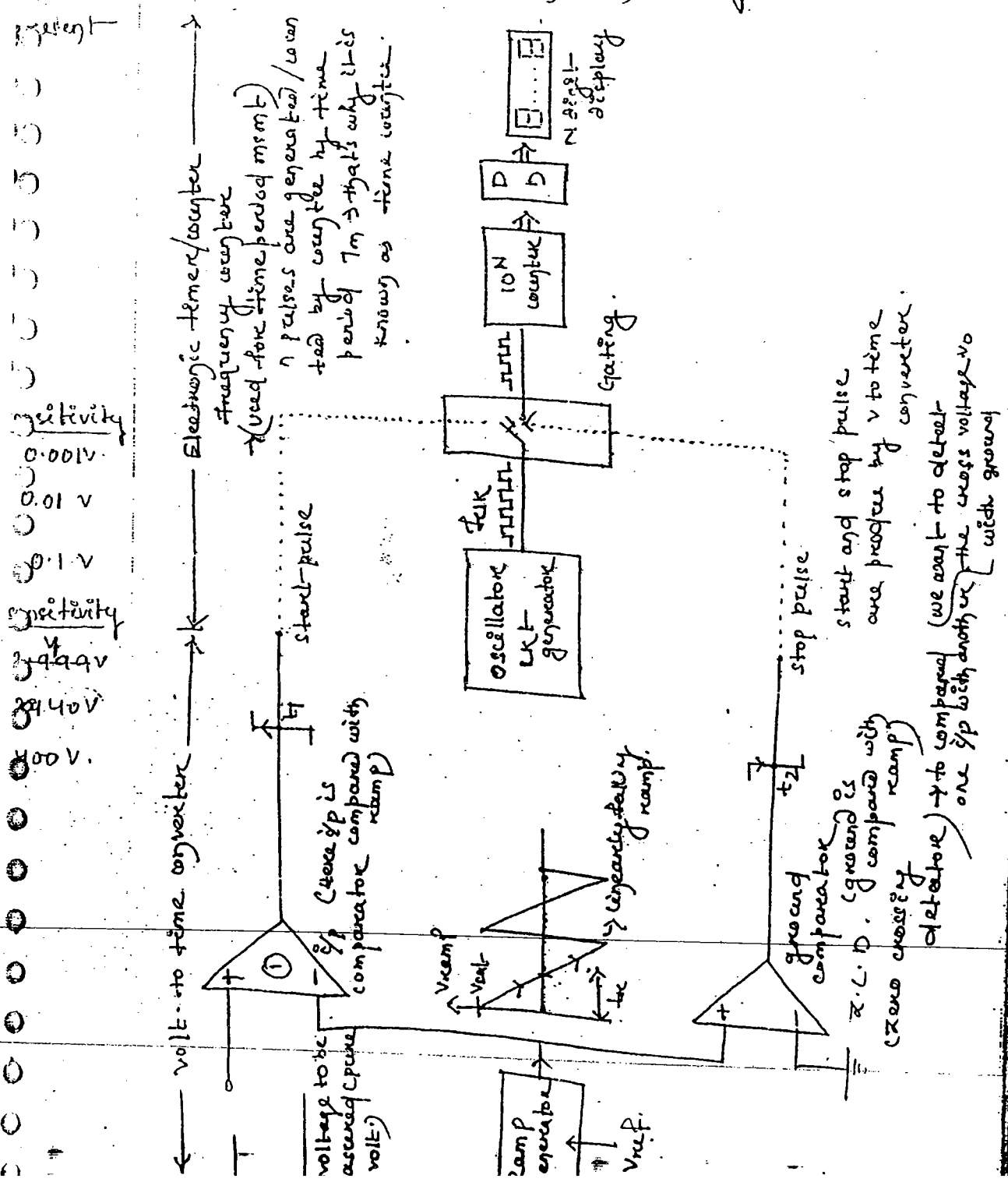
$$= t_2 - t_1$$

$$= t_m$$

$$t_{conv} = n t_{clk}$$

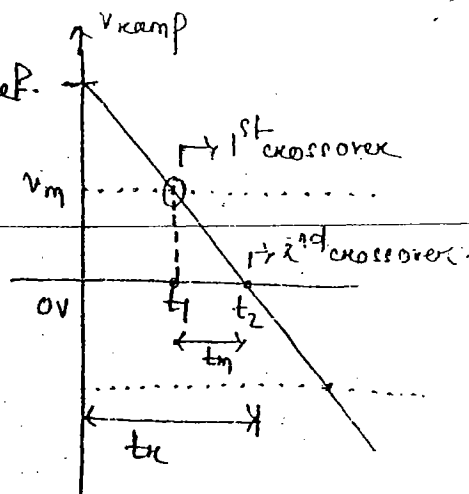
Ramp - Type Digital Voltmeter : (magnitude of voltage converted into time)
 operating principle : voltage to time converter.

This DVM measures the unknown voltage by measuring time taken for a linearly falling ramp voltage, to fall from level of unknown voltage to zero volt.



→ i/p comparator compare $+V_{ref}$ ramp with V_m until ramp voltage is coincide with

V_m unknown volt. when ramp volt. cross the unknown volt. is known as 1st cross over at time t_1 . After t_1 the ramp voltage is less than V_m and become zero.



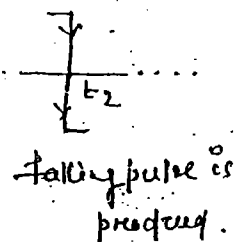
So

$0 \text{ to } t_1 \rightarrow V_{ramp} > V_m$	(-)	(+)	$\left. \begin{array}{l} \text{ve of o/p to i/p} \\ \text{comparator} \end{array} \right\} \begin{array}{c} \text{rising pulse is produced} \end{array}$
$t = t_1 \rightarrow V_{ramp} = V_m$			
$t > t_1 \rightarrow V_{ramp} < V_m$	(+)	(-)	

→ Again after coincide with 0V at time t_2 it cross the -ve region. This the time at which / point at which this ramp crosses the 0V line is known as 2nd crossover. The time b/w t_1 and t_2 is

the time to be measured

$0 \text{ to } t_2 \rightarrow V_{ramp} > 0V$	(+)	(-)	$\left. \begin{array}{l} \text{of o/p to gnd comparator} \end{array} \right\} \begin{array}{c} \text{falling pulse is produced} \end{array}$
$t_1 = t_2 \rightarrow V_{ramp} = 0V$			
$t_1 > t_2 \rightarrow V_{ramp} < 0V$	(-)	(+)	



$$\frac{V_m}{t_m} = \frac{V_{ref}}{t_r}$$

t_r = time taken by ramp volt. to fall from V_{ref} to 0

t_m = time take by same ramp to fall from V_m to 0.

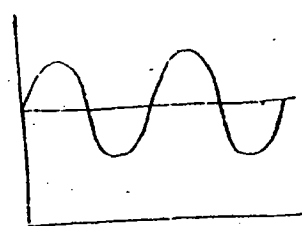
$$t_m = t_r - t_1$$

gating
comparator
pulse

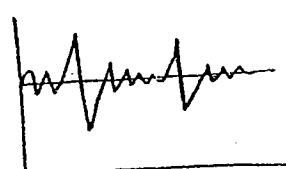
∴ Ramp type DVM (or ADC) has variable conversion time.

$$t_{conv} \propto |V_m|$$

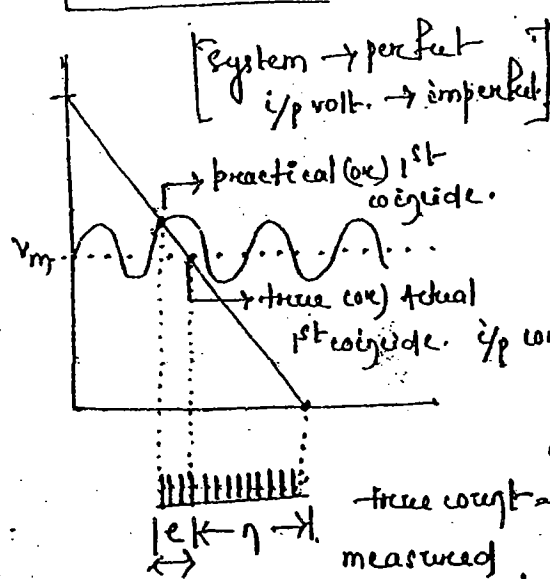
(ii) Stability :



A/c signal is superimposed on DC voltage (\$V_m\$) to be measured



Noise as present on \$V_m\$.



Here the error is itself in the measurement i.e. in the volt. which is given to be measured. So the i/p amplifier doesn't avoid this error and add this error with no. of pulses.

True count = η
 measured count = $\eta + e$
 ↑ error.

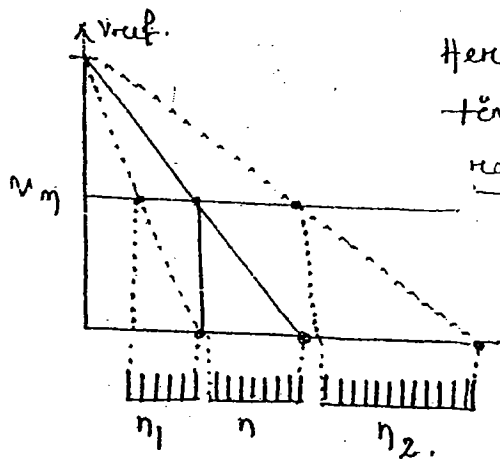
∴ If either AC signal or noise superimposed on DC voltage to be measured then error is introduced into measurement.

Effect of noise on msmt → Highest noise opposition → Lowest

Stability of Ramp type DVM in noisy cond } lowest (proof).

(iii) Measurement Accuracy :-

If R, L, C value are changed due to aging then linearity of the ramp is affected and in turn error will be introduced into measurement.

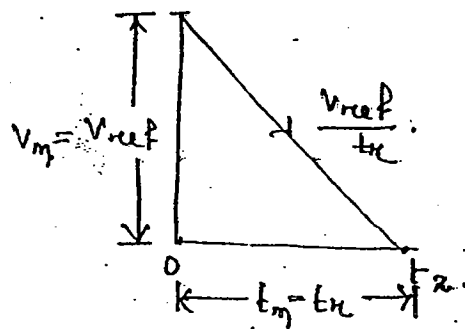


Here the error is due to the time that depend upon the ramp generator (basic error source)

In a single slope if we are getting an error that's why we develop dual slope or ADC.

measurement accuracy of Ramp type DVM } lowest (depending on RLC values)

Note : occurrence of max^m count :-



max^m no. of pulses are counted by Ramp type DVM :

↳ if $V_m = V_{ref}$.

or

↳ if 1st coincidence occurs at $t=0$.

or

↳ if t_m (gating close time) = t_r .

(ii)

94

$$\eta_{max} = ?$$

we know, $V_m = \frac{V_{ref}}{t_n} \times \eta \times t_{clk}$.

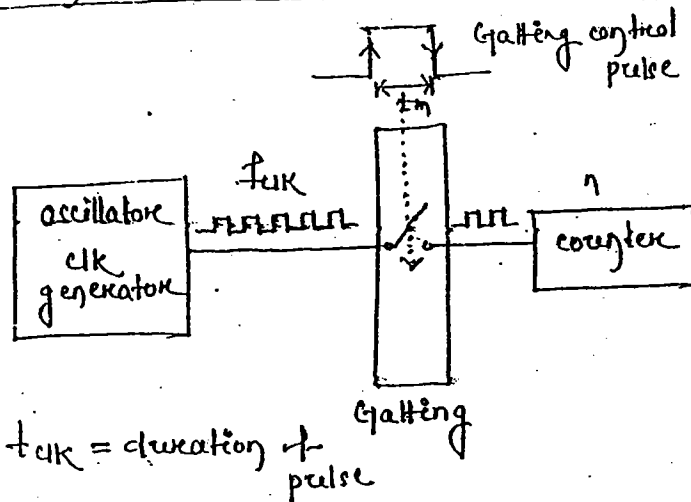
for $\eta_{max} \Rightarrow V_m = V_{ref}$.

$$\therefore V_{ref} = \frac{V_{ref}}{t_n} \times \eta_{max} \times t_{clk}$$

$$\eta_{max} = \frac{t_n}{t_{clk}}$$

Note: A ramp type digital voltmeter is also known as single slope type DVM.

Electronic timer / counter : (Frequency counter)

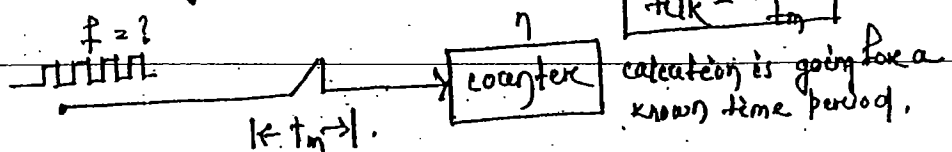


$$t_{clk} = \frac{1}{f_{clk}}$$

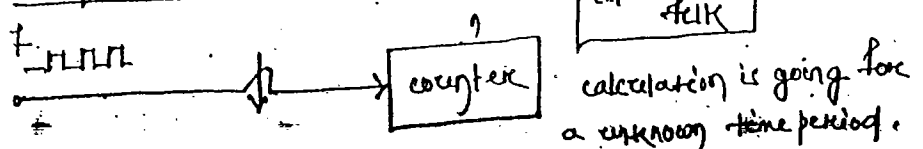
$$t_m = \text{gate closing time} = \eta t_{clk}$$

$$\eta = \text{final count}$$

(i) Frequency measl-



(ii) Time period measl-



Accumulator

Special purpose
register.

Program counter

Special purpose
register. It

is a pointer register
i.e. the pointer is
a ROM pointer.

Integrator :-

$$\hookrightarrow I = \frac{V_{in}}{R}$$

$$\hookrightarrow V_o = -V_c$$

$$V_c = \frac{1}{C} \int_{-\infty}^t i \cdot dt$$

$$V_o = \frac{V_{in}}{R \cdot C} \int_0^t dt \quad \left(\because \text{no initial cond}^n \right)$$

voltage.

$$\text{At } t = t_1$$

$$V_{c1} = \frac{V_{in}}{R \cdot C} (t_1 - 0)$$

$$= \frac{V_{in}}{R \cdot C} (t_1 - 0)$$

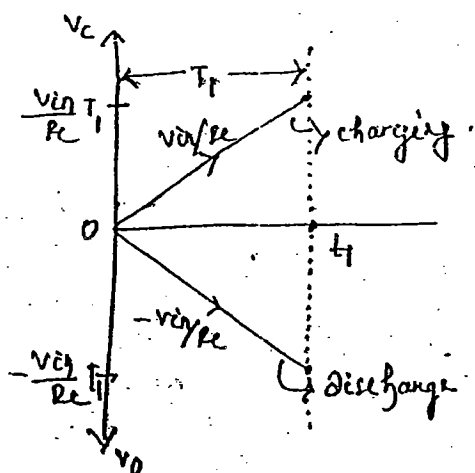
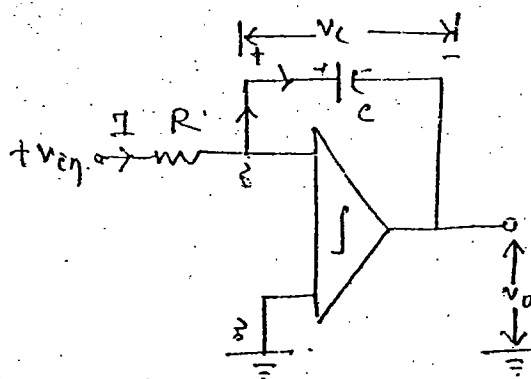
$$V_{c1} = \frac{V_{in}}{R \cdot C} T_1$$

during T_1

$$\hookrightarrow V_o = -\frac{V_{in}}{R \cdot C} \int_0^t dt$$

At T_1

$$V_{o1} = -\frac{V_{in}}{R \cdot C} T_1$$

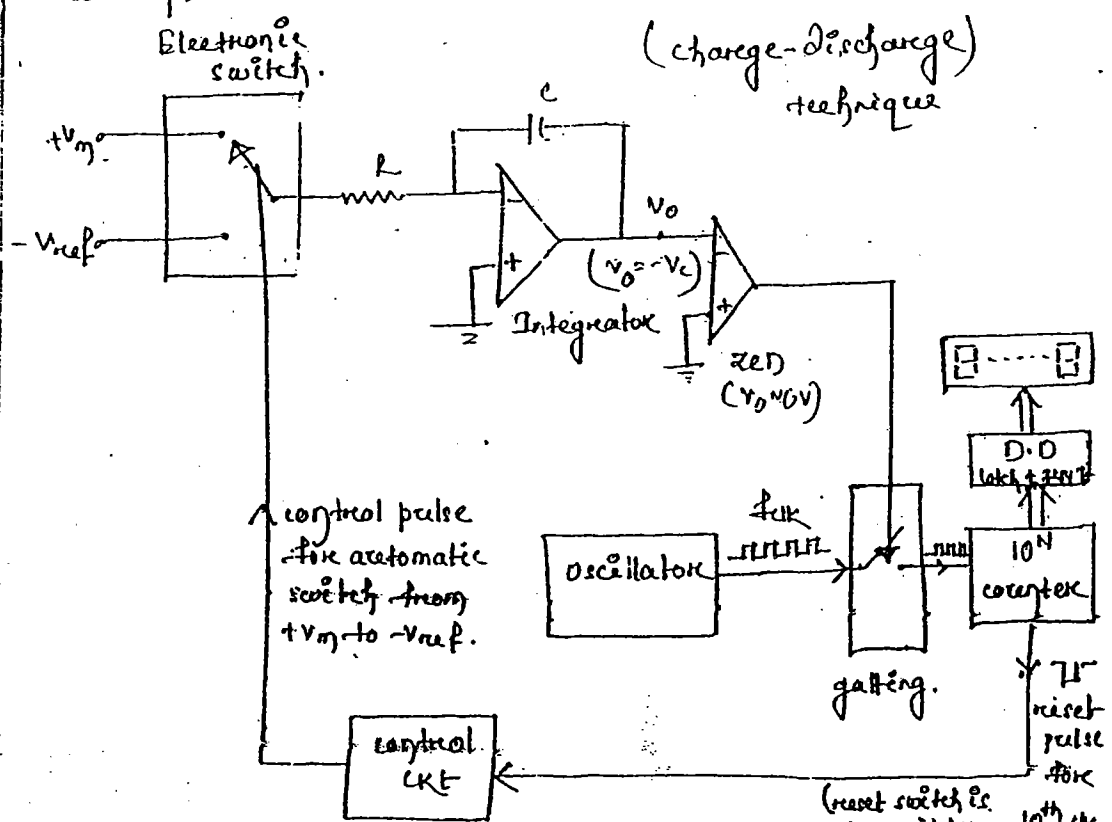


95

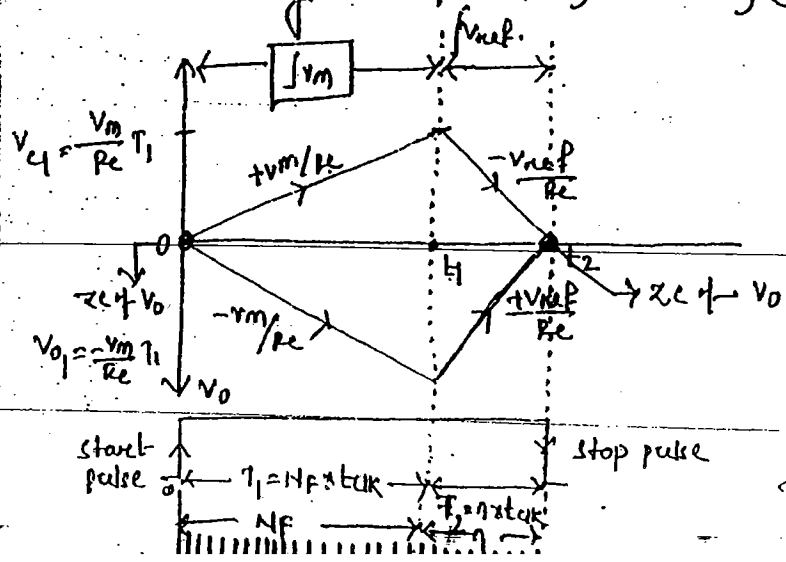
28/10/10

Dual Slope Integrator type DVM :-

dual slope dvm measures the unknown voltage by charging an integrating capacitor, for a fixed time period and then discharging it with a fixed current.



dual slope means first two of slope setting c.e. we are using two phase one is unknown voltage V_m



dual slope dvm give highest detecting time so it is a slow process, but this is the most widely used D.C. in conversion time $\propto t_2 - t_0$

$T_1 = 1^{st}$ integration time period (fixed = maxⁿ rate period counted $\times T_{clk}$).

$T_2 = 2^{nd}$ integration time period (variable)
= de-integration time period $\rightarrow \propto |V_m|$

$$T_2 = n T_{clk}$$

1st slope = $\frac{V_m}{R_c} \Rightarrow$ variable (due to V_m)

charging current = $\frac{V_m}{R} \Rightarrow$ variable.

2nd slope = $\frac{V_{ref}}{R_c} \Rightarrow$ fixed. (Here all the parameters discharging current = $\frac{V_{ref}}{R_c} \Rightarrow$ fixed. are fixed).

During T_1
(V_m is connected as i/p to integrator)
 $V_0 = -\frac{1}{R_c} \int V_m \cdot dt$
 $V_{00} = 0V$ at z.c. (in time to)

$$V_{01} = -\frac{V_m}{R_c} T_1$$

no initial voltage at t_1

$$\therefore V_0 = -\frac{V_m}{R_c} \int_0^{t_1} dt$$

(- ∞ to 0 $\rightarrow$ zero work done so neglected)

During T_2
(V_{ref} is connected as i/p to integrator)
 $V_0 = -\frac{1}{R_c} \int V_{ref} \cdot dt$
 $V_{02} = 0V$ at z.c. (in time t_2)

$$V_0 = +\frac{V_{ref}}{R_c} \int_{t_1}^{t_2} dt + V_{01}$$

$$V_0 = +\frac{V_{ref}}{R_c} (t)_{t_1}^{t_2} - \frac{V_m}{R_c} T_1$$

$$\text{at } t_2, V_{02} = 0V$$

$$0 = \frac{V_{ref}}{R_c} T_2 - \frac{V_m}{R_c} T_1$$

$$\frac{V_m}{R_c} T_1 = \frac{V_{ref}}{R_c} T_2$$

$$\frac{V_m}{R_c} N_f \times T_{clk} = \frac{V_{ref}}{R_c} n \cdot T_{clk}$$

$$\Rightarrow \frac{V_m}{N_f} \quad V_m = \frac{V_{ref}}{N_f} n$$

Here 'n' variable is multiplied with const $K = \frac{V_{ref}}{N_f}$

Measurement accuracy in dual slope dvm is high.

$$V_m T_1 = V_{ref} T_2$$

(i) conversion time :

$$\begin{aligned} t_{conv} &= \text{start to stop} \\ &= 0 \text{ to } t_2 \\ &= t_2 - 0 \\ &= t_1 + t_2 \end{aligned}$$

$$t_{conv} = (N_F + 1) t_{CLK}$$

$\xleftarrow{\text{fixed}}$ $\downarrow$ variable $\xrightarrow{\text{fixed}}$

$$\begin{aligned} N_F &= 10^N - 1 \text{ for } N \text{ digit DVM.} \\ &= 2^N - 1 \text{ for } n \text{ bit ADC.} \end{aligned}$$

$\therefore$ conversion time of dual slope DVM is highest (or) longest.

$$\Rightarrow \text{Slope speed} \propto \frac{1}{t_{conv}}$$

Dual slope DVM is slowest DVM

Measured value :-

In dual slope dvm we get three arg values ^{at i/p} before we integrate the i/p voltage value for a fixed time interval. that's why

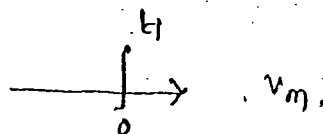
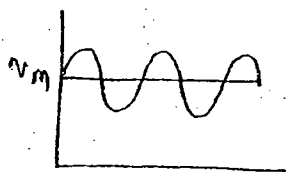
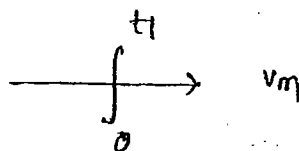
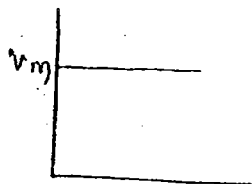
V_m integrated for a long fixed time period,

$$V_0 = \frac{1}{T_1} \int_0^{T_1} V_m dt$$

where $0 \text{ to } T_1 = T_1$

if T_1 are

$T_1, T_2, \dots$ (three arg value of V_m)

(iii) Stability : i_p being measured.msmt
(avg. value of i_p)

If either the signal or noise is present on the voltage to be measured then it'll avg out to be zero, becoz of integration during T_i .

Effect of noise on msmt $\rightarrow$ Lowestnoise rejection $\rightarrow$ Higheststability $\rightarrow$ Highest(iv) Measurement accuracy :

msmt accuracy of dual slope form is highest since there is no dependency on R , C & temp.

Q8/11/10. A digital DVM with 100 mV lowest full scale range have a sensitivity of how much value, the resolution of dvm is 0.0001?

- a) 0.1 mV b) 0.01 mV c) 1.0 mV d) 10 mV

Pb1: The i_p resistance of dvm is 0 of the range of

- a) k Ω b) ohms c) m Ω d) Hundreds of Ω

Pb2: The resolution of a 6 digit dvm is 0.000001

solⁿ-① :

Q5: The sensitivity of a 4 digit digital multimeter in 1V range is 0.0001.

Q6: The min^m voltage that can be read by a $4\frac{1}{2}$ digit DMM is 0.0001 10V range.

Q7: The resolution of a 2-1V 4 digit dual slope DMM is 0.001 (same) to resolution of a 2-2V, $4\frac{1}{2}$ digit dual slope DMM.

Q8: The count range of a 10-V 2-1V, 4 digit dual slope DMM is half of count range of a 2-2V, $4\frac{1}{2}$ digit dual slope DMM.

notes

	N digit DMM	$N\frac{1}{2}$ digit DMM	$N\frac{3}{4}$ digit DMM	$N\frac{5}{6}$ digit DMM
Resolution	$\frac{1}{10^N}$	$\frac{1}{10^N}$	$\frac{1}{10^N}$	$\frac{1}{10^N}$
sensitivity	$\frac{1}{10^N}$	$\frac{1}{10^N}$	$\frac{1}{10^N}$	$\frac{1}{10^N}$
Total states (scale)	10^N	2×10^N	4×10^N	6×10^N
Counter Range	0 to $10^N - 1$ ↑FSR	0 to $2 \times 10^N - 1$ ↑FSR	0 to $4 \times 10^N - 1$ ↑FSR	0 to $6 \times 10^N - 1$ ↑FSR

Eg: 4 digit DMM = 0000 to 9999 = 10,000

$4\frac{1}{2}$ digit DMM = 00000 to 19999 = 20,000

$4\frac{3}{4}$ digit DMM = 00000 to 39999 = 40,000

$5\frac{1}{6}$ digit DMM = 00000 to 59999 = 60,000

Pb: consider the following statement,

The A/D converter used in a digital instrument would be

- a) successive approximation conversion time type. e) dual slope converter (D.S.T) type.
- b) flash conversion type (L.V.T) f) the accuracy sequence by the increasing order of conversion type is 2-1-3.

Pb: A dual slope integrating type D/A has an integrating capacitor of $1 \mu\text{F}$ and a resistor of $100 \text{ K}\Omega$. The reference volt. is 2 V and the op-amp integrator not to exceed 10 V . Then the max. time for which reference volt. can be integrated is

$$C = 0.1 \mu\text{F}$$

$$V_{\text{ref}} = 2 \text{ V}$$

$$R_i = 100 \text{ K}\Omega$$

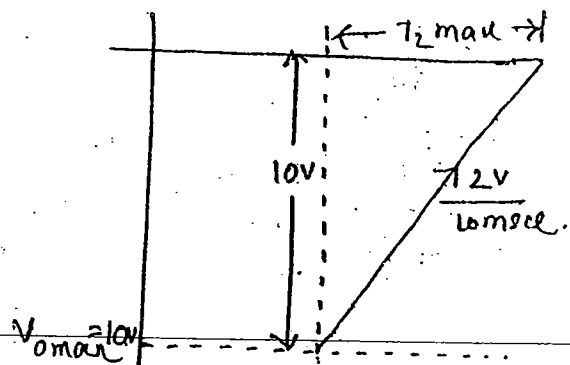
$$V_{0 \text{ max}} = 10 \text{ V}$$

$$R_e = \text{slope}$$

$$\frac{V_{\text{ref}}}{R_e} = \frac{2}{100 \times 10^3 \times \frac{1}{10} \times 10^{-6}}$$

$$= \frac{2}{10 \text{ msec.}}$$

$$\begin{aligned} 2 \text{ V} &\longrightarrow 10 \text{ msec.} \\ 10 \text{ V} &\longrightarrow \frac{10 \text{ V} \times 10 \text{ msec}}{2 \text{ V}} \\ &= 50 \text{ msec.} \end{aligned}$$



1102
3145

pb: The count range of a $4\frac{1}{2}$ digit dvm is from 0 to ? Ans: 19999

~~P.B.C~~ ~~Prob~~ In a digitized voltmeter, the oscillation frequency is 400 kHz. The ramp volt falls from 8 V to 0 V in 20 ms. The maxⁿ no. of pulses that can be counted by this dvm is _____.

Solⁿ ①

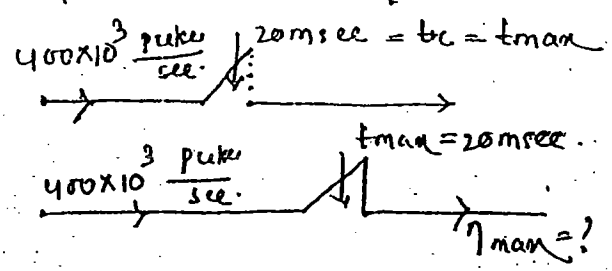
$$\begin{aligned} \text{sensitivity} &= \text{Resolution} \times \text{Range} \\ &= \frac{1}{10^4} \times 100 \text{ mV} \\ &= 0.0001 \times 100 \text{ mV} \\ &= 0.01 \text{ mV} \end{aligned}$$

Solⁿ ②

$$R = \frac{1}{10^6} = 0.000001 \approx 0.$$

Sol: 4:

$$\begin{aligned} \eta_{\text{max}} &= \frac{t_c}{t_{\text{dr}}} = \frac{20 \text{ msec}}{\left(\frac{1}{400 \text{ kHz}}\right)} \\ &= 400 \text{ kHz} \times 20 \text{ msec} \\ &= 8000 \text{ pulses} \end{aligned}$$



$$\begin{aligned} 1 \text{ sec} &\rightarrow 400 \times 10^3 \text{ pulses} \\ 20 \text{ msec} &\rightarrow 20 \text{ msec} \times 400 \times 10^3 \frac{\text{pulses}}{\text{sec}} \end{aligned}$$

pb: The maxⁿ voltage that can be measured by 4 digit dvm is 99.99 V in 100 V range.

pb: A 0-2 V, $4\frac{1}{2}$ digit dual slope integrating dvm can measure up to 1.999 V.

Pb: Full scale voltage of a $4\frac{3}{4}$ digit DVM in 1V range of operation 3.9999V ;

Pb: Resolution of DVM is a funcⁿ of digits

Pb: Overranging in DVM implies _____

a) All full digit are changed on

b) $\frac{1}{2}$ digit is switched off

b) $\frac{1}{2}$ digit is switched on

c) All full digit are changed off

Pb: In a dual slope integrating type DVM, the 1st integration is carried out for 10 periods of supply frequency of 50 Hz. The reference volt is 2V. Then total conversion time for 1V voltage of 1V is _____?

Solⁿ:

$$V_m = 1V$$

$$V_{ref} = 2V$$

$$f_s = 50 \text{ Hz} \Rightarrow \frac{1}{50} = T_1$$

$$T_1 = 10 \times \frac{1}{50} = \frac{1}{5}$$

$$V_m T_1 = V_{ref} T_2$$

$$\frac{1}{5} \times 1 = 2 \times T_2$$

$$2) \frac{1}{5} \times \frac{1}{2} = T_2$$

$$3) \frac{1}{10} = T_2$$

$$T_2 = T_1 + T_2 = \frac{1}{10} + \frac{1}{5} = \frac{1+2}{10} = \frac{3}{10} \text{ sec.}$$

Eg

Pb: A frequency of

of 10 msec counts 1254 cycles of an i/p square wave. Then frequency of the i/p wave is 99

$$t_m = n \cdot t_{clk}$$

$$t_m = \frac{n}{f_{clk}}$$

$$f_{clk} = \frac{n}{t_m} = \frac{1254}{50} = 25.08 \text{ KHz}$$

Pb: Pulses from the source of frequency 100 KHz pass through the counter of a digital multimeter during a gate period of 7.75 msec. Then the no. of pulses counted by counter will be _____

$$f_s = 100 \text{ KHz}, t_m = 7.75 \text{ msec}$$

$$t_m = n \cdot t_{clk}$$

$$n = \frac{t_m \cdot f_s}{1} = \frac{7.75}{100} = 775 \text{ pulses}$$

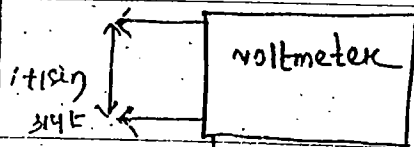
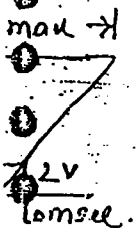
Pb: A dual slope A/D uses a 7 bit counter. when the i/p signal var is being integrated, the counter allow to count upto a value upto $2^N - 1$

Pb: A three and half digit, 2V full scale dual slope ADC has an i/p as $1 + 1.593141 \text{ V}$. Then the o/p of this ADC will be _____

a) 1.999V c) 0.001

b) 1.000V d) 0.707

3 1/2 (2)



→ A DC voltmeter --- $V_{DC} = 1V$
 → 0-10V moving iron --- $V_{rms} = \sqrt{1^2 + (\frac{1}{\sqrt{2}})^2} V$
 → 0-20V, 3 1/2 digit --- $V_n = 1V$

to 5 counts. When the meter reads 100 mV, the value being measured is _____

a) Any value b/w 99.5 mV & 100.5 mV c) Exactly 99.5 mV

b) Any value b/w 99.0 mV & 101.0 mV d) Exactly 100 mV

$$\Delta_{\text{rev}} = 200 \text{ mV}$$

$$\Delta = \pm 0.5 + 5 \text{ counts}$$

$$V_m = 100 \text{ mV}$$

1/2 digit

1 count

(2 mV) 1 mV range $\rightarrow 0.001 \text{ mV}$

(20 mV) 10 mV range $\rightarrow 0.01 \text{ mV}$

(200 mV) 100 mV range $\rightarrow 0.1 \text{ mV}$

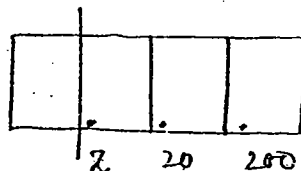
range $\Delta = \pm 0.5\%$ of reading plus 5 counts

$$\text{range} = \pm \left[\frac{0.5}{100} \times 100 \text{ mV} + 5 \times 0.1 \text{ mV} \right]$$

$$\text{range} = \pm [1 \text{ mV}]$$

$$\Rightarrow 100 \text{ mV} \pm 1 \text{ mV}$$

$$99.0 \text{ mV to } 101.0 \text{ mV} //$$



Pb: A galvanometer (dc ammeter) with internal resistance of 100Ω and full scale current of 1 mA is used to realize a dc voltmeter with full scale range of 1 V . The full scale range of this voltmeter can be extended to 10 V by connecting

~~100~~

100

an internal resistance of value

✓ 9.1 K Ω c) 10 K Ω ✓ 9.9 K Ω d) 11 K Ω

$$R_i = 100 \text{ K}\Omega$$

0-1V DC voltmeter $\leftarrow$ 0-1 mA, 100 Ω

$$I = 1 \text{ mA}$$

$$V_{fsv} = 1 \text{ V}$$

$$9 \text{ K}\Omega \downarrow$$

0-10V DC voltmeter $\leftarrow$

$$R_{se} = \frac{1 \text{ V} - 100 \Omega \times 1 \text{ mA}}{1 \text{ mA}} = 0.9 \text{ K}\Omega$$

$$R_{se} = \frac{10 \text{ V} - 100 \Omega \times 1 \text{ mA}}{1 \text{ mA}} = 9.9 \text{ K}\Omega$$

PB: A 2Amp full scale DMMC type DC ammeter

has a volt drop of 100 mV at 2 mA, the meter can be converted into a 10 Amp full scale DC amp.

by connecting a

50 Ω : 2A $\xrightarrow{\times 5}$ multiplying factor $\rightarrow$ 10A

at fs. volt. drop is 100 mV $\downarrow$ $R_{sh} = ?$

$$= \frac{R_m}{m-1}$$

$$\therefore R_m = \frac{100 \text{ mV}}{2 \text{ A}} = 50 \text{ m}\Omega$$

$$\therefore R_{sh} = \frac{50 \text{ m}\Omega}{4} = 12.5 \text{ m}\Omega \quad (\text{so it is connected in parallel with the ammeter})$$

resistance

Advantages of digital voltmeter over analog voltmeter

(i) DVM offers very high i/p resistance in the range of M Ω .

adv: As such loading under the x/t under test become negligible.

(ii) Dvm gives / offers superior (to analog) resolution, $1:10^6$.

(iii) Dvm offers better accuracy

(iv) Dvms are compact in size and hence portable.

(v) O/p of Dvm is available in digital form,

adv: as such reading speed of the user increases;

adv: such digital o/p can further be processed we can store it.

adv: Reading error like parallax error can be eliminated.

IES

Pb: Identified the wrong statement from the below given regarding DVM.

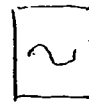
a) They offer better accuracy.

b) They can present a value in their full extent of range

c) Reading errors are justified while using DVM.

d) They offer superior resolution.

KK [no dvm can present its in full scale division value]



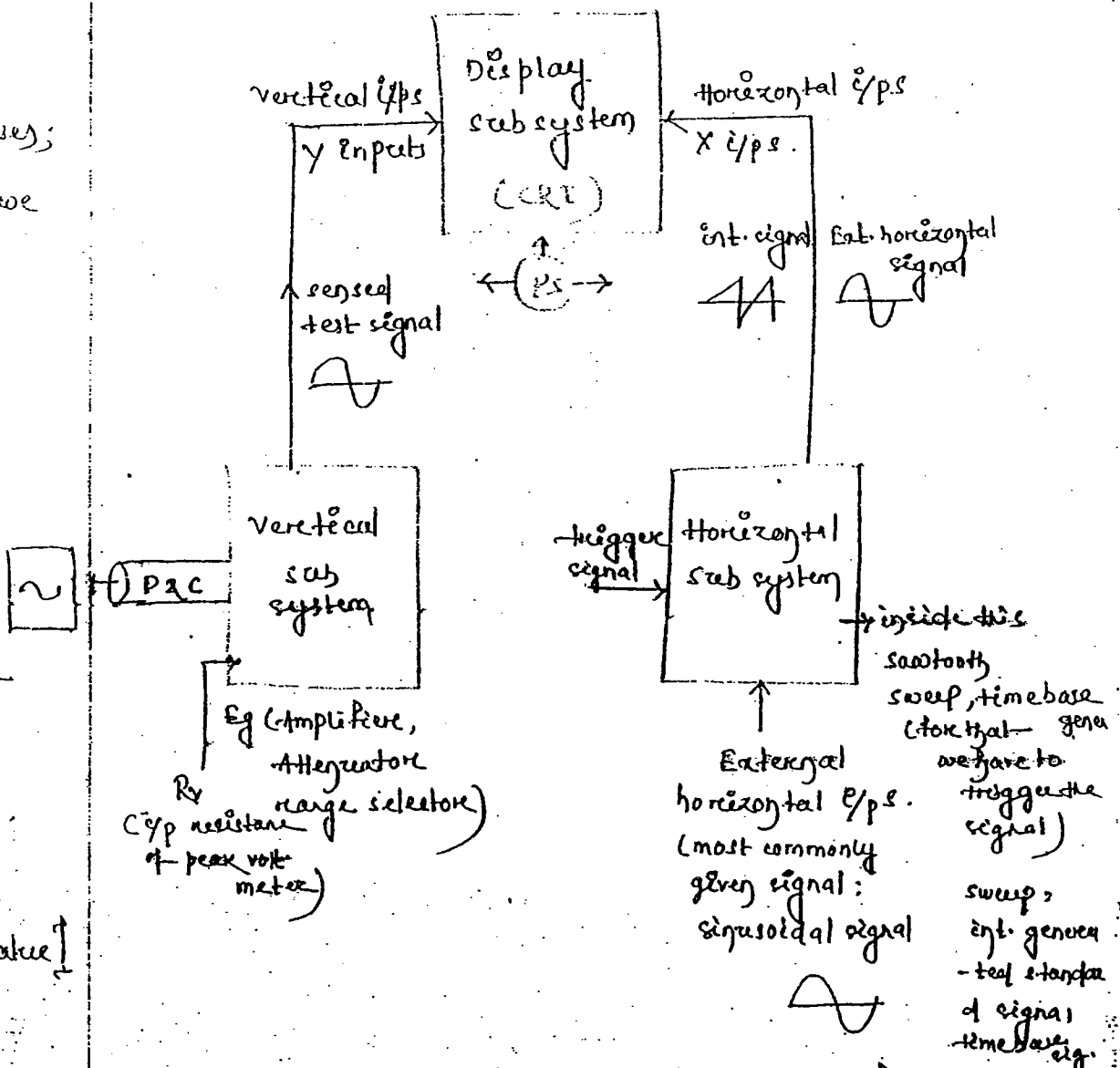
11) DVM

Cyp

ber

CRO

A CRO is an Electronic peak voltmeter which works for both a/c and dc i/p signal.



internally generated signal is known as reference signal because it is the signal which we want to be examined. we sense the signal by the help of probe is transmitted to vertical subsystem and o/p of vertical subsystem is known as sensed test signal.

CRO is an image plotter

↳ Y-t plot

↳ X-y plot

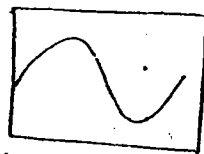
Y-t plot :-

Y = sensed test signal (is nothing but amplitude w.r.t. reference variation) signal.

t = reference signal.

Y-t plot means : Amplitude variation of sensed test signal displayed w.r.t time is a Y-t plot i.e., test signal displayed on screen.

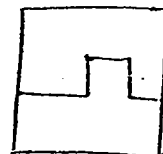
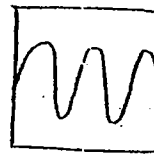
Eg:



(more than 1 cycle)

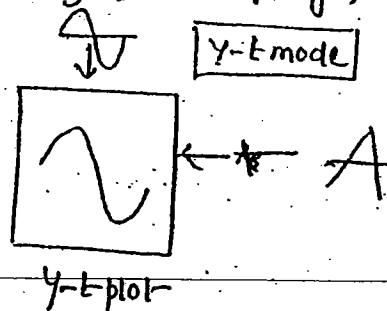


(more than one cycle)



(not only sinusoidal signal)

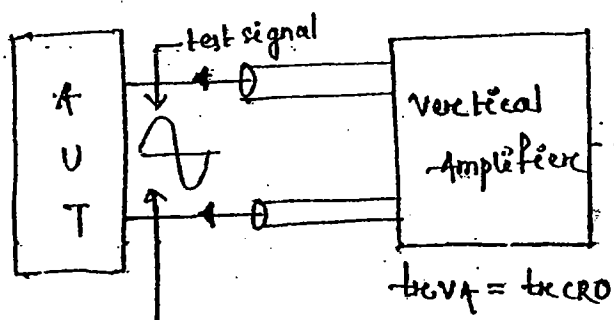
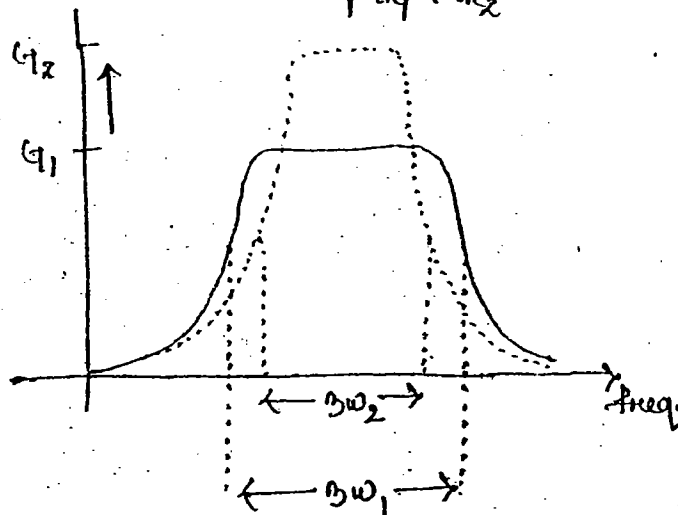
↳ A Y-t plot is produced on the screen when Y i/p's are driven with sensed test signal & X i/p's are driven with internally generated sawtooth.



↳ measurements using Y-t plot :

(i) measmt of peak-to-peak volt of signal (V_{pp})

$$\begin{aligned} \rightarrow \text{overall gain} &= G_1 \times G_2 \\ \rightarrow \text{overall rise time} &= \sqrt{t_{r1}^2 + t_{r2}^2} \\ \rightarrow \text{overall B.W.} &= \frac{0.35}{\sqrt{t_{r1}^2 + t_{r2}^2}} \end{aligned}$$



Actual (or)
true rise
time of signal = 2

At screen
measured = 20 ns
rise time
= overall rise
time

$$t_{rVA} = t_{rCRO} = 15 \text{ ns}$$

$$\text{measured rise time} = \sqrt{t_{rA}^2 + t_{rVA}^2}$$

$$\text{So } 20 \text{ ns} = \sqrt{t_{rA}^2 + (15 \text{ ns})^2}$$

$$2) \quad t_{rA} = \sqrt{(20 \text{ ns})^2 - (15 \text{ ns})^2}$$

$$t_{rA} = 13.28 \text{ ns}$$

$$\left. \begin{aligned} \text{B.W. of CRO} &= \text{B.W. of V.T.} \\ \text{Rise time of CRO} &= \text{Rise time of V.T.} \end{aligned} \right\} \text{Frequency range of operation.}$$

Primary stage of V.T. consist of a FET.

∴ I/p resistance of CRO is in MΩ which causes less on AVT (amp. under test)

Pb: If the B.W. of an oscilloscope is driven as 0-10 MHz. what is the fastest rise time a sigwave can have to be produce accurately by the oscilloscope.

Pb: The B.W. of CRO is from 0-20 MHz. The fastest rise time which a square wave can have in order that it is accurately reproduced by 'CRO'.

Amplifier

$$\rightarrow \text{B.W.} \times \text{rise time} = 0.35$$

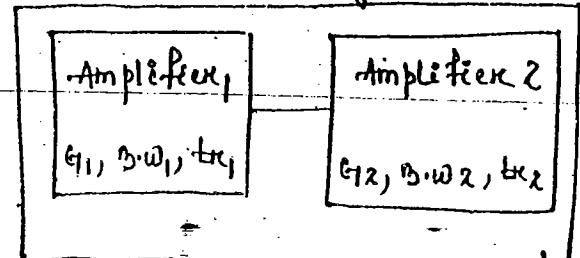
$$\rightarrow \text{Gain} \times \text{B.W.} = \text{const.}$$

Solⁿ: $\Rightarrow \frac{10 \times 10^6}{0.35} = \text{rise time}$

$\Rightarrow \text{rise time} = \frac{0.35}{10 \times 10^6} = 35 \text{ nsec.}$

Solⁿ: $\Rightarrow \text{rise time} = \frac{0.35}{20 \times 10^6} = 17.5 \text{ nsec.}$

Pb: A CRO with a rise time of 15 nsec. measures the rise time of a signal as 20 nsec. Then the actual rise time of signal is _____



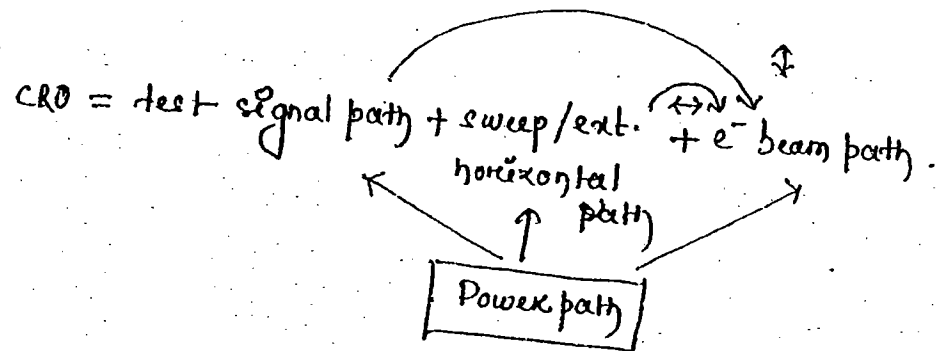
$$\rightarrow \text{Gain} \times \text{B.W.} = K$$

$$\rightarrow tr \times \text{B.W.} = 0.35$$

11/11/10

103

A vertical subsystem drives the



- ↳ A vertical subsystem provides a path for test-signal to reach vertical deflecting plate.
- ↳ The horizontal subsystem provides a path either for internally generated sweep or for externally applied horizontal signal to reach horizontal deflecting plate.
- ↳ A display subsystem provides a path for an e^- beam to reach its target (screen)
- ↳ The test signal is sensed using probe ϵ_p of the oscilloscope and transmitted to vertical ϵ_p terminal via a cable.
- ↳ By adjusting $\frac{\text{Voll}}{\text{DIV}}$ control (sensitivity control), the user can offer either attenuation or amplification.
- ↳ If both the top plate and bottom plate are to be driven with voltages, then only there is a need for vertical main amplifier in push pull configuration otherwise it's required.
- ↳ ϵ_p resistance of CRO = ϵ_p resistance of V.A. }

both
 when the vertical plates having same voltage then there is no need of push pull amp. it is required to give same peak amp. of both of plates. but in case of opposite phase volt. we need n.b. require any push pull amp. (i.e. the bottom & R plate).
 gain, rise, time of cto is nothing but the gain rise time of v.t.
 In cto the i/p resistance is less than 50m.

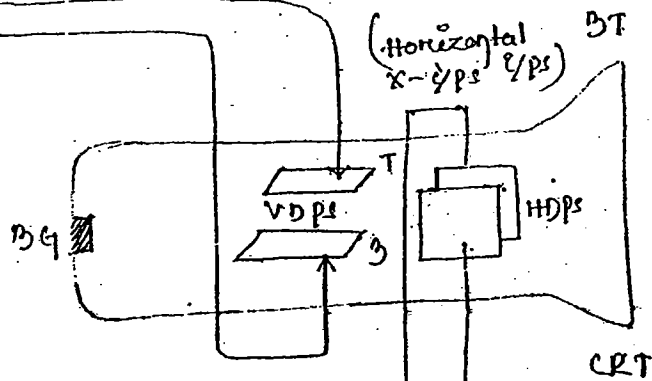
also mod

or be

Delay line

(vertical i/ps)
 $Y-i/ps$

(Horizontal i/ps)
 $X-i/ps$



trigg. signal

trigg. plus

TIME DIV

sawtooth signal

trigg. signal
 or
 pulse generator

Time Base generator
 (sweep gen.)

Y-t mode

X-y mode

External Horizontal i/p.s.

Horiz. Pre Amp.

Horiz. main Amp.

(trigg. setting voltage level, slope)

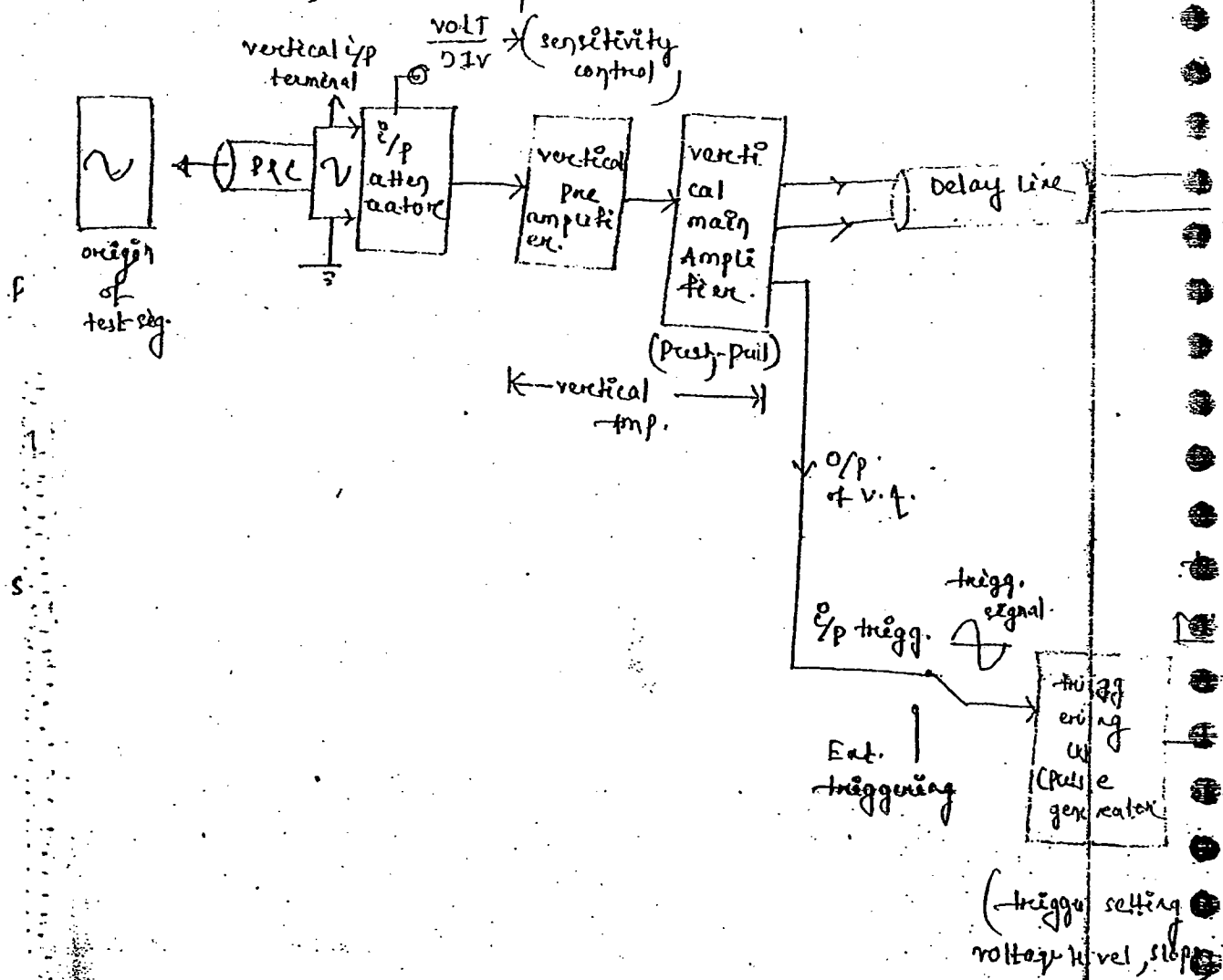
(sawtooth generator) (time base control)

Horizontal Amplifier

Measurements using C.F.S.

- (i) measmt of frequency
- (ii) measmt of phase.

Note : Using a special technique known as x -axis mod or intensity modulation a x, y, z plot can be produce on the screen.



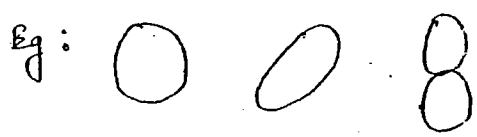
- (i) msmt of Amplitude of signal (V_p)
- (ii) msmt of dc value & rms value of signal (V_{avg} , V_{rms})
- (iii) msmt of time period of signal (T)
- (iv) msmt of frequency of signal (f)
- (v) msmt of rise time, fall time etc.

② X-Y plot :-

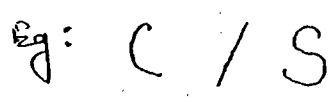
X-Y plot is nothing but a "Lissajous figure/pattern"

There are 3 types of Lissajous figure :-

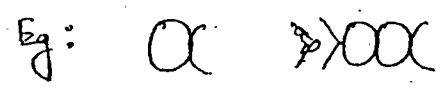
(i) closed loop L.Fs : (there is no breaking the figure)
/no free arms



(ii) Open loop L.Fs : (It has free arms)

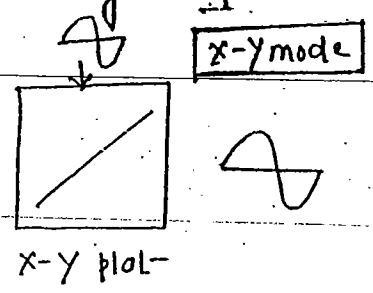


(iii) Mixed/Hybrid L.Fs : (one closed loop followed by an open loop)



4 A X-Y plot is produced when X-Y i/p's are driven with sinusoidal* signal.

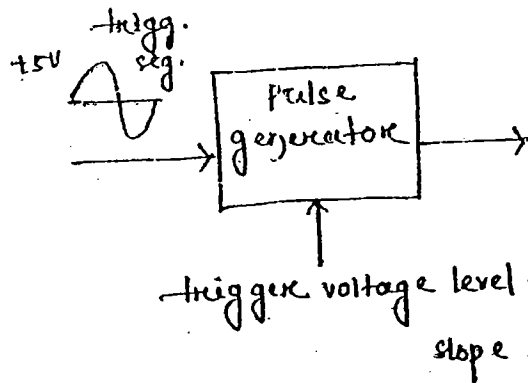
[* $\rightarrow$ it can be both sinusoidal signal or with rectangular or can be a dc signal.]



105

Q10: - which of the following measuring instrument has min^m loading effect on the quantity to be measured.

- a) PMMC b) CRO c) Rectifier inst. d) m.i. inst.

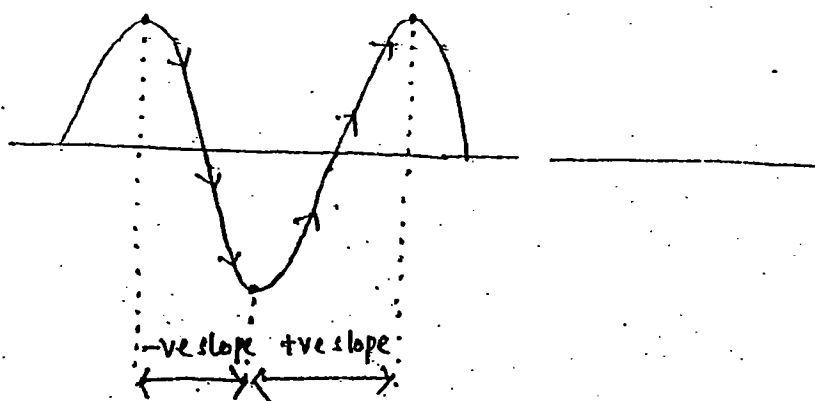


whenever the trigger signal cross the trigger volt. level then only it is going to produce a pulse.

207 sec

Horizontal subsystem :

- ↳ In internal triggering the o/p of the vertical amp. is used as triggering signal, which acts as a stimulus to produce standard sweep.
- ↳ Whenever the triggering signal crosses the preselected voltage level and slope condⁿ. (trigger point) as set by the user, pulse generator produces a trigger pulse.
- ↳ This is a trigger pulses are given to a sawtooth generator, which initiates and runs one cycle of sweep signal for every each one trigger pulse.
- ↳ The sweep frequency can be varied by user by adjusting (time/div) control.



- ↳ trigger volt. level can either be +ve or -ve or 0.
- ↳ trigger slope can either be -ve or +ve.

Eq:

(trig)

Eq:

(ov)

Emitt

trigger

pulse

Pulse

sweep

sweep

sweep

↳ In

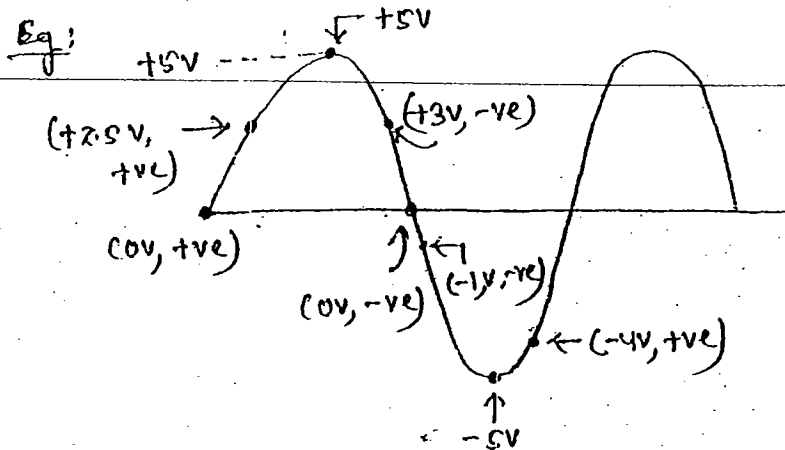
to

on

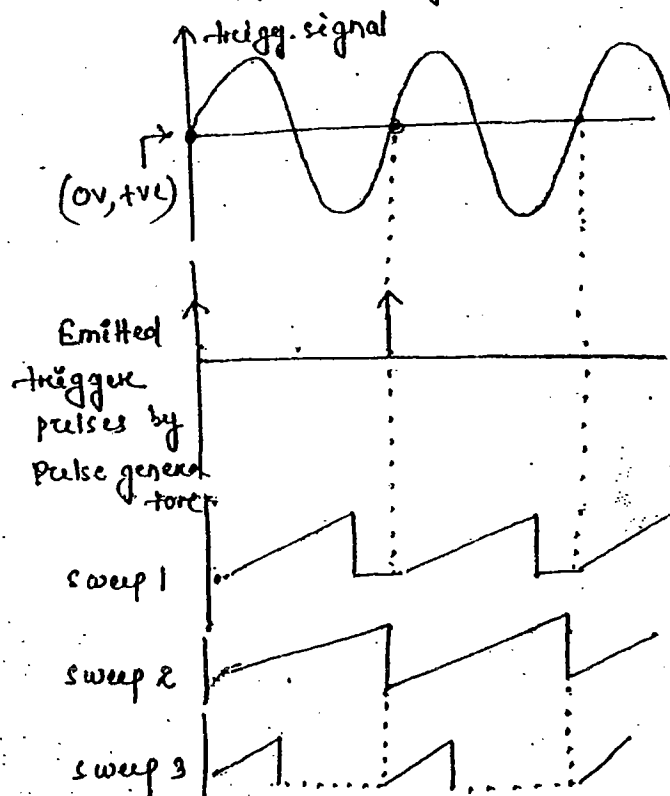
(a)

pl

1106



Eq: triggering signal = $5 \sin 314t - V$
 trigger setting $\rightarrow 0V, +ve$.

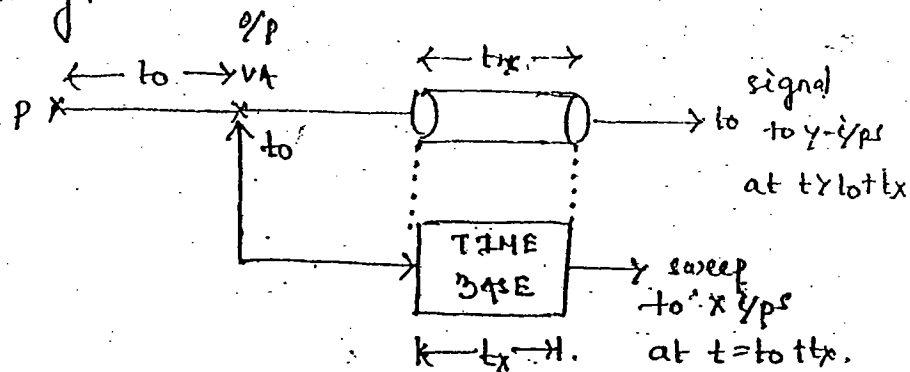


sweep generated by
 time base generator
 with diff. $\frac{\text{Time}}{\text{Div}}$
 control values.

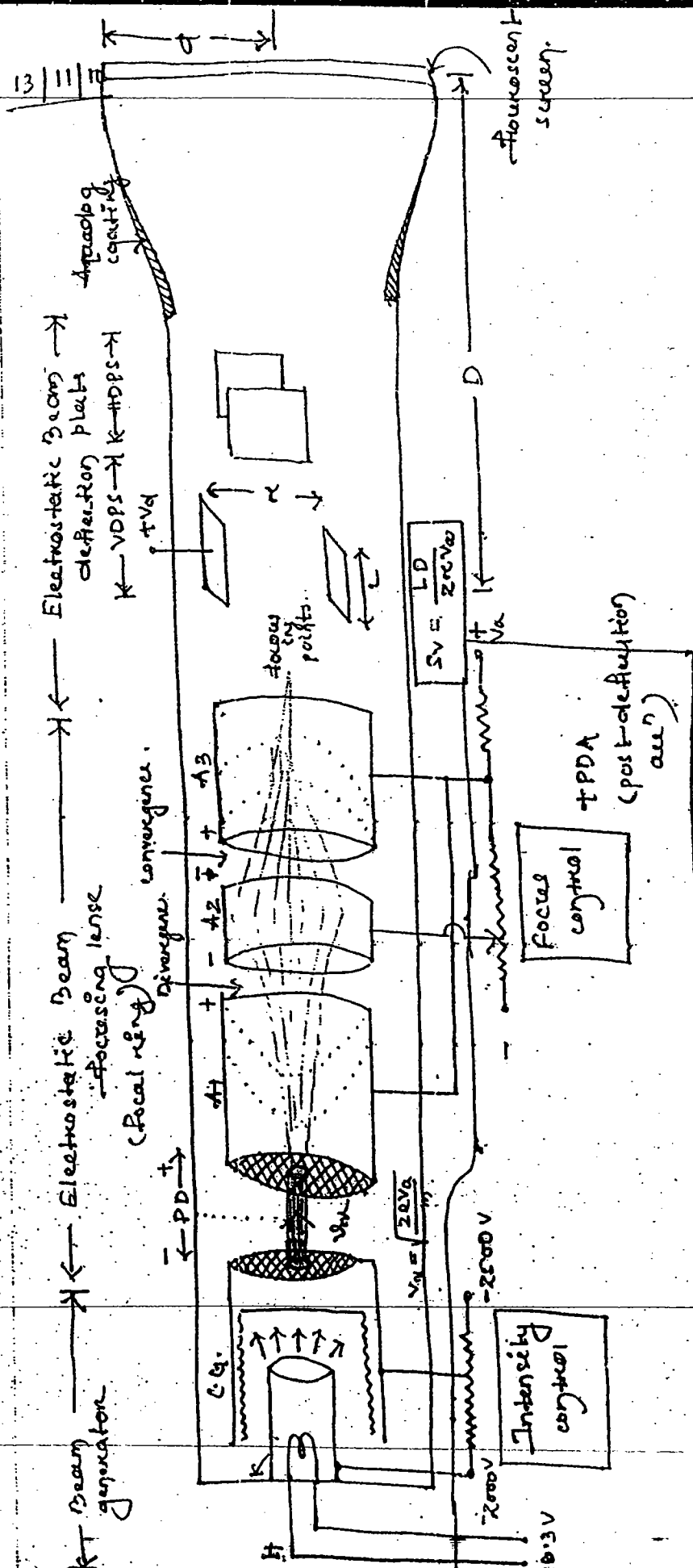
Internally generated/
 In Y-T mode the standard sweep signal is amplified
 to the horizontal deflection mode plate, whereas
 in X-Y mode externally applied horizontal signal
 (any signal) is amplified and driven to horizontal
 plates.

Need for delay line :-

A delay line is purposefully inserted into design b/w o/p of vertical amplifier and y-ips. (vdps) to delay the test signal by time amount slightly greater than time consumed in time base circuitry.

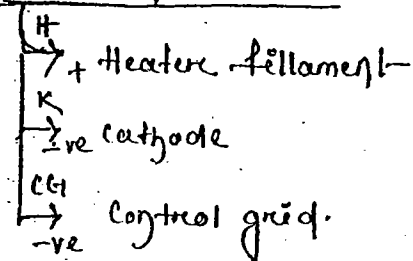


- 1) to
- 2) γ - ϵ/μ
- 3) amount
- 4) base
- 5)
- 6) signal
- 7) γ - ϵ/μ
- 8) γ - ϵ/μ
- 9) γ - ϵ/μ
- 10) γ - ϵ/μ
- 11) γ - ϵ/μ
- 12) γ - ϵ/μ
- 13) γ - ϵ/μ
- 14) γ - ϵ/μ
- 15) γ - ϵ/μ
- 16) γ - ϵ/μ
- 17) γ - ϵ/μ
- 18) γ - ϵ/μ
- 19) γ - ϵ/μ
- 20) γ - ϵ/μ
- 21) γ - ϵ/μ
- 22) γ - ϵ/μ
- 23) γ - ϵ/μ
- 24) γ - ϵ/μ
- 25) γ - ϵ/μ
- 26) γ - ϵ/μ
- 27) γ - ϵ/μ
- 28) γ - ϵ/μ
- 29) γ - ϵ/μ
- 30) γ - ϵ/μ
- 31) γ - ϵ/μ
- 32) γ - ϵ/μ
- 33) γ - ϵ/μ
- 34) γ - ϵ/μ
- 35) γ - ϵ/μ
- 36) γ - ϵ/μ
- 37) γ - ϵ/μ
- 38) γ - ϵ/μ
- 39) γ - ϵ/μ
- 40) γ - ϵ/μ
- 41) γ - ϵ/μ
- 42) γ - ϵ/μ
- 43) γ - ϵ/μ
- 44) γ - ϵ/μ
- 45) γ - ϵ/μ
- 46) γ - ϵ/μ
- 47) γ - ϵ/μ
- 48) γ - ϵ/μ
- 49) γ - ϵ/μ
- 50) γ - ϵ/μ
- 51) γ - ϵ/μ
- 52) γ - ϵ/μ
- 53) γ - ϵ/μ
- 54) γ - ϵ/μ
- 55) γ - ϵ/μ
- 56) γ - ϵ/μ
- 57) γ - ϵ/μ
- 58) γ - ϵ/μ
- 59) γ - ϵ/μ
- 60) γ - ϵ/μ
- 61) γ - ϵ/μ
- 62) γ - ϵ/μ
- 63) γ - ϵ/μ
- 64) γ - ϵ/μ
- 65) γ - ϵ/μ
- 66) γ - ϵ/μ
- 67) γ - ϵ/μ
- 68) γ - ϵ/μ
- 69) γ - ϵ/μ
- 70) γ - ϵ/μ
- 71) γ - ϵ/μ
- 72) γ - ϵ/μ
- 73) γ - ϵ/μ
- 74) γ - ϵ/μ
- 75) γ - ϵ/μ
- 76) γ - ϵ/μ
- 77) γ - ϵ/μ
- 78) γ - ϵ/μ
- 79) γ - ϵ/μ
- 80) γ - ϵ/μ
- 81) γ - ϵ/μ
- 82) γ - ϵ/μ
- 83) γ - ϵ/μ
- 84) γ - ϵ/μ
- 85) γ - ϵ/μ
- 86) γ - ϵ/μ
- 87) γ - ϵ/μ
- 88) γ - ϵ/μ
- 89) γ - ϵ/μ
- 90) γ - ϵ/μ
- 91) γ - ϵ/μ
- 92) γ - ϵ/μ
- 93) γ - ϵ/μ
- 94) γ - ϵ/μ
- 95) γ - ϵ/μ
- 96) γ - ϵ/μ
- 97) γ - ϵ/μ
- 98) γ - ϵ/μ
- 99) γ - ϵ/μ
- 100) γ - ϵ/μ



Def: "CRT is an evacuated glass tube with beam generator at one end and beam target at other end."

① Beam Generator



Cathode is a nickel cylinder whose surface is coated with oxide material (for high emission).

- ↳ Control grid is a nickel cup which is coated.
- ↳ When the cathode is indirectly heated by heater filament e^- are evaporated from its metallic surface (thermionic emission).
- ↳ Since grid volt. is -ve the emitted e^- experience a repulsion from the inner cylindrical sidewalls of grid.
- ↳ As such the repelled e^- electrodes try to come out of grid and stream out of pin hole on the other side of grid exactly as a beam.
- ↳ Brightness of image display on the screen will be decided by 3 following factors.
 - (i) Phosphor coating: given inside of fluorescent screen (fixed)
 - (ii) Speed of the e^- beam: with which it strikes the beam (fixed)
 - (iii) no. of e^- in a beam: (no. of e^- in the beam intensity)

of beam (variable)

↳ Brightness of image can be adjusted by user by adjusting grid volt. known as intensity control.

A_1 = Pre accelerating anode.

A_2 = Focusing anode.

② Beam Focusing Lens

— A_1 (1st accelerating anode)

— A_2 (focusing anode)

— A_3 (2nd accelerating anode)

↳ ' A_1 ' and ' A_3 ' are applied with a typical potential ' V_a '

V_a = accelerating anode voltage. (+ve, fixed)

A_2 is applied with +ve, fixed high, variable -ve potential.

↳ Due to different potentials applied to A_1, A_2, A_3 equipotential surface are set up in the lens.

↳ Whenever an e^- crosses equipotential surface, it experiences a force that changes its direction of travel, but not speed.

↳ It change the direction of the beam.

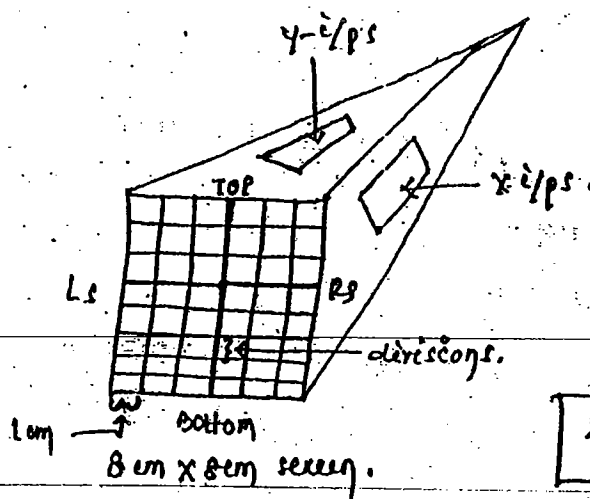
↳ Due to high potential difference, A_1 and A_3 , the e^- beam is attracted and accelerate towards

A_1 and enters into lens via the pinhole of lens. A_1 with the velocity ' v_a '.

4) The velocity with which the beam enters the lens
will be the velocity with which the beam leaves the
ret. lens. This is known as narrowing the e⁻ beam
or sharpening or focusing beam.

Horizontally
mounted plate
diffuser - e-beam
vertically (up-down)
(vops)

vertically
mounted plates
which deflect e-
beam horizontally (left-right)
(H.D.P.C.)



$$\boxed{S = \frac{d}{v_d}} \quad \frac{dv}{v \text{ (Hz)}}$$

Δ = amt of vertical deflection.
 Δ & deflection vertical equal.

① Bugi

4

मं

4

10

Deflection Sensitivity :-

It is represented as 's'

$$s = \text{Deflection per unit voltage}$$

s = amount of distance travelled by e^- beam per unit voltage

$$\text{units : } \frac{\text{cm}}{\text{volt}} \text{ (or) } \frac{\text{divs}}{\text{volt}}$$

$$\text{sensitivity} = \frac{\text{Deflection}}{\text{voltage}}$$

Deflection Factor :

$D_f = \text{reciprocal of sensitivity}$

$$D_f = \frac{1}{s}$$

$$\text{units : } \frac{\text{volts}}{\text{cm}} \text{ (or) } \frac{\text{volts}}{\text{div}}$$

2 sensitivities

↳ vertical deflection sensitivity, $S_v = \frac{y}{V_y}$

↳ horizontal deflection sensitivity, $S_H = \frac{x}{V_x}$

Design Issue : High sensitivity which can suggest low deflection factor.

① Beam Target

↳ A fluorescent screen coated inside with phosphor material is the target for e^- beam.

↳ When the beam strikes the screen visible light is produced due to phosphor excitation.

↳ Fluorescence is the property of emitting light when beam strikes.

↳ Phosphorescence is the property of emitting light even after beam is turned off.

↳ The time taken / exact period for which phosphorescence exist is called as persistence of phosphores.

Need for
PD ↑ :

$$S_v = \frac{LD}{2s v_a} \quad (s=r)$$

(↑ speed = S_v = vertical deflecting plate.

↑ brightness) L = length of each vdp

D = Distance b/w vdps and screen.

$s = r$ = separation distance b/w both vdps.

v_a = accelerating anode volt.

To obtain high S_v :

$S_v \propto L \Rightarrow$ vdps must be longer plates.

$\uparrow S_v \propto D \uparrow \Rightarrow$ vdps must be kept away from screen

$\uparrow S_v \propto \frac{1}{s} \downarrow \Rightarrow$ vdps must be closely spaced to anode.

$\uparrow S_v \propto \frac{1}{v_a} \downarrow \Rightarrow$ accelerating anode volt. must be kept low.

$$\downarrow v_a \propto \sqrt{v_a} \downarrow$$

↳ If ' v_a ' is kept low, then speed of ' v_a ' will be low.

Since $v_a \propto \sqrt{v_a}$, but the slowly moving e⁻ beam gives rise to high sensitivity.

110

1. when

right

dispho

→ whereas once the beam crosses deflection plates assembly. It will be accelerated once again by a very high +ve volt. attached to the screen, known as 'PDA'.

→ e⁻ beam is accelerated twice

- 1st time, prior to focusing due to 'A'
- 2nd time, post to deflection due to PDA.

→ 'A' is known as 1st accelerating anode (or)

Pre accelerating anode.

→ 'PDA' is known as 2nd accelerating anode. (or)

Post deflection accelerating anode.

Deflection & X inputs to CRO :-

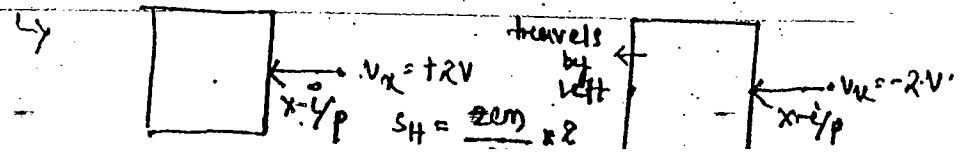
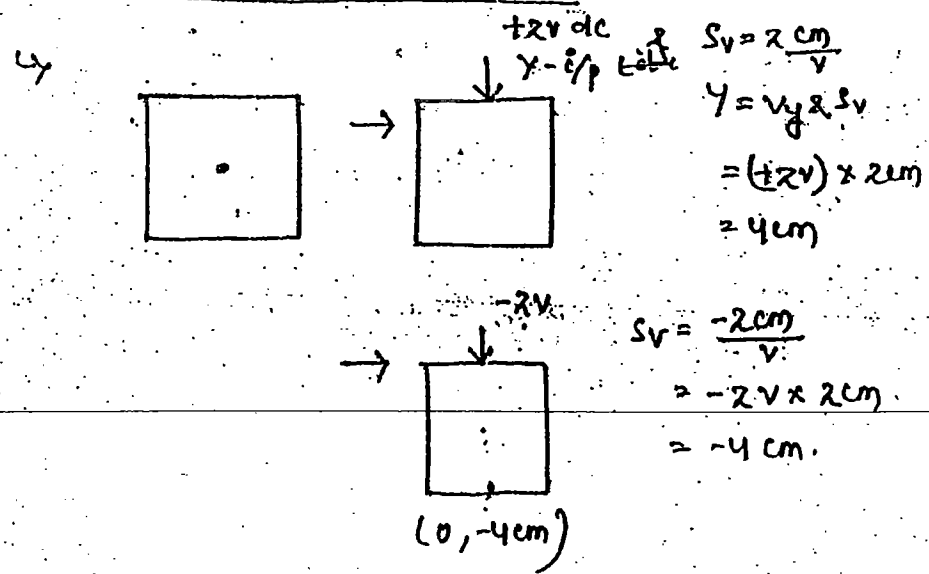
from screen

to area

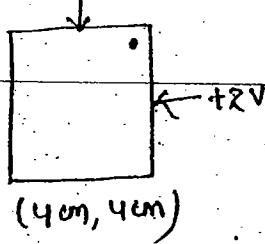
it be low.

low.

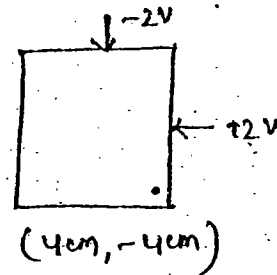
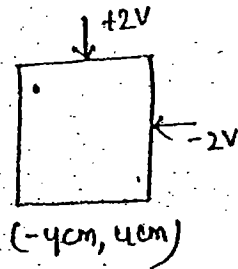
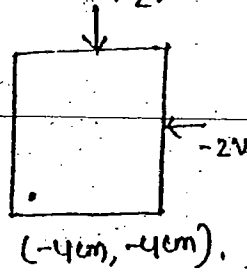
beam



1st move right-
then up



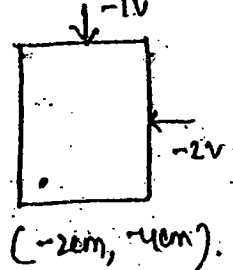
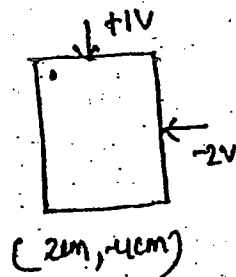
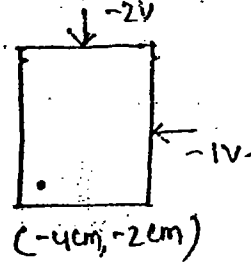
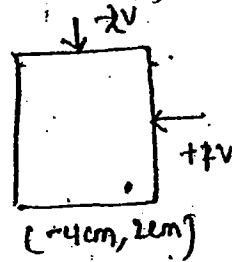
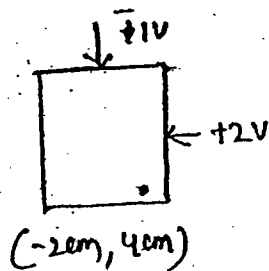
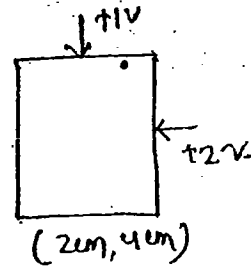
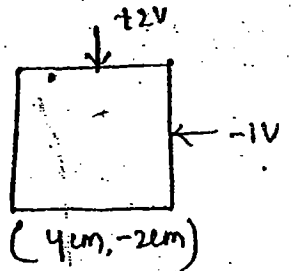
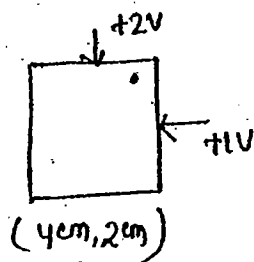
1st move down then
left



1st move up
then left

1st move down
then right

Eg:



The
the

Horiz
n+el
vne

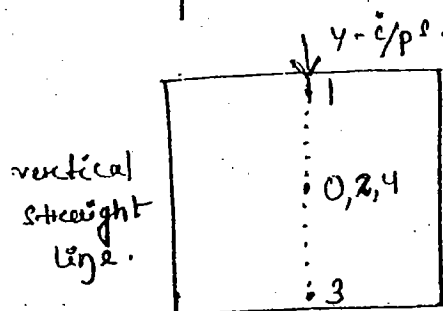
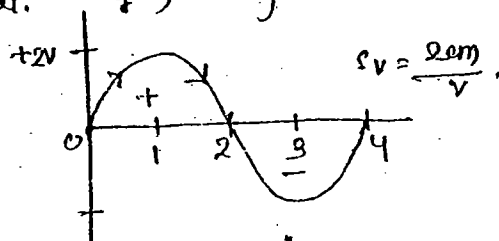
is

15/10/10

Sinusoidal signal applied to y input :-

→ required test signal. $V_y(t) = 2 \sin 314t \text{ V}$

The y-T plot is getting built the signal in the screen.

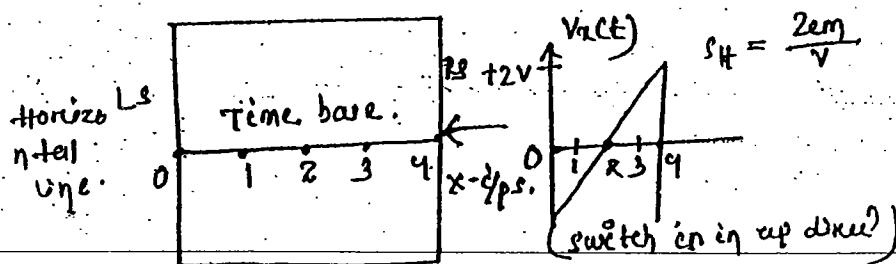


t	$V_y \xrightarrow{\times S_v} y$
0	0 → 0
1	$2V \rightarrow +4 \text{ cm}$
2	0 → 0
3	$-2V \rightarrow -4 \text{ cm}$
4	0 → 0

Saw tooth signal applied to x-i/p.s :-

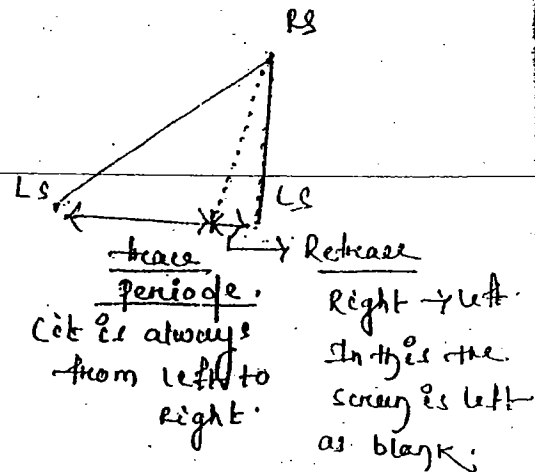
→ standard, int. generated sweep signal.

This i/p is an alternating sweep signal becoz it is going to



this is an free running sweep. This free running sweep is generated by trigger pulse.

t	V_m	$\times S_H \rightarrow u$
0	-2V	$\rightarrow -4\text{cm}$
1	-1V	$\rightarrow -2\text{cm}$
2	0V	$\rightarrow 0$
3	+1V	$\rightarrow +2\text{cm}$
4	+2V	$\rightarrow +4\text{cm}$

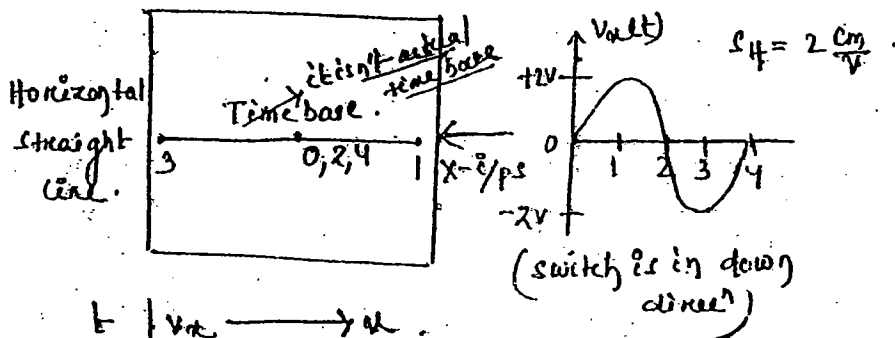


This horizontal line is nothing but the beam that moving from left to right one and right to left within no time.

Retrace period $\ll$ trace period.

Sinusoidal signal applied to x-plates :-

$\rightarrow$ Externally applied horizontal signal.



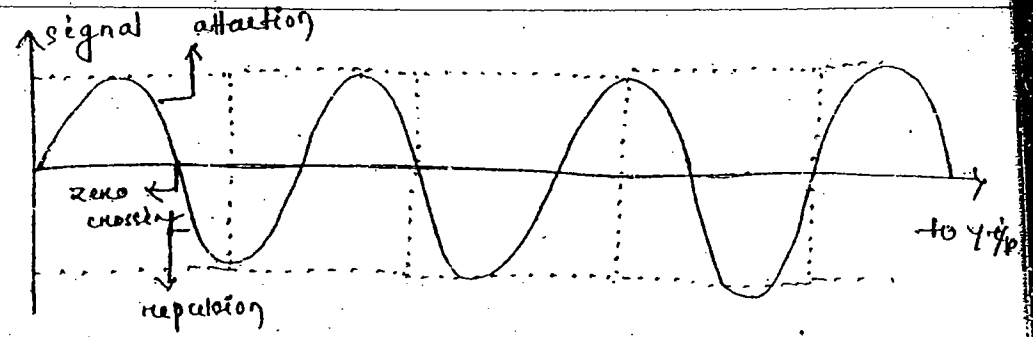
t	V_m	$\rightarrow u$
0	0V	$\rightarrow 0$
1	+2V	$\rightarrow +4\text{cm}$
2	0V	$\rightarrow 0$
3	-2V	$\rightarrow -4\text{cm}$
4	0V	$\rightarrow 0$

center to right $\rightarrow$ center to left
(center)

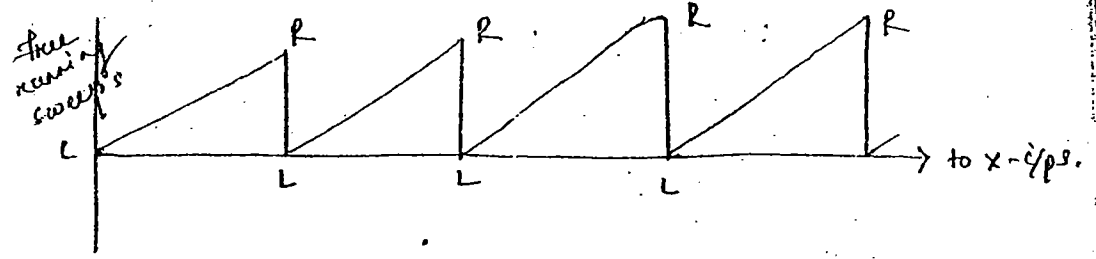
Sign
sine
test
containing
one
(V_m , V)
the
M
base

113

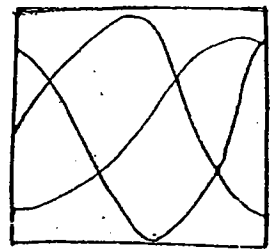
to adjust
setting



given
signal
along as

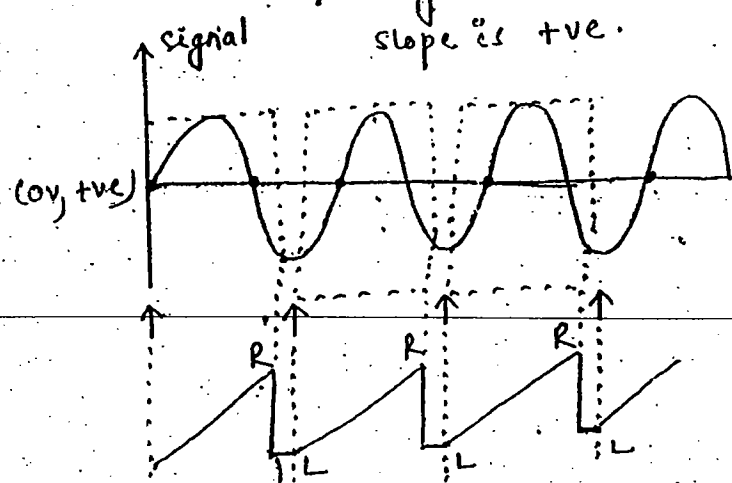


Jumble



0V = voltage level.
+ve = slope

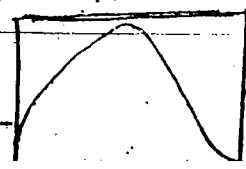
case (2) Trigger settings are made
→ voltage level is 0V.
slope is +ve.



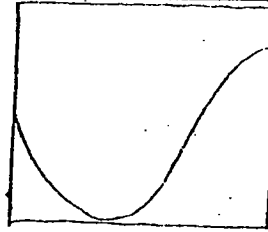
↑ trigger pulse
↓ applied to
sawtooth
signal.

same portion
of signal is
repeatedly
displayed on
screen (trigger)

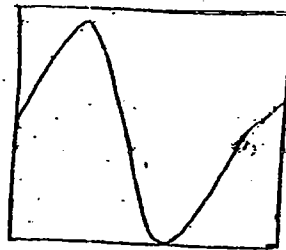
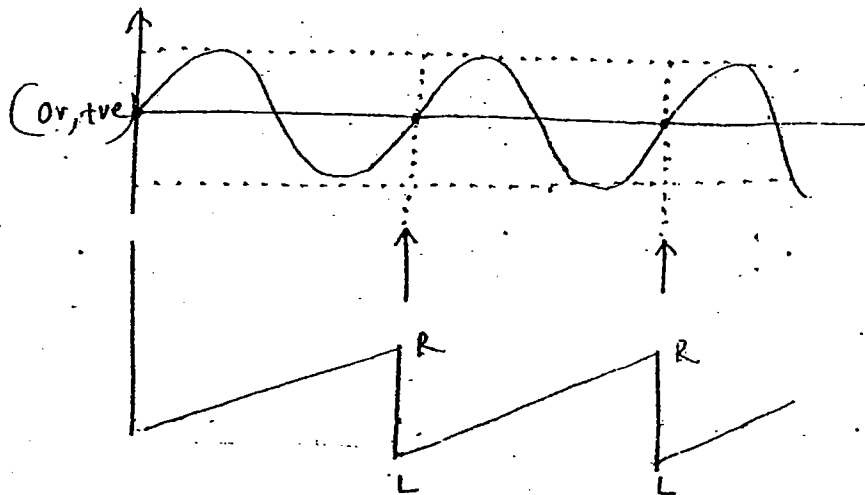
steady
steady



Note-1 If trigger voltage level is 0V and
trigger slope = -ve.



case-③ Along with trigger settings and adjust
 $\frac{\text{Time}}{\text{DIV}}$ to make $T_{\text{sweep}} = T_{\text{signal}}$.

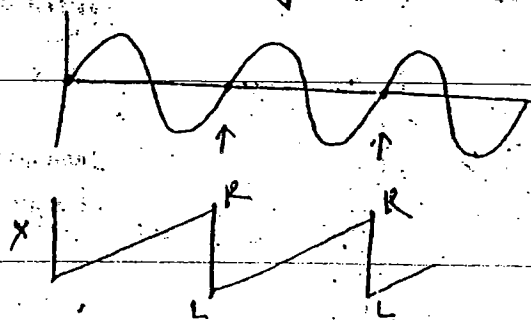


→ Proper triggering
→ Steady display of
1 cycle of signal

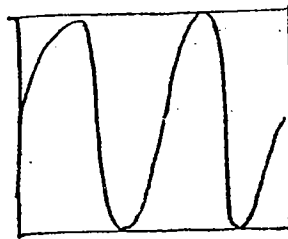
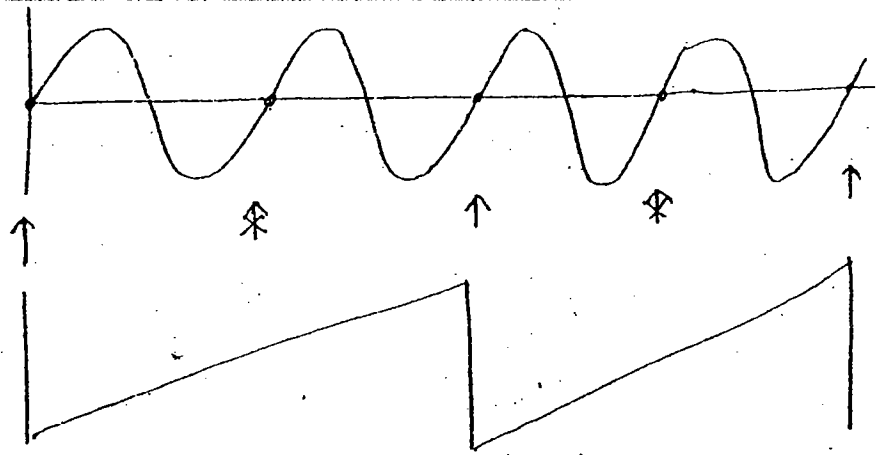
$T_{\text{sweep}} = T_{\text{signal}}$

synchronisation

case-④ If $T_{\text{signal}} > T_{\text{sweep}}$



114



- If $f_{\text{signal}} < f_{\text{sweep}}$, then less than 1 cycle of signal will be displayed on screen.
- If $f_{\text{signal}} = f_{\text{sweep}}$, then 1 cycle of signal will be displayed on screen.
- If $f_{\text{signal}} > f_{\text{sweep}}$, then more than 1 cycle of signal displayed on screen.

→ $f_{\text{signal}} \gg f_{\text{sweep}}$ $\rightarrow$ locking cond.
(for proper synchronisation)

→ $f_{\text{signal (min)}} = f_{\text{sweep}}$

$$f_{\text{signal}} = n f_{\text{sweep}}$$

$\rightarrow n \gg 1$ (improper signal is nothing but jumble).

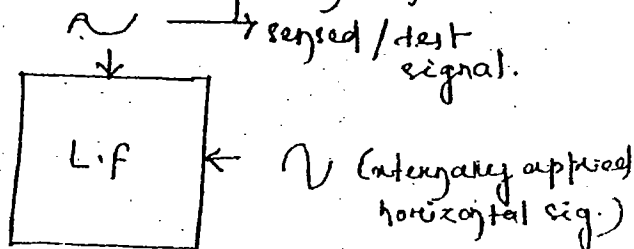
Triggering
play of
signal

Signal.
synchronisation?

16/11/10

x-y plot :-

A x-y plot is produced on the screen of CRO when both x and y - i/p's are driven with sinusoidal signals.



- ↳ This mode of operation is known as x-y mode of operation.
- ↳ x-y plot are called as "Lissajous figure / pattern".
- ↳ 3 types of Lissajous figure : a) closed loop L.F.
b) open loop L.F.
c) Hybrid L.F.

$$v_y(t) = v_y \sin(2\pi f_y t + \phi)$$

$$v_x(t) = v_x \sin(2\pi f_x t)$$

— where v_x & v_y are amplitudes

f_y = vertical frequency

It is nothing but vertical i/p signal frequency.

f_x = Horizontal frequency

ϕ = phase difference.

- ↳ 2 measurements using L.F.s. namely frequency mmt and phase mmt.

① Unknown Frequency measl- using L.F. :-

there are two methods :

Tangent Method (touch technique)

↳ Draw Horizontal & vertical tangent lines touching the peaks of L.F.

↳ Then apply the formula:

$$\boxed{\frac{f_y}{f_x} = \frac{n_x}{n_y}} \quad \begin{matrix} \text{freq.} \\ \text{ratio} \end{matrix}$$

n_x = no. of peaks as touch by Horizontal line tangent

n_y = no. of peaks as touch by vertical tangent.

Intersection Method (cut technique)

↳ Draw Horizontal and vertical lines passing through L.F.s.

RULE: Never Draw via preexisting intersection

↳ then apply the formula:

$$\boxed{\frac{f_y}{f_x} = \frac{n_x}{n_y}}$$

n_x = no. of cuts as made by horizontal lines.

n_y = no. of cuts as made by vertical lines.

now by

$$\boxed{f_y = \left(\frac{n_x}{n_y}\right) f_x}$$

↳ ratio

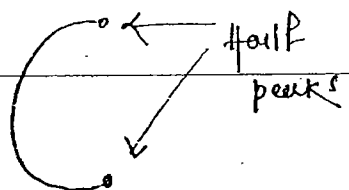
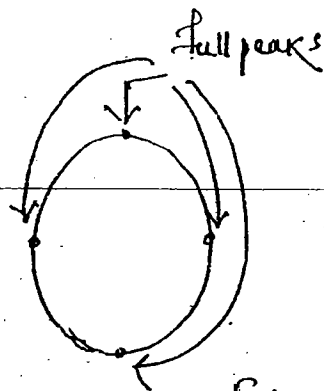
↳ known frequency

↳ unknown frequency

unknown measured by 'known' terms of 'ratio'

this principle is known as 'Bridge principle'.

Note :



[Lissajous technique]

② Phase measurement using L.F.s :-

↳ One typical condⁿ is made here to understand the analysis

* Condⁿ : Equal amplitudes : $V_y = V_x = V$
 Equal frequency : $f_x = f_y = f$
 Equal sensitive : $S_v = S_H = S$

$$\begin{aligned} \therefore V_y(t) &= V \sin(2\pi ft + \phi) \\ V_x(t) &= V \sin(2\pi ft) \rightarrow (0^\circ \text{ to } 360^\circ) \end{aligned}$$

↳ As the horizontal and vertical beams are having the same frequency and amplitude then it is obvious that they should maintain the same distance. For this there are 3 cases:

Case ① : A sinusoidal signal with equal amplitude and equal frequencies with no phase difference are applied to both i/p of CRO :

Imp

0°

Not

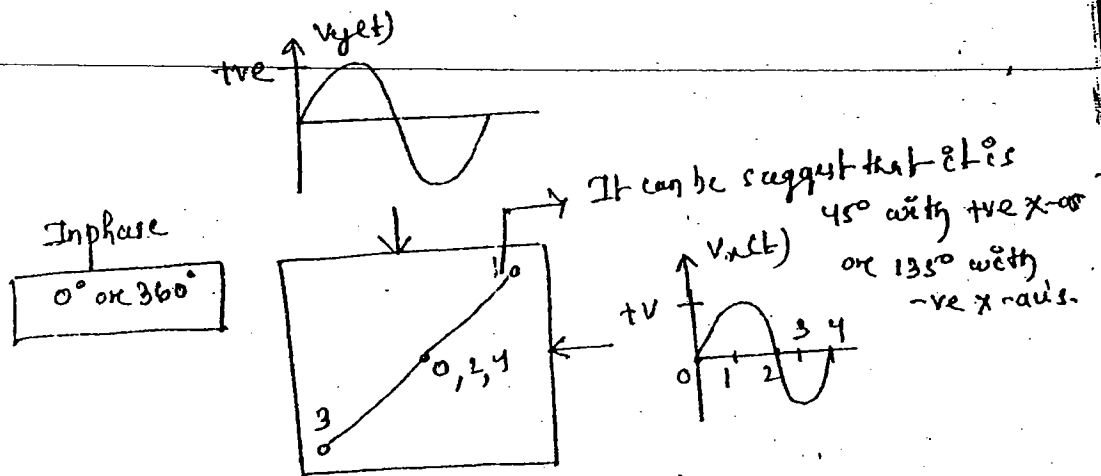
45°

90°

Case

50°

90°



$(v_x, v_y) \rightarrow (0,0) - (1,1) - (0,0)$
 $(-1,-1) - (0,0) \rightarrow$ this means that there is no phase difference.

In above fig if vertical i/p is more than horizontal i/p then it will tilt upward / toward vertical lines and vice versa.

Note : if $v_x = v_y$, $f_x = f_y$ & $\phi = 0$

A diagonal line observed on the screen made exactly 45° with the x -axis.

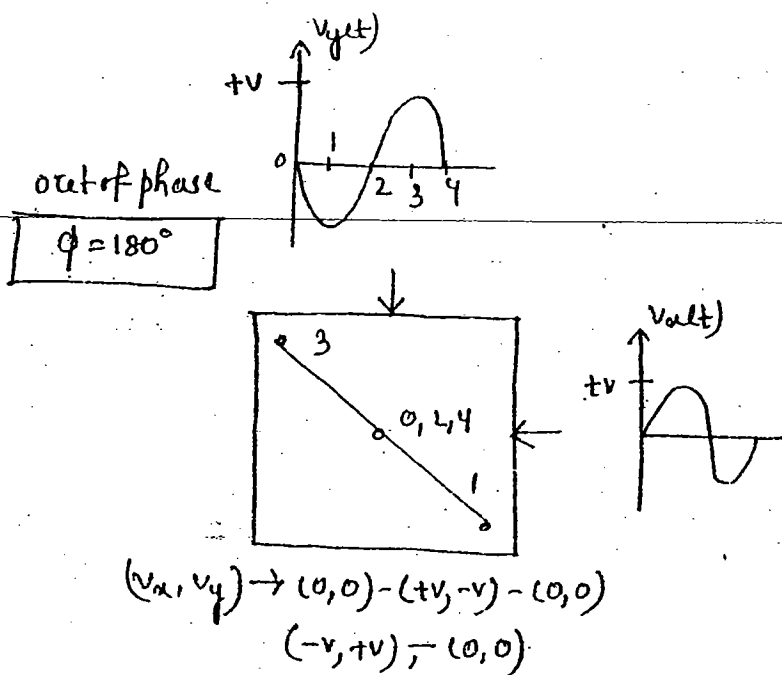
if $v_y > v_x$, $f_x = f_y$, $\phi = 0$

A diagonal line observed on the screen made greater than 45° with the x -axis.

if $v_y < v_x$, $f_x = f_y$, $\phi = 0$

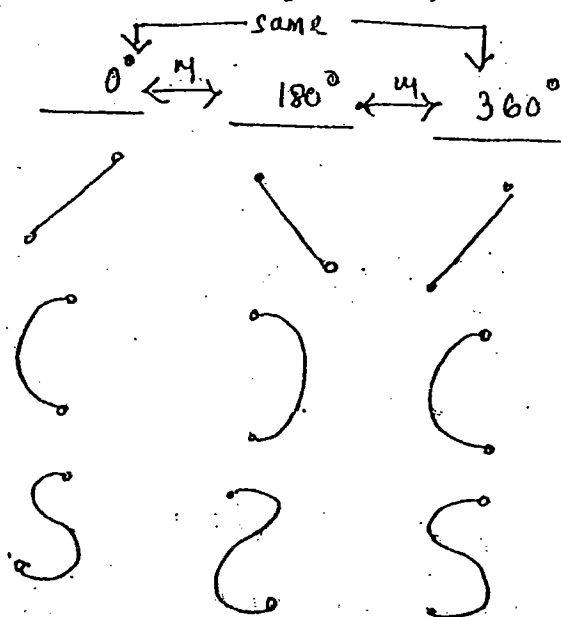
A diagonal line observed on the screen made less than 45° with the x -axis.

Case (2) : 2 sinusoidal signals with equal amplitude and equal frequencies with having phase difference of 180° are applied to both i/p s of CRO.



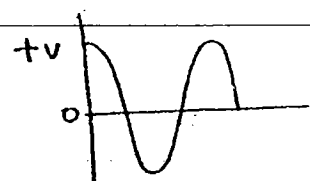
→ Here diagonal straight line making 135° with the x -axis and with quadrant (x, y) .

Note:

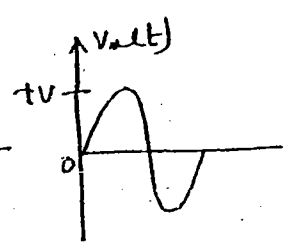
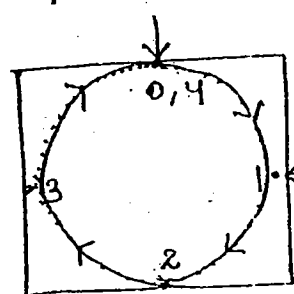


case ③: 2 sinusoidal signal with equal amplitude and equal frequencies, but having a phase difference of 90° are applied to both i/p of CRO

180°

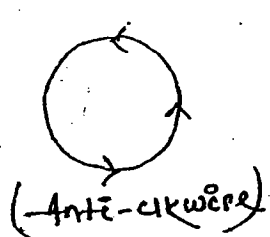
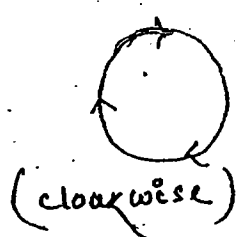


$\phi = 90^\circ$
clockwise
rotating
circle.



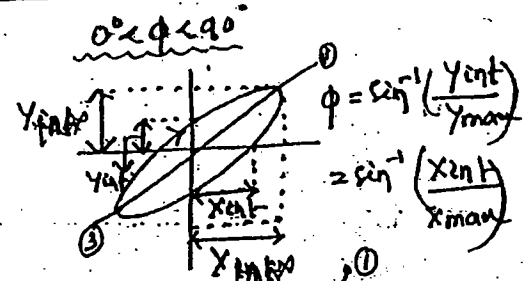
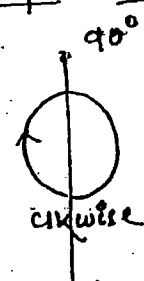
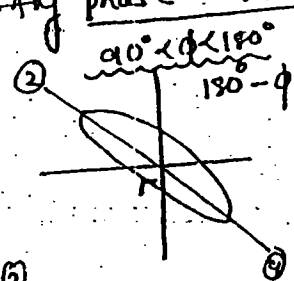
$(v_x, v_y) \rightarrow (0, v) - (v, 0) - (0, -v)$
 $(-v, 0) - (0, v)$

Note : 90° 270° (i.e. $360^\circ - 90^\circ$)

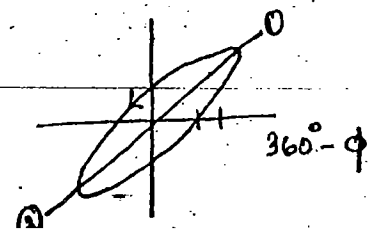
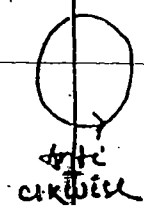
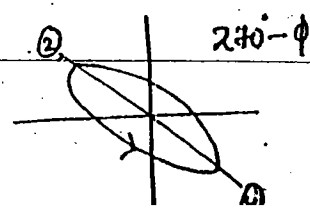
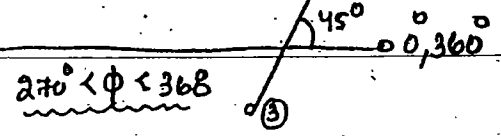
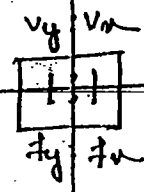
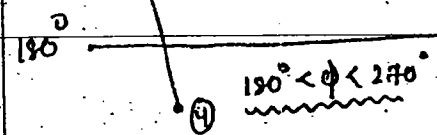


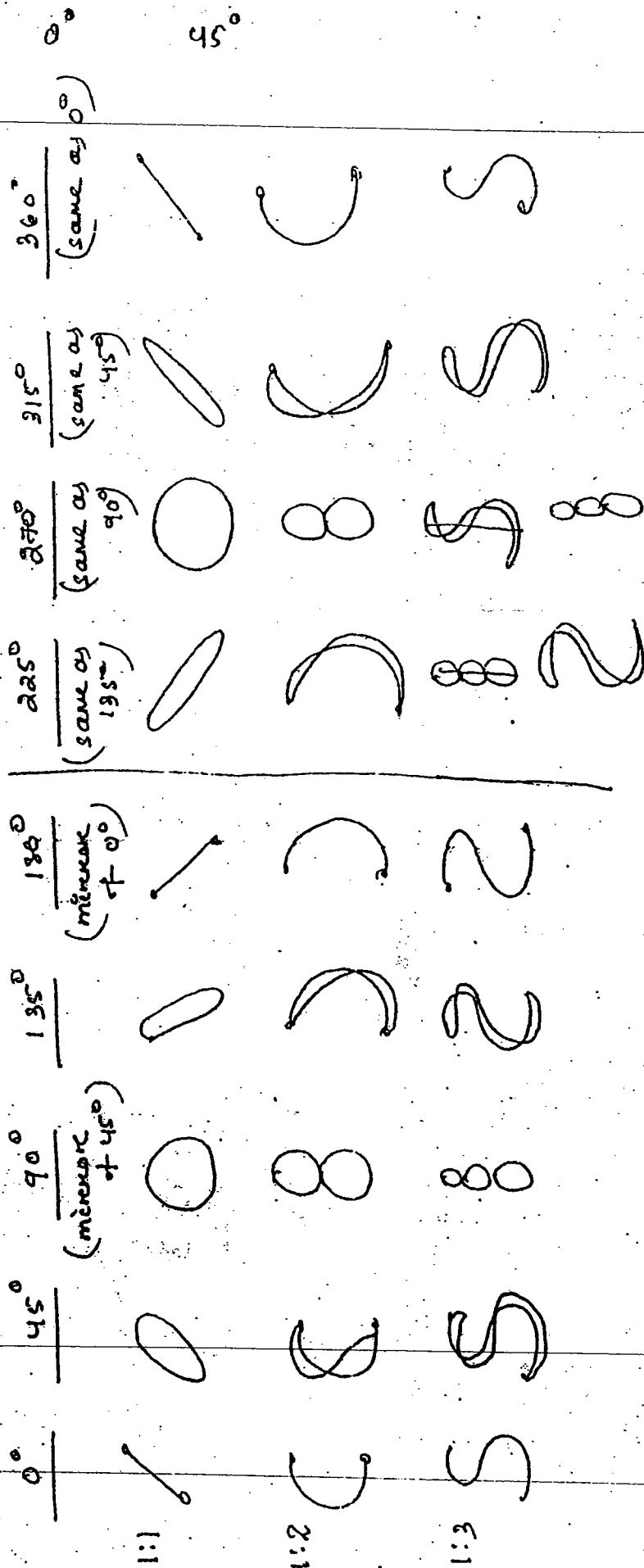
Any other phase difference b/w two c/p's we are going to get an ellipse on the CRO.

Any phase difference ($0^\circ, 90^\circ, 180^\circ, 270^\circ, 360^\circ$)



Sample -
 Phase
 of CRO





20/11/2008

sol

pb!

foot

20/11/2008

pp

p

118

20/11/10

2086

QES: one cycle of square wave signal is observed on oscilloscope found to occupy 6 cm at a scale setting of 30 $\mu\text{s}/\text{cm}$. what is the scale frequency.

solⁿ: time period = $N \times X$

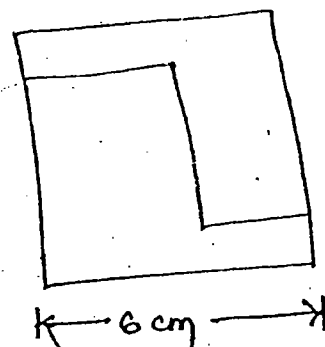
$$X = 30 \mu\text{s}/\text{cm}$$

$$f_{\text{square}} = ?$$

$$T = 30 \frac{\mu\text{s}}{\text{cm}} \times 6 \text{ cm}$$

$$T = 180 \mu\text{s}$$

$$f = \frac{1}{180 \mu\text{s}} = 5.55 \text{ kHz}$$



Q2: An oscilloscope is operated with scale setting of 0.5 mV/div and vertical setting of 100 mV/div. Hence two cycle of sine wave is observed on the screen which occupy 8.8 horizontal division and 4.6 vertical division. Then the rms voltage and frequency of sine wave are respectively —

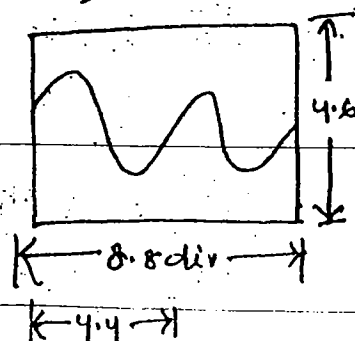
solⁿ: Horizontal division = 8.8 (4.4 $\times$ 2)
vertical division = 4.6 (NV)

$$X = 0.5 \frac{\text{mV}}{\text{div}}$$

$$Y = 100 \frac{\text{mV}}{\text{div}}$$

$$V_{pp} = N_v (Y)$$

$$T = N_h \cdot X$$



$$V_{pp} = 4.6$$

$$T = 4.4 \text{ div} \times$$

$$0.5 \text{ mV/div}$$

$$= 2.2 \text{ mV}$$

$$= 460 \text{ mV}$$

$$V_{rms} = \frac{230}{\sqrt{2}} \text{ mV}$$

Pb: The cpo screen has 10 div on the horizontal scale of a voltage signal $5 \sin(314t + 45^\circ)$ is examined with a time base setting of 5 msec/div . then the no. of the cycle of signal displayed on the cpo screen will be _____.

$$v(t) = 5 \sin(314t + 45^\circ)$$

$$x = \frac{5 \text{ msec}}{\text{div}}$$

no. of cycle displayed = ?

$$T = N \times x$$

$$5 \sin(314t + 45^\circ)$$

$$V_p \leftarrow \quad \leftarrow f = 50 \text{ Hz} \quad \leftarrow \phi$$

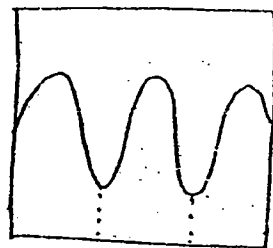
$$\frac{1}{50 \text{ Hz}} = N \times \frac{5 \text{ msec}}{\text{div}}$$

$$N = \frac{20 \text{ msec}}{5 \text{ msec}} = 4 \text{ div.}$$

1 cycle occupy 4 div.

$\therefore$ 10 div occupy 4×2.5 cycles.

Pb: A symmetrical squarewave of frequency 25 kHz on peak to peak amplitude of 10 V is fed to the y-c/p of an oscilloscope. The screen appears as shown in below fig. Then the vertical setting and time setting values of slope values are _____



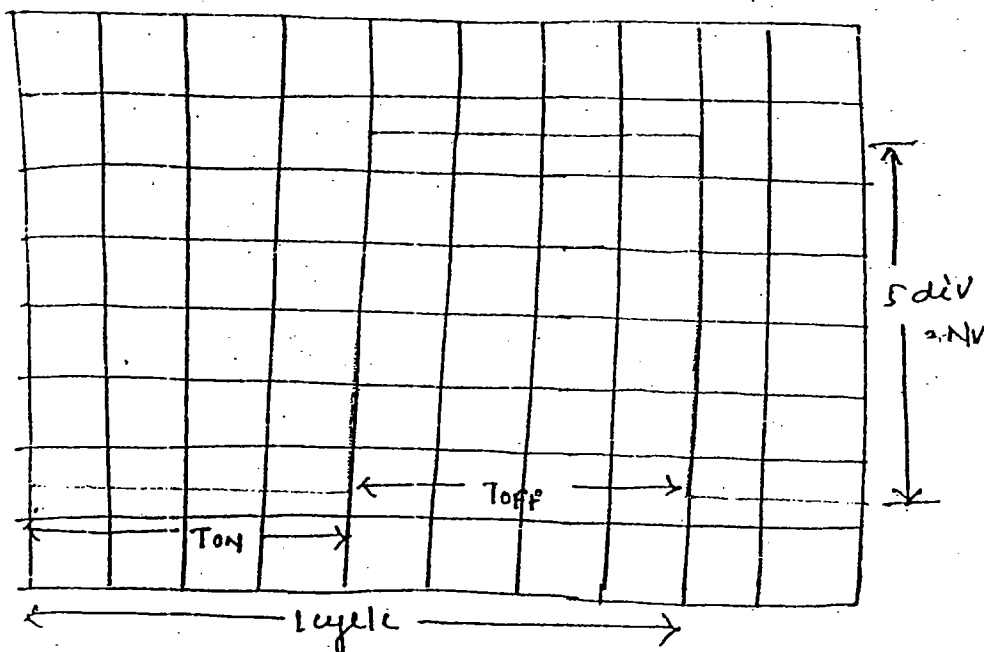
$\leftarrow 4 \rightarrow \leftarrow 2 \rightarrow$
 $\leftarrow 10 \text{ div} \rightarrow$

Pb:

level
 rise
 time

Symmetrical square wave $\rightarrow T_{ON} = T_{OFF}$

$$\rightarrow 4 \text{ div} = 4 \text{ div} = 8 \text{ div} = N_H$$



$$V_{PP} = 10V$$

$$N_V = 5 \text{ div}$$

$$f = 25 \text{ kHz}$$

$$T = \frac{1}{25} = 4 \text{ msec}$$

$$V_{PP} = N_V \times Y$$

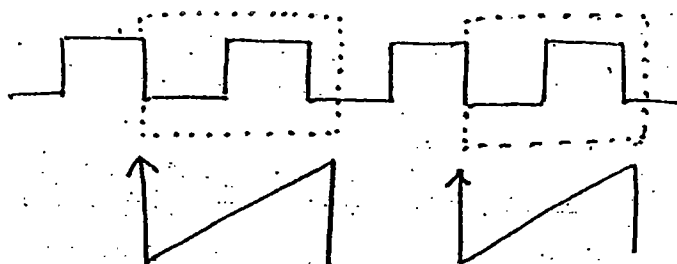
$$10V = 5 \text{ div} \times Y$$

$$Y = 2 \text{ V/div}$$

$$T = N_H \times X$$

$$4 \text{ msec} = 8 \text{ div} \times X$$

$$X = 5 \frac{\text{msec}}{\text{div}}$$

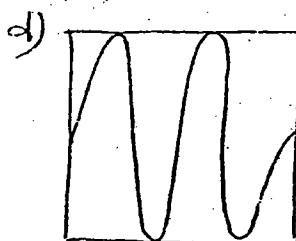
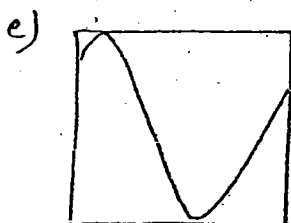
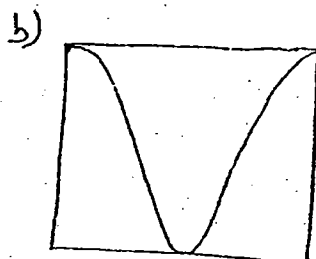
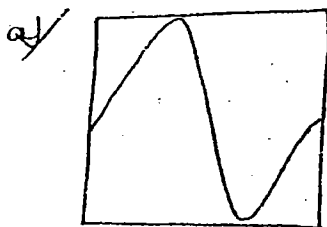


slope = -ve always.

Ph: In a cathode ray oscilloscope by x and y sensitivities are set as 1 msec/div and 1 V/div respectively. The y-amp is connected to a voltage

is integral and the level source is zero. and slope is +ve. The display on the screen is —.

Eno of horiz. div = 10, vertical div = 8



$$X = 1 \text{ ms/div.}$$

$$Y = 1 \text{ volt/div.}$$

solⁿ: $4 \cos(200\pi t - 45^\circ) \text{ V}$

$$V_p \swarrow$$

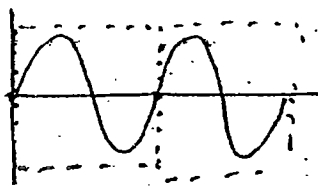
$$f = 100 \text{ Hz}$$

$$T = 10 \text{ msec.}$$

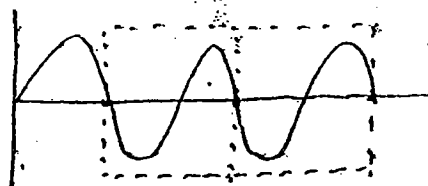
Integral trigger source

trigger level = +0V

trigger slope = +ve.



(0V, +ve)



(0V, -ve)

Pb: The x and y sensitivities of an analog oscilloscope are set as 2 msec/cm. and 1 volt/cm respectively.

The trigger is set at 0 volts and -ve slope and.

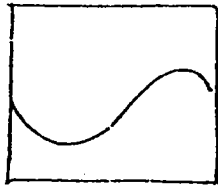
An i/p of $2 \cos(100\pi t + 30^\circ)$ volts is fed to Y- $\uparrow$ p. of oscilloscope. The waveform seen on the scope will be —.

120

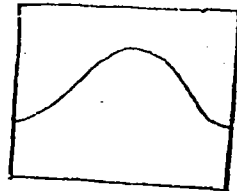
and

is —

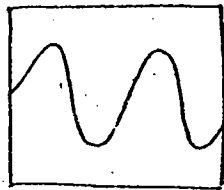
(a)



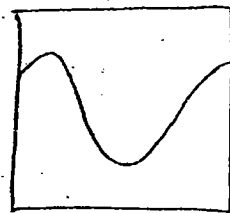
(b)



(c)



(d)



$$X = 2 \text{ cm/cm} \cdot 2 \text{ sec/cm}$$

$$Y = 1 \text{ volt/cm}$$

$$2 \cos(100\pi t + 30)$$

$$\hookrightarrow f = 50 \text{ Hz}$$

$$t =$$

Source

or

= xue

IBS
PS:

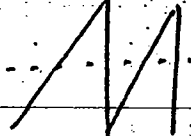
A sinusoidal signal of frequency 2 kHz is applied to the x-deflection plate and a saw tooth frequency of 1 kHz is applied to the y-deflection plate (vertical) of CRO. The wave form shown in the screen is



(b)



d)

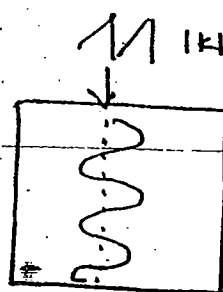


Oscilloscope

actively

scope and

to y-i/p.



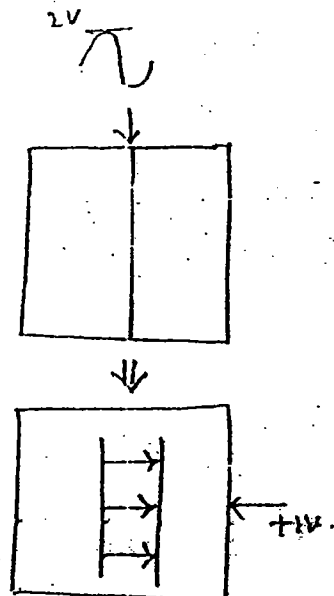
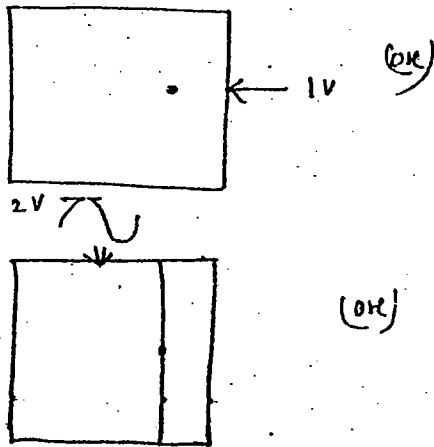
1 kHz

2 kHz

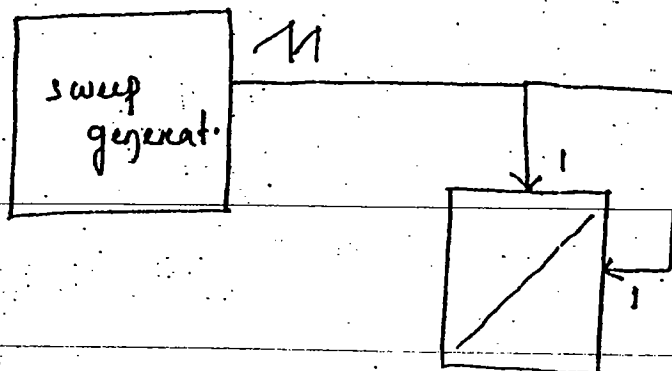
$$\text{Slope} = \frac{2 \text{ time}}{1 \text{ sec}} = 4 \text{ cm/s}$$

Pb: A dc voltage of 1 volt is applied to the X-plate of CRO and an ac volt. of 2 sin 100t is applied to Y-plates. The resulting display on the screen will be

- vertical st. line
- horizontal st. line.
- sine wave.
- sawtooth wave line.



Pb: A certain oscilloscope with 4cm x 4cm screen has its own sweep $\% / p$ fixed to 2 $\% / p$. If the X-Y sensitivities are equal, the oscilloscope will display a ———. (diagonal line)



Qb: For measurement of modulation factor by an CRO, a trapezoidal pattern is obtained on the CRO screen as shown in fig. (b) given below. What is the value of modulation factor 'm'?

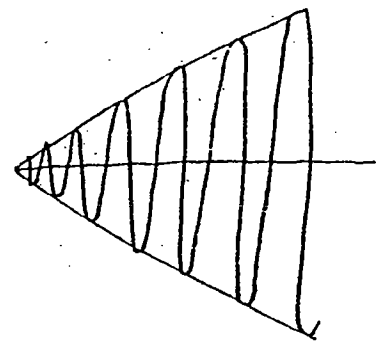
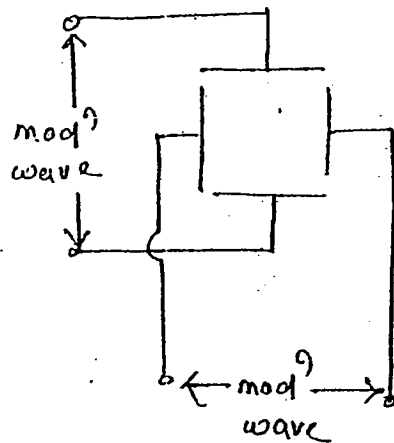
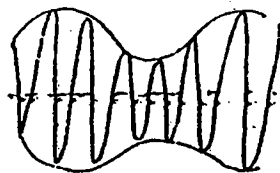


Fig. (b)

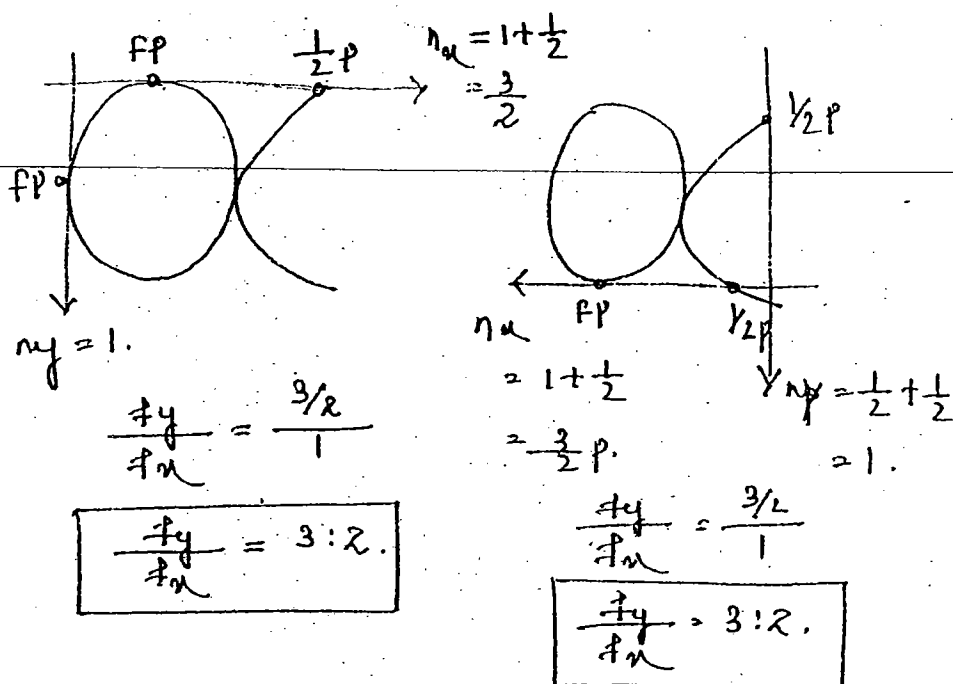


$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

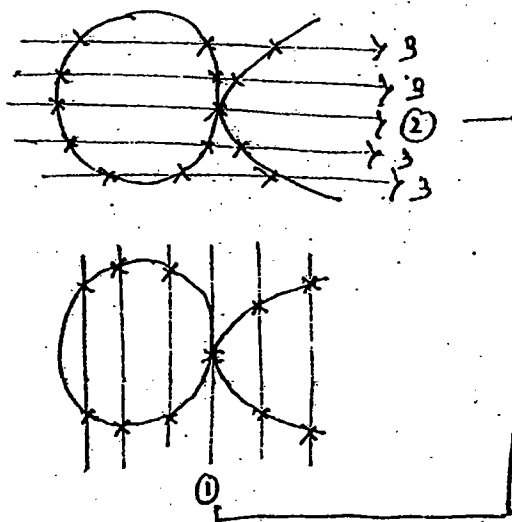
Qb: The relationship b/w T_s = Rise time of signal, T_o = Rise time of oscilloscope is T_q (Rise time of signal observed on the oscilloscope is equal to —)

$$T_q = \sqrt{T_s^2 + T_o^2}$$

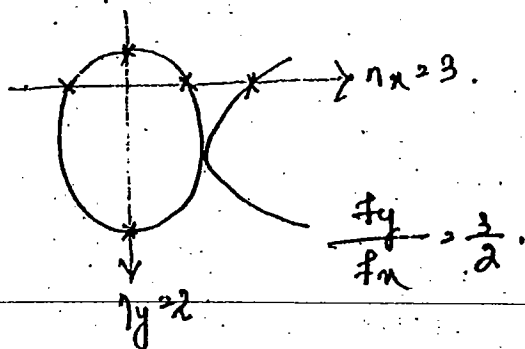
Qb: An oscilloscope is operated in x-y mode. The below Lissajous fig is displayed on the screen. If the frequency of signal is applied to x- input is 1 kHz. then the frequency of signal applied to y- input is —



Cut method:



Rule is violated.



The cut method is efficient - where the no. of intersection is simple / or it is a trace method.

like peak

Pb:

frequency

CR0

peak

caption

diff

(c) If

x-axis

with

(5)

Pb:

showing

phase

both

The touch method is efficient where the peak points are given in the fig.

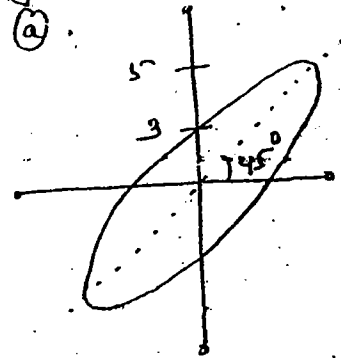
Pb: Two sinusoidal voltage of equal amp- and equal frequency are applied to the x- and y i/p of CRO and ellipse is examined on the screen. The peak y-deflection is at 5 div and its interception is at 3 div. Then the value of phase difference b/w the signals —

(c) If the major axis of ellipse is inclined with x-axis at 45° (d) If the major axis is inclined with x-axis at 135° .

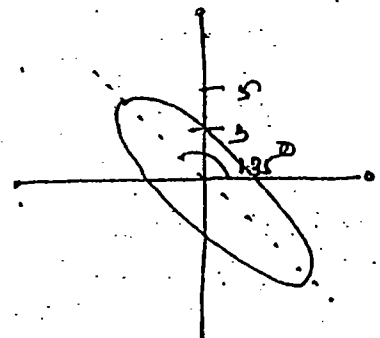
$$Y_{\text{deflection}} = 5 \text{ div.}$$

$$Y_{\text{intercept}} = 3 \text{ div.}$$

$$\phi = \sin^{-1} \left(\frac{Y_{\text{int}}}{Y_{\text{def}}} \right) = 36.8^\circ$$



$$\begin{aligned} \phi &= 180^\circ - \sin^{-1} \left(\frac{Y_{\text{int}}}{Y_{\text{def}}} \right) \\ &= 180^\circ - 36.8^\circ \\ &= 143.2^\circ \end{aligned}$$



Pb:

In x-y mode of operation of CRO the below shown ellipse is observed on the screen. Then the phase difference and frequency ratio b/w

both the i/p signals are _____ respectively.

Q no.

Ques. method.

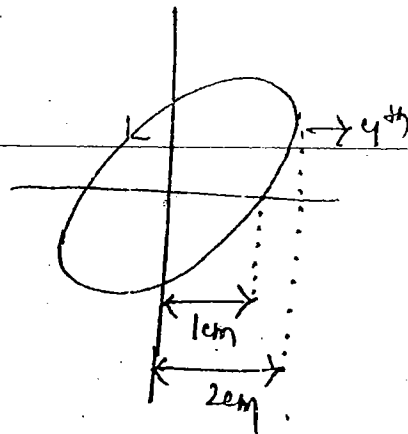
$$\phi = \sin^{-1}\left(\frac{1}{2}\right)$$

$$= 30^\circ$$

$$\rightarrow \phi = 360^\circ - \sin^{-1}\left(\frac{1}{2}\right)$$

$$= 360^\circ - 30^\circ$$

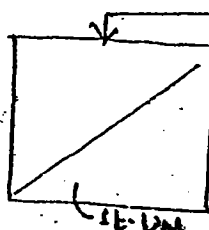
$$= 330^\circ$$



Pb: While measuring the phase difference b/w the signals $\eta \sin \omega t$ and $\eta \sin(\omega t + \phi)$, the Lissajous fig. observed in the screen is a circle, the value of $\phi = ?$ ($90^\circ \rightarrow$ clockwise, $270^\circ \rightarrow$ anticlockwise)

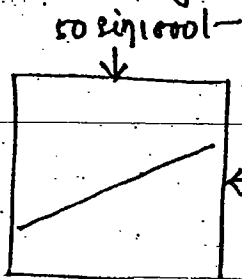
Pb: Voltages $100 \sin 1000t$ and $50 \sin 1000t$ are connected to vertical or horizontal terminals of 'CRO'. Then the resulting Lissajous fig is —.

sol:



st. line making an angle greater than 45° with (true) x-axis.

Pb: Voltages $50 \sin 1000t$ and $100 \sin 1000t$ are connected to y and x-terminals of CRO. Then the resulting Lissajous fig is —.



st. line making an angle less than 45° with (true) x-axis.

Pb:

are

part

sol:

Pb:

fig

of

the

a)

b)

Pb:

for

encl

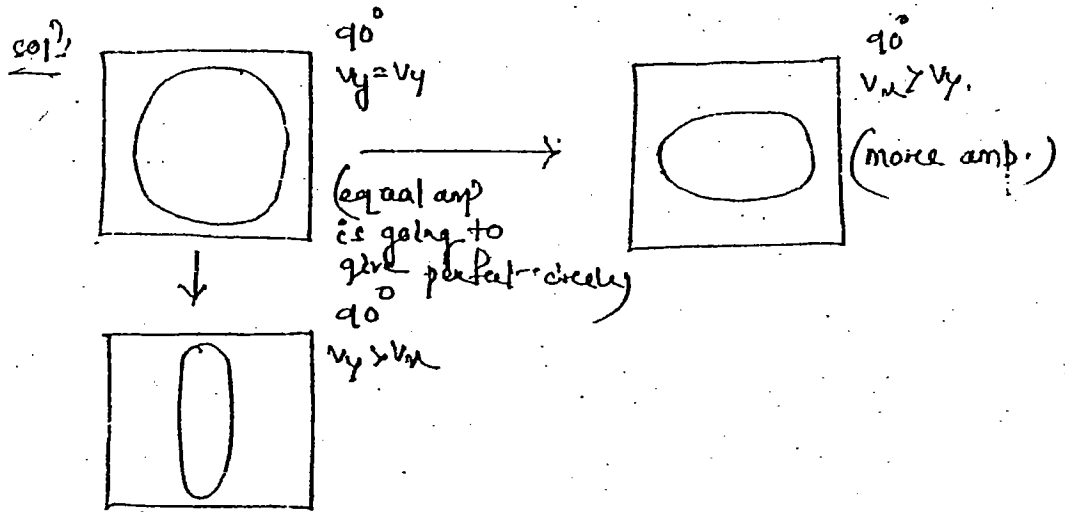
any

a)

b)

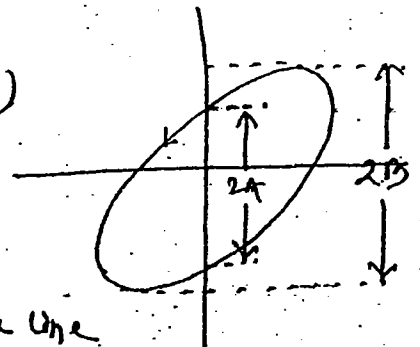
✓

Qb: The x and y i/p's to a CRO are $10 \cos(100t + \phi)$ and $10 \sin(100t + \phi)$. The resulting Lissajous pattern on the screen is _____.



Qb: The elliptical Lissajous pattern shown in below fig was observed from a sinusoidal signal sources of same frequency on a CRO. The phase angle b/w the signal is = ?

- a) $\cos^{-1}(\pi/3)$ b) $\sin^{-1}(\pi/3)$
 c) $\tan^{-1}(\pi/3)$ d) $\pi/3$



Qb:

An oscilloscope screen displays a line inclined at 45° . If its y-i/p is a sine wave of frequency f . Then the x-i/p should be _____.

- a) sawtooth wave of freq. f
 b) sine wave of frequency f and 90° phase shift with y-
 ✓ c) sine wave of freq. f and 0° phase shift with y-i/p

248

124

74

