AMIT KUMAR 102/-SP

Electrical and Electronics Measurement & Instrumentation

Electronics : 30V 11KV
Frequency {KHz 33KV, MHz :, GHz 1000KV}

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 :

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

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 substracted 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.

$$\boxed{\begin{aligned} R.S.E. &= \frac{A_m - A_t}{A_t} = \frac{\epsilon}{A_t} \\ \%\, R.S.E. &= \frac{A_m - A_t}{A_t} \times 100 \end{aligned}}$$

% RSE determines the quantity of an instrument.

	A	B
$A_t =$	2A	1000A
$\epsilon =$	1A	10A
% RSE =	50%	1%

∴ B is the best as compare to 'A'.

Limitting Error :- (tollerence/uncertainity)

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

** The % LE. is n't zero at all.

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(0-10)A ; % LE = ±1%

$2A;\ 2 \times \frac{\pm 1}{100} = (2 \pm 0.2) = (1.98 - 2.02)$ } measured value (A_m)

$10A;\ 10 \times \frac{1}{100} = (10 \pm 0.01) = 9.9 - 10$

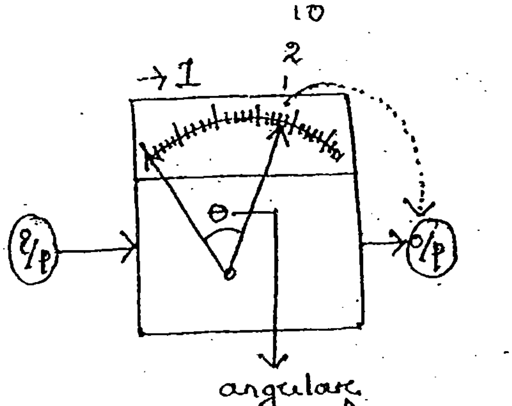
[9.9-10.1 → is the wrong one becoz the meter it-self range from (0-10)A].

A meter ranges from (0-10)A → full scale value.

Basic characteristic of Instruments :-

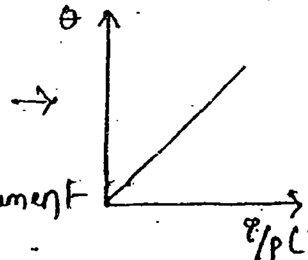
A = Accuracy
P = Precision
L = Linearity
S = Sensitivity
Dead time
d zone

29/08/10 **Linearity :—**



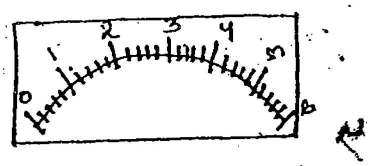
— Whatever the reading = o/p.
Here the o/p of all the any elec. Instrument is 'θ'.
— Whatever the parameter is given as i/p to the instrument but the instrument always take current as i/p. And the current is proportional to angular frequency 'θ'. And this relation b/w θ and I shows whether the instrument is linear or non-linear one.

$\theta \propto I$ →



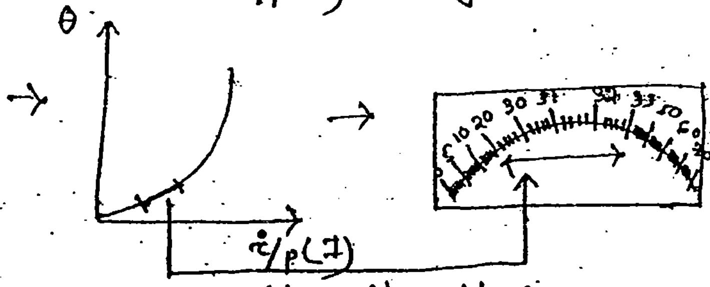
Linear Instrument

→



Eg: PMMC Instr.

$\theta \propto I^2$ →



linearity appear for some instant.

Eg: MI instr.

Q: $A_t = 17A$. then which of the following will give more accuracy:

(i) (0–100) A
(ii) (0–20) A
✓(iii) (0–30) A

note: Even an instrument is an a non-linear one, but we have to choose a ~~i point that i the pointer choose enter~~ into the no linear region.

"The o/p follows the i/p with linear relatn or linear eqn is known as linearity. It is a desireable condn, but n't nessecery, ~~but~~ (n't compulsory)".

→ we select the meters always in such a way that the pointer should enter into linear region. So that we mayn't loose the accuracy.

Sensitivity :—

→ we have to choose always high sensitive instruments.

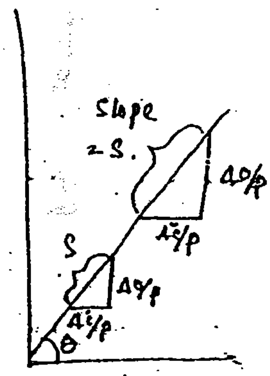
If in a instrument ; for $2.1\ (i/p) = 2\ (o/p)$
and $2.0\ (i/p) = 2\ (o/p)$ } low sensitive instrument.

High sensitive = wide response = more accuracy.
Low sensitive = Less response = Less accuracy.

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

How the sensitivity place in Linear scale :-

↳ For the linear scale sensitivity is always const.

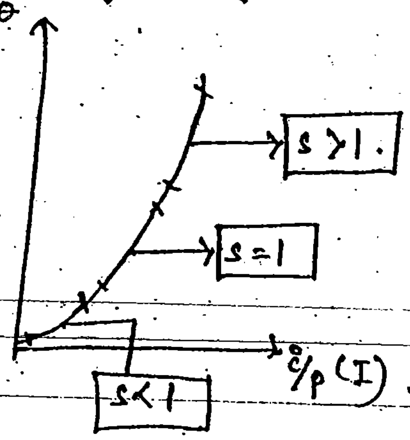


↳ For linear scale/ instruments :

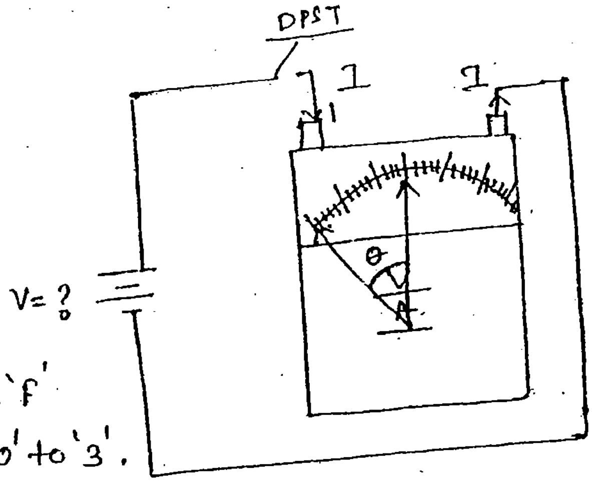
$$\boxed{S = \tan\theta = 1} \quad (\theta = 45^\circ)$$

→ what about the sensitivity in non-linear scale :

↳ Sensitivity is very throughout the scale in non-linear instre.



Dead time :-



In this instru. 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 allways the current is the i/p of meter. In current measurement system the connection should be in series.

↳ In all electrical instrument the responsible quantity is current.

↳ If $\theta \propto I^2 \propto V^2$ 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.

becoz: In electronic instru. 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 instru. there is energy converter is occurs, that convert I to F by the rela^n $\boxed{F = BIL \sin\theta}$

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 it's 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 prepaire / get a 100% accuracy instrument, becoz we can't prepaire a '0' weight pointer **.

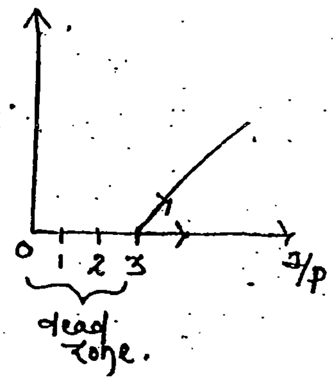
** All the instrument will subjected to both transient and steady state stability **.

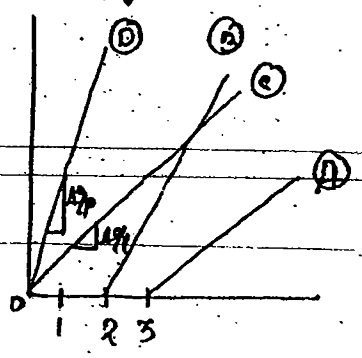
Dead zone :—

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

↳ It is also known as threshold.

↳ It defines the smallest measurable i/p.



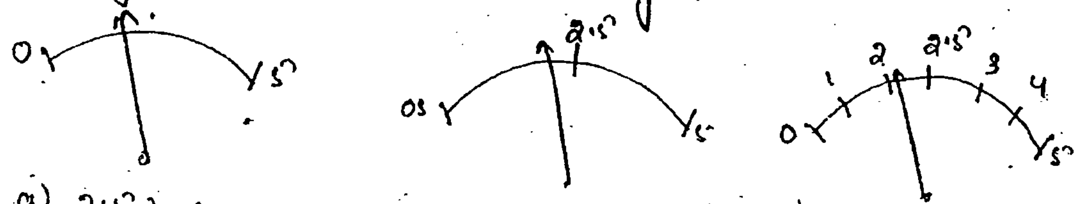


Among 4 of them 'D' is the best one. It is linear as well as high sensitive one also. Here is no dead zone also.

Resolution :— (R).

— we prefer always high resolution.

high resolution ⇒ more clarity ⇒ more accurate.



a) 2.5
b) 2.2
c) 1.9.
d) 1.7

} becoz the scale has only '2' resolution. so less accuracy is there.

a) 2.1
b) 2.2
b) 2
d) 2.5

The clarity is much better then previous one., but still we aren't accurate.

there also the clarity is much better than previous two, but still we are unable to give accurate.

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

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

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

↳ ** no. of division increases = Resolution increases **

Types of Errors :—

(i) Gross Error (It is due to only human negligency)

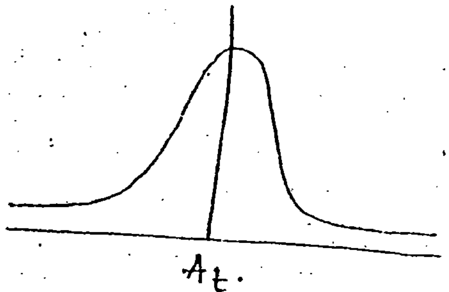
(ii) Systematic error → Instrumental error (manufacturing error, inst aging error) → Environmental error (→ Overservational error. (parallax error)

(iii) Random Error :- There is no perticular 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 methematical tool 'stastics'.

** parallen errore ⇒ Gross errore, but it undergoes in systematic errore. becoz it is common for all human being (parallen errore = due to eye defect)

** common for all ⇒ Systematic errore.

** n't common for all ⇒ Gross errore.



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

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Random Errore Analysis :—

• 50 times

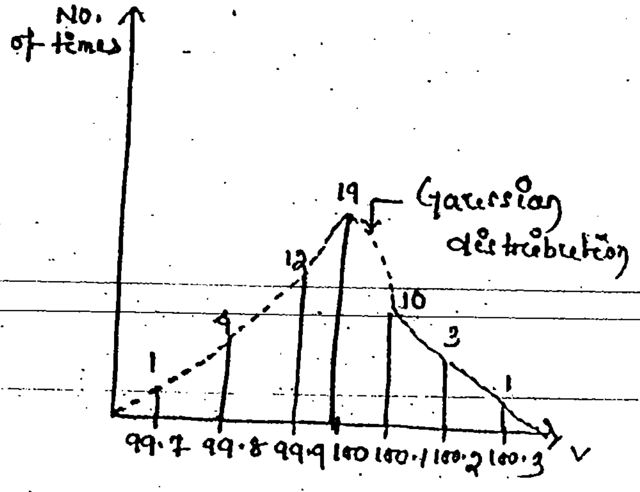
$(0-150)$ V , $A_t = 100$ V.

99.7 V ⟶ 1
99.8 V ⟶ 4
99.9 V ⟶ 12
100 V ⟶ 19
100.1 V ⟶ 10
100.2 V ⟶ 3
100.3 V ⟶ 1

Here we get 100V 19 times:
so it is a accurate as well as precise one.

Here ±.1 deviation = 22 times.
±.2 " = 7.
±.3 " = 2.
} Probable, errore

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



If we integrate the samples from 99.7 to 100.3 we get the total area bet^n the two point. In state this we'll get all the 50 samples.

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

$$\text{standard deviation } (\sigma) = \sqrt{\frac{d_1^2+d_2^2+\cdots d_n^2}{n-1}} \; ; \; n \not> 20.$$

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

Small deviations are more probable compare to large deviation.

Pb: $A_t = 230$ find the range of error?

~~230.1~~

$229.8 \rightarrow -0.2$

$230.2 = \pm 0.2$

$230.1 = +0.1$

$230 = 0$

$229.9 = -0.1$

$230 = 0$

$230 = 0$

$$\frac{229.8+230.2+230.1+230+229.9+230+230}{7} = 230 = A_t$$

$V_{max} - V_{av} = 230.2 - 230 = +0.2.$

$V_{av} - V_{min} = 230.2 - 229.8 = 0.2.$

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

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

Find the probable error.

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

$$= 0.129.$$

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

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 substraction the absolute errors

$R_1 \times R_2 = \cancel{88}\ 1500 \pm 6\%$, $R_1/R_2 = 1500 \pm 6\%$.

In the case of mul^n and div the % errors should be added.

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

Pb: The i/p of the machine is $\cancel{60}$ 6500 ± 3% and the o/p of the machine is 5000 ± 2%. Find the losses in the machine.

Sol^n:

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

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

$65000 \pm 2\% = 65000 + \frac{2}{100} = 100$
$\overline{295}$.

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

$x = 19.6\%$

Ans: $1500 \pm 19.6\%$.

$\eta = \dfrac{65000 \pm 2\%}{6500 \pm 3\%} = 0.76 \pm 5\%$..

The supply volt = (230 ± 10)V ; supply current = (100 ± 5)

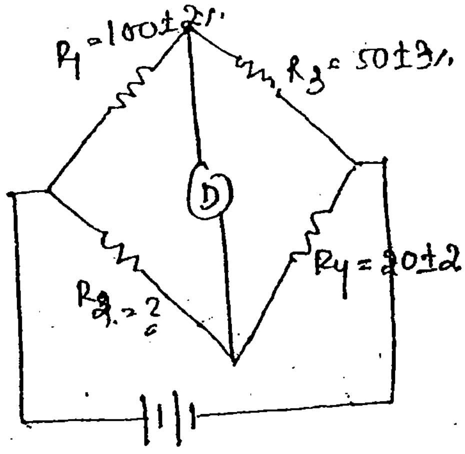
$\dfrac{230 \pm 10}{100 \pm 5} \Rightarrow$ $230 \times \frac{x}{100} = 10 \Rightarrow x = 4.3$.
$100 \times \frac{x}{100} = 5 \Rightarrow x = 5$.

$\cancel{230} \Rightarrow P = 2.3 \pm 9.3\%$.

sol^n:

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

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



Pb: A three phase power is measured by using 2 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 $\pm 5\%$. both the wattmeter are having a f.s.v is 150 watt. The total power in the 3-phase circuit is :

$$50 \times \frac{x}{100} = 1.5 \qquad 125 \times \frac{x}{100} = .5$$

$$\Rightarrow x = \frac{1.5 \times 100}{50} = 3 \qquad x = 0.4$$

50 ± 3 $\qquad$ 125 ± 4

total power $= 125 \pm 03 + 50 \pm 4$

$= 175 \pm 7$.

$175 \times \frac{x}{100} = 7. \quad 175 \pm 1.94$

$\cancel{x = 4\%}$

$\cancel{\frac{50 \times x}{100}}$ $\quad$ In 1st wattmeter $= 50 \pm 1.5\%$

2nd " $= 125 \pm 1.5\%$

$= \cancel{1250} \times \frac{.5}{100} = 0.75$

now, if 2^{nd} wattmeter $= 125 \pm 0.75$.

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

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

$$= 50 \pm 0.75.$$

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

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

$$\Rightarrow x = 0.857.$$

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

Basic Instruments :-

Basic parameters : voltage → Electrical, → Electronics

current → Electrical, → Electronics

(Electrical Instrument.) (Electronics Instrument)

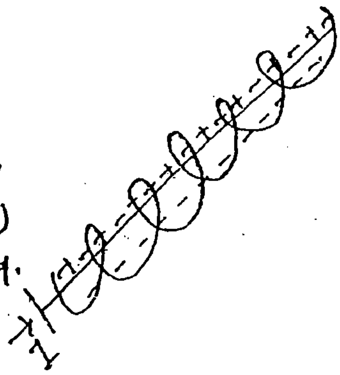
Electrical Instruments :

due to the current 'I' the force is generated. Somewhat how 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.

$I \rightarrow$ | Magnetic effect, thermal effect, Electrostatic effect, Induction effect | $\rightarrow$ F (or) Tq.

720%



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

(Electrical Instrument.)
(Electronics Instrum)

<u>Deflection Torque</u> : This is the force required to move the pointer from it's initial position due to any one of effect is called deflection torque.

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

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

<u>Control Torque</u> : This is the force opposite to the deflection torque. Becoz of the control torque we can stop the pointer at various level.

a path

↳ When $\boxed{T_d = T_c}$ then the pointer will come to steady state.

Func^n of control torque :-

(i) control torque'll provide a proportional o/p to the i/p.

(ii) It'll removed the i/p and make the pointer to come back to the initial pos^n. ($I=0$, $F=0$, $T_q=0$).

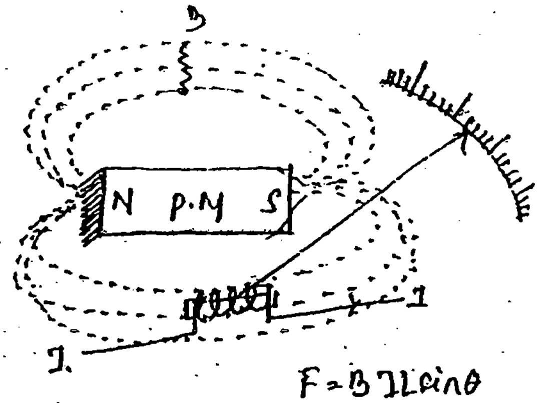
(iii) when $T_q = T_c$ there is occure a no. of oscillation at steady state.

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

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

Mechanism for producing deflection torque :- (magnetic effect)

(i) Force bet^n permanent magnet and current carrying coil.



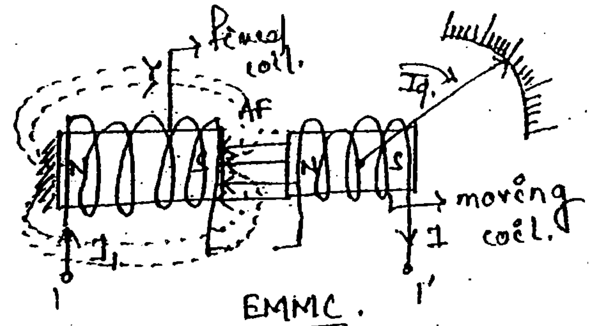
$F = BIL\sin\theta$

temp↑ = B↑

copper = +ve temp. coefficient

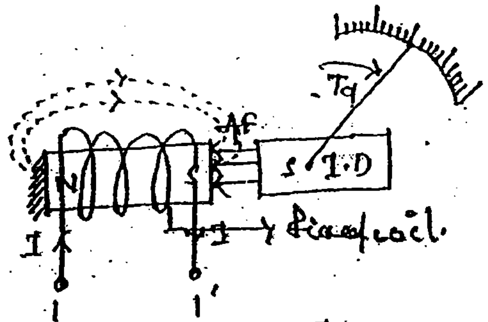
Force bet^n two current carrying coil :

↳ when



EMMC.
Dynamometer type

Force bet^n current carrying coil and soft iron disc :-



Moving Iron Instr.
Fixed coil = to make the iron peice movable.

10/09/10

Mechanism fore producing control torque : (Tc)

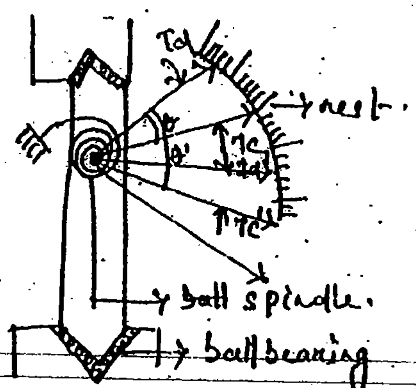
(i) Spring control = Springs having property of restoring the energy. (elasticity property). when we give a current then a force will generated. and this force on the spring generate a deflection force, due to this deflection force the spring itself generate a controling opposition force (i.e. controlling torque) which oppose the deflection force. when the deflection force and control toque will equal then only the spring come under a steady state. when there is no current, then no deflection force is there and the control torque that is generated inside the spring make the spring to come back to it's initial position.

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

(i) Helical spring (Here compression will occure).

(ii) Spherical spring → this can be used in measuring devices (in place of pointer).

Here in spherical spring angular movement'll occure that why here exactly known as deflection torque occur. 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.



$$\boxed{T_c \propto \theta}$$

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

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

Advantages :

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

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

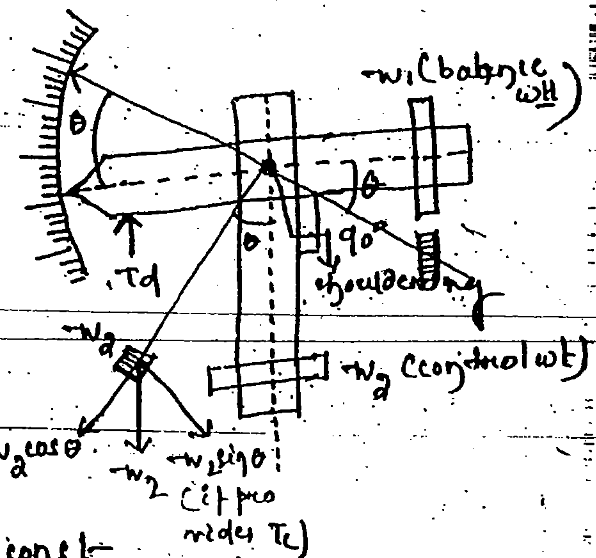
(iii) **Disadvantages :**

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

(ii) temp. error (temp↑ = stiffness↓ = T_c↓ = T_d↑ = θ↑).
if temp↑ = B↓ = T_d↓ = θ↓. ($F = BIL\sin\theta$).
so the total deflection is depend upon temp not on current).

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

(ii) Gravity Control :



↳ Here the balance wt is to reduce the oscillation.

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

↳ Here the shoulding is made in order to made const ... beam used.

↳ Once current will flow through it, the deflection torque will generate. This deflection torque produce as control torque which always try to bring the one of the beam spring to it's original position.

↳ Here $W_2 \sin\theta$ acts as a control torque.

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

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

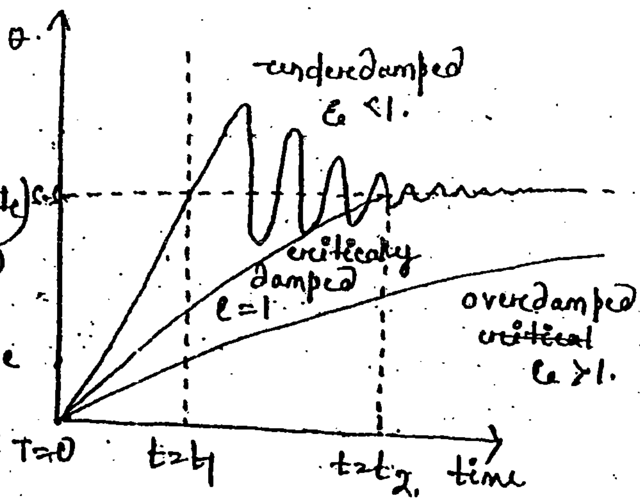
↳ no. less time gap

↳ more no. of oscillation.

critical damped oscillⁿ

↳ moderate time period.

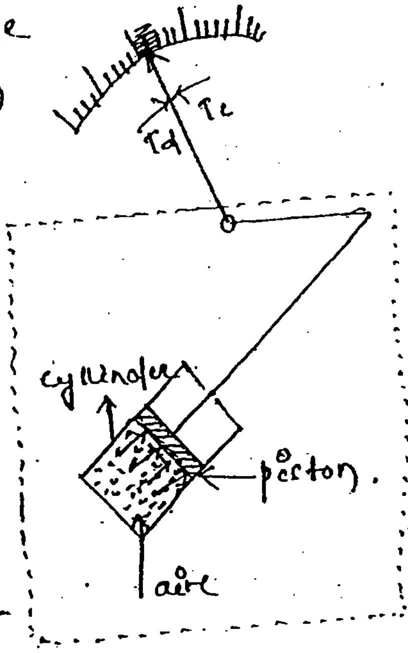
↳ no. oscillatⁿ.



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

(i) Air friction damping :

Here the pointer will move when the piston will go inside, but inside the cyllinder 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~~ 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.

$\boxed{\text{fluid} > \text{air}}$ preference of effectiveness

$\boxed{\text{air} > \text{fluid}}$ 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 maintaince cost etc is also more.

(iii) Eddy current damping :

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

ii

Eddy current > Air friction > Fluid friction

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

Eg: PMMC instrument.

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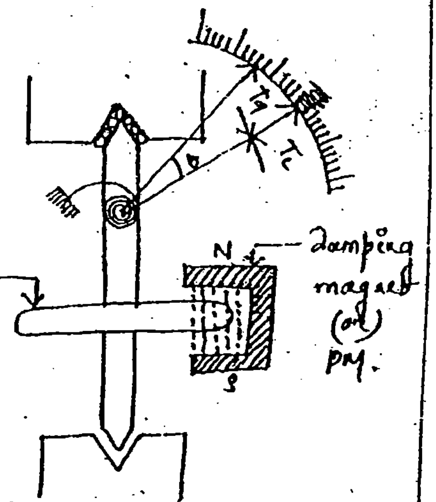
Here the spindle is strictly bounded under the ball bearing. whenever any force applied to it the spindle will rotate (due to deflection torque the spindle will rotate). Here our motto is to reduce the speed by reducing no. of ~~ot~~ oscillation. For this we use here an aluminium disc. and a permanent magnet. when the spindle is rotates the (attached) alluminium disc is also rotating and there also a permanent magnet is present.



In this PM the magnetic field ~~w~~ 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 a it's own resistance and due to this induced e.m.f it produce a current.

~~(we can collect current a current will generate.~~

~~(we can ~~c~~ collect current only on 'cu' wires)~~

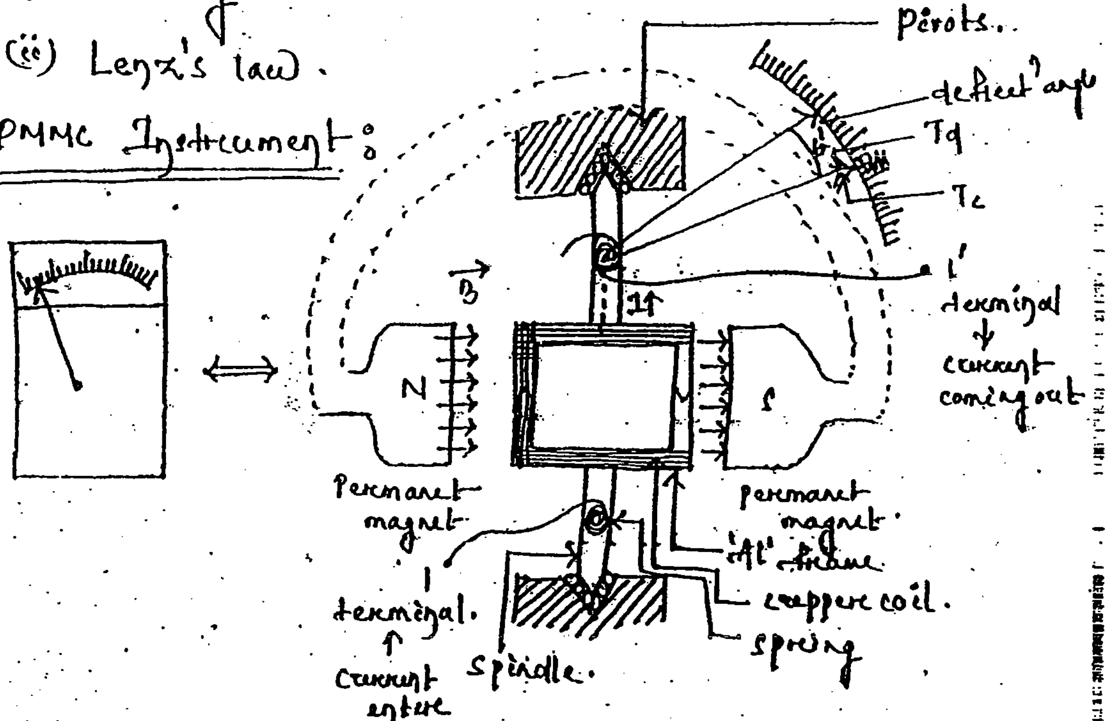
Here we can't collect current that's why it is known as <u>eddy current</u>. This eddy current reduce the no. of oscillation and thus speed will also decrease. Here we use <u>spring control</u> mechanism.

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

(i) Faraday's law

(ii) Lenz's law.

<u>PMMC Instrument</u>:



<u>construction</u> →

Here a spindle is under the force of Jolwel bearing. Two permanent magnet is also there. At the center of both spindle and permanet magnet a 'al' frame is placed. This is wounded by 'cu' coil. There are two terminal '1' (current entere) and 1' (current comes out).

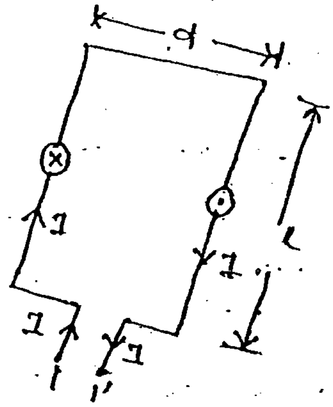
Operation → Once the switch is closed Due to the permanent magnet a magnetic field is passed through the 'cu' wire ('Al' frame) and due to the induced e.m.f. current is flowing through the 'cu' coil. Once the switch is closed the current enters to the terminal '1'. due to this current the pointer will rotate a.

Here three of the following mechanism occur.

~~damping force~~ deflecting torque = b/w current carrying coil and pm.

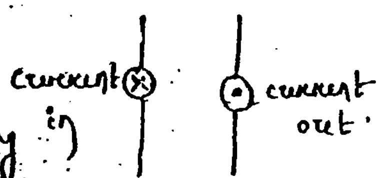
damping force = eddy current

control torque = Spring control mechanism.



In PMMC instrument it's our responsibility to develop radial flux density. (i.e. the angle b/w magnetic field and current must be 90°)

$\boxed{F = BIL\sin\theta}$ Basic working principle of PMMC (Lorenz's eqn)



$\theta = 90°$.

$F = BIL$.

Deflection torque, T_d = Force × $\perp^{r}$ distance.

$T_d = BIL \times d$

$T_d = BIL \times d \times N$. (for no. of turns)

$\boxed{T_d = BINA}$ $(\because L \times d = A)$

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

Here the relation b/w i/p (I) and o/p (deflection torque) is linear. And the scale that are used in this instrument is linear one. bcoz

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

Deflection angle : $T_c = K_c \theta$.

$T_c = T_d$ (at steady state).

$K_c \theta = BINA$.

$$\boxed{\theta = \frac{BINA}{K_c}}$$

$\theta \propto I$.

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

Motor principle → Flemming's left hand rule.
Generator principle → Flemming'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 "Flemming's left hand rule".

- when current ↑ (upword) → force (↓) downword.
  current ↓ → force ↑.

Advantages :-

(i) Scale is linear.

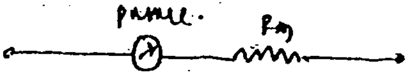
(ii) It is a high accurate and high sensitive instrument (∵ powerfull eddy current damping is used).

Disadvantages :

(i) If By using basic PMMC instrument we can't measured high current, since the spring/leads are being used as current carrying conductor (Here the coil and spring are connected in series).

(The max^m allowable current in PMMC is 50mA) = I_m

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



(simplified diag). Here we shown only resistance becoz it is a dc current instrument.

$\theta \propto I_m$. I_m = meter current.

$I_m = \frac{V_m}{R_m}$ (R_m = 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.

Metre : It has a specific/perticular application.

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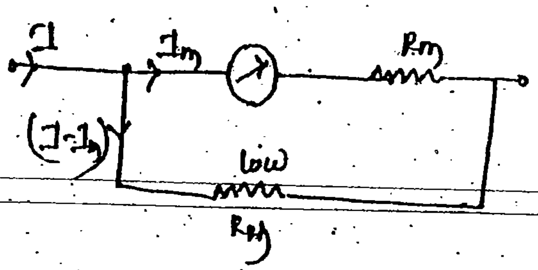
Extension Ranges of basic PMMC instrument :-

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.

$$\theta \propto I_m \underbrace{\left(\frac{I}{I_m}\right)}_{}$$ ← multiplication factor.

$\theta \propto I$.

We know that

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

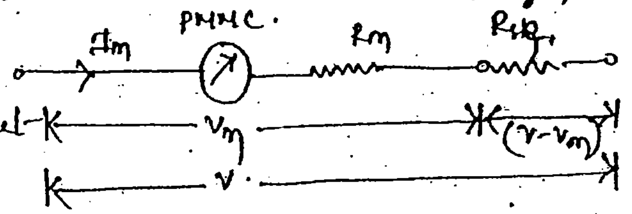
** $$\boxed{\frac{I}{I_m} = 1 + \frac{R_m}{R_{sh}}}$$ multiplication factor.

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

R_m = moving coil resistance.

PMMC as a voltmeter :-

When we apply 'V_m' the current is 'I_m', but when we apply 'V' volt, then we get I_m. It is possible when only we connected a shunt resistance in series with 'R_m'



$\theta \propto I_m \propto V_m$:

$\theta \propto V_m$.

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

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

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

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

Ammeter

Here 'R_{se}' should be high.

Ideal internal resistance of voltmeter $= \infty$

" " " " Ammeter $= 0$.

In ordere to measure high current (1KA, 10KA) the PMMC instrument is n't at all a suitable one. For this we have to choose current transformer.

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

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

In case of max^m voltage, the resistance is 10 times high then ammeter. due to high resistance the ~~care~~ less current will flow through it. Here the meter / scale can't detect such a small current bcoz the spindle friction is so high.

In both cases the $R_{th} = R_{se}$ = 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. = $I\uparrow = \overleftrightarrow{R}$ (const) eg: Mn, constantan.

(iv) zero = at $0°K$ the resistance is exactly 0.

eg: Pt-Ir (at $37°K \rightarrow R \rightarrow 0$).

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

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

~~For high sensitive temp. we go for constantan.~~

~~'constantan' gives 100% accuracy.~~

In case of A/c instrument the multiplier is made up of constantan, but in dc instrument the multiplier is made up of 'Mn'.

Errors in PMMC :—

(i) Frictional Error :

From the bearing we get frictional energy. In PMMC we got the electrical energy at spring. In PMMC when the spindle ~~is~~ start 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 greeze inside the bearing. (to avoid the bearing ~~b~~ to bearing friction).

**(The electronic device ~~has no~~ are more accurate then 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. co-efficient

+ve → $T\uparrow \rightarrow R\downarrow$ → eg: cu, all metals

−ve → $T\uparrow \rightarrow R\downarrow$ → eg: semiconductor and insulator.

const → $T\uparrow \rightarrow \overleftrightarrow{R}$ (const) → eg: Mn, constantan.

zero → 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 reduce by providing swamping resistor in an basic meter.

Mn + Cu

swamping resistor.

(iii) Frequency Error :

The frequency error is absent in PMMC instrument, becoz we measure d/c only here, n't a/c.

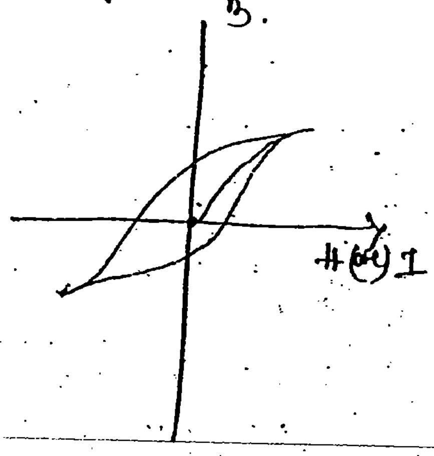
(iv) Hysteresis Error :

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

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

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

$$\boxed{\vec{H}\cdot\vec{L} = NI}$$



If we take any point in loop neither H nor B will be zero simmultaneously 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 (strong one). 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 mirror.

• All the errors are very less / minm in PMMC instr. So that it high accurate or high sensitive instrument.

Drawback :

→ By using PMMC instrument we can measure dc current / dc voltage and can't measure a/c current / volt. or power.

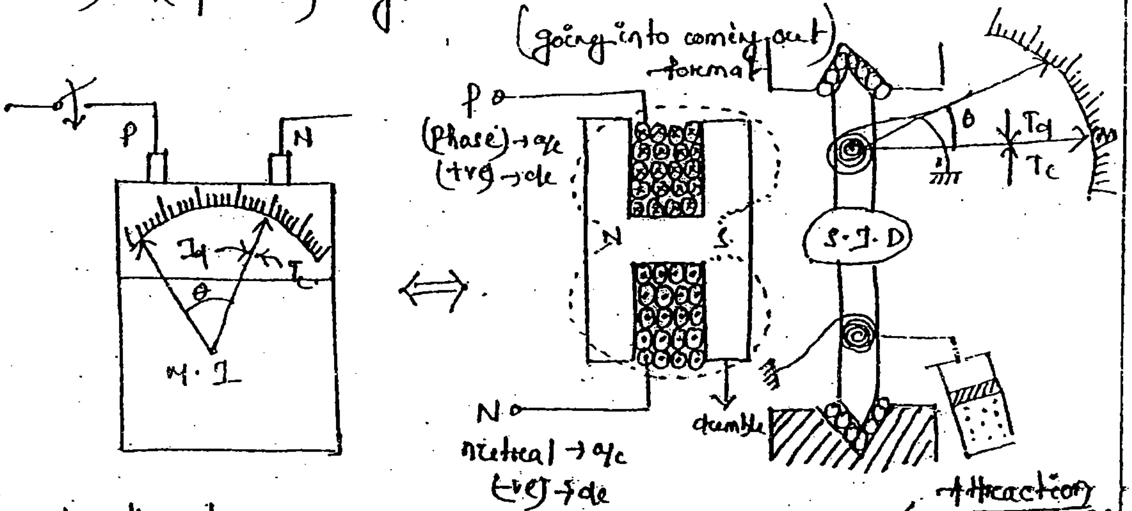
↳ PMMC always read avg value / dc value.

Moving Iron Instrument : (self inductance of fixed coil)

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

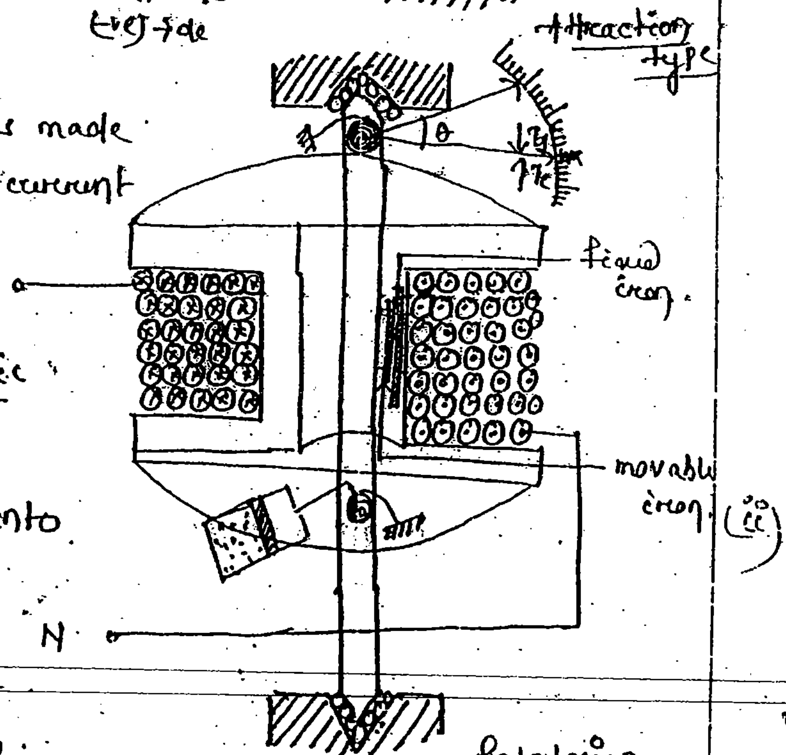
(i) Attraction type

(ii) Repulsion type.



N = thumb.

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



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 attaction force will convert into rotating force. As the SID starts rotating the corresponding spindle will also starts 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 (Td).

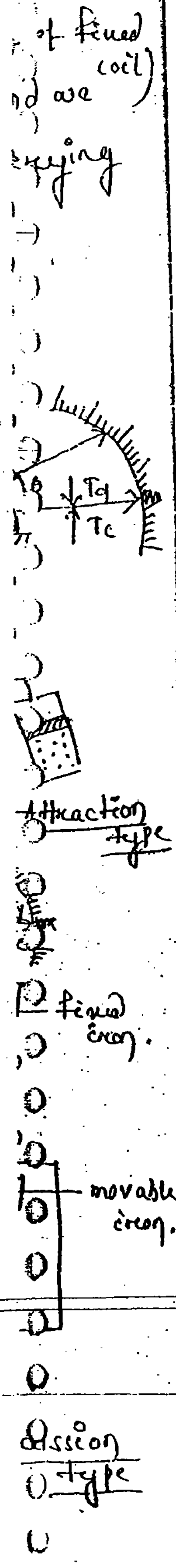
In case of A/c the polarity of the magnetic field will change alternatively, but it has no effect on the attraction force / direc^n (but in PMMC the change in current direc^n effect the force direc^n.)

As the spindle rotate the springs will start tightening.

Here air friction damping is used (bcoz it is a E.M n't PM).

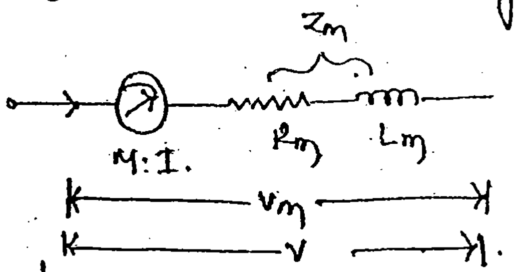
(ii) Repulssion type :

If we make a 90° shift to the attraction type M.I instrument then it will become a repulsion type moving iron instrum. Here the handle is totally vacant/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 Td will generate. And finally the electronic element will convert into mechanical force and pointer will start rotating.

R_m = ~~moving iron~~ fixed coil resistore.



$\underline{L_m}$ = ~~self~~ fixed coil self ~~resisto~~ inductance.

The inductance which will n't allow a sudden change in current until ore unless the ~~flux~~ linkage will close is nothing but self inductance.

L_m

$\Downarrow$

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

I - high current

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

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

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

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

3) $I \times dt = dw$ → the total amt. of energy drawn from the source at time 'dt' sec.

2) $\boxed{LI\,dI + I^2 dL = dw}$ — ①

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

work done $= T_d \cdot d\theta$ — ②

↳ this much electrical energy will convert into mechanical energy in 'dt' sec. causing displacement

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

Energy stored in 't+dt' sec − energy stored in 't' sec

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

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

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

equ^n 1 = equ^n 2 + equ^n 3'

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

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

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

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

$T_d \propto I^2 \propto V^2$ → non-linear one.

Again,

Spring control $\Rightarrow T_c = \theta K_c$

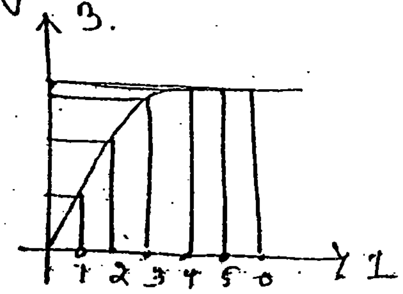
at steady state $T_c = T_d$.

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

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

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

Though the high current is pass through the spring in M.I. it can't able to measure the high current becoz of magnetic saturation.



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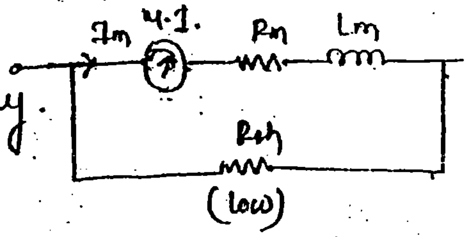
<u>Extension ranges of M.I. Instruments</u> :-

<u>M.I. instrument as an ammeter</u> (to measure I)

All the instrument is independent of frequency.



In prime instrument in order to measure the current I we connect a shunt resistance (R_{sh} = low).

$L_m = X_m = 2\pi f L_m$
↳ self inductive reactance.

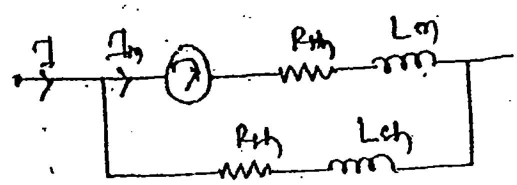
but in M.I although we are connecting a R_{sh} then the magnetic saturation error is can be minimized, but the another pb is arise i.e.

In order to make an instrument we have to connect 'L_{sh}' in series with 'R_{sh}'. but this is also n't sufficient.

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

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

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



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

$\frac{L_{sh}}{L_m} = \tau$ = (time const. of shunt resistance)

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

In case of M.I 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.

$\underline{\tau = sec}$? $\quad \tau = R-L \Rightarrow \tau = \frac{L}{R} = H/\Omega$

$R-C \Rightarrow \tau = RC.$

$$v_L = L\frac{dI}{dt}.$$

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

$$= \frac{IR \times sec}{dI}$$

$= R \times sec.$

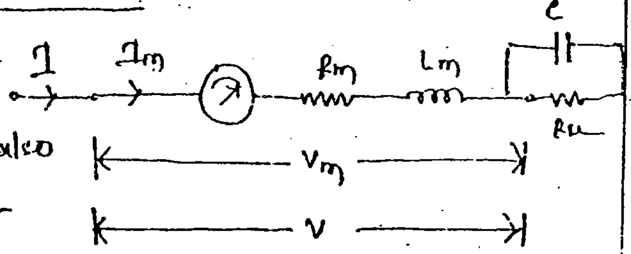
$\tau = \frac{L}{R}$

$= \frac{R\text{-}sec}{R}$

$\tau = sec.$

M.I instrument as volt-meter :

The moment we give high voltage 'v' then also we get max^n current 'Im' instead of getting 'I'.



In this case if we connect a 'Rse' in series with 'Lm'. Then also the pb. is n't completely eliminated.

(Pb: If reactance 'X_m' change then the induct ance 'L_m' then current I_m is also varries and the corresponding frequency is also varrying).

so we have to connect a capacitore in parallal with 'Rse'. Then the inductance reactance is cancelled by the capacitive reactance. and the meter is independence of frequency.

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

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

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

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

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

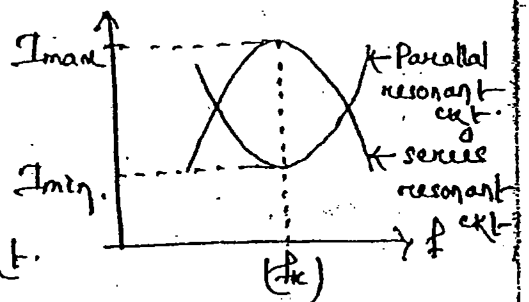
$$L_m = R_{se}^2 C$$

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

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

— why we connect the 'C' in parallal 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) Parallal resonant ckt

(ii) series resonant ckt.

In series resonant ckt the current is max^n so again magnetic saturation pb. is there; but in parallal resonant ckt the current is min^n. and we can reduce the magnetic saturation pb. ~~The instru~~

Errors in Moving Iron Instrument :-

(i) Friqctional 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 error are more compare to PMMC.

(ii) Temperature error :

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

(iii) Frequency error :

The frequency error is more compare to PMMC ~~com~~ 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.I instrument compare to PMMC since directly iron related matterial is being used in the moving system. For iron related matterial the hysteresis loop is thick. we can't avoid the hysteresis ~~loo~~ error aswell as we can't reduce. ~~becoz we can't~~ ~~p~~ 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 PMMC since a weak magnetic field is inside the M.I. instrument.

<u>conclusion</u> : All the error is more compare to PMMC. So it is less accurate and less sensitive.

$\boxed{\text{PMMC} > \text{M.I}}$ (order of sensitivity and accuracy)

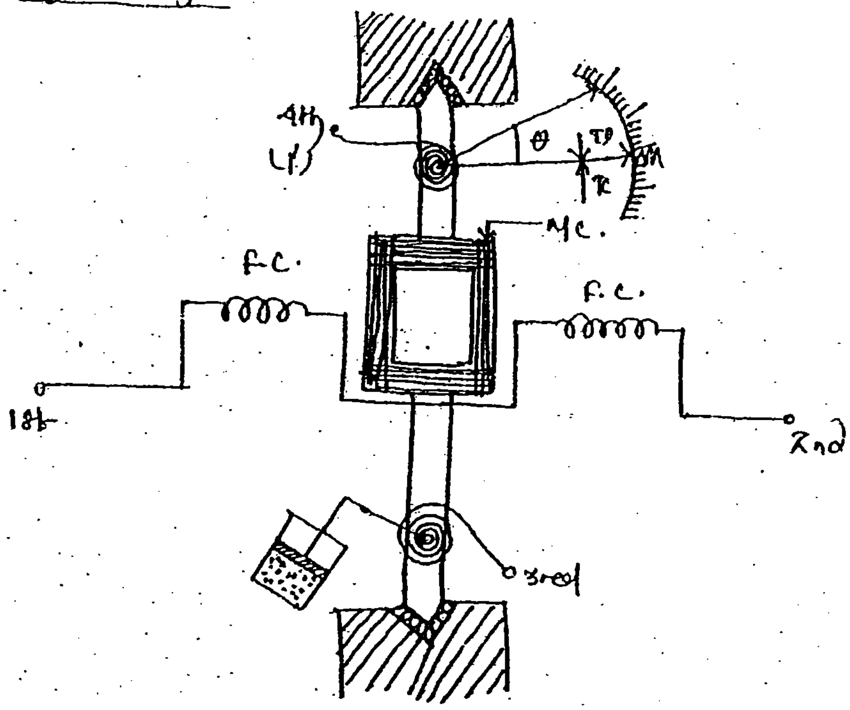
<u>Note:</u>

- By using M.I instrument we can measure ac/DC current or voltage, but n't 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, but we shouldn't measure DC current / volt., but because it is less accurate and less sensitive for ~~a/c~~. dc.

<u>Electro magnet moving coil Instrument</u> :-

- We can measure I, (ac/DC), V (ac/DC), P (ac/DC) and power factor also.
- EMMC instrument is nothing but the combⁿ of PMMC + MI.
- It is the only instrument which is having two coil one is → <u>fixed coil</u> (in order to provide EM) another is → <u>moving coil</u> (in order to provide torque) that's why it is known as <u>Dynamometer</u> type instrument.

↳ The working principal of EMMC is mutual inductance.



↳ The moment when we short ckt the 2nd and 3rd terminal then it has 2 terminals. The current that enter into the instrument is responsible to producing e magnetic force as well as torque.

↳ In EMMC we use air friction damping force.

↳ It has a non-linear or linear characteristic that can be decided by the i/p - o/p relationship.

↳ Again here current flow through the spring.

↳ Both the current is connected in series.

↳ In EMMC instrument if small current is passing through the instrument then the spring will damage but the sufficient magnetic field will n't 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.

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

$$\boxed{\phi \propto NI}$$

↳ we know that,

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

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

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 effected.

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

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

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

$$T_d \propto I^2$$

$$T_d \propto I^2 \propto V^2$$

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

We know that,

$$T_c = K_c \theta.$$

at steady-state, $T_c = T_d$.

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

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

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

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

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

note: ~~try current in 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 measure power the connection should be make parallal.

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

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

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

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

$$I_1 = I_{m_1} \sin \omega t$$

$$I_2 = I_{m_2} \sin(\omega t - \phi).$$

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

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

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

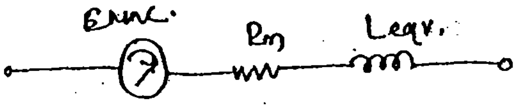
$$= \frac{1}{2\pi}\,\frac{I_{m1} I_{m2}}{2}\,\frac{dm}{d\theta}\int_0^{2\pi} 2\sin(\omega t-\phi)\cdot\sin\omega t\cdot d(\omega t).$$

$$\boxed{T_d = I_1 I_2\cos\phi\,\frac{dm}{d\theta}}$$ → (this is the required eqn to design a wattmeter).

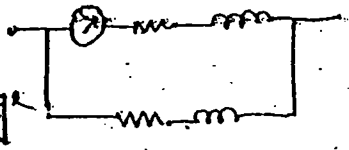
$$= I_1\,\frac{v_{in}}{R}\cos\phi\,\frac{dm}{d\theta}.$$

$$= \frac{1}{R}\, v_{in}\, I\cos\phi\,\frac{dm}{d\theta}.$$

~~not~~ simplified dig:



In order to measure the high current we have to connect the Rsh and Lsh are series to each other. but across parallal to the ckt. The extension range is same as MI instrument.



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

Errors in EMMC Instrument:

(i) Frictional error:

frictional error is more than compare

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

EMMC > M.I > 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 resister.

EMMC > M.I > PMMC.

(iii) Frequency error:

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

EMMC > M.I > PMMC.

(iv) Hysteresis error:

Hysteresis loss is allmost all absent in EMMC. In PMMC Al frame is there due to eddy current damping force. But here no iron related matterial in moving system and we are using here air friction damping force.

M.I > PMMC > EMMC.

(v) Stray Magnetic field error:

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

15 11
~~29~~|10|10

$$\boxed{\text{order of accuracy} = \text{PMMC} > \text{M.I} > \text{EMMC}}$$

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

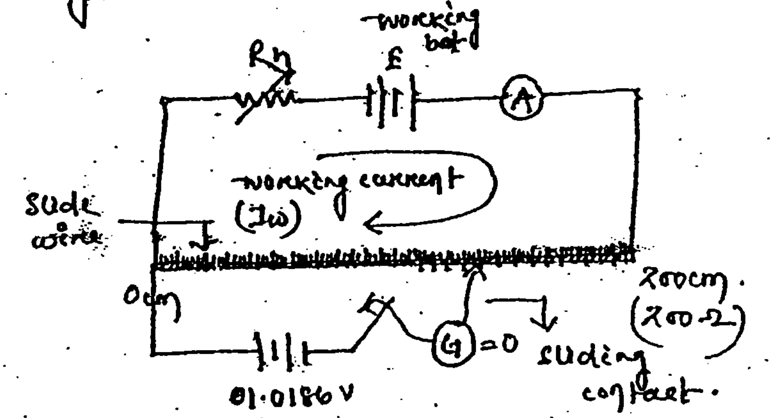
$$\boxed{\text{Power}_{(DC)} = V \cdot I}$$

15 11
~~29~~|10|10

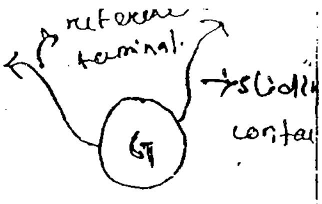
Pottentiometer :-

To measure a very low voltage with accuracy we are pot prefering pottentiometer.

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



Here our purpose is to check whether actual 10mA (assuming current (Iw) is flowing through the meter is or n't. But we have no faith on Ammeter, that's why for cross checking we have to connect a standard cell of watt having pottential 1.0186 V across the pottentio meter. 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 galvano 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.

So
$$10mA \times R = 1.0186\,V$$
$$R = 101.86\,\Omega \qquad (1\,\Omega = 1\,cm)$$
$$= 101.86\,cm.$$

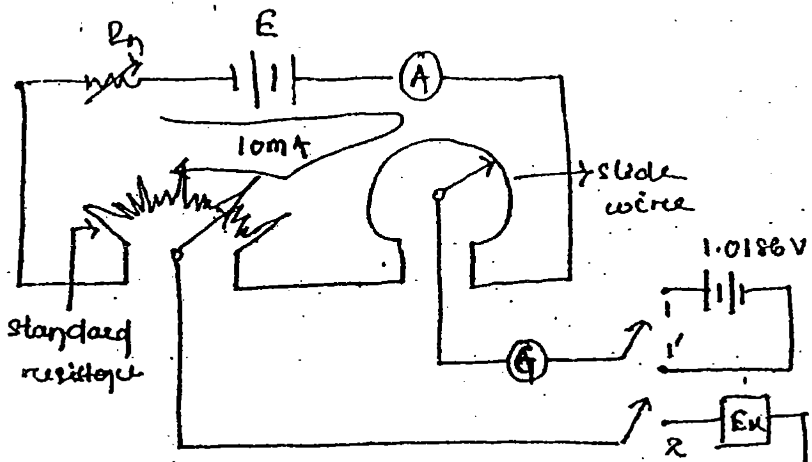
∴ Hence at scale reading 101.86 cm the galvanometer shows zero reading. and from that we can assure that there is exact 10mA amount of current is flowing through the potentiometer.

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.

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

Crompton Potentiometer :-



In potentiometer the total 101.86V is completely contributed by slide wire. so we are using a long fillament like slide wire. But we In order to reduce/compact the pottentiometer size we are spliting it (slide wire) into two parts by putting a standard resistance across it. and instead of using a long slide wire we are using a small scale cylinderical scale having resistance 1.86 i.e. the 100Ω is offered ~~and~~ by standard resistance

$$101.86\,\Omega \rightarrow 100\,\Omega,\ 1.86\,\Omega$$

Pb! A mag swamp resistance is connected in series with moving ammeter ~~connected~~ with consist of mf with a suitable shunt in order to

a) minimize the effect of temp variation.

b) obtain the large deflecting torque.

Pb: The effect of stray magnetic field on the actuating torque of a portable instrument is maxⁿ when the operating field of instrument and stray magnetic fields are

a) perpendicular

b) parallal

c) Inclined at 60°

d) Inclined at 30°.

actuating torque = inside mag. field.

Stray torque = outside mag field

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

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

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

where θ = deflection of radious from zero posⁿ. the control spring torque is ~~20~~ 25×10^{-6} Nm/rad. The deflection of the pointer in 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.

$T_c = 25\times10^{-6}$ Nm/rad.

$I = 5$ amp.

We know that, $T_c = T_d$

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

$$25\times10^{-6}\times\theta = \frac{1}{2}(5)^2\left(3-\frac{\theta}{2}\right)\times10^{-6}$$

$$\frac{25\times10^{-6}}{\frac{1}{2}\times(5)^2} = \frac{\left(3-\frac{\theta}{2}\right)\times10^{-6}}{\theta}$$

$$\frac{25\times10^{-6}}{\frac{25}{2}} = \frac{(6-\theta)\times10^{-6}}{2\theta}$$

$$2\times10^{-6} =$$

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

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

a) 1.0 volt

b) 1.34 volt

c) 1.50 volt

d) 1.70 volt

1 cm = 1 Ω.

10^{-1} mm = 1 Ω

$\frac{1}{10}$ mm = 1 Ω

1 mm 10 Ω

800 = 8000 Ω

$V = IR$

$I = \frac{2}{8000} =$

10^{-1} mm = 1 cm

1 mm = 10 cm.

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

$I_w = 1.96$ mA

$I_w = 1.96\times10^{-3}\times680$

Pb: A galvanometer with full scale current of ~~1000 Ω A~~ 10 mA has a $r = 1000\,\Omega$. The multiplying power of $100\,\Omega$ 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 mm x 20 mm respectively. It is positioned in a uniform radial flux density of 200 m tesla. The coil carries a current of 50 mA. Then the torque on the coil is :

sol^n:

$N = 100$ turns

$l \times d = 10\,mm \times 20\,mm$.

$\phi = 200\,mT = B$

$T_q = BINA$

$$T_d = 200\,mT \times 10\times10^{-3} \times 20\times10^{-3} \times 100$$

$$= 200\ \mu\text{m}.$$

Pb: A moving iron ammeter produces a full scale torque of 240 μNm. with a f.s.d 120° at a current of 10 Amp. The rate of change of self inductance at full scale is :

$T = 240\,\mu Nm$.

$I = 10$ Amp.

$$T_c = T_d$$

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

10mA
$\varepsilon \cup I t$

a length

city

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

$\Rightarrow$ $\frac{240}{2 \times 100} = dL/d\theta$

$\Rightarrow$ $4.8\ \mu H/deg. = dL/d\theta$.

Pb: A PMMC volt-meter is connected across a series combination of a dc voltage source of 2V and ac voltage source 3 sin4t then the meter read

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

Pb: A dc ammeter has a resistance of 0.1 Ω and it's current range is 0-100 Amp. If the range is to be extended 0-500 Amp. then the meter requires the following shunt resistance.

soln:

$R = 0.1$
$I = 100A$.

$$R_{sh} = \frac{R_m}{\frac{I_{FSD}}{I_{mFSD}} - 1}$$

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

$$= 0.25$$

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

$I = -8$ (PMMC).

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

$= 10$

$I = 10$ (M.I.)

Pb: A variable 'ω' is related to 3 other variables (x, y, z) as $\omega = \frac{xy}{z}$. 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 uncertainity in the 'ω' will be.

$fsv = 100$

$x = 0.5\% \times 80 =$

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

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

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

Assersion: comparision methods of direct msmt are most widely used in electrical engg.

Reason: comparission methods of direct msmt gives high accuracy.

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

b) Both 'A' and 'R' individually true & 'R' is not the correct explan^n of 'A'.

c) 'A' is true & 'R' is false.

d) 'A' is false & 'R' is true.

Pb: A 0-250 volt voltmeter has a guarnteed accuracy error of 2% of it's full scale value. The voltage measured by this voltmeter is ~~250~~ 150 volt, then the percentage limitting error is:

Ans:
$$gae = 2\%$$
$$= \frac{2}{100} \times 250 = 5$$
$$\% L.E = 100 \times \frac{x}{100} = 5$$
$$x = 3.33\%$$

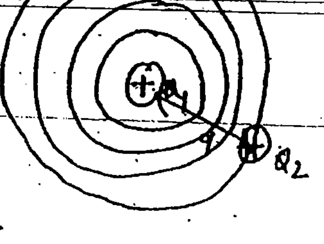
Electrostatic Effect :—

coulomb's law :

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

This is colomb's law :

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

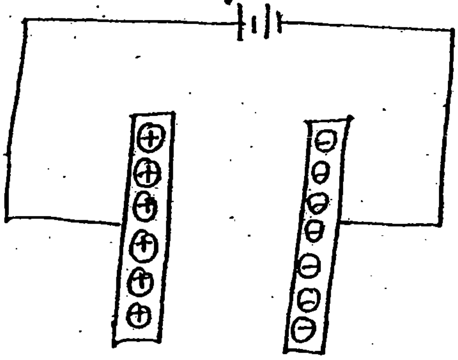


If another charge 'Q_3' is placed outside of the electric field ~~they~~ then we are unable to experience the force at 'Q_3'.

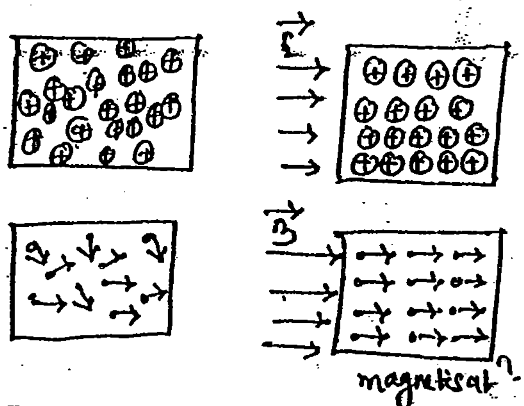
This electric field is given by Faraday law of electromagnetic induction.

$$E = F/q$$ → this force is nothing but columb's law.

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



In Electrostic field we can only measure voltage becoz $\boxed{Q \propto V}$



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

↳ Inductore stores energy in form of magnetic field.

↳ capacitore stores energy in form of electric field.

↳ Although the capacitore 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 developed. this high amount of charge cause to devlop high force that result in movement of metalic 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 ~~big~~ resultant high voltage. The max^m 500KV we can measure by the help of electrostatic voltmeter.

~~The relation b/w force and voltage~~

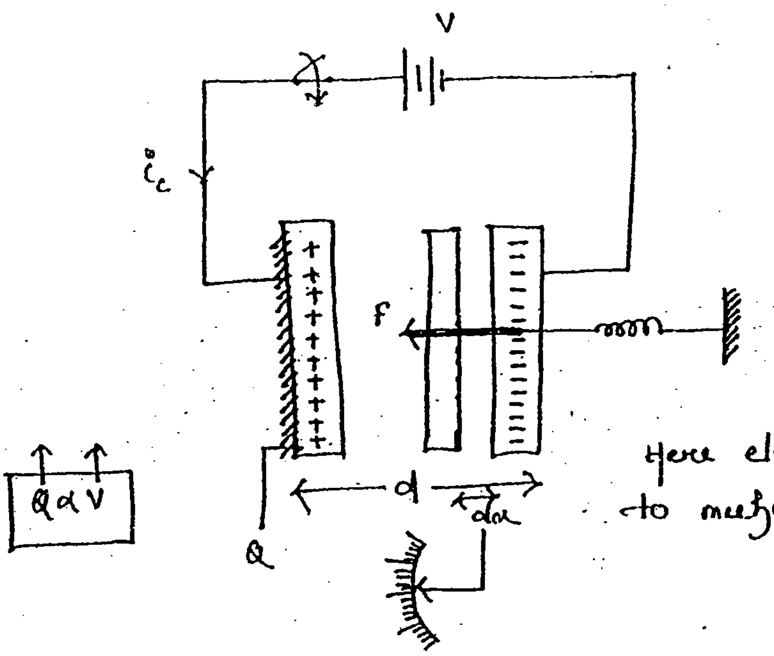
Whether this electrostatic voltmeter is linear or non-linear that depends upon the relation b/w force and voltage.

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

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

dipole :

14/11/10 **Electrostatic Voltmeter :-**



Here electrical energy to mechanical energy.

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 5 variables are there i.e. Q, V, F, d & C. All this variable are depend upon charge.

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

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

So

$$C\frac{dv}{dt} + v\frac{dc}{dt} = i_c$$

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 or power converter.

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

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

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

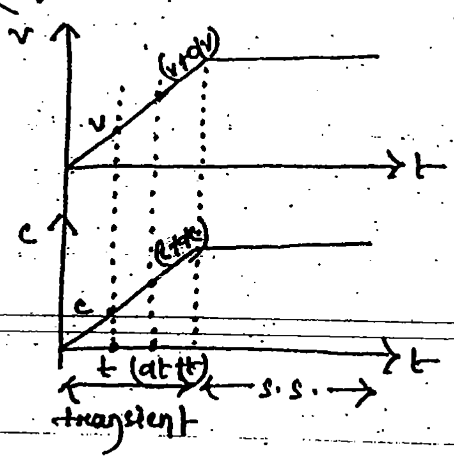
$$\Rightarrow \boxed{cv\frac{dv}{dt} + v^2\frac{dc}{dt} = dw} \quad — (1)$$

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

This much electrical energy converted into mechanical energy that will do some useful workdone. Therefore mechanical work done in 'dt' sec. = $\underbrace{F \times dx}_{\text{linear displacement}}$ — (2)

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

Becoz 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

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

$$= \frac{1}{2}(c+dc)(v^2+\cancel{dv^2}^{0}+2v.dv) - \frac{1}{2}cv^2$$

$$= \frac{1}{2}\left[cv^2+2v.c.dv+dcv^2+2v.dv.dc\right] - \frac{1}{2}cv^2$$

$$= \frac{1}{2}cv^2 + cvdv + \frac{1}{2}v^2dc - \frac{1}{2}cv^2$$

$$= cvdv + \frac{1}{2}v^2dc. \quad — (3)$$

n/w according to law of conservation of energy:

$$(1) = (2) + (3)$$

$$cv\cancel{dv} + v^2dc = Fdx + cv\cancel{dv} + \frac{1}{2}v^2dc$$

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

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

this is the required relat^n b/w F & V.

∴ Hence the scale is non-lineare.

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

— we know that $F \propto V^2 \propto I^2$

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

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

↳ 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 capacitance doesn't change it's polarity until or unless

↳ Th
mea
d
↳ A
m
↳
n
t
c
P
↳ w
s.c
M
(i)
(ii)
(iii)
Eg
Eg
L
me
H

↳ Inductor can reverse it's polarity by it's own that means after it storing energy fully it will delivered it to source.

↳ Again when it stores energy it's size becomes 10 times more than capacitance

↳ capacitance storing energy very slowly that no-noise can be intercepted. 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 catagories

(i) Low resistance (< 1Ω) Eg: Ammeter shunt, diode F.B Armature winding, series field winding resistance.

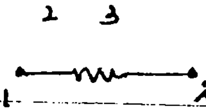
(ii) Medium resistance (1Ω ⇒ 100KΩ)

(iii) High resistance (R > 100KΩ)

Eg : shunt field winding, potentiometer slide wire

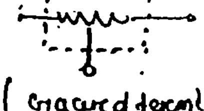
Eg : Diode R.B, all insulation resistance etc. leakage resistance, op-amp i/p impedence,

~~Low resistance having '4' terminals~~



medium resistance having '2' terminals

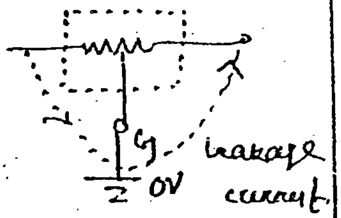
High resistance having '3' terminals



(guard terminal)

The purpose of guard terminal :

- In order to measure the High resistance we have to make the third terminal ground i.e. to avoid leakage current. Once we make it grnd then the leakage current will bypass through the ground.
- So the purpose of guard terminal is to avoid leakage current.



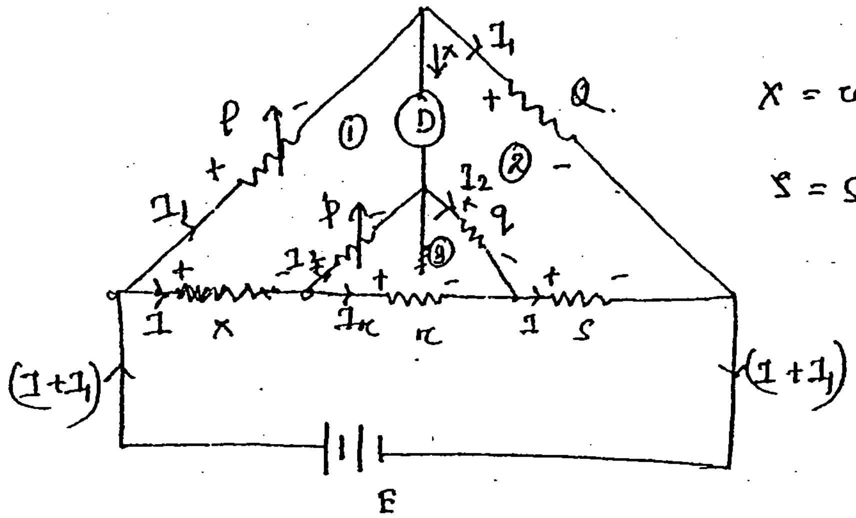
- We can measure the low resistance by using Kelvin's double bridge.
- We can measure the medm resistance by following '4' method.
  - (i) Wheatstone bridge method (It is an accurate one)
  - (ii) V-A / A-V } method ($R_m = \frac{Volt}{Amm}$)
  - (iii) Substitution method.
  - (iv) ohm meter (worst one)
- We can measure the High resistance by following '4' methods
  - (i) Megger
  - (ii) Loss of charge methode (accurate one)
  - (iii) Direct deflection methode
  - (iv) Mega ohm bridge (worst one)

Kelvin's double bridge :-

P, Q, p, q = Known resistance / bridge resis.

X = unknown low resis.

S = Stand. resis.



r = contact / lead resistance.

under bias current cond^n there is no current through 'g'.

By KVL ;

$$-I_1 P + I_2 p + I X = 0 \quad \text{—}$$

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

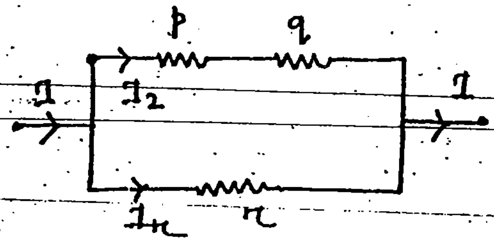
By KVL ;

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

$$I_1 Q = I_2 q + I_S \quad \text{— (2)}$$

Again by KVL,

$$-I_2 p - I_2 q + I_r r = 0$$



$$I_2 = \frac{I r}{p+q+r} \quad \text{— (3)}$$

now, $$I_1 P = \frac{Ir}{p+q+r} p + Ix$$

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

similarly, $$I_1 Q = \frac{Ir}{p+q+r} \cdot q + Is$$

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

now divide eqn (4) by (5)

$$\frac{I_1 P}{I_1 Q} = \frac{\frac{pr}{p+q+r} + X}{\frac{qr}{p+q+r} + s}$$

$$\Rightarrow \frac{P}{Q} = \frac{\frac{pr}{p+q+r} + X}{\frac{qr}{p+q+r} + s}$$

$$\Rightarrow \frac{P}{Q}\left[\frac{qr}{p+q+r} + s\right] = \frac{pr}{p+q+r} + X.$$

$$\Rightarrow X = \frac{P}{Q}s + \frac{P}{Q}\frac{qr}{p+q+r} - \frac{pr}{p+q+r}$$

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

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

↳ It's purpose is to measure low resistance.

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

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

$$\therefore \quad X = \frac{P}{Q}S + \left[\frac{rq}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]\right]$$

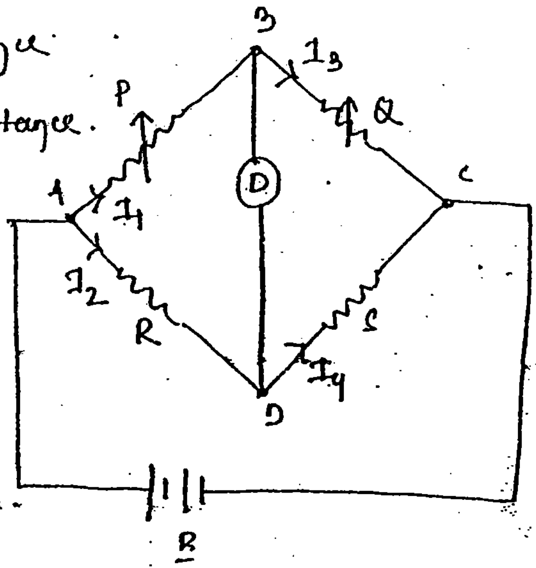
$$\boxed{X = \frac{P}{Q}S}$$

Hence it is the eqⁿ of wheatstone bridge.

Wheat stone bridge :—

R = unknown resistance

S = standard resistance.



$I_1 P = I_2 R$

$$\frac{I_1}{I_2} = \frac{R}{P} \quad —①$$

drop across BC = drop across DC.

$I_3 Q = I_4 S$

$$\frac{I_3}{I_4} = \frac{S}{Q} \quad —②$$

But $I_1 = I_3$ & $I_2 = I_4$

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

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

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

Sensitivity :

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

$$S_D = \frac{\text{change in deflection}}{\text{change in P.D}} = \frac{\Delta\theta}{e}$$

two

ensure

(ii) Bridge sensitivity (S_B) :

$$\boxed{S_B = \frac{\text{change in resistance deflect}}{\text{unit change in Resis.}} = \frac{\Delta\theta}{\Delta R/R}}$$

From deflection sensitivity,

$$\Delta\theta = S_D e$$

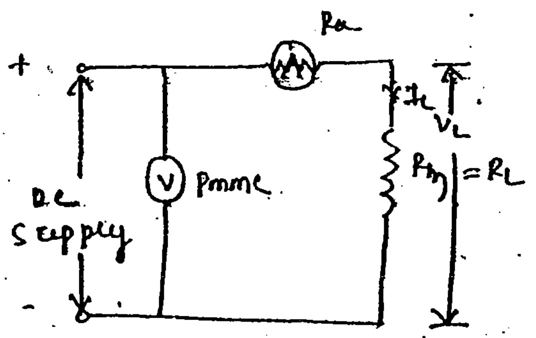
now

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

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

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

voltmeter - Ammeter method :-



$$(R_m)_m = \frac{\text{volt-}}{\text{Ammeter}}$$

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

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

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

(i) $R_m > R_T$

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

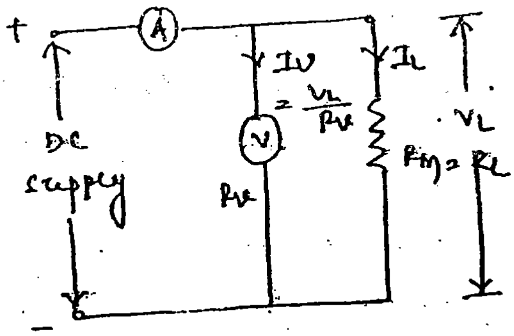
(iii) $\% \text{ error} = \dfrac{A_m - A_t}{A_t} \times 100$

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

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

→ so this measure <u>high resistance</u> in <u>medium range</u>

<u>Ammeter - voltmeter method</u> :-



$(R_m)_m = \dfrac{\text{volt}}{\text{Ampere}}$

$(R_m)_m = \dfrac{V_L}{I_L + I_V}$

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

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

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

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

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

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

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

(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.

∴ 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:

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

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

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

∴ medium resistance = $\sqrt{\text{ammeter resistance} \times \text{load resistance}}$

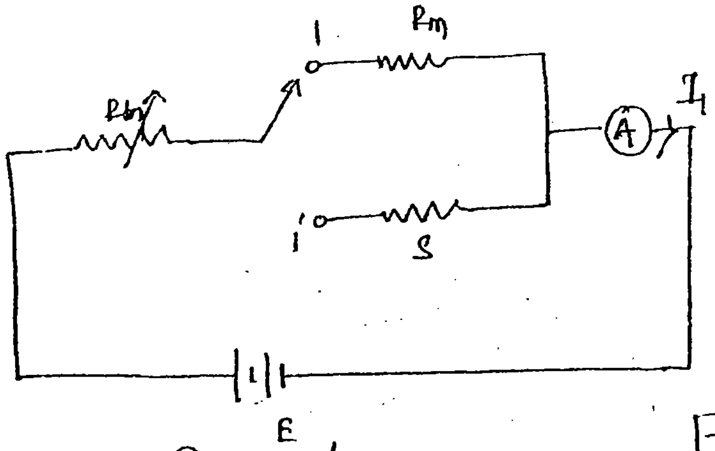
Note:
Always the error becoz of always load side of the instrument.

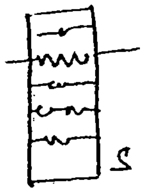
Substitution Method :-

R_m = unknown med. resistance.

S = standard resistance.

$$I_1 = \frac{E}{R_h + R_m}$$



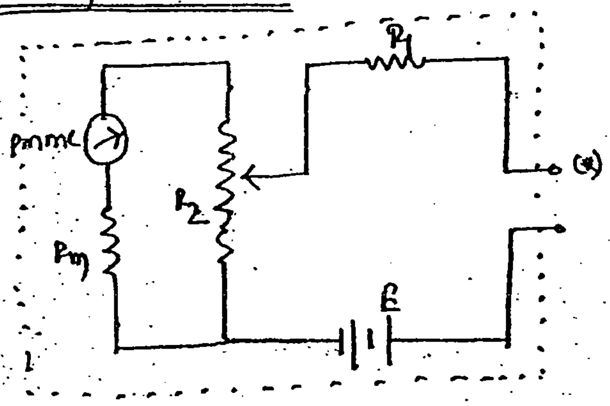


now it switched to 1' ;

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

Instead of charging rehostat we have to substitute the different recistance in the standard resistance for that we are will getting 'R_m' for a perticcular resistance.

Ohm meter :—



R_m, R_1, R_2 = known recistance / internal resistance.

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

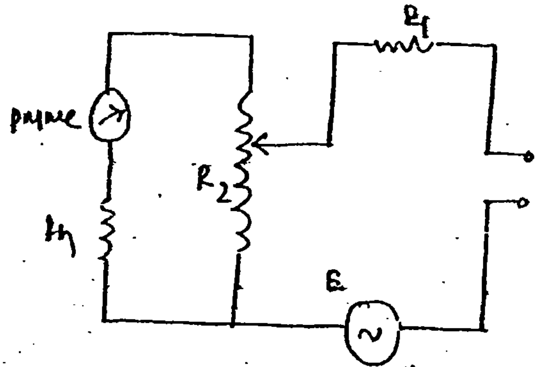
$$I_1 = \frac{E}{(R_m \| R_2) + R_1}$$

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

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

Megger :—

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



Hand driven generator.

17/11/16

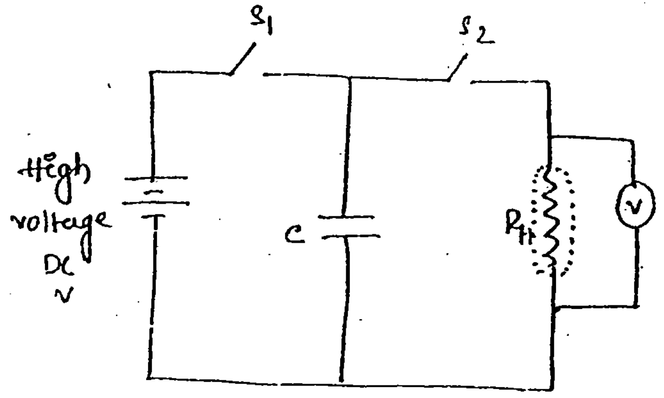
High voltage DC V

at t see of three n

Note: the CRO indi capa & meas

terminal

17/11/10 Loss of charge method :-



Here R_H is high that's why we apply here High voltage. Due to this high voltage we are using E.S.V.

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

at 't' see the amt. of voltage pass through resis.

V → supply volt.

conti-

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

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

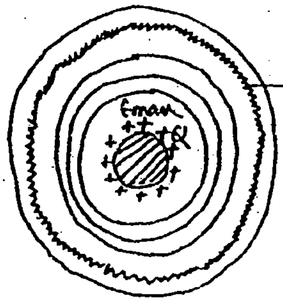
$$\ln\left(\frac{V}{v}\right) = t/RC$$

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

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_H); 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 decreas.

Loss of charge method is best suitable for the msmt of insulation resistance in case of cables. becoz the capacitor that are used in cable that only use in directly as the capacitor in Loss of charge method. Hence it is less expensive.



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

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

surface charge → Electric field is max^{m} on the surface of the conductor.

$$\bar{E}\cdot 4\pi r^2 = \frac{1}{\epsilon_0} Q$$

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

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

parallal plate capacitance $= \frac{\epsilon A}{d}$ —||—

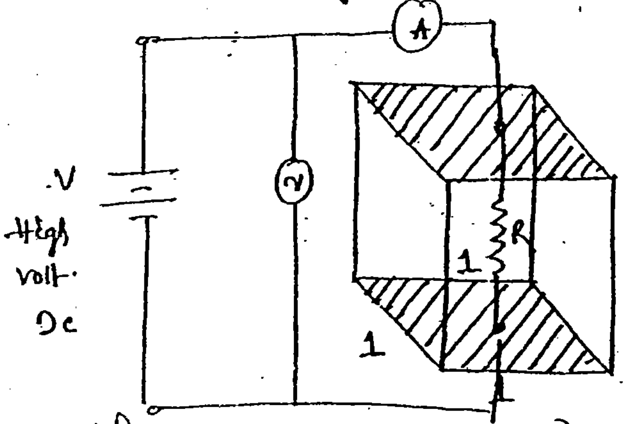
cylindrical plate capacitance $= \frac{2\pi\epsilon}{\ln(b/a)}$

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 msmt 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'.

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

$\boxed{\rho = R}$ 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:

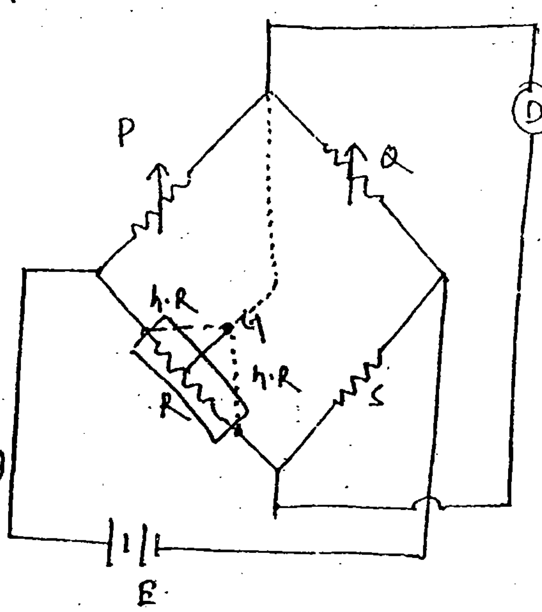
$$\boxed{\frac{V}{I} = R = \rho}$$

Mega ohm bridge :-

$R =$ measⁿ resistance.

we know that

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



But we want to measure high resistance. Then we have to connect a high resistance in place of measⁿ 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 guared terminal as a high resistance.

↳ one side high resistance is connected parallal across the 'P' terminal and another is parallaly connected to the 'D' (i.e. nothing but internal resistance).

↳ But both 'P' and 'D' are very small. so as a result the high resistance is cancelled out and a very small amount of resistance equ. to 'P' and 'D' are getting.

Measurement of Inductance / AC bridge :-

(i) Maxwell's inductance bridge.

(ii) Maxwell's inductance - capacitance bridge.

(iii) Hay's bridge.

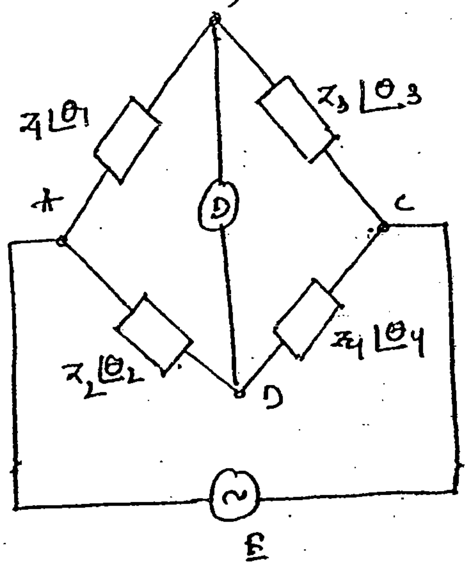
(iv) Owen's bridge.

(v) Anderson's bridge.

A/C bridge :-

Balancing cond^n

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



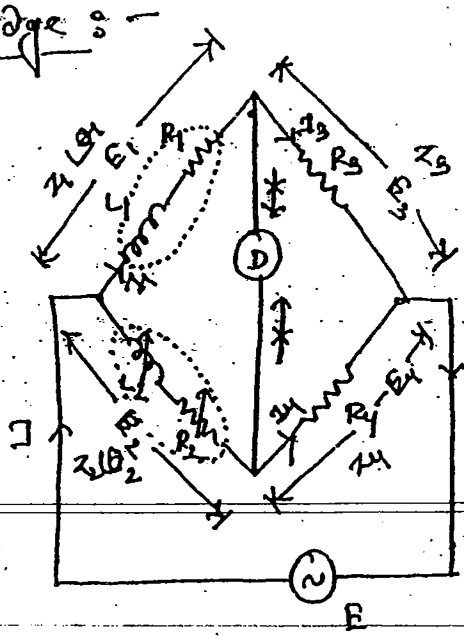
(i) Maxwell's induction bridge :-

L_1 = unknown inductance.

L_2 = known inductance.

Under balance cond^n:

there is no current across detector.

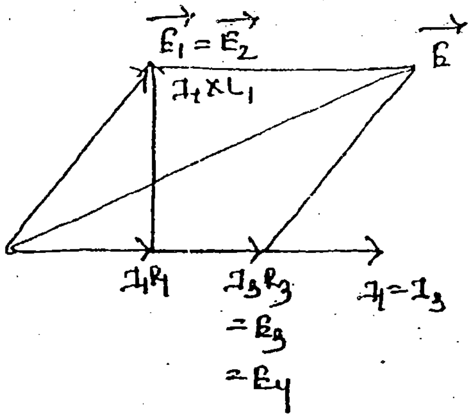


$$\angle\theta_1 + \angle\theta_4 = \angle\theta_2 + \angle\theta_3$$

$$Z_1 Z_4 = Z_2 Z_3$$

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

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



now,

$$R_1 R_4 = R_2 R_3 \qquad L_1 R_4 = L_2 R_3$$

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

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

In The quality meter 'Q' indicates the quality of an inductor.

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

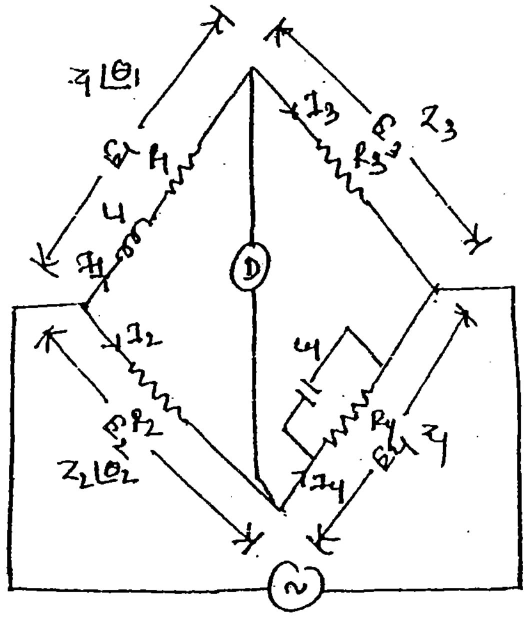
$Q = 60\%$ → It indicates 60% of inductive nature and 40% of resistive.

Generally,

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

But in we can only measure the quality factor (Q) in resonance cond^n (i.e. $X_L = X_C$). For that we required an capacitance in the ckt. But in this above in bridge there is no capacitance. Hence we can't ~~fin~~ find out the quality factor.

Maxwell inductance bri - capacitance bridge :-



$$Z_1 Z_4 = Z_2 Z_3$$

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

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

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

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 → variable (easy to manufacture)
→ fixed (n't so easy)

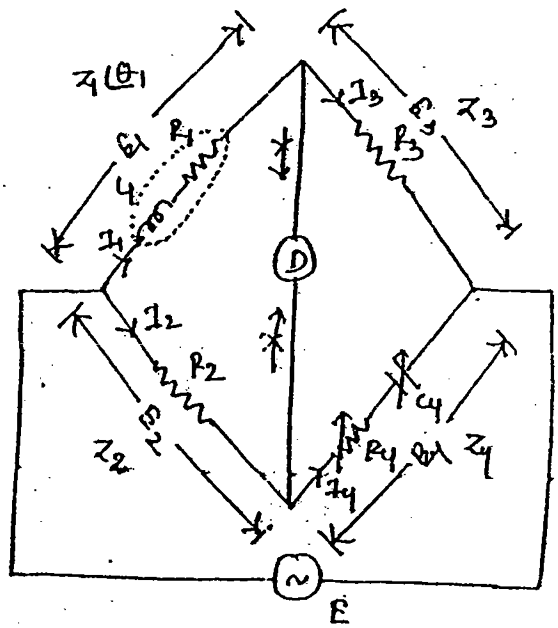
(ii) capacitance → variable (n't so easy)
→ fixed (easy to manufacture)
because $C = \frac{\epsilon A}{d}$

(iii) Inductance → variable, → fixed } n't at all easy to manufacture due to no. of turns.

these turns are effected by reluctance and mag. field.

↳ In this we can't measure high quality factor. Becoz in order to measure high quality factor we have to design a high variable capacitor, but design of variable capacitor is n't so easy. that's why in this case quality factor (Q) is restricted to a cond^n: $\boxed{Q < 10}$

Hey's bridge :-



$$Z_1 Z_4 = Z_2 Z_3$$

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

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

$$\Rightarrow R_1 R_4 = R_2 R_3$$

$\Rightarrow$

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

$\Rightarrow$

$$R_1 = \frac{\omega^2 C_4^2 R_2 R_3 R_4}{1 + \omega^2 C_4^2 R_4^2} \qquad L_1 = \frac{R_2 R_3 C_4}{1 + \omega^2 C_4^2 R_4^2}$$

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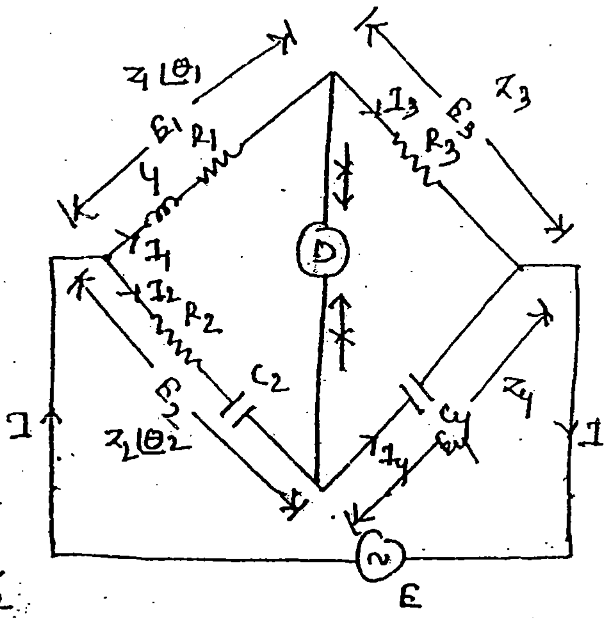
$$\boxed{\text{quality factor } (Q) = \frac{\omega L_1}{R_1} = \frac{1}{\omega C_4 R_4}}$$

$$\boxed{Q_4 \propto \frac{1}{C_4}} \quad (Q > 10)$$

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

Owen's Bridge :-



$$Z_1 Z_4 = Z_2 Z_3$$

$$(R_1 + j\omega L_1)\, j\omega C_4 = \left(R_2 + \frac{1}{j\omega C_2}\right) R_3$$

$$R_1 j\omega C_4 + j\omega L_1 j\omega C_4 = R_2 R_3 + \frac{R_3}{j\omega C_2}$$

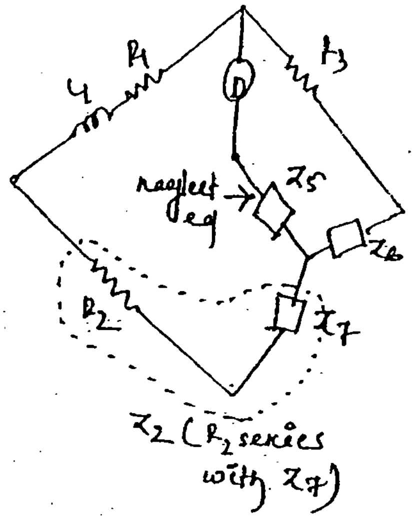
$$\boxed{R_1 = \frac{R_3 C_4}{C_2}} \quad \Rightarrow \boxed{L_1 = R_2 R_3 C_4}$$

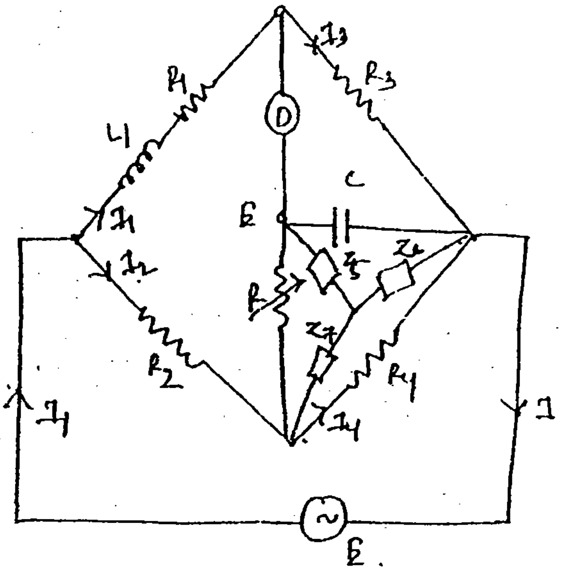
quality factor : $Q = \dfrac{\omega L_1}{R_1}$

$$\boxed{Q = \omega R_2 C_2}$$

$$\boxed{Q \propto C_2} \quad (Q < 10).$$

Anderson's bridge :-





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

$$L_1 = \frac{CR_3}{R_4}\left[RR_2 + RR_4 + R_2R_4\right]$$

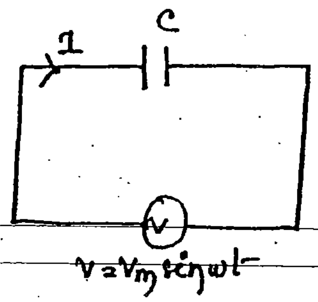
Here we can't measure Q-factor becoze we are connecting here a fixed capacitor.

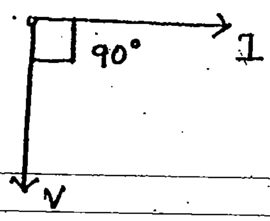
10/11/10 **Measurement of capacitance bridges :-**

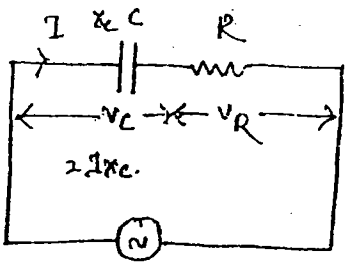
(i) Desauty bridge

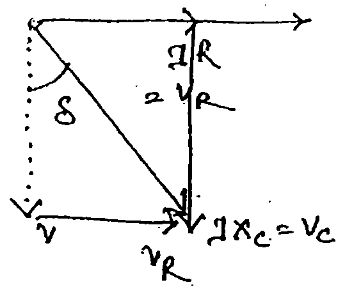
(ii) Modified desauty bridge.

(iii) Schering bridge. (Highly accurate bridge)









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

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

$$\tan\delta = \frac{V_R}{V_C}$$
$$= \frac{IR}{I X_C}$$
$$= \frac{R}{1/\omega C} = \omega C R$$

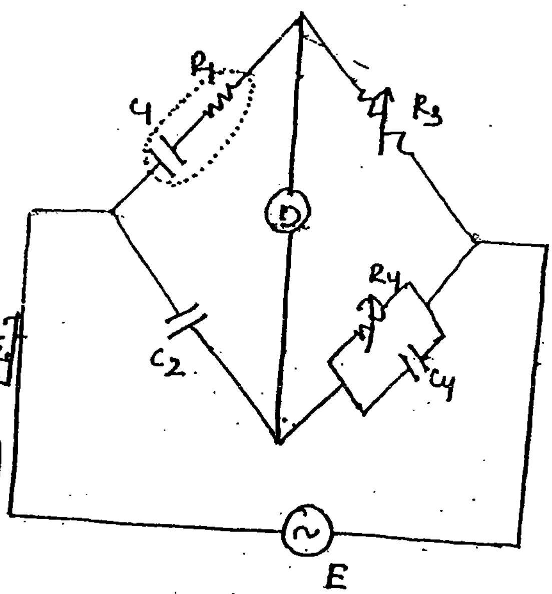
$\boxed{\tan\delta = \omega C R}$ ⟹ D-factor (that determine the quality of capacitor)

(iii) <u>Schering bridge</u> :-

C_1 = unknown capacitor.

<u>Balancing cond^n</u>:

$$Z_1 Z_4 = Z_2 Z_3$$



$$\left(\frac{1}{j\omega C_1} R_1\right)\frac{1}{j\omega C_2} = R_3\left[R_4 \,\|\, \frac{1}{j\omega C_4}\right]$$

$$\Rightarrow \frac{-R_1}{\omega^2 C_1 C_2} = R_3\left[\frac{R_4 \cdot \frac{1}{j\omega C_4}}{R_4 + \frac{1}{j\omega C_4}}\right]$$

$$\Rightarrow \frac{-R_1}{\omega^2 C_1 C_2} = R_3\left[\frac{R_4/j\omega C_4}{\frac{R_4 j\omega C_4 + 1}{j\omega C_4}}\right]$$

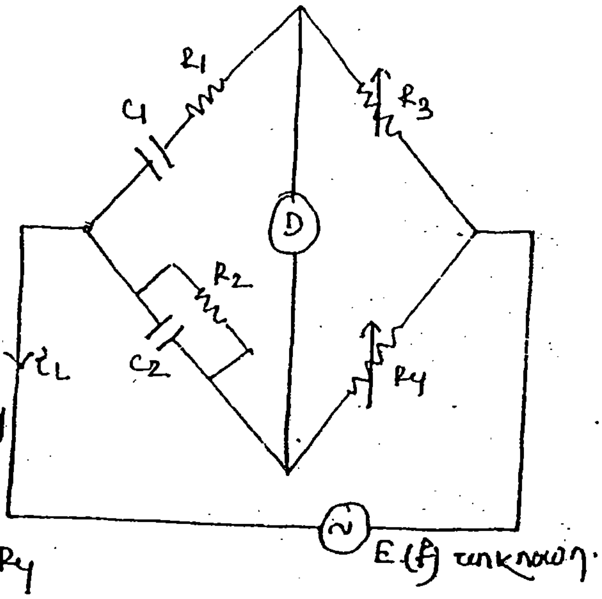
$$C_1 = \frac{C_2 R_4}{R_3}, \quad \text{D factor} = \omega C_1 R_1$$
$$= \omega C_4 R_4$$
$$R_1 = \frac{R_3 C_4}{}$$

Measurement of frequency :-

(i) Wein's bridge :

Balancing cond^n :

$Z_1 Z_4 = Z_2 Z_3$



$$\Rightarrow \left(\frac{R_1}{j\omega C_1}\right)\left(R_2 \parallel \frac{1}{j\omega C_2}\right) = R_3 R_4$$

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

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

$$\Rightarrow \frac{R_1 R_2}{-R_2\omega^2 C_1 C_4 + 1} = R_3 R_4$$

$$\Rightarrow R_1 R_2 = -R_3 R_4 R_2 \omega^2 C_1 C_4 + R_3 R_4$$

$\Rightarrow$

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

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

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

Measurement of power :-

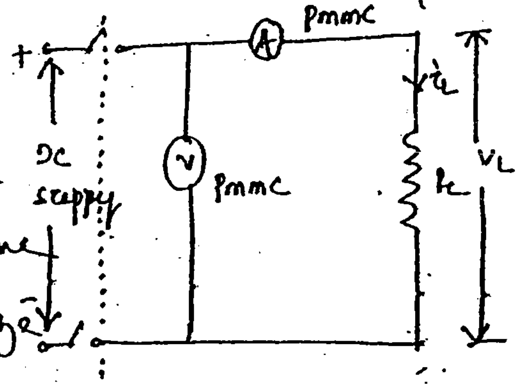
(i) DC power $(P = VI)$ → V-A / A-V } method

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

(ii) A/C power $(P = VI\cos\phi)$ → (Dynamometer type wattmeter)

(i) DC 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 DPS 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

$$\boxed{P_L = V_L I_L}$$

Again $P_m =$ ~~R~~ volt × Ammeter

$= (V_L + V_a)\, I_L = V_L I_L + V_a I_L$

$$\boxed{P_m = P_L + I_L^2 R_a}$$

nothing but product of V-A

loss due to ammeter.

conditions :

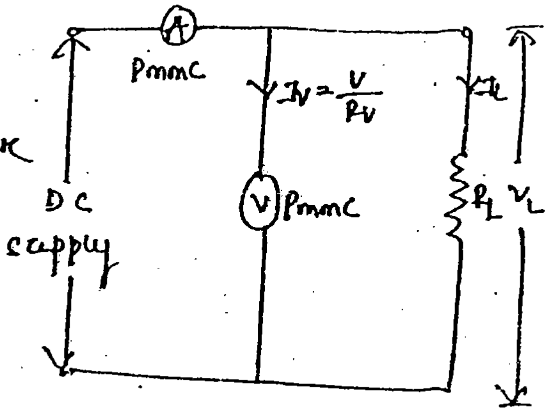
(i) $P_m > P_L$.

(ii) Power loss is due to ammeter.

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

$\therefore$ So V-I method is best suitable for msmt of high resistive load and low load current.

Ammeter - voltmeter method :-



$P_t = V_L I_L$ → true power.

P_m = voltmeter x ammeter

$= V_L(I_L + I_V)$

$= V_L I_L + V_L I_V$

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

P_m → measured power.

$\frac{V_L^2}{R_V}$ → power loss due to voltmeter.

cond^n:

(i) $P_m > P_t$.

(ii) Error is due to voltmeter.

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

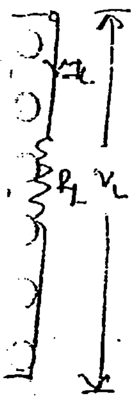
conclusion :

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

A/c power measurement :—

In order to measure A/c power the supply must be 1-phase a/c supply. (single phase)

Resistive load ⇒ $V_L = I_L$
inductive load ⇒ I_L leads V_L
capacitive load ⇒ I_L lags V_L.

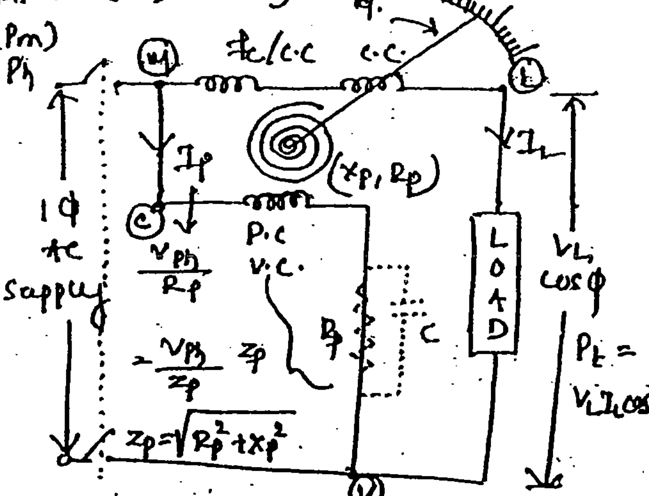


In order to measure the power across the load we are connecting a watt-meter (dynamometer type wattmeter / EMMC)

The moment we close the dps switch the load draws $V_L I_L \cos\phi$ amt of power from the source i.e. nothing but true power.

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

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



→ Both the coils are conneted in parallal. So that 2 different current will flow through the coils i.e. 'I_L' and 'I_p'.

In order to measure t/c 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)

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

Assumption-②: Pressure coil is purely & 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 $X_p = 0$.

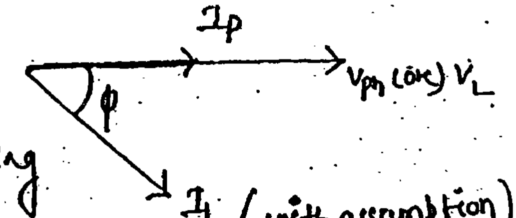
$I_p = ?$

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

↳ 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 dig:



initial $\beta = 0$ due to purely resistive

- when two currents are moving with a phase angle 'ϕ'.

then $T_q = I_1 I_2 \cos(I_1 \& I_2) \frac{dm}{d\theta}$

~~I_1 = current across c.c = I_L~~

I_2 = current across mc/p.c = I_p

So

$$T_q = I_L I_p \cos(\phi) \frac{dm}{d\theta}$$

$$= I_L \frac{V_{ph}}{R_p} \cos\phi \frac{dm}{d\theta}$$

$$\boxed{T_q = I_L \frac{V_L}{R_p} \cos\phi \frac{dm}{d\theta}} \Rightarrow P_L \text{ —— (1)}$$

(with assumption)

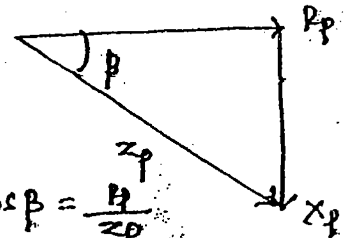
$$\boxed{T_q \propto \text{Ac power}}$$

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.

Impedence triangle :



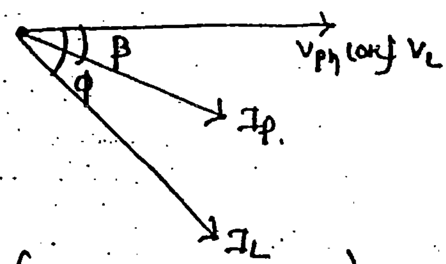
z_p = pressure coil impedence

β = Impedence angle of pressure coil.

$\cos\beta = \frac{R_p}{z_p}$

$z_p = R_p / \cos\beta$

$$\boxed{T_q = I_L \frac{V_L}{z_p} \cos(\phi \mp \beta) \frac{dm}{d\theta} = P_m}$$



(i) $P_m > P_L$

$$= I_L \frac{V_L}{R_p} \cos\beta \, (\cos(\phi - \beta)) \frac{dm}{d\theta} = P_m \text{ —— (2)}$$

(without assumption)

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

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

(iii) $$\boxed{C.F = \frac{\cos\phi}{\cos\beta \cos(\phi \mp \beta)}}$$

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

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

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

$$\boxed{\% \text{ err.} = \pm\left(\frac{1}{c \cdot f} - 1\right) \times 100}$$

(in dynamometer type wattmeter)

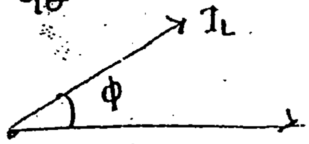
(iv) $$\boxed{\% \text{ error} = \pm(\tan\phi \cdot \tan\beta) \times 100}$$

$\therefore$ All the above power is due to reactance of pressure coil (becoz $X_p \neq 0$ practically)

All the above formulas are valid only for lagging load.

In case of leading:

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



$P_m < P_t$.

$$c \cdot f. = \frac{\cos\phi}{\cos\beta \cos(\phi + \beta)}$$

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

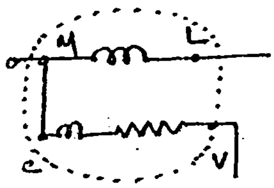
$$\% \text{ error} = \pm\left(\frac{1}{c \cdot f} - 1\right) \times 100$$

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

↳ If we $x_p = 0$ ~~then~~ (by connect a capacitor in parallal to R_p) then capacitor reactance is cancelled out by inductance reactance of pressure coil. Then the pressure coil is purely resistive.

$$\boxed{\text{The Value of } C = 0.41 \frac{L_p}{R_p^2}}$$

L_p = Pressure coil inductance.



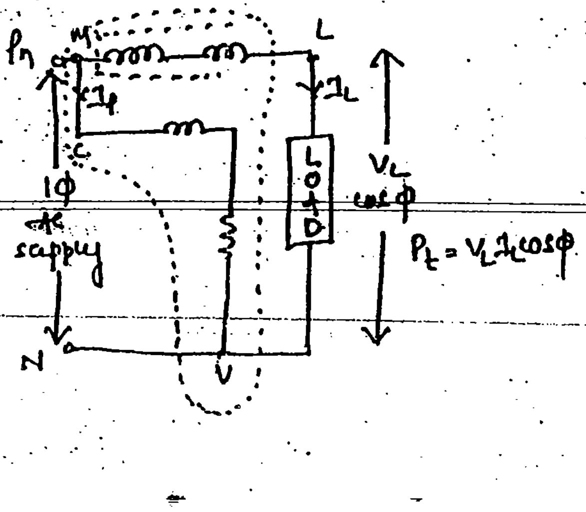
M = main terminal
L = Load terminal
C = common terminal
V = voltage terminal.

↳ M-C shot wattmeter = connection ~~before~~ of pressure coil. before C.C.

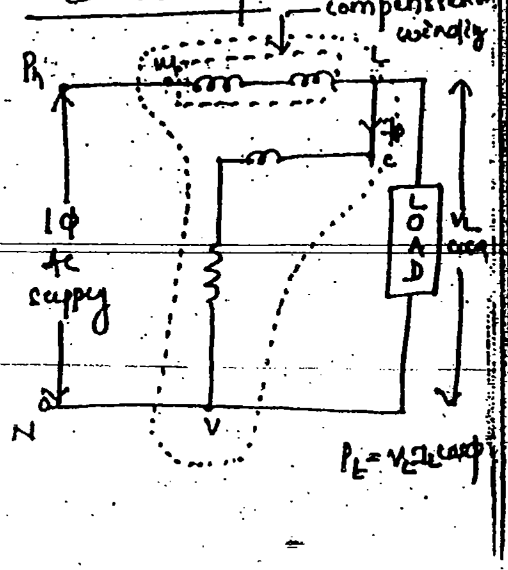
↳ L-C shot connection wattmeter = connection of pressure coil after C.C. coil.

Error due to coil connection :-

M-C shot connection



L-C short connection



$$P = I_{c.c}\, I_{p.c} \cos(I_{cc} \,\&\, I_{pc}) \frac{dm}{d\theta}$$

M-C shot connection :-

$$P = I_L I_p \cos(\,) \frac{dm}{d\theta}$$

L-C shot connection :

$$P = (I_L + I_p) I_p \cos(\,) \frac{dm}{d\theta}.$$

compensation winding is required only in L-C shot-connection. It isn't present in M-C shot (becoz only one current is flowing through winding).

in M-C :

$P_m = P_L + P.L$ in c.c.

$P_m > P_L$ $\boxed{P_m = P_L + I_L R_{c.c.}}$

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

in L-C :

$P_m = P_L + P.L.$ in P.C.

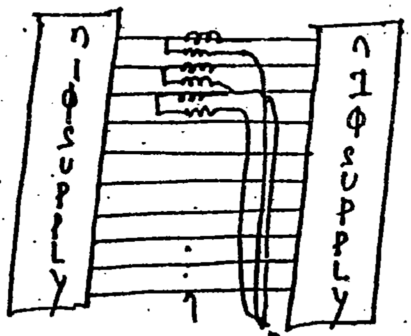
$\boxed{P_m = P_L + \frac{V_L^2}{R_{p.c}}}$

$P_m < P_L$.

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

Measurement of polyphase (n phase) power :-

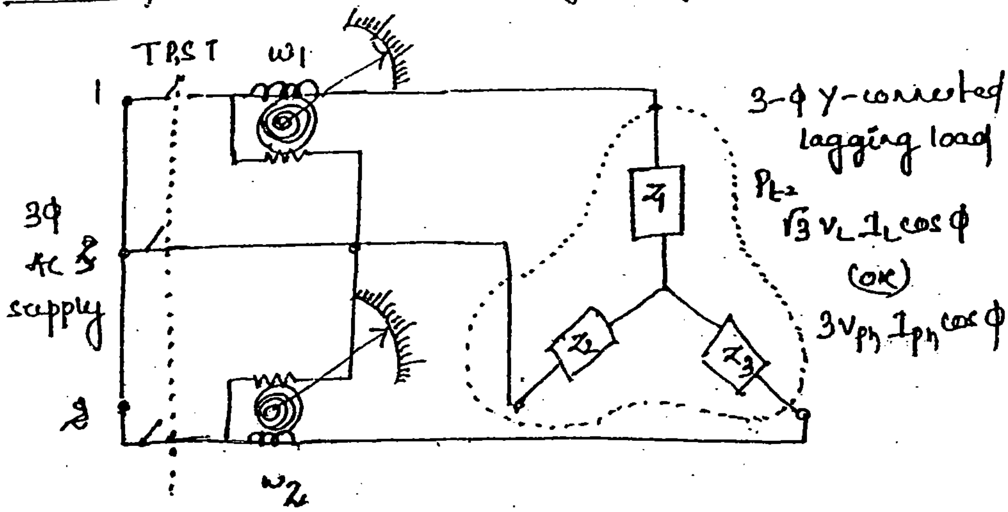
Blondel's



To measure power in this case how many wattmeter are required that can depends upon neutral point. if there is a common neutral point then 'n' wattmeter is needed, if several neutral point are there then 'n-1' wattmeter is needed. (According to Blondel's theorem).

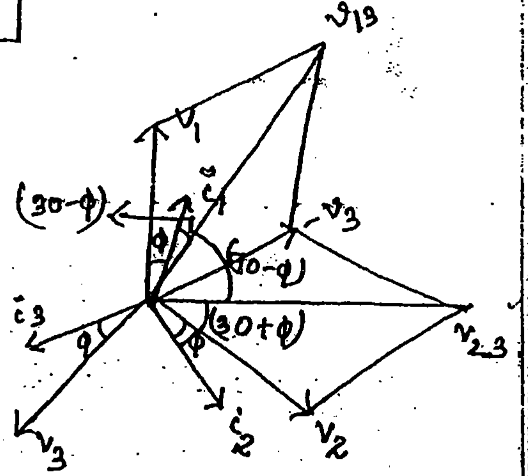
4 If the neutral point is n't available then one of the line act as common line.

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



$$\boxed{P = I_{c.c} \cdot V_{p.c} \cos(I_{c.c} \,\&\, V_{p.c})}$$

Phasor dig :



$w_1 = i_1 v_{13} \cos(i_1 \,\&\, v_{13})$

$v_{13} = v_1 - v_3$
$= v_1 + (-v_3)$

$i_1 = i_2 = i_3 = i_{ph}$

$v_1 = v_2 = v_3 = v_{ph}$.

$$\boxed{\begin{aligned} w_1 &= I_{ph} \sqrt{3} v_{ph} \cos(30-\phi) \\ &= V_L I_L \cos(30-\phi) \end{aligned}}$$

$w_2 = i_2 v_{23} \cos(i_2 \,\&\, v_{23})$

$v_{23} = v_2 - v_3$

stol- becoz

i becoz

meter

point

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

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

Total power :

$$W = W_1 + W_2$$

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

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

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

Again $W_1 - W_2$

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

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

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

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

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

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

now equate equ (1) & (2)

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

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

In case of leading :

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

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

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 =

$$P = I_{cc} V_{pc} \cos(I_{c.c} \,\&\, V_{p.c})$$

$$= i_1 v_{23} \cos(i_1 \,\&\, v_{23})$$

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

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

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

Measurement of Energy :—

Rel^n b/w power and time :

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

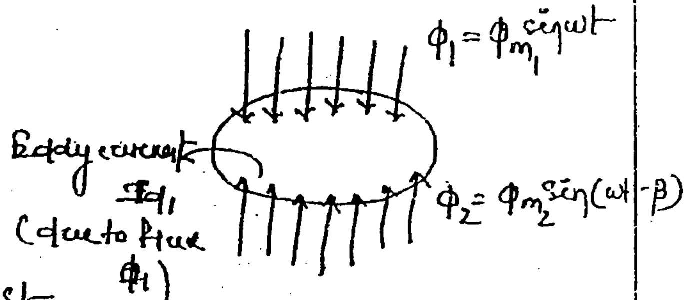
that's why we are using integrated type (energy meter) instrument.

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

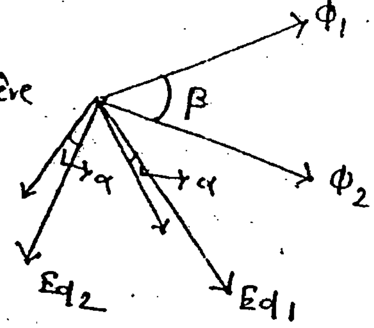
The working principle of energy meter is <u>inductive effect</u>.

$$\boxed{T_d = T_{d_1} \sim T_{d_2}}$$

→ driving torque.



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



$T_d = T_{d_1} \sim T_{d_2}$

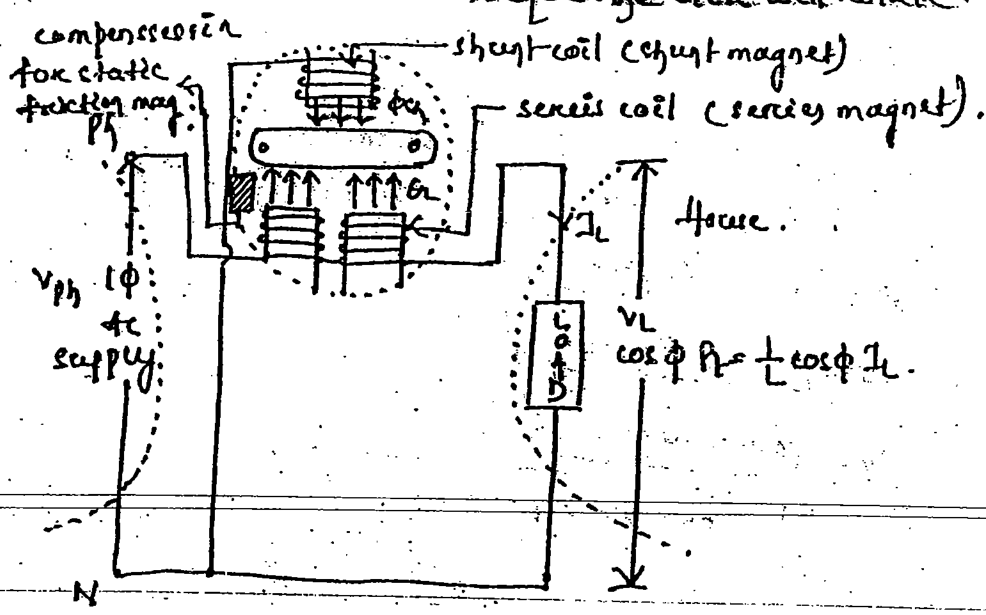
$$\boxed{T_d = \phi_1\phi_2\sin\beta\cos\alpha}$$

→ driving torque.

But, $\alpha \cong 0$

$$\boxed{T_d = \phi_1\phi_2\sin\beta}$$

with this deflecting torque the disc will rotate.



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.

$\phi_L \propto I_L$

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

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

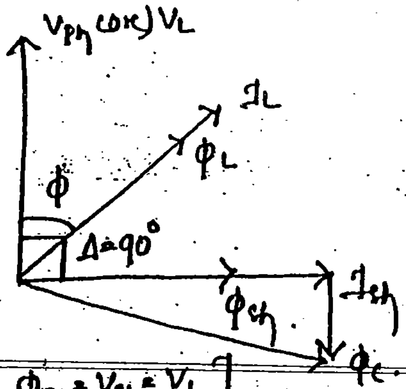
$\phi_{sh} \propto V_{ph}$

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 dig: (Here the load is assumed to be lagging load)



$T_q = \phi_1 \phi_2 \sin(\phi_1 \& \phi_2)$

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

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

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

↳ driving torque.

$T_q = \phi_L V_L \cos\phi$ (when $\Delta = 90°$) — ①

$T_q \propto$ AC 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 shunt coil is purely inductive in nature.

Inside the energymeter the copper coil is there to make $\Delta = 90^\circ$. that's why it is named as lag adjustment device.

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

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

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

At steady state,

$$T_B \propto T_d$$

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

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

Although the load is totally derminated from the mainsupply then at also the disc will rotate, bcoz Although $I_L = 0$, $\Rightarrow \phi_L = 0$, but still ϕ_{sh} is there to make the disc rotate.

Creeping effect : Under no load cond^n 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 compensated by the magnet.

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

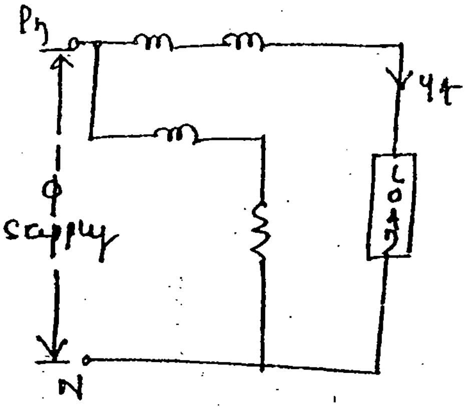
The units of meter const = $\frac{\text{revolution}}{\text{Kwatt hour}}$.

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 electrodynamometer type wattmeter has a resistance of current and potential coil 0.5 Ω and 12.5 KΩ respectively. The % error due to each of two method (M-C short & L-C short) of connection with unity p.f. load at 250 volt with a load current of 4A is:

M-C short



$\cos\phi = 1$

$P_t = V_L I_L \cos\phi$

$= 250 \times 4 \times 1$

$= 1000$ watts

$P_m = P_t + I_L^2 R$

$= 1000 + 4^2 \times 0.5$

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

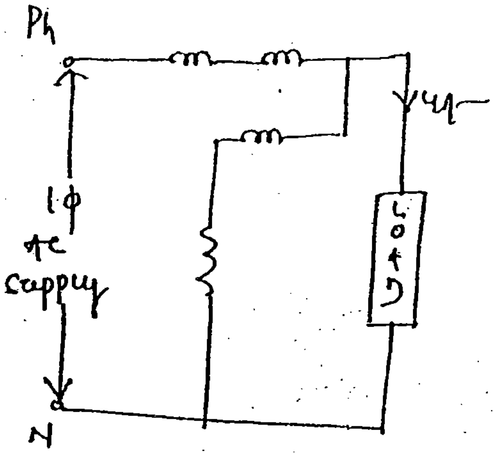
$= 1008$ watt.

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

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

$= 0.8\%$

L-C short



$\cos\phi = 1.$

$P_t = V_L I_L \cos\phi$

$= 250 \times 4 \times 1$

$= 1000$ watt.

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

$= 1000 + \frac{250 \times 250}{12.5 \times 1000}$

$= 1005$ watt.

$\% \text{ error} = \frac{1005 - 1000}{1005} \times 100$

$= 0.5\%$

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

Read out c.f.

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

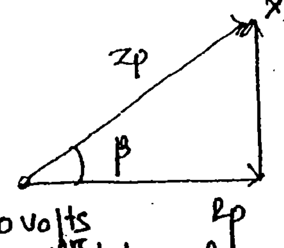
$= +(\sqrt{3}\%)$

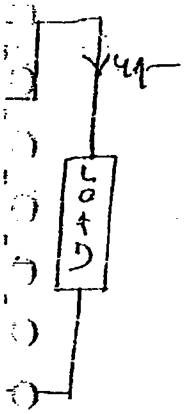
Pb: real load -Ans:

$\% \text{ error} = \left(\frac{1}{C \cdot F} - 1\right) \times 100$ (it should less than 1 becoz lagging)

$\tan \beta = \frac{X_p}{R_p} = \frac{0.9 R_p}{R_p} = 0.01.$

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





Pb: The meter const. of a 5 Amp. ac 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 × m.c

$= 1.1 \times 3275$

$= 3602.5$ rev.

speed = $\frac{\text{revolution}}{\text{sec}}$

$= \frac{3602.5}{3600} \cong 1$ rps.

$\frac{0.005 - 1000}{0.005} \times 100$

6%

2 wattmeter

e error

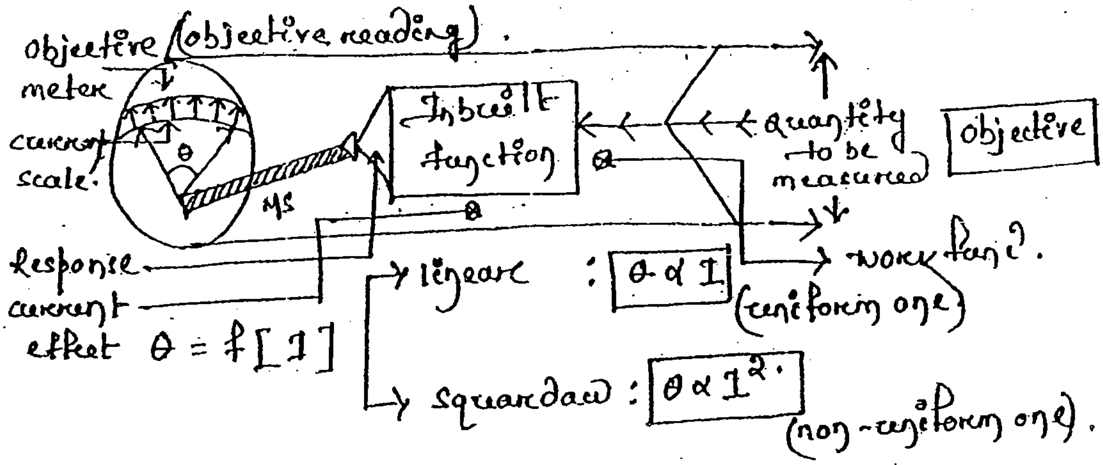
eng is —

ve)

0100
7

04/09/10

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



Work function : (types).

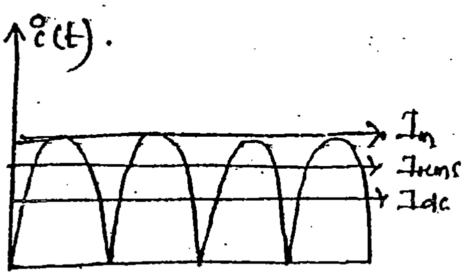
- meter only works for D.C. i/ps. eg: Pmmc.
- meter only working for a/c. i/ps. eg: Induction type.
- meter which works for both a/c and dc i/ps.
  eg: thermocouple.
  moving iron.
  Electrodynamometer.
  Electrostatic.
  Rectifiers etc.

Types of current effects :

- Electromagnetic effect (when a current carrying conduct ~~placed~~ acts as a electromagnet ~~when it~~ carrying current).
- Electrostatic effect
  - Eg : Electrostatic voltmeter
  - capacitor 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 inbuilt force to the objective scale is nothing but measurement.

Types of Response : (types of measurement carried out)

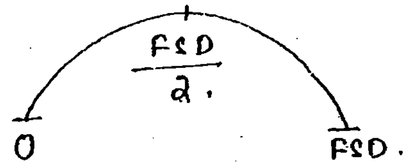


- Avarage response (DC)
  - Eg : PMMC.
- Rms response
  - Eg : thermocouple
  - moving iron.
  - Electrodynamometer
- Peak response
  - Eg : CRO
  - Peak responding voltmeter.

Types of Indicators :

↳ Linear scale / uniform scale . $\boxed{\theta \propto I}$

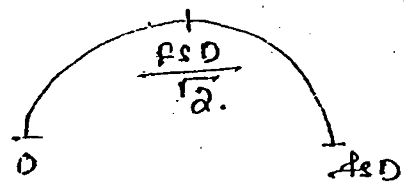
$$\boxed{\frac{\theta_2}{\theta_1} = \frac{I_2}{I_1}}$$



↳ Squarelaw scale / non-uniform / eg non-linear

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

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



DC meter	AC meter
(i) works only for dc i/ps.	(i) It works both for a/c and d.c. i/ps.
(ii) D.C. meter always measure avg. value or produces dc response or avg. response.	(ii) measure rms value. (produce rms response)
(iii) It follows linear rel^n $(\theta \propto I)$	(iii) It follows squarelaw rel^n. $(\theta \propto I^2)$.
(iv) It indicates measured avg. value via linear scale.	(iv) It indicatores measure rms value via a non-linear scale.

Dc meter : "An average measuring / responsing and avg indicating / reading meter with linear scale which only works for dc i/ps."

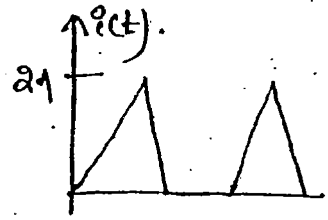
eg: PMMC.

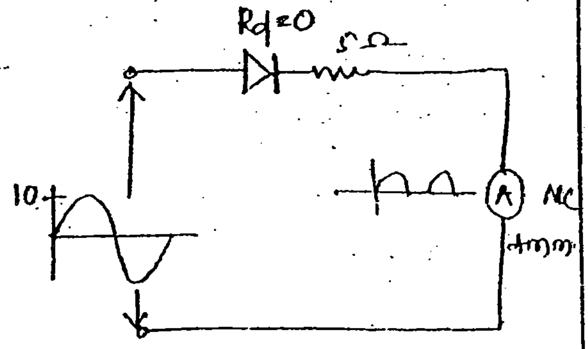
A/c meter: "A rms measuring and rms indicating meter squaddaw scale which works for both A/c and dc i/ps."

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 it's reading would be ______.

sol^n: $\frac{10}{5} = 2A = I_m$.





↳ MC Ammeter rdg $= I_{dc}$. Here $I_m = \frac{V}{R_d + R + R_A}$

$= \frac{I_m}{\pi}$ or $0.318\, I_m$.

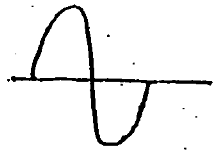
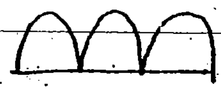
$= \frac{2}{\pi} A$.

↳ MI Ammeter rdg $= I_{rms}$ (In halfwave cycle rms value

$= \frac{I_m}{2}$. never be $I_m/\sqrt{2} = \text{rms}/2$.)

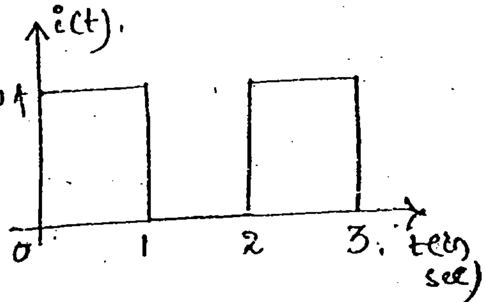
$= \frac{2}{2} = 1A$.

Ans: $\left(\frac{2}{\pi} A, 1A\right)$.

	I_{rms}	I_{dc}
	$I_m/\sqrt{2}$	0
	$\frac{I_m}{\sqrt{2}}$	$\frac{2I_m}{\pi}$
	$\frac{I_m}{2}$	$\frac{I_m}{\pi}$

IES-2006

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 ammeter ____ respectively.



Sol^n: the alternating current for rms value $= \dfrac{I_m}{\sqrt{2}}$.

$= \dfrac{100}{\sqrt{2}}$.

$$I_{dc} = \frac{1}{T_0}\int_0^{T_0} i(t)\cdot dt \quad \text{(mean)}.$$

$$I_{rms} = \left[\frac{1}{T_0}\int_0^{T_0} i^2(t)\cdot dt\right]^{1/2}.$$

$$\boxed{\begin{aligned} I_{rms} &= I_m\sqrt{\alpha} \\ I_{dc} &= I_m\alpha. \end{aligned}}$$

α = duty cycle.
(only for half-wave rectifier).

Sol^n:
$$\left.\begin{aligned} i(t) &= 100\,A, & 0<t<1 \\ &\;\;0, & 1<t<2 \end{aligned}\right\} \text{ \& } T_0 = 2. \text{ (ON-OFF condition)}.$$

MC ammeter rdg $= I_{dc}$

$$= \frac{1}{2}\int_0^1 100\, dt$$

$$= 50\,A.$$

TC ammeter rdg $= I_{rms}$

$$= \frac{1}{2}\int_0^1 100^2 \cdot dt$$

$$= \frac{100}{\sqrt{2}}\,A.$$

Another method:

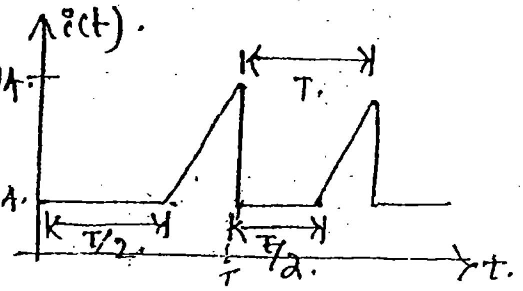
Here $\alpha = \dfrac{T_{ON}}{T_{ON}+T_{OFF}} = \dfrac{1}{1+1} = \dfrac{1}{2}$.

$I_{dc} = I_m\alpha = 100 \times \dfrac{1}{2} = 50\,A$.

$I_{rms} = I_m\sqrt{\alpha} = 100 \times \dfrac{1}{\sqrt{2}} = \dfrac{100}{\sqrt{2}}\,A$.

r 106

Pb: An ideal electrodynamo ammeter is used to measure a time-varying current which is a clipped saw-tooth ~~superimposed of 1 amp. dc. as shown in~~ below fig. Then the ammeter reading ______



sol^n:

$$I_{dc} = 2\cdot\frac{T}{T} = 2A.$$

$$I_{rms} = 2\left(\frac{T}{T}\right)^{1/2} = 2(1)^{1/2} = 2A.$$

X.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^{T/2} 1^2\cdot dt + \int_{T/2}^{T} (\,?\,)^2 dt}.$$

(T, 3A)

Now,

$$y - y_1 = m(x_2 - x_1)$$

(T/2, 1A)

$$i(t) - 1A = \left(\frac{3-2}{T - T/2}\right)\left(t - t/2\right).$$

$$i(t) = \frac{4t}{T} - 2 + 1.$$

$$= \frac{4}{T}t - 1.$$

$$= \frac{1}{T}[4t - T].$$

$$\therefore\ i(t) = 1A, \quad 0 < t < T/2.$$

$$= \frac{1}{T}[4t - T], \quad T/2 < t < T.$$

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^{T/2} (1A)^2 dt + \frac{1}{T}\int_{T/2}^{T} \left[\frac{1}{T}(4t - T)\right]^2 \cdot dt}.$$

$$= \sqrt{\frac{1}{T} \times \frac{T}{2} + \frac{1}{T^3}\left[\frac{(4t-T)^3}{3 \times 4}\right]_{T/2}^{T}}$$

$$= \sqrt{\frac{1}{2} + \frac{1}{12T^3} \times (27T^3 - T^3)}$$

$$= \sqrt{\frac{1}{2} + \frac{26T^3}{12T^3}}$$

$$= \sqrt{\frac{32}{12}}$$

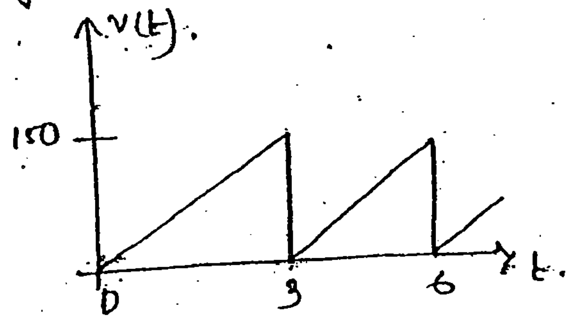
$$= 1.63 A.$$

Pb: A thermocouple voltmeter is used to measure a time varying voltage whose waveform is shown below. then the reading of the voltmeter is ______.

Sol:

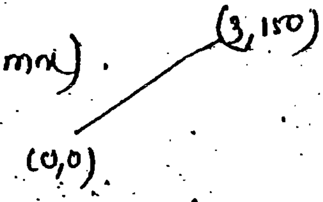
$$I_{rms} = \sqrt{\frac{1}{3}\int_0^3 v^2(t) \cdot dt}$$

$$= \sqrt{\frac{1}{3}\int_0^3 (50t)^2 \cdot dt}$$



$v(t) = \frac{150}{3} \times t$ (Here $y = mx$).

$v(t) = 50 \times t \quad 0 < t < 3$.



$$= \sqrt{\frac{1}{3} 50^2 \left[\frac{t^3}{3}\right]_0^3}$$

$$= \sqrt{\frac{50^2}{3 \times 3}[3^3 - 0]}$$

$$= \sqrt{50^2 \times 3}$$

$$= 50\sqrt{3} = 86.6 V.$$

Pb:
A thermocouple ammeter produces fullscale deflection for a current of 10 A then $\frac{1}{5}$th of fullscale deflection is produce by a current of ______ Amp.

Sol^n:

If $\theta_{FSD} = I_{FSD}$
$\theta_x = I_x = ?$

Now,

I_x
→ Dc meter $[\theta \propto I]$.
$$I_x = \left[\frac{\theta_x}{\theta_{FSD}}\right] I_{FSD}.$$

→ Ac ammeter $[\theta \propto I^2]$.
$$I_x^2 = I_{FSD}^2 \frac{\theta_x}{\theta_{FSD}}.$$
$$I_x = I_{FSD}\sqrt{\frac{\theta_x}{\theta_{FSD}}}.$$

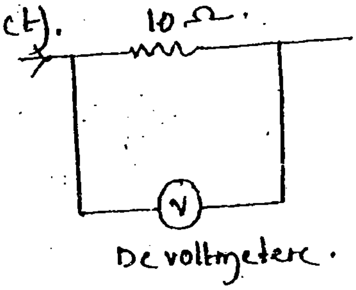
note: If Tc ammeter produces FSD for 10A.
then,
→ 20% FSD is produced by $= 10\sqrt{\frac{0.2\theta_{FSD}}{\theta_{FSD}}}$
$= 10\sqrt{0.2} = 4.47$
→ 50% of FSD is produced by $= 10\sqrt{\frac{0.5\theta_{FSD}}{\theta_{FSD}}}$
$= 10\sqrt{0.5} = 7.07A$

$\frac{1}{4}$th of FSD produced by

Pb: as then across Ano... I_d V_{dc} = = = Pb: is ac Sol^n: Eg:

Pb: A current I(t) passing through a 10 Ω resistor as shown in fig-A, has a waveform shown in fig-b. then the reading of dc voltmeter connected across 10 Ω resistor is ______.

Another method:



$$I_{dc} = \frac{1}{2}\left[\int_0^T 12\cdot dt + \int_T^{2T} 5A\cdot dt\right]$$

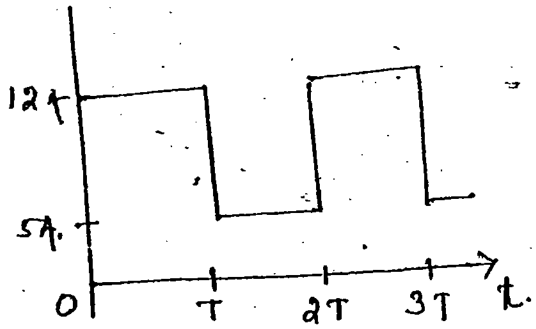
$$V_{dc} = I_{dc} \times 10\,\Omega$$

$$= \left(\frac{12+5}{2}\right)\times 10$$

$$= \frac{17}{2} \times 10$$

$$= 8.5 \times 10$$

$$= \frac{85}{10} \times 10 = 85 \text{ volt}$$



Pb: 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 ______.

Soln: $I_{dc} = 1A$

$$I_{rms} = \sqrt{1^2+\left(\frac{\sqrt{2}}{\sqrt{2}}\right)^2+\left(\frac{2}{\sqrt{2}}\right)^2}$$

$$= 2A.$$

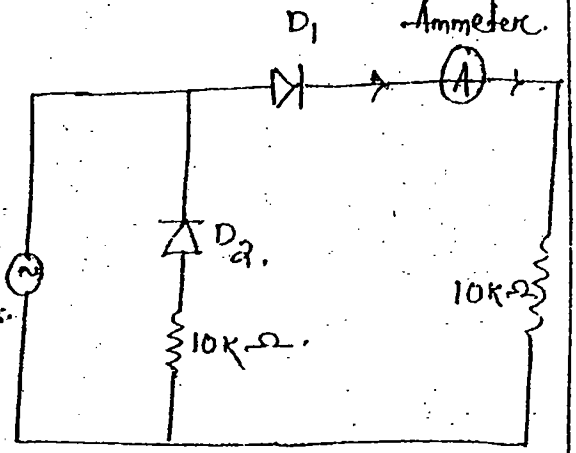
eg: $i(t) = 5+10\sin 314t$

$I_{dc} = 5A$

$$I_{rms} = \sqrt{5^2+\left(\frac{10}{\sqrt{2}}\right)^2} = \sqrt{25+\frac{100}{2}} = \sqrt{75} = 5\sqrt{3}\,A.$$

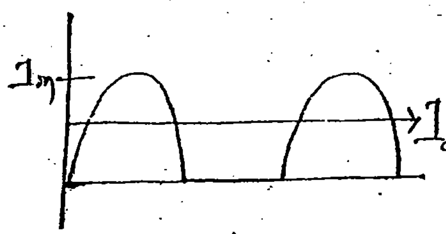
0.2 θFSD
θFSD
0.47
0.5 θFSD
θFSD
0.7A

Pb: In the ckt shown in below fig the ammeter is an avg. indicating ammeter with zero internal resister and both the diodes are ideal. Then the reading of ammeter is ———.



sol:

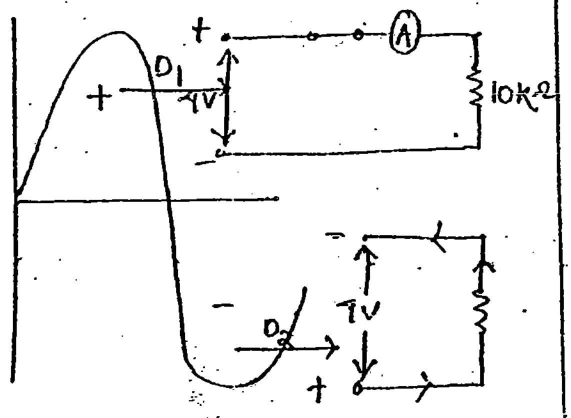
Avg ind. amtr = I_{dc}.



$I_{dc} = \frac{I_m}{\pi}$

$= \frac{4/10\times10^3}{\pi}$

$= \frac{0.4}{\pi}$ mA



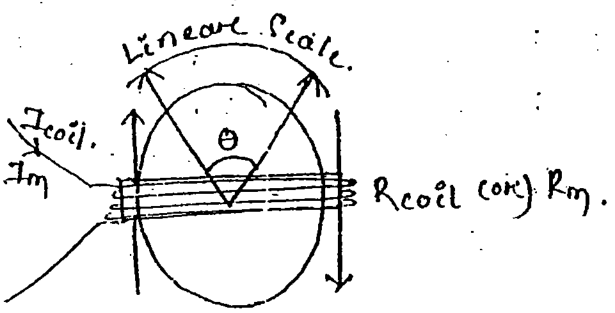
**
$I_{rms} = \frac{I_m}{2}$

$= \frac{0.4}{2}$ A

PMMC Instrument :- [utilization,

A PMMC instrument consist of a cylinderical iron core inserted into a rectangular Al frame. Around which a thin wire coil of N-turns is wound. A free rotating spindle attached to it and fine pointer deflected a over a

~~calculated~~ ~~calibercated 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.

$= I_{m(max)} = I_{m(FSD)}$ } $\therefore 0 < I_m \leq I_{m(FSD)}$ ← range →

(ii) R_{coil} = coil Ω

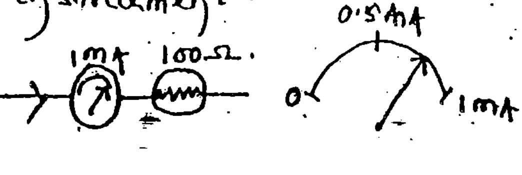
= meter's internal Ω

$= R_m$.

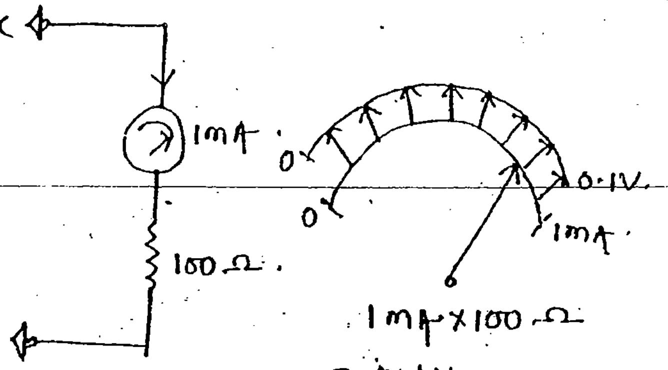
↳ Utilization : [only current measurement].

eg: 0-1mA, 100Ω PMMC instrument.

0-1mA Ammeter



A 0 – 0.1V voltmeter should be parallal.



Here volt. rating cap is low, becz the current sensing capacity is low becz here we are using a thin ~~cor~~ 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) multipliere. (series)

↳ A low valued shunt resistance is connected in parallal in PMMC for extending current range.

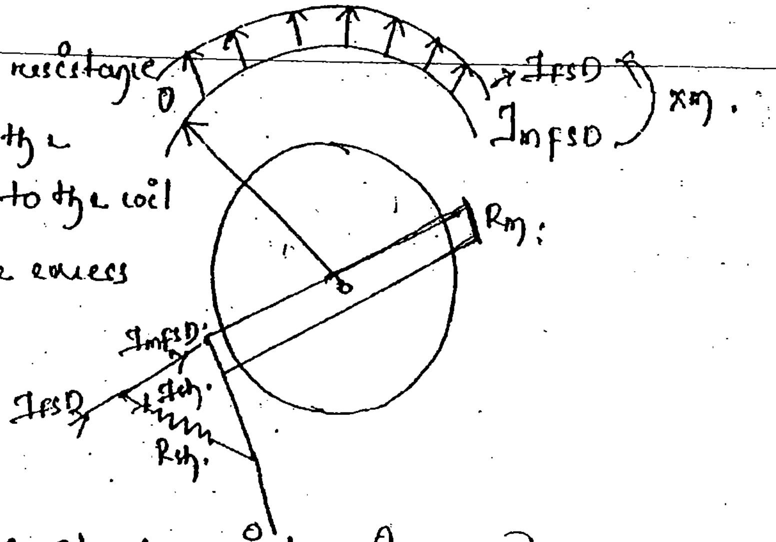
↳ A high value multiplier resistance is connected in series with PMMC to extend the voltage wave.

Extending current range :-

The available range of current $[I_{m_{FSD}} \xrightarrow{x_m} I_{FSD}]$

x_m = to be extended.
↳ multiplying factor.

R_{sh} = shunt resistance placed inside the coil/parallal to the coil to bypass the excess current



→ A low value shunt resistere is placed parallal to the coil to bypass the excess amt. of current.

$$I_{sh} = I_{FSD} - I_{mFSD}.$$

$$\boxed{m = \frac{I_{FSD}}{I_{mFSD}}} = \text{multiplying power}.$$

→ Since R_m and R_{sh} is in parallal,

$$\boxed{V_{sh} = V_m.}$$

$$I_{sh} \times R_{sh} = I_{mFSD} \times R_m. \quad (R_m = \text{meter coil resistance})$$

$$(I_{FSD} - I_{mFSD}) R_{sh} = I_{mFSD} \times R_m.$$

$$R_{sh} = \frac{R_m}{\frac{I_{FSD} - I_{mFSD}}{I_{mFSD}}}$$

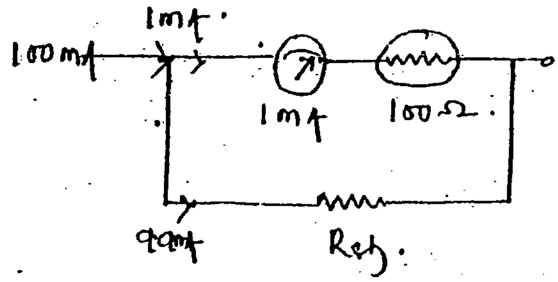
$$R_{sh} = \frac{R_m}{\left(\frac{I_{FSD}}{I_{mFSD}} - 1\right)}$$

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

Q: A PMMC mAmeter which produces ~~FSD~~ for a current of 1mA is to be converted ~~100~~ into 100mA ampere. If the internal resistance of PMMC is 100 Ω. Then the value of required shunt resistance is ______.

sol^n: $1\,mA, 100\,\Omega \xrightarrow{\times 100} 100\,mA$.

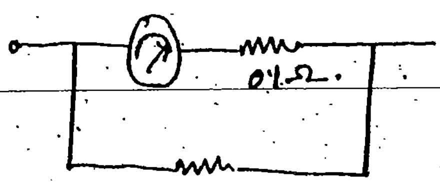
$R_{sh} = \frac{100}{99} = 0.01\,\Omega$.

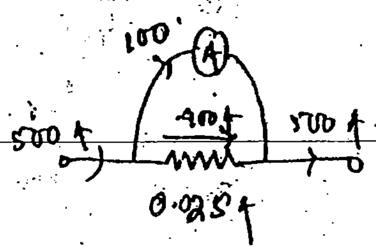


→ A 0–1mA DC ammeter is used in 100mA DC current range.

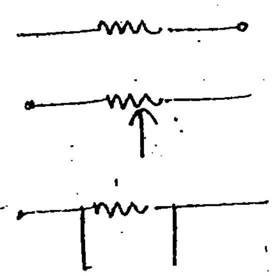
eg: A dc ~~...~~ ammeter has a resistance of 0.1Ω and it's current range is (0–100)A. If this range is to be extended to 500A, then the value of required shunt resistance is ______

sol^n: $R_e = 0.1\,\Omega$.





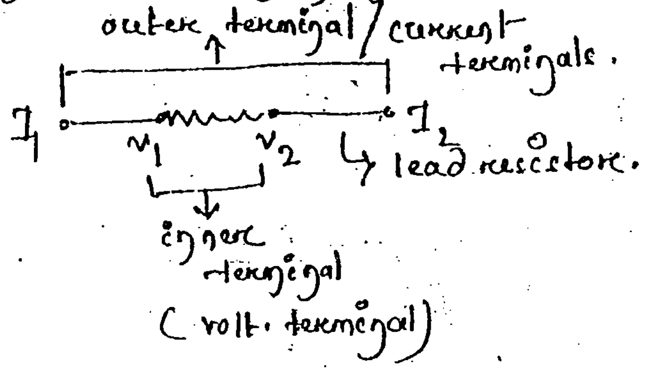
Among four of these below which one is two one.

a) 

b)

c)

d) none.

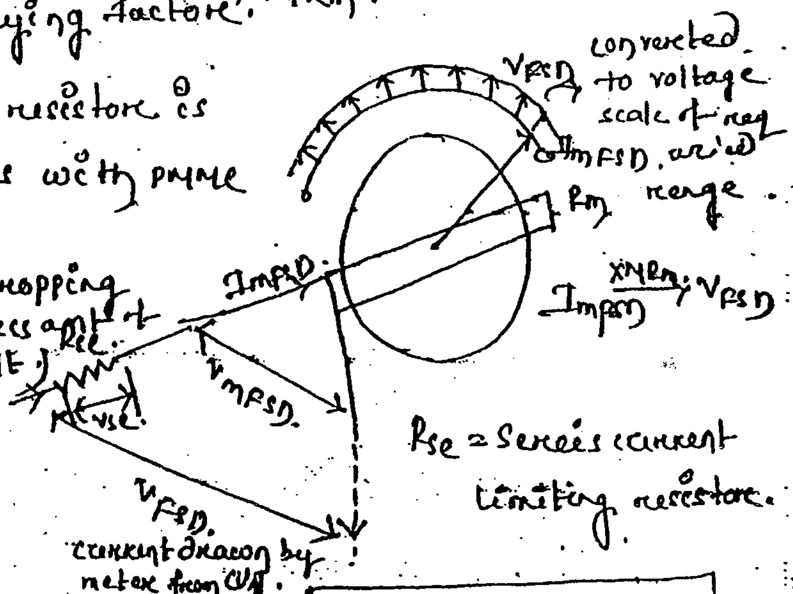


Extending voltage range :-

$$I_{mFSD} \times R_m = V_{mFSD} \xrightarrow{\times M} V_{FSD}$$

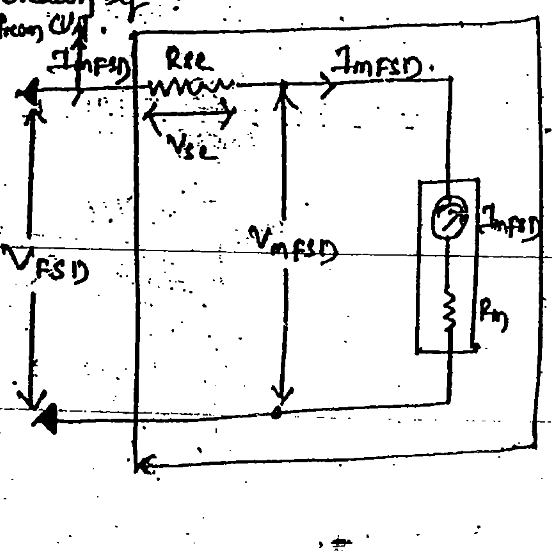
M = multiplying factore. $\times MR_m$.

A high valued resistore is placed in series with PMMC instrument inorder to limit the i/p current upto 'I_{mFSD}'.

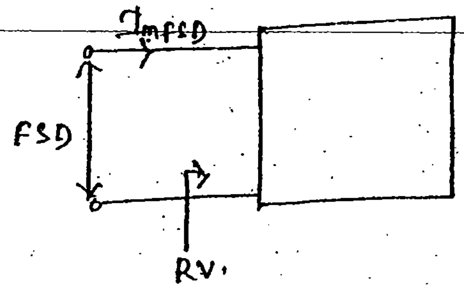


R_{se} = Series current limiting resistore.

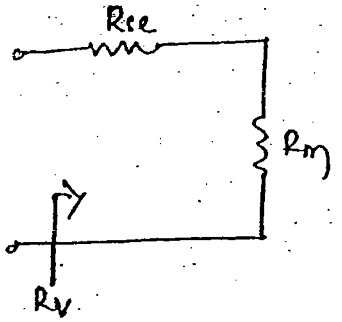
The value of 'R_{se}' :



I/p resistance of voltmeter :



$\rightarrow R_V = \frac{V_{FSD}}{I_{mFSD}}$



$R_V = R_{se} + R_m$.

$R_V = R_m [M-1] + R_m$

$= MR_m - R_m + R_m$

$= MR_m$.

Again, R_V = Sensitivity x range

Series current limiting :

$R_{se} = R_V - R_m$.

$= \frac{V_{FSD}}{I_{mFSD}} - R_m$.

$= R_m \left[\frac{V_{FSD}}{I_{mFSD} \times R_m} - 1 \right]$

$= R_m \left[\frac{V_{FSD}}{V_{mFSD}} - 1 \right]$

$\boxed{R_{se} = R_m [M-1]}$

Sensitivity of volt-meter :-

S_V = Resistance per volt-meter rating of a volt meter.

= Sensitivity of volt-meter.

= Fig. of merit of volt-meter.

units : ohms/volt.

$$\boxed{S_{DC} = \frac{R_V}{V_{FSD}}}$$

$$= \frac{V_{FSD}/I_{mFSD}}{V_{FSD}}$$

$$\boxed{S_{DC} = \frac{1}{I_{mFSD}}}$$

+ Rm

+ Rm

tivity xrange

41-8

A

Pb: Th

ei-

a)

b)

c)

✓d)

Pb:

Dc

sersi

how

A dc ammetere is nothing but a

th: The sensitivity of a 200µA metere movement when it is used as a dc voltmetere is ______.

a) 500 Ω/mV.
b) 5 Ω/V.
c) 0.5 Ω/mV.
✓d) 5 Ω/mV.

sol^n:

$$S_V \text{ or } S_{dc} = \frac{1}{I_{mFSD}}$$

$$= \frac{1}{200 \times 10^{-6}}$$

$$= 0.5 \times 10^{-2} \times 10^{6}$$

$$= 5\,K\Omega/V.$$

$$5\,K\Omega/V = 5\,\Omega/mV$$

Pb: The value of the multiplier resistance for a Dc voltmetere having 50 V range with 5 KΩ/V sensitivity, employing a 20µA metere movement and having internal resistance of 100 Ω is given by ______.

Ammetere to voltmetere
$(0 - I_{mFSD}, R_m)$

- → Ammetere → voltmetere $(0 - I_{mFSD}, R_m)$ $(0 - V_{FSD})$.

$$R_{se} = R_V - R_m = \frac{V_{FSD}}{I_{mFSD}} - R_m$$

- → Ammetere → voltmetere $(—, R_m)$ $(0 - V_{FSD}, S_V)$

$$R_{se} = R_V - R_m = S_V \times V_{FSD} - R_m$$

3.

(or)

A 200μA DC ammeter with internal resistance of 100Ω is to be converted into 0-50V DC voltmeter. The required series limiting resistor is ______?

(or)

A 50v dc voltmeter with figure of merit of 5kΩ/v is constructed using dc ammeter whose internal resistance is 100KΩ. Then value of R_{se} is ______?

sol^n:

$$R_{se} = R_V - R_m$$
$$= S_V \times V_{FSD} - R_m$$
$$= \frac{5K\Omega}{V} \times 50V - 100\Omega.$$
$$= \frac{5\times10^3\Omega}{V} \times 50 - 100\Omega.$$
$$= 249.9K\Omega.$$

Pb: A 1mA meter movement with an internal resistance of 100Ω is to be converted into 0 to 100mA. To achieve this value of shunt resistance is given by ______?

sol^n:

$$R_{sh} = \frac{R_m}{m-1}$$
$$= \frac{100}{100-1} = \frac{100}{99} = 1.01\Omega.$$

Pb: A moving coil ammeter having a resistance of 1Ω gives full scale deflection when a current of 10mA is passed through it. The instrument can be used for the measurement of volt. upto 10volt.

a)

to

b)

to

c)

d)

sol^n

ITO
E

Pb:

is

a) connecting a resistance of 999 Ω in parallel to the ~~load~~ ammeter

b) " " " 999 Ω " " to the load.

c) " " " 1000 Ω in series with the ammeter.

d) " " " 999 Ω. " with the load.

sol^n: 10mA, 1Ω ⟶ 10V.

$$R_{se} = \frac{10V}{10mA} - 1\Omega$$
$$= 1K\Omega - 1\Omega$$
$$= 999\Omega$$ in series with ammeter.

(or)

$$R_{se} = R_m(m-1)$$
$$= 1\Omega\left(\frac{10V}{10mA \times 1\Omega} - 1\right) = 999\Omega.$$

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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 100μA. The value of shunt resistance needed for obtaining an ammeter of 10mA used in the same galvanometer is _____.

$I_{mFSD} = 1mA$ 11Ω, 1mA ⟶ 10mA.

$R_{sh} = 11\Omega$

$100\mu A \longrightarrow 1mA$ $\qquad$ $100\mu A \longrightarrow 10mA$

$R_{sh_1} = 11\Omega.$ $\qquad$ $R_{sh_2} = \frac{R_m}{m_2 - 1}$

$\frac{R_m}{9} = 11\Omega$ $\qquad$ $= \frac{R_m}{99}$

$R_m = 99\Omega.$ $\qquad$ $= \frac{99\Omega}{99}$

$= 1.0\Omega.$

GATE EEE

Pb: A dc voltmeter having a fig of merit of 20kΩ/V is used to measure half full scale voltage in 10V range. Then the current through the meter is ______?

Sol:

$$\left[\begin{array}{l} V_{FSD} = 10V. \\ S_V = 20k\Omega/V. \end{array}\right.$$

$\frac{V_{mFSD}}{R} = \frac{10}{2\times10^3} = 5\times10^{-3}$

$\frac{1}{I_{mFSD}} = 5\times10^{-3}$

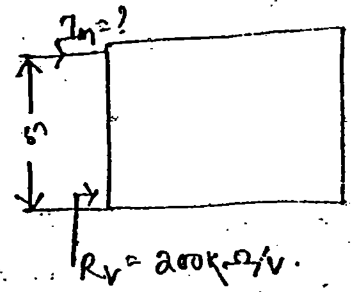
$V_{mFSD} = \frac{1}{2}\times FSD = \frac{1}{2}\times10 = 5V.$

$R_V = 200k\Omega/V \times 10V$

$= 200k\Omega$

$I_m = \frac{5V}{200k\Omega}$

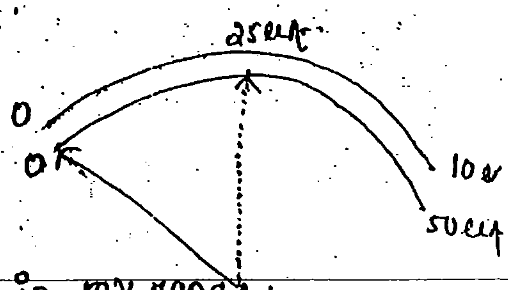
$= 2.5\times10^{-5}A = 25\mu A.$



(or)

$I_{mFSD} = \frac{1}{20k\Omega}$

$= 50\mu A.$



Pb: $\frac{1}{4}$ of FSD is measured in 50V range.

Then current through the meter is $\frac{1}{4}\times50\mu A.$

Pb: 80% of FSV is measured in 30V range, then

$I_m = \underline{0.8 \times 50\mu A}$.

GATE (2014) Pb: A galvanometer (dc ammeter) with full scale current rating of 10mA has a resistance of 1000 Ω. 100A the multiplying power of a 100 Ω shunt resistance with this galvanometer is ______

op 20KΩ/V

Sol:

$I_{mFSD} = 10mA$; $R_m = 1000\,\Omega = 1K\Omega$.

$R_{sh} = 100\,\Omega$.

$$\boxed{m = \frac{I_{FSD}}{I_{mFSD}} = \frac{R_m}{R_{sh}} + 1.}$$

m = multiplying power

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

$$10\,mA \xrightarrow{\times 11} 110\,mA$$

Again,

$$\boxed{M = \frac{V_{FSD}}{V_{mFSD}} = \frac{R_{se}}{R_m} + 1}$$

Pb: To triple the current range of an ammeter, the ratio of ammeter to shunt resistance is ______

Sol:

$$m = \frac{R_{sm}}{R_{sh}} \cancel{+1}$$

$$3 - 1 = \frac{R_m}{R_{sh}} \Rightarrow \frac{R_m}{R_{sh}} = 2.$$

Pb: ~~200V dc voltages~~ two 100 volt dc voltmeter with figure of merit of 10KΩ/V and 20KΩ/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 is ______ respectively.

100

50μA

Sol: ~~$V_{FSD} = 100$~~

a) 200V, 100V, 100V.
b) 100V, 50V, 50V,
c) 150V, 50, 100V,
d) voltmeter can never be ~~parallal~~.

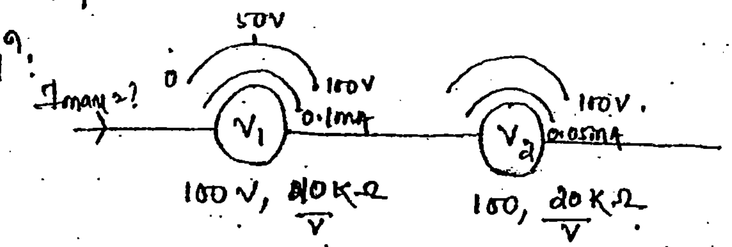
(voltage source of different rating we can connect in '||'. and current source in series. ~~series.~~)

~~sol^n: $V_{FSD} = 100V$~~

When three of the coil is connected in series having different current rating we ~~can't~~ ~~must~~ be then the max^n allowable current is the least value of of current rating among of the three coil. and sensitivity must be high.

The same rule / cond^n i can be applicable when two voltmeter of different rating connected in parallal.

sol^n:



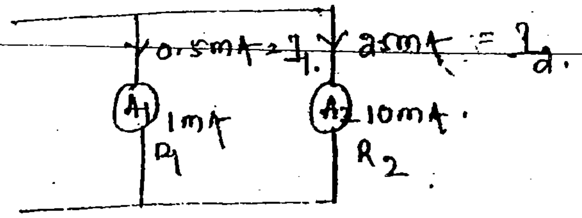
I_{max} = Lowest FSD current rating.
= FSD current rating of voltmeter with high sensitivity.

= 0.05mA

$V_{max} = I_{max}\,[R_{V_1} + R_{V_2}]$.
$= 0.05\,mA\,[1000K\Omega + 2000K\Omega]$
$= 150V$.

Pb: 1 one mA ammeter and a 10mA ammeter are connected in parallal. If there is readings of 0.5 mA and 9.5mA then the ratio of their internal resistances is ______ ?

Sol^n:

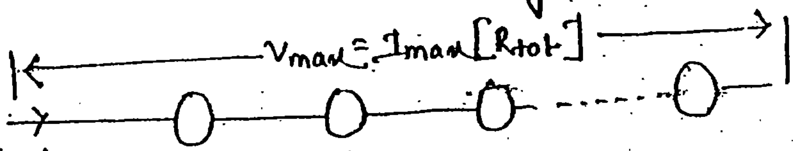


$$\frac{V/R_1}{V/R_2} = \frac{I_1}{I_2} \Rightarrow \frac{R_2}{R_1} = \frac{0.5\,mA}{2.5\,mA} = \frac{1}{5}$$

$$\Rightarrow \frac{R_1}{R_2} = \frac{5}{1}$$

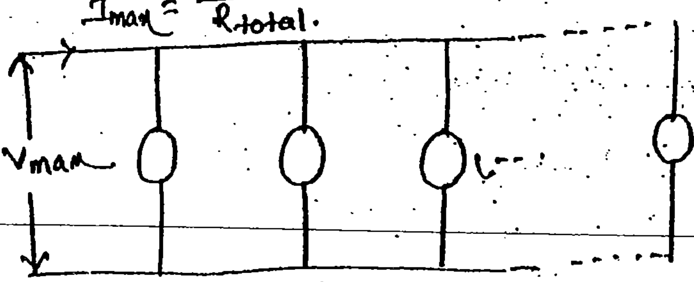
Q5: Two different dc ammeters with full scale current rating of 1mA and 10mA are connected in parallel. Their internal resistance are 100Ω and 25Ω respectively. The max^m current which can be measured by this parallel combination is ______. The reading of both the ammeters is ______ respectively.

Sol^n:

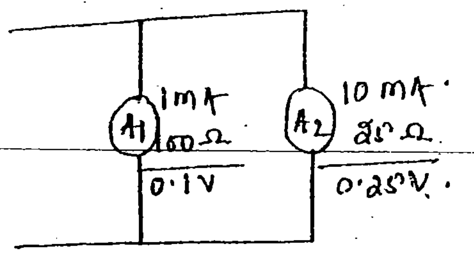


I_{max} = least (or) lowest full scale current rating value.

$$I_{max} = \frac{V_{max}}{R_{total}}.$$



V_{max} = least (or) lowest FSV.



0.1 V ∼ 0.25V.

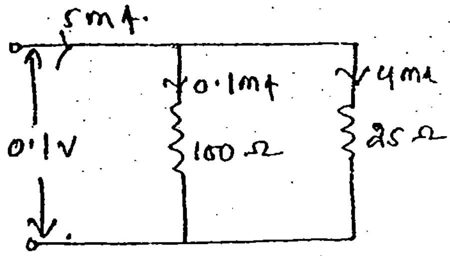
$\rightarrow V_{max} = 0.1V.$

$I_{max} = \frac{0.1V}{R_t}$.

$R_t = 100\Omega / 25\Omega$

$= 20\Omega$.

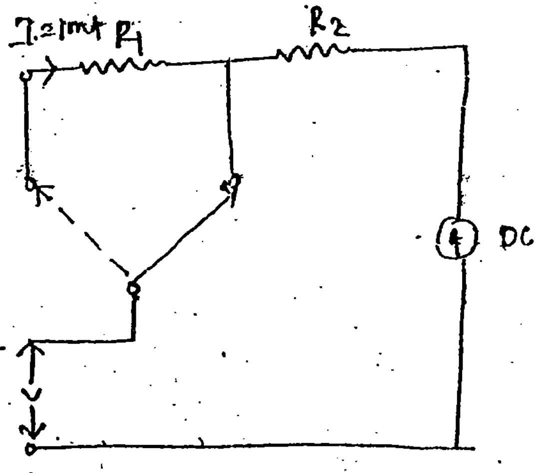
$I_{max} = \frac{0.1V}{20\Omega} = 5mA$.



5mA, 4mA, 0.1mA.

Pb: In the voltmeter 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^n:



$I_{FSD} = 1mA$.

$R_m = 100\Omega$.

For 10V range

$R - 100k\Omega = \frac{V}{I} = \frac{10}{1mA} \cancel{+100\Omega}$

$= \frac{10}{1\times10^{-3}} \cancel{+100}$

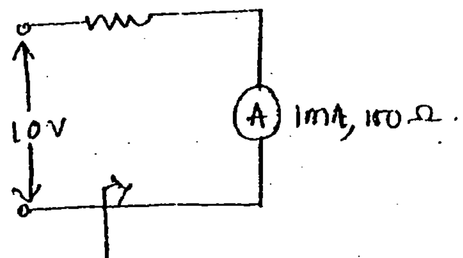
$= 10\times10^{3} \cancel{+100}$

$R + 100 = 1000 \cancel{+100}$

$R = 10000 - 100$

$= 900$

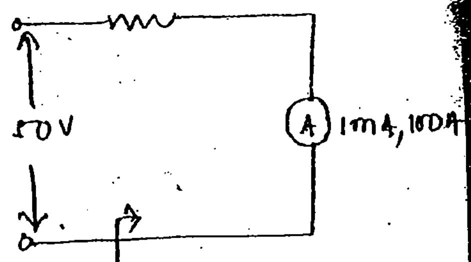
SW-(A)



$\frac{10V}{1mA} = 10K\Omega$

$R_1 = 10K\Omega - 100\Omega$
$= 9.9K\Omega$.

SW-(B)



$\frac{50V}{1mA} = 50K\Omega$.

$R_2 + R_1 = 50K\Omega - 100\Omega$
$= 49.9 - 9.9$
$= 40K\Omega$.

Pb: A 35 volt dc source is connected to series combination of 600 Ω and R_x. A volt-meter connected across 600 Ω indicates 5 volts. If the i/p resistance is 1.2 KΩ then the value of R_x is ______.

Sol^n: $V_{FSD} = 35$ volt.

$I = \frac{5}{600/120} = \frac{1}{120} = \frac{1}{120}$ mA

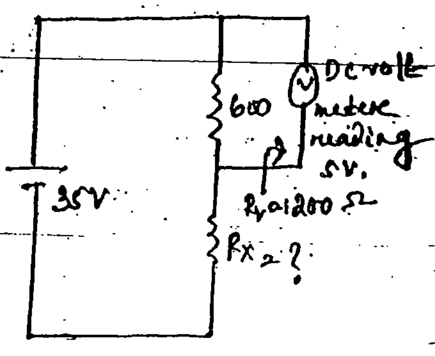
$\frac{1}{120} \times 35 = \frac{1}{120}(600 + R_x + 1.2)$.

$\Rightarrow 35 = \frac{1}{120}(600 + R_x + 1.2\times10^3)$.

$\Rightarrow 35 = \frac{1}{120}(601.2\times10^3 + R_x)$.

$\Rightarrow 35\times120 = 601.2\times10^3 + R_x$.

$\Rightarrow (35\times120) - 601.2\times10^3 = R_x$.



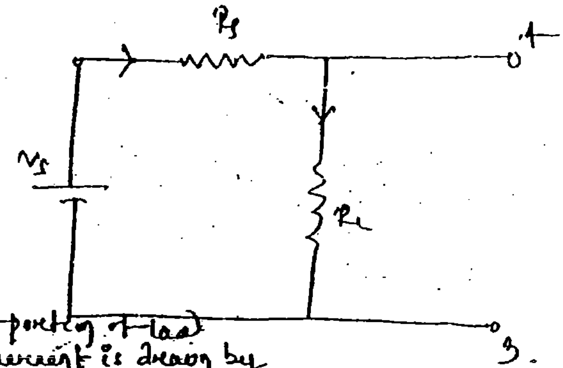
$I = \frac{5V}{400}$

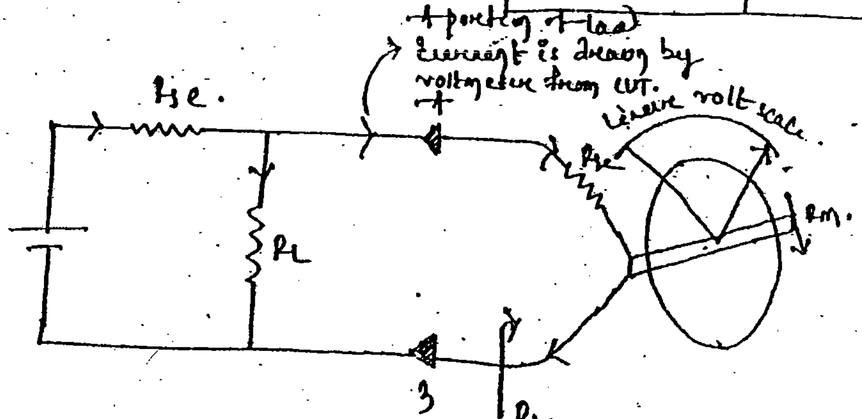
$V_x = 35 - 5 = 30V$

$$R_x = \frac{300\times 400}{5} = 2400\,\Omega = 2.4\,k\Omega.$$

$$V_x = 35\times\frac{2.4\times10^3}{2.4\times10^3+400}$$

Loading effect due to volt-meter Resistance :-





∞ gap is filled with R_v.

without voltmeter		with voltmeter	
$R_{L(true)} = R_L \parallel \infty = R_L$	>	$R_{L(eff)} = R_L \parallel R_V$	Loading
$V_{L(true)} = \frac{V_s}{R_s+R_L}\times R_L$	>	$V_{L(eff)} = \frac{V_s}{R_s+R_{Leff}}\times R_{Leff}$	effect
true/actual value		measured/indicated volt.	

$\xleftrightarrow{\text{loading error}}$

** An ideal voltmeter with i/p zero resistance is a worst meter, when there is no 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 and it changes the value of loading resistance and in terms of voltage across it this is known as loading effect due to voltmeter resistance."

$$\boxed{\begin{array}{l} \text{Loading effect} = V_{ind} - V_{true} = (-ve) \\ \text{\% Loading error in reading due to voltmeter} = \dfrac{V_{ind} - V_{true}}{V_{true}} \times 100 \end{array}}$$

$V_{ind} < V_{true}$

↳ Error is zero if voltmeter resistance is ∞.

Eg: Ideal voltmeter with i/p resistance = ∞.

Best with a ckt.
Worst w.r.t. measurement.

↳ Loading error never be eliminate. It can be reduced.

↳ To reduce the loading error, a voltmeter should have very high i/p resistance. ($R_v \gg R_L$).

$\boxed{R_{v\,min} = 10 R_L}$ (for 90% accuracy)

$R_v = 100 R_L$ (for 99% accuracy).

↳ $\boxed{R_{v\,min} \geq 10 R_L}$

loading

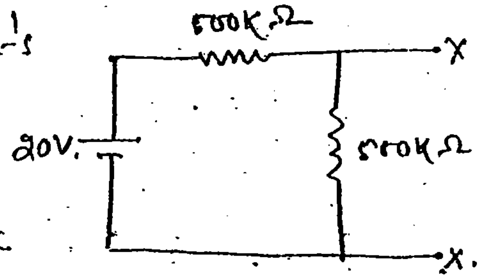
× R_{eff} eff

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 resis. is zero in order to reduce the drop error.)

Pb: The ckt shown in below fig a volt-meter with a fig of merit of $20 K\Omega/V$. 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 ____ ?.

sol^n:

$$S_V = 20 K\Omega/V.$$

$$V = 50 \text{ volts.}$$

$$S_V = \frac{V}{R_m}$$

$$R_m = 20 \times 10^3 \times 50V = 1000 K\Omega.$$

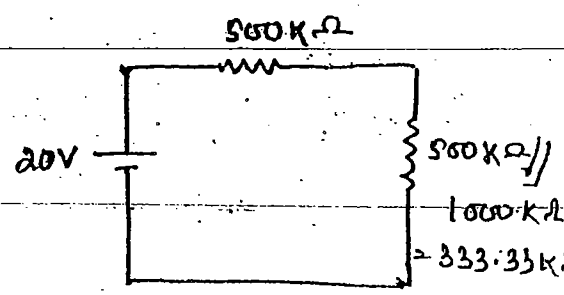
without voltmeter.

$$V_{500K\Omega} = 10V$$

with voltmeter:

$$V_{333.3K} = 20 \times \frac{333.3}{833.3}$$

$$= 8V = V_{ind}.$$



(ii) Percentage error $= \dfrac{8V - 10}{10} \times 100$

$= \dfrac{-2}{10} \times 100$

$= -20\%$, (Here the UE = +2V i.e. − of L.E.)

(reduce in voltage) −ve sign.

(+ → high indication in voltage).

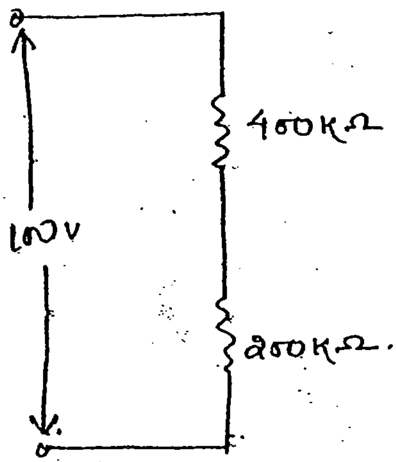
Pb: In the ckt shown in below fig the voltmeter with a fig of merit of 2000 Ω/v is connected across 200KΩ. The range of voltmeter is 100V. The % error is in the reading in is ______ .

sol^n:

$S_v = 2000\ \Omega/V$

$V = 100V$

$R_v = 2000 \times 100 = 200K\Omega$



$V_{indi} = 100 \times \dfrac{200 \| 200}{200\|200 + 400}$

$= 100 \times \dfrac{100}{500}$

$= 20V$

$V_{true} = 100 \times \dfrac{200}{200 + 400}$

$= 100 \times \dfrac{200}{600} = 33.33V$

% Error $= \dfrac{20 - 33.3}{33.3} \times 100$

$= -40\%$

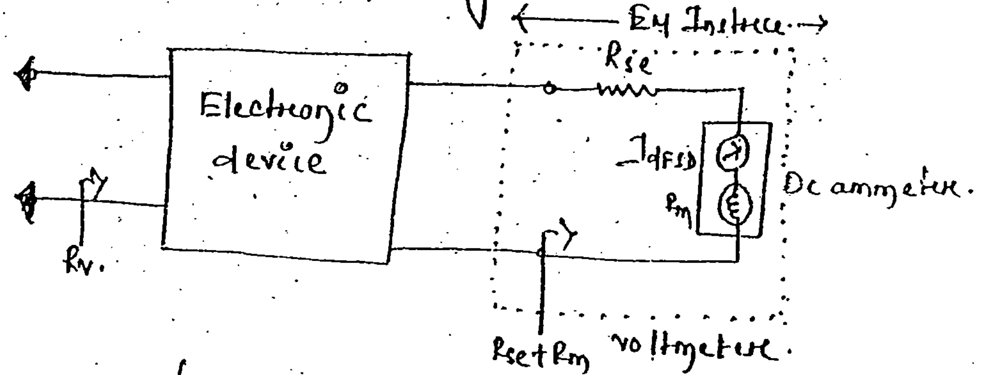
pro
th a
ing load
ing to
500KΩ // 1000KΩ = 333.33KΩ

132

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 caliberated.



(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 current sensing element.

A

(i) Rectifier type A/C voltmeter :

Statement : A rectifier voltmeter is nothing but a dc voltmeter with a rectifying device with the i/p side and the scale calibrated to read true rms value of sinusoidal i/p.

↳ M I instrument are A/C voltmeter, but they are going to measure the true rms value.

↳ If $\theta \propto I^2$.

$$\boxed{\theta = K I^2}$$

$K \rightarrow$ const. then only the device is a true square law device / instrument.

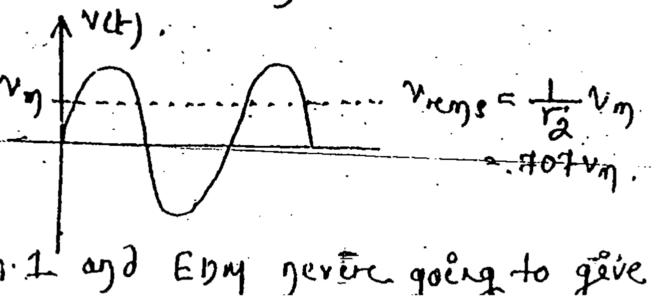
↳ But in M.I instrument : $\theta = \frac{1}{2} I^2 \frac{dL}{d\theta}$.

It is a perfect rms instrument.

Here $K = \frac{1}{2}\frac{dL}{d\theta}$, but this is n't const. It seems to be perfect square instrument, but exactly they are n't.

↳

↳ In perfect square instrument



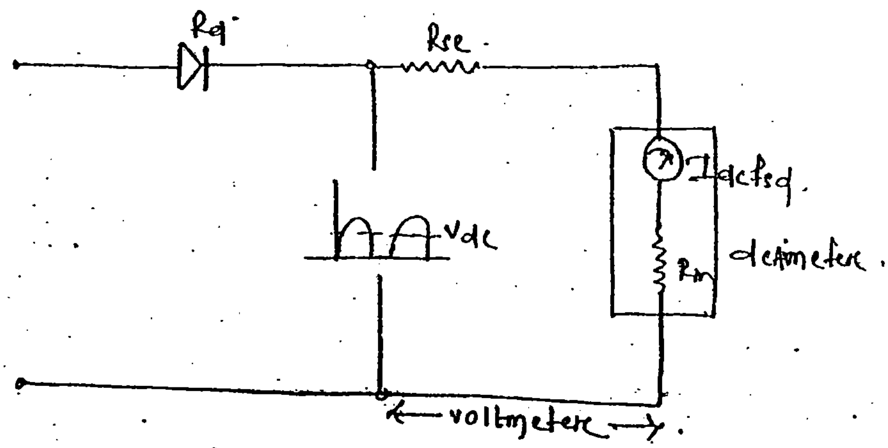
But M.I and EDM never going to give accurate

Objective of the design:

The available electromechanical A/c voltmeters are n't true rms meter since they don't follow perfect square low. As such rectifier type are design (in order to measure the true rms).

↳ Either a half wave rectifier or full wave rectifier is used.

(a) Half wave rectifier voltmeter →



Half wave rectifier voltmeter is nothing but a h.w ckt, but here the half wave resistor is replacing by a dc voltmeter.

↳ This dc voltmeter doesn't response for A/c si 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 Vrms, but the instrument respond to Idc. In h.w

$I_{dc} = \frac{I_m}{\pi}$.

Ac voltage range require HWR

↳ If ... fo ... it

→ So we have to find out the relat^n b/w 'I_{dc}' and 'V_{rms}' i.e. do caliberation in order to get exact objective.

objective ⇒ $V_{rms} = \frac{V_m}{\sqrt{2}}$.

Ammeter respond ⇒ $I_{dc} = \frac{I_m}{\pi}$.

⇒ So the rel^n b/w objective and respond (Form factor)

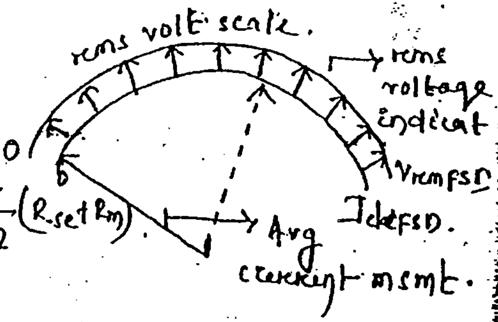
$$V_{rms} = \frac{1}{\sqrt{2}} V_m$$
$$= \frac{1}{\sqrt{2}} (R_d + R_{se} + R_m)\, I_m$$
$$= \frac{1}{\sqrt{2}} (R_{se} + R_m)\, I_{dc} \cdot \pi$$

$$\boxed{V_{rms} = \underbrace{\frac{\pi}{\sqrt{2}} (R_{se} + R_m)}\, I_{dc}}$$

↳ const factor that we have to multiply after reading the dc current.

R_{se} = Series limitting resistor

(It is required to convert the dc ammeter value to HWR value)



$$\underbrace{V_{rms\,FSD}} = \underbrace{2.22(R_{se}+R_m)}\, \underbrace{I_{dc\,FSD}}$$

Ac volt. range of required. HWR volt. ←

calibration factor

dc current range (or) Available Dc ammeter.

(ZRP = zero resting position)

→ If the HWR is used for alternating sinusoidal wave form then there is no error, but in other waveform it will give error.

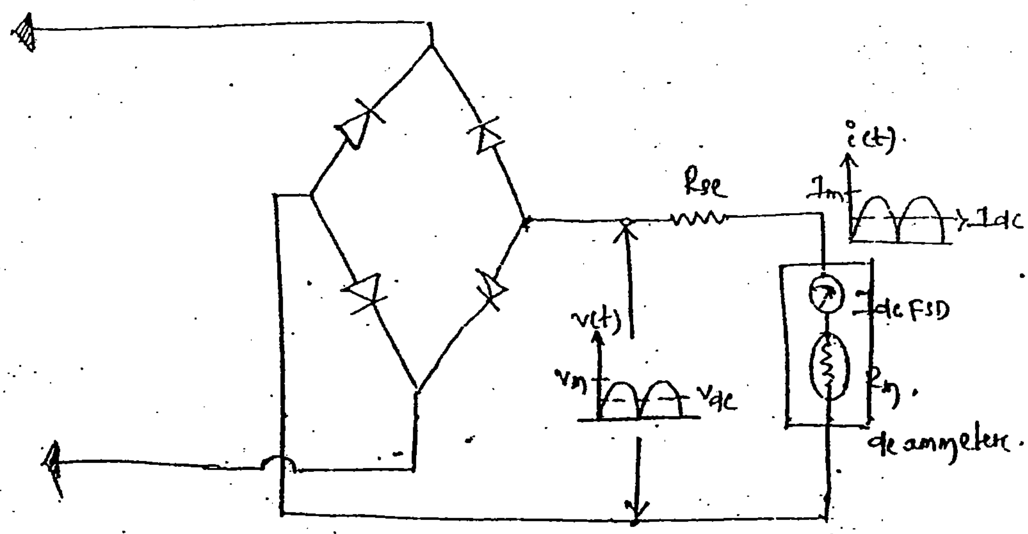
↳ If we are going to connect a dc voltmeter, then the rela^n b/w objective and response is

$$V_{rms\,FSD} = \underbrace{2.22}_{\text{form factor}}\ V_{dc\,FSD}.$$

(b) <u>Full wave rectifier voltmeter</u> :

In this case we can also use a bridge rectifier.

Pb.



sol.

The available electronic electromechanical meter are n't going to measure true rms value.

<u>Objective of design</u> :

objective of FWR voltmeter ⇒ $V_{rms} = \frac{V_m}{\sqrt{2}}$.

Response of dc Ammeter ⇒ $I_{dc} = \frac{2 I_m}{\pi}$

$$\boxed{V_{rms\,FSD} = \frac{\pi}{2\sqrt{2}} \cdot (R_{se} + R_m)\, I_{dc\,FSD}}$$

$$V_{rms\,FSD} = 1.11\,(R_{se} + R_m)\, I_{dc\,FSD}$$] dc ammeter into FWR voltmeter

(This is useful for construction point of view)

$$V_{rms\,FSD} = 1.11\, V_{DC\,FSD}$$] DC voltmeter into FWR voltmeter.

(This is use for utilizatn point of view)

→ It is useful for calculation of 'R_{se}', 'R_{dc}' 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 n't give true

Important note about Rectifier voltmeter :

(i) A rectifier voltmeter works for both A/c & Dc i/ps.

(ii) A rectifier voltmeter is an electronic voltmeter.

(iii) Inbuilt func^n : PMMC Instrument.

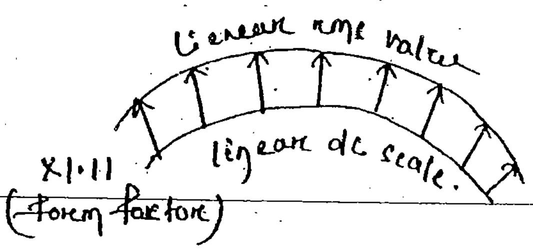
measurement (or) response ⟶ Avg value

indication (or) reading ⟶ rms value.

∴ It is a rectifier A/c 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 low Instrument).

becoz : It is n't designed for square-low, it is



$\overset{\circ}{i}/p$ = alternating sinusoidal $\overset{\circ}{i}/p$.

∴ It is also a <u>derived</u> <u>rms meter</u>.

Therefore Error will be introduced into voltage measurement / indication when used for non-sinusoidal wave-form.

- Alternating sinusoidal
- Full wave Bridge rectifier

] For these two i/p the full wave rectifier isn't going to give any error.

	Full wave rectifier A/c voltmeter.	Half wave rectifier
① rel^n b/w reading & response	$V_{rms} = 1.11(R_{se}+R_m)I_{dc}$	$V_{rms} = 2.22(R_{se}+R_m)I_{dc}$
② Reading for any i/p rectify → DC msmt → multiply	$V_{rms\,(indi)} = 1.11\,V_{dc}$	$V_{rms\,(indi)} = 2.22\,V_{dc}$
③ Error in reading for sinusoidal i/p	—	—
④ Error in reading for non-sinusoidal i/p	$V_{rms\,(indi)} - V_{rms\,(true)}$ $= \pm\left[1.11V_{dc} - \underbrace{K_f V_{dc}}_{\text{depends upon the i/p signal}}\right]$	$V_{rms\,(indi)} - V_{rms\,(true)}$ $= \pm\left[2.22V_{dc} - K_f V_{dc}\right]$
⑤ % error in non-sinusoidal i/p	$\pm\dfrac{\left[1.11V_{dc} - K_f V_{dc}\right]}{K_f V_{dc}}\times 100$ (or) $= \pm\left[\dfrac{1.11 - K_f}{K_f}\right]\times 100$	$\pm\dfrac{\left[2.22V_{dc} - K_f V_{dc}\right]}{K_f V_{dc}}\times 100$ (or) $= \pm\dfrac{\left[2.22 - K_f\right]}{K_f}\times 100$

) - sinusoidal i/p

$$= \pm \frac{\left[1.11 V_{dc} - K_f V_{dc}\right]}{K_f V_{dc}} \times 100 \quad \text{(or)} \quad = \pm \left[\frac{1.11 - K_f}{K_f}\right] \times 100$$

$$\pm \frac{\left[2.22 V_{dc} - K_f V_{dc}\right]}{K_f V_{dc}} \times 100 \quad \text{(or)} \quad = \pm \frac{\left[2.22 - K_f\right]}{K_f} \times 100$$

error.

...ification for constr.

i/p — for rectifier volt meter (Assuming ideal diode)

$$R_{V(F.W)} = R_{se} + R_m.$$

$$= \frac{1}{1.11} \frac{V_{rms FSD}}{I_{dc FSD}}.$$

$$\boxed{R_V = 0.9 \frac{V_{rms FSD}}{I_{dc FSD}}}$$

$$R_V = R_{se} + R_m$$

$$= \frac{1}{2.22} \frac{V_{rms FSD}}{I_{dc FSD}}.$$

$$\boxed{R_V = 0.45 \frac{V_{rms FSD}}{I_{dc FSD}}}$$

$$R_{V(F.W)} = S_{ac(F.W)} * V_{rms FSD}.$$

$$R_{V(H.W)} = S_{ac(H.W)} \times V_{rms FSD}.$$

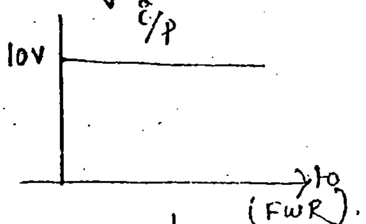
Series multi... resistor for conversion of DC ammeter to rectifier ... ammeter)

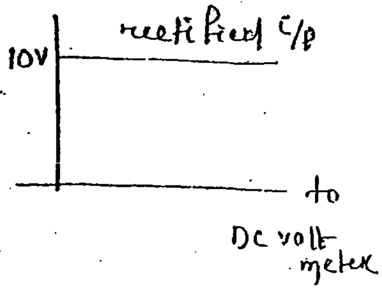
$$R_{se} = R_{V(F.W)} - R_m.$$

$$R_{se} = R_{V(H.W)} - R_m$$

Q: A dc volt of 10 volt is applied in a fw rectifier volt meter then the reading of voltmeter is ______

sol: reading of voltmeter is.





DC voltmeter mennt $= V_{dc}$

$= 10\ V.$

reading $= 1.11 \times V_{dc}$

$= \frac{\pi}{2\sqrt{2}} \times 10$

$= 11.1V$ or $\frac{5\pi}{\sqrt{2}}$ v.

Error $= V_{rms(indi)} - V_{rms(true)}$

$= 11.1 - 10$

$= +1.11 V.$

% error $= \frac{11.1 - 10}{10} \times 100$

$= +11\%.$

(7) The sensitivity of rectifier volt meter.

sol:

$S_{ac(FW)} = \frac{R_{V(FW)}}{V_{rms\,FSD}} = \frac{0.9\,\frac{V_{rms\,FSD}}{I_{dc\,FSD}}}{V_{rms\,FSD}} = 0.9\,S_{DC}$.

Pb.

$S_{ac(HW)} = \frac{R_{V(HW)}}{V_{rms\,FSD}} = \frac{0.45\,\frac{V_{rms\,FSD}}{I_{dc\,FSD}}}{V_{rms\,FSD}} = 0.45\,S_{DC}$.

Q: subjective type
A 0-1mA dc ammeter having internal resistance of 100 Ω is to be used in the following volt. ranges.
(i) 0-10V dc range (ii) 0-10V A/c range using a FWR
(iii) 0-10V A/c range using a HWR.
Calculate the i/p resistance; series multiplier resistor and sensitivity of each volt-meter.

(i) A 0-10 V dc voltmeter using a 1mA dc ameter ⇒.

$R_V = \frac{10V}{1mA} = 10 K\Omega$.

$R_{se} = 10K\Omega - 100\Omega = 9.9 K\Omega$.

S_V or $S_{dc} = \frac{1}{1mA} = 1K\Omega/V$.

(or)

$S_{dc} = \frac{10K\Omega}{10V} = 1K\Omega/V$.

(ii) 0-10V A/c range using a FWR

$R_V = 0.9 \times \frac{10V}{1mA} = 0.9 \times 10 K\Omega$
$= 9 K\Omega$.

$R_{se} = 9K\Omega - 100\Omega = 8.9 K\Omega$.

$S_{a/c} = \frac{9K\Omega}{10V} = 0.9 K\Omega$.

$S_{dc} = \frac{1}{1mA} = 1K\Omega/V$.

(iii) 0-10V a/c range using HWR

$R_V = 0.45 \times \frac{10}{...} = 0.45 \times 10K\Omega$.

$\Rightarrow R_{se} = 4.5 K\Omega - 100\Omega = 4.4 K\Omega$. (loading errors is less in dc measure. & more in A/c msmt.)

$\Rightarrow S_{a/c} = \frac{4.5 K\Omega}{10} = .45 K\Omega$.

$S_{DC} = \frac{1}{1 mA} = 1 K\Omega/V$.

(& sensitivity is high in dc msmt compare to A/c msmt.)

Comparission :

(i) $R_V > R_{V(FWR)} > R_{V(HWR)}$.

$S_{DC} > S_{A/c (FWR)} > S_{A/c (HWR)}$.

(ii) $R_{V(F.W)} = 0.9 R_V$.

$= 2 R_{V(H.WR)}$.

$S_{A/c (FWR)} = 0.9 S_{DC}$

$= 2 S_{A/c (HWR)}$

(iii) $R_{V(HWR)} = 0.45 R_V$

$= \frac{1}{2} R_{V(FWR)}$.

$S_{A/c (HWR)} = 0.45 S_{DC}$

$\frac{1}{2} S_{A/c (FWR)}$.

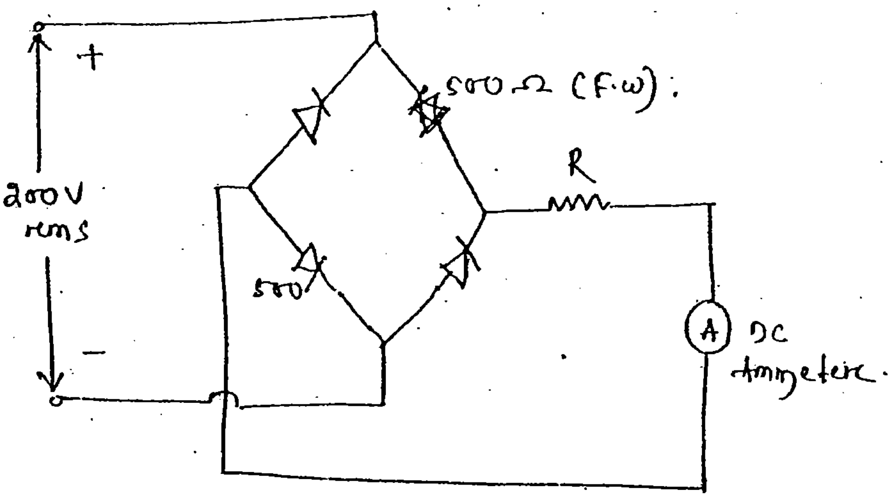
(iv) Loading error in a ckt is less in DC measurement A DC voltmeter (EM type) offers i/p —m— & high sensitivity then a rectifier voltmeter.

(v) Convention rectifier A/c voltmeter is FWR type voltmeter. A FWR voltmeter offers high i/p —m— & high A/c sensitivity then a HWR ~~sensitivity~~ volt.

GATE

Q: In the rectifier voltmeter shown in below fig. the ammeter used produces full scale deflecn for 25 mAmp. The internal resistance of Ammeter is 100 Ω. Each diode has forward resistance of 500 Ω and an '∞' reverse resistance. The value of 'R' is ______.

Sol^n:



Here $R = R_{se}$.

It is a construction based ckt.

$I_{dcFSD} = 25\text{ mA}$.

$R = 100\ \Omega$.

$R_{se} = 0.9 \times \dfrac{200}{25\times10^{-3}} - R_m$ (Assuming ideal diodes)

$= 0.9 \times \dfrac{200}{25\times10^{-3}} - R_m - 2R_d$.

$= 0.9 \times \dfrac{200}{25\times10^{-3}} - 100 - 2\times500$

$= 6.1\text{ K}\Omega$.

Q: A rectifier voltmeter has a dc sensitivity of 20 KΩ/V. It's i/p resistance is ______ in 50V A/c range.

Sol^n: $S_{dc} = 20\text{ K}\Omega/V$

$$S_{dc} = \frac{R_V}{V_{rms(FSD)}}$$

$$20\times10^3 = \frac{R_V}{50}$$

$$1000\times10^3 = R_V$$

$$R_V = 1000\,K\Omega$$

$$S_{ac} = 0.9 \cdot S_{DC}$$
$$= 0.9 \times 20\,K\Omega$$
$$= \frac{9}{10} \times 20\,K\Omega$$
$$= 18\,K\Omega$$

2) i/p resistance = $18\,K\Omega \times 50$

2) i/p resistance = $900\,K\Omega$

Q: A fullwave rectifier has $S_{dc} = 1K\Omega/V$, then it's i/p Ω is ______ in 10V a/c range.

Sol^n: $S_{a/c} = 0.9 \times 1\,K\Omega$

$= 0.9\,K\Omega$

2) i/p resistance = $0.9\,K\Omega \times 10$

$= \frac{9}{10} \times 10 = 9\,K\Omega$

Q: A 1mA dc ammeter is to be used in 10volt a/c range used in FWR. It's i/p Ω in 10V range is ______.

Sol^n: i/p resistance = $0.9 \times \frac{10}{1mA}$

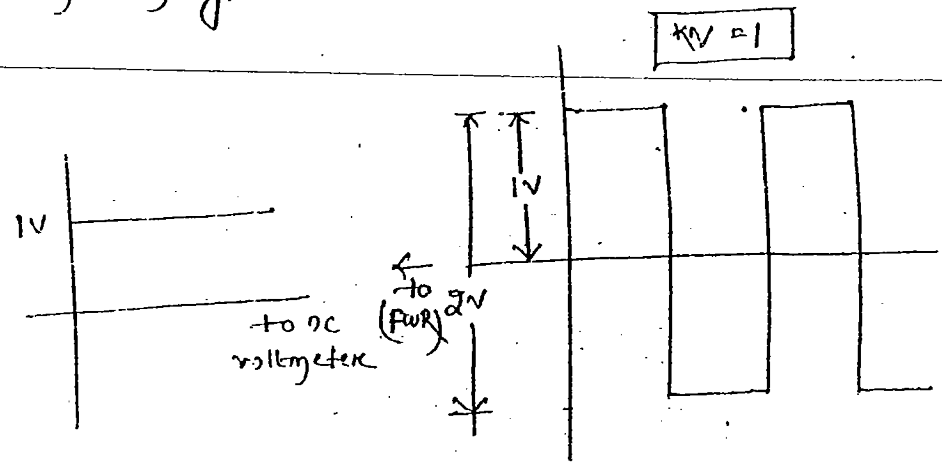
$= 0.9 \times 10 = 9\,K\Omega$

Q: GATE

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.

Sol^n:

when nothing is



→ A symmetric square wave follows a full wave ckt.

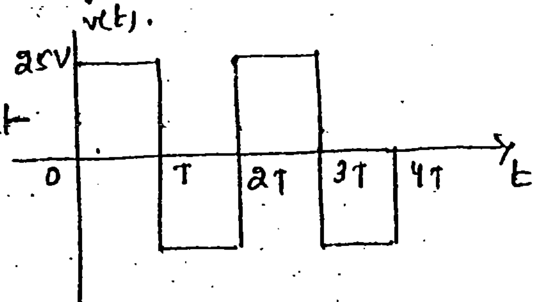
↳ DC msmt = 1 V = V_{dc}

reading = $1.11 \times V_{dc}$ = 1.11 V.

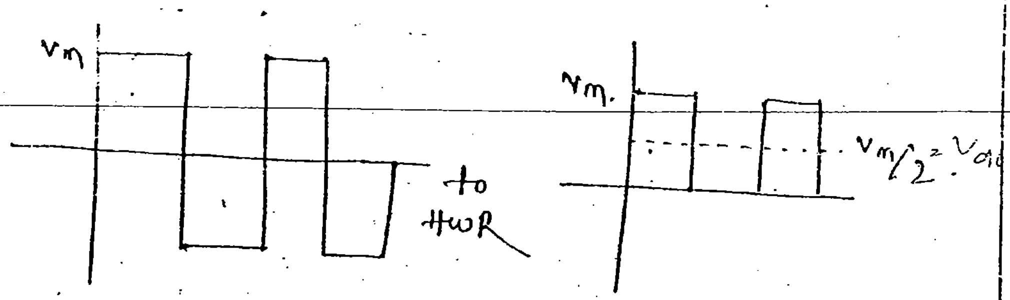
↳ % error = $\frac{1.11V - 1V}{1V} \times 100$ = + 11 %

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 %.

The variation in peak to peak volt. doesn't affect the amt of error i.e. introduce.



Q: An Electronic Avg. measuring and rms reading voltmeter has a scale caliberated 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 ________ sol^n: $V_{rmsFSD} = 24V$.



Vm(actual) is nothing but peak-to peak voltage..

↳ Dc voltmeter msmt $= V_{dc} = \frac{V_m}{2}$.

↳ reading $= 2.22 \cdot V_{dc}$

Pb

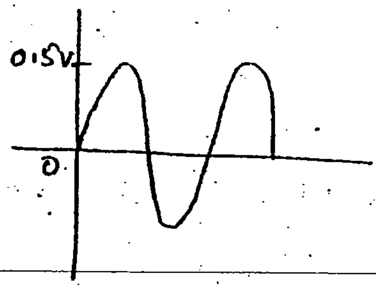
$$= 2.22\, V_{dc} = \frac{\pi}{\sqrt{2}} V_{dc}.$$

$$24\,V = \frac{\pi}{\sqrt{2}} \times \frac{V_m}{2}.$$

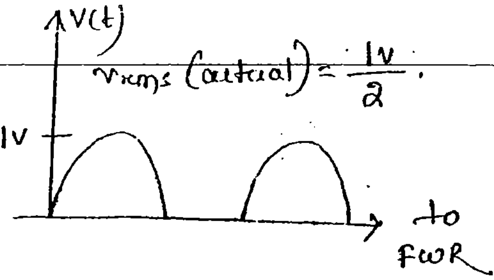
$$\Rightarrow \frac{48\sqrt{2}}{\pi} = V_m \cdot (\text{actual rms})$$

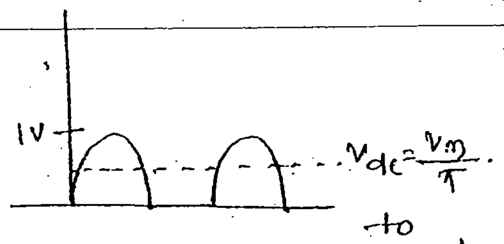
(d)
Q: A full wave rectifier A/c voltmeter is used to measure full wave rectified sinusoidal volt, with a peak value of 1V. then the reading of voltmeter and % error in the reading are $\frac{1}{\sqrt{2}}$V, 0% respectively. 071

Q sol^n:



(d)
Q: A fwR A/c voltmeter is used to measure a half wave rectified sinusoidal volt., then reading of voltmeter is $\frac{1}{2}$ and % error in voltmeter is ____ (consider peak volt = 1V.)





DC voltmeter msmt $= V_{dc}$

$= \frac{V_m}{\pi} V$

$= \frac{1}{\pi} V$

reading of FWR

$= \frac{\pi}{2\sqrt{2}} \times \frac{1}{\pi} V$

$= \frac{1}{2\sqrt{2}} V$

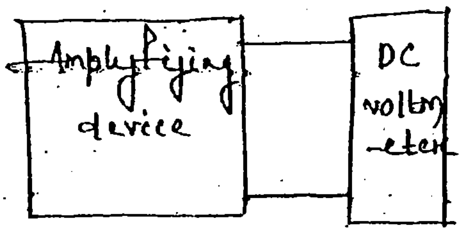
$$\% \text{ error} = \frac{\frac{1}{2\sqrt{2}} - \frac{1}{2} V}{\frac{1}{2} V} \times 100$$

$$= \left(\frac{1}{\sqrt{2}} - 1V\right) \times 100$$

$$= (0.707 - 1V) \times 100$$

$$= -30\%$$

07/10/10

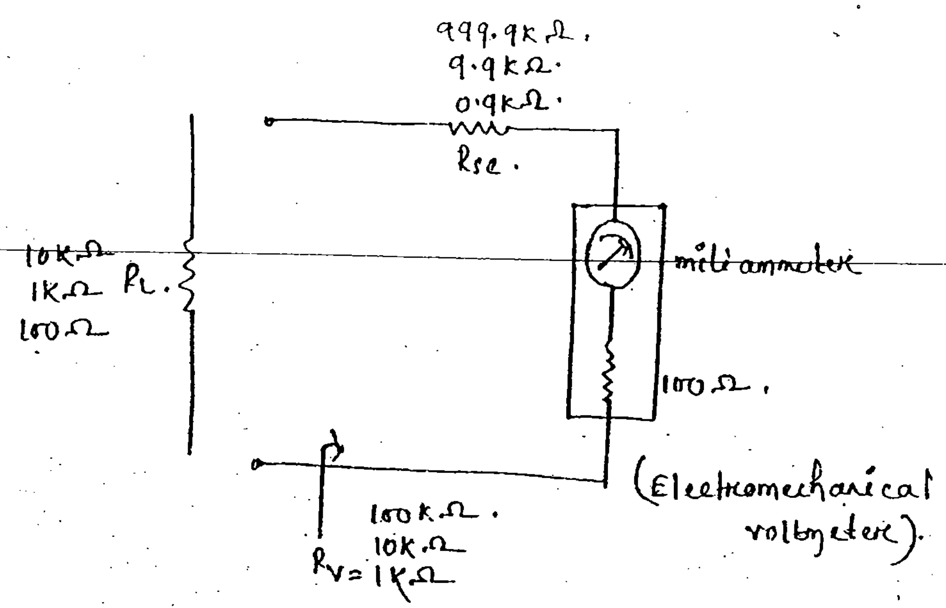


objective of design :

The PMMC instrument has a following limitations when used a very high resistive ckt as given below

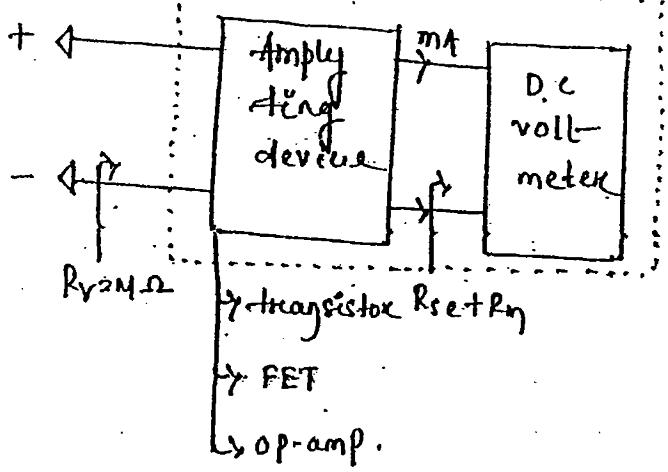
(i) The PMMC instrument are having very ~~high~~ low i/p resistance.

(ii) This instrument can't sense a very small o/p resistance (even in ckt).



→ PMMC has low sensitivity as such amplifier type voltmeter are designed to achieve the objectives of high sensitivity and high i/p resistance.

→ Dc amplified voltmeter / Analog Electronic amplifying type / Electronic Dc voltmeter



→ Here when we give a ~~ext~~ current to the device it'll amplified into 100 times and pass to the volt-meter.

A zero-1 mA PMMC mili ammeter is to be converted into the following volt-meter

(i) A 0-10 volt electromechanical dc volt-meter.

(ii) A 0-10 volt electronic volt-meter using a transistor with a current gain of 100.

The internal resistance of PMMC is 100 Ω. Calculate required R_{se}, i/p resistance, sensitivity of both voltmeters.

$V_{in} = 0 - 10V$.

$I = 0 - 1\,mA$.

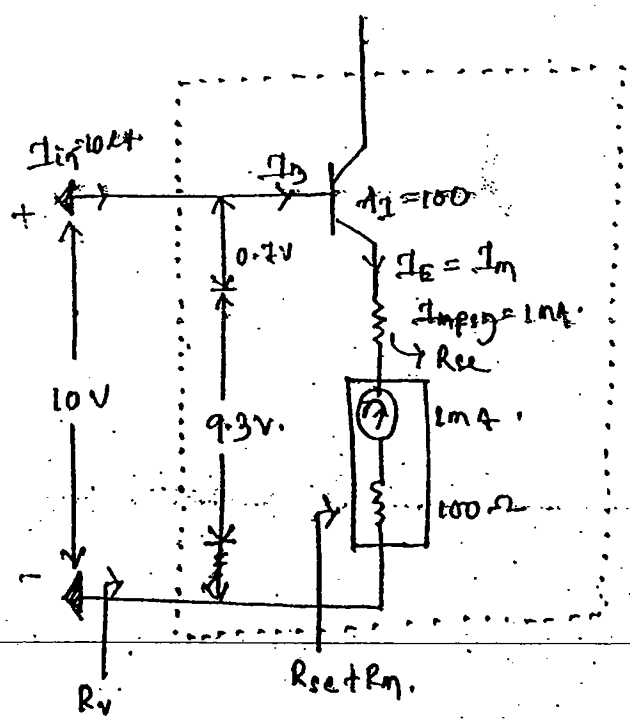
$R = \dfrac{10}{1 \times 10^{-3}} = 10\,k\Omega$.

$R_{se} = 9.9\,k\Omega$.

(ii) $S_{DC} = \dfrac{10\,k\Omega}{10V} = 1\,k\Omega/V$

$S_{DC} = \dfrac{1}{1mA} = 1\,k\Omega/V$

(2)(b). $V = 0 - 10$ volt. electronic voltmeter



$A_I = \dfrac{I_E}{I_B}$

$A_I = \dfrac{I_m}{I_{in}} \Rightarrow 100 = \dfrac{1mA}{I_{in}} \Rightarrow I_{in} = \dfrac{1}{100}\,mA$

ractical (dc) type of Electronic lifying type/ tronic voltmeter it'll R-meter converted be transistor

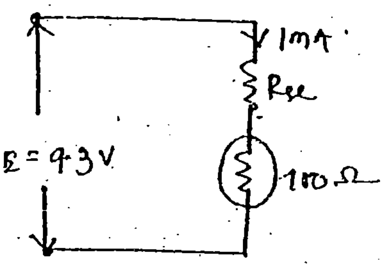
↳ $R_V = \frac{10V}{10\mu} = 1M\Omega = 1000 K\Omega$.

Here the total 10V is n't appear across the voltmeter. due to transistor. there is a volt drop across this transistor

$(R_{se} + 1000) \times 1mA = 9.3V$

$R_{se} = \frac{9.3}{1mA} - 100\Omega$

$= 9.2 K\Omega$.



Here we caliberate 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 errors can be eliminated.

↳ $S_{DC} = \frac{1000 K\Omega}{10 V} = 100 K\Omega/V$.

(or)

$S_{dc} = \frac{1}{10\mu A} = 0.1 \frac{M\Omega}{V} = \frac{100 K\Omega}{V}$,

↳ Error in scale caliberation:

0V — 10V ↳ but 9.3V must required.

↳ External supply of +5V is required.

↳ Ico & V_{BE}

↳ $\frac{dV_{BE}}{dT} = -2.5 mV/°C$.

double in every 10°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 MΩ.
- An electronic amplifier voltmeter offer very high sensitivity in the range of MΩ/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 opera^n.
- Transistor parameter like I_{CO} and V_{BE} are temp. sensitive as such entire measuring unit become sensitive to temp.

Eg. of Electronic DC voltmeter

- Transistor voltmeter
- Emitter follower voltmeter
- Differential voltmeter
- FET i/p voltmeter.
- op-amp voltmeter.

R_v (op vt.) $>$ R_v (FET volt) $>$ R_v (EF volt) $>$ R_v (FW AC volt) $>$ R_v (H.W volt)

$R_v >$

S_{DC} (op-volt) $>$ S_{DC} (FET volt) $>$ S_{DC} (EF volt) $>$ S_{AC} (F.W volt) $>$ S_{AC} (H.W volt)

$S_{DC} >$

|← Electronic DC voltmeter →| EM type DC voltmeter |← Electronic A/C → voltmeter|

conclusion: $\boxed{\text{Sensitivity} \propto \text{i/p resistance}}$

Differential voltmeter is the integral part of FET i/p voltmeter.

FET i/p voltmeter :-

$$V_m = V_{E_1} - V_{E_2}$$

$$= V_{B_1} - 0.7 - (V_{B_2} - 0.7)$$

$$= V_s - 0.7 - (V_p - 0.7)$$

$$= V_G - V_{GS} - 0.7 - (V_p - 0.7)$$

$$= V - V_{GS} - \cancel{0.7} - V_p + \cancel{0.7}$$

$$\boxed{V_m = V - V_{GS} - V_p}$$

V_{GS} = -ve for FET (n-channel)

$V = V_{in}$ in selected range

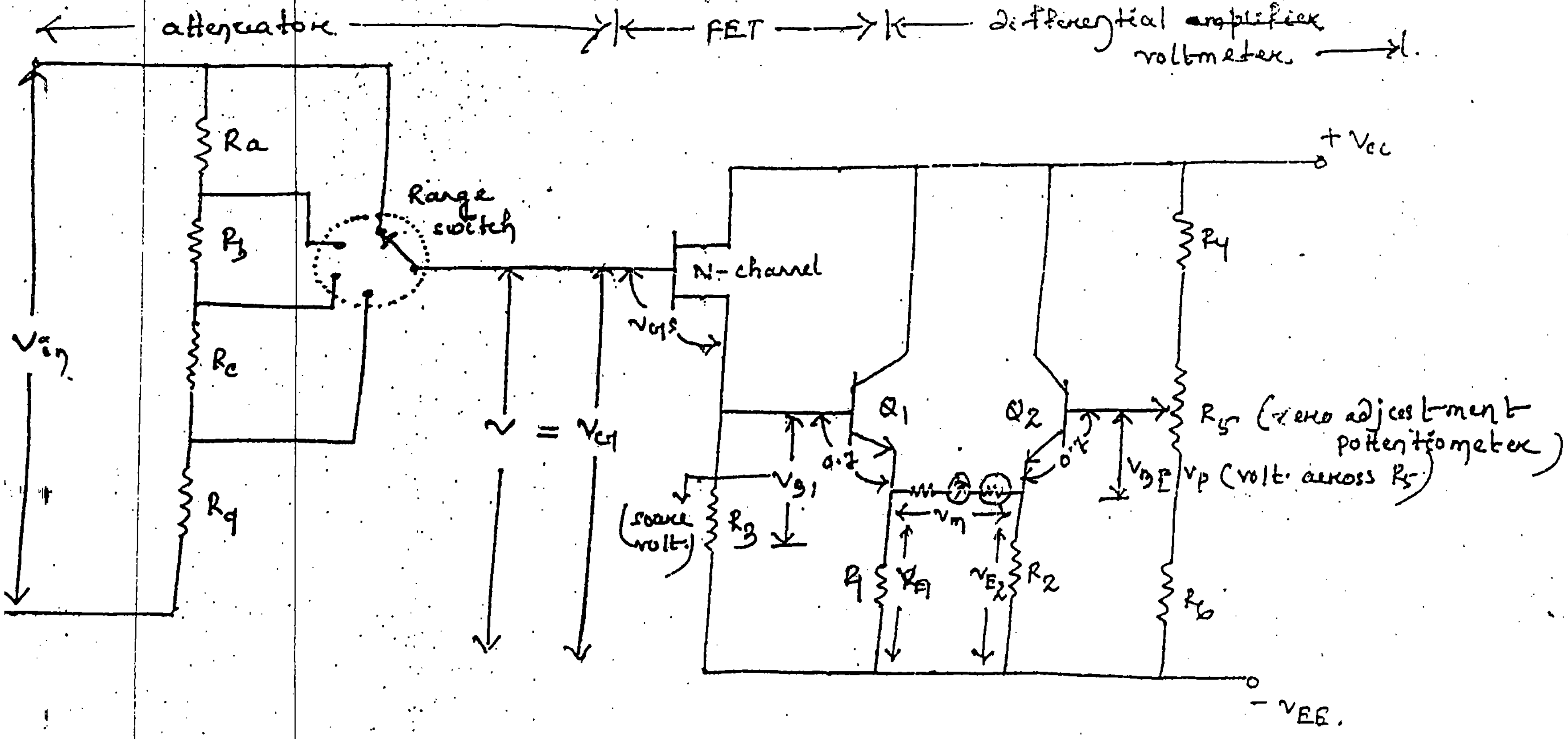
if sw - (A) $\Rightarrow V = V_{in}$.

if sw - (B) $\Rightarrow V = V_{in};\ \dfrac{R_b + R_c + R_d}{\Sigma R}$

if sw - (C) $\Rightarrow V = V_{in};\ \dfrac{R_c + R_d}{\Sigma R}$

if sw - (D) $\Rightarrow V = V_{in} \dfrac{R_d}{\Sigma R}$.

← attenuator → |← FET →|← differential amplifier voltmeter →|


attenuator
FET
differential amplifier voltmeter
+ Vcc
Ra
Rb
Rc
Rd
Range switch
N-channel
Vgs
Vin
~ = Vcl
Q1
Q2
0.7
Vg1
(source volt.)
R3
R1
VE1
VE2
R2
Vm
R4
R5 (zero adjustment potentiometer)
Vp (volt. across R5)
VBE
R6
- VEE.

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↳ Prior to any practical measurement of voltage zero adjustment must be carried out where 'R_S' is varied to get / achieve $|V_P| = |V_{GS}|$. Such that $V_m = V$. (this is done with zero i/p)

Eg: $V_{GS} = -3V$.
$V = 10V = V_G$

↳ $V_S = 10V - (-3V) = 13V$.

↳ $V_{E_1} = 13V - 0.7V = 12.3\ V$.

$V_{G_2} = V_P = 3V$ (fixed during ZAP)

$\therefore V_{E_2} = 3V - 0.7V$
$= 2.3V$.

↳ $V_m = 12.3 - 2.3$
$= 10V$.
(or)
$V_m = V$ (after ZAP)

15/10/10

Q-METER :-

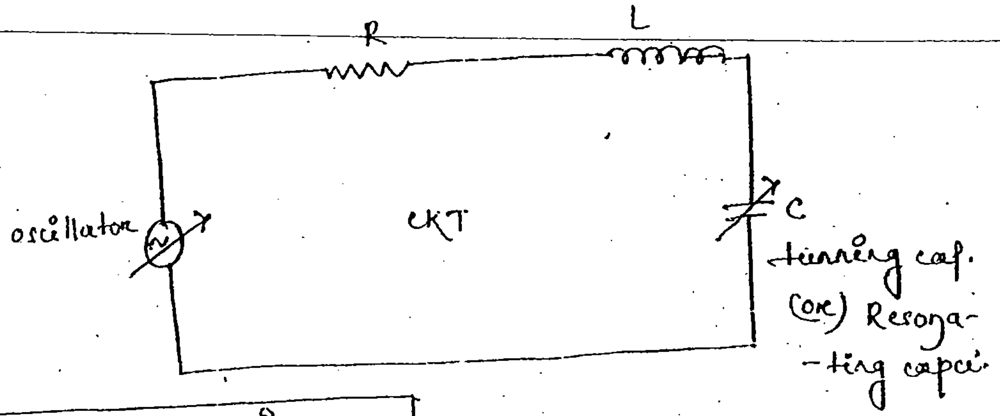
↳ A Q-meter (quality factor meter) is basically used for the msmt of following property of a given test

(i) True Q-coil. msmt (~~Q~~ true msmt)
(ii) Self capacitance (or) Distributed capacitance msmt (C_d)
(iii) Self inductance of coil (L).

In Q-meter there are actually 3-connections.

Basic Principle of operation: (calculation point of view)

Q-meter is ~~nothing but~~ having a series resonance
~~since Q-meter is nothing but series R-L-C ckt.~~



$\boxed{\text{Resonance cond}^{n}: X_L = X_C}$

But initially, $2\pi f L \neq \frac{1}{2\pi f C}$

Now set the freq. $= f_r$

Here we are n't going to vary the i/p. we are varying the capacitance i.e.

$$2\pi f_r L \neq \frac{1}{2\pi f_r C}$$

But at $C = C_x$ $2\pi f_r L = \frac{1}{2\pi f_r C}$.

Properties of series R-L-C ckt at Resonance:

(i) impedence of ckt (Z) is nothing but purely resis-tive (i.e. $Z = R$).

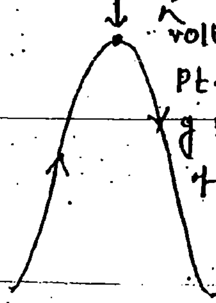
(ii) Resonance frequency, $f_r = \frac{1}{2\pi\sqrt{LC_x}}$

(iii) volt. at capacitanc 'c' when the capacitance value is C_x

i.e. $V_{C_x} = V_{cmax}$

$\boxed{V_{cmax} = Q \cdot V}$ ← Applied volt.

↑ max^{m} volt. across cap. at res.   ↑ quality factor



at resonant pt. volt. is at peak pt. i.e. nothing but Q-time of applied volt.

** Series R-L-C ckt is act as 'voltage magnifier'.

** parallal R-L-C ckt is act as 'current magnifier'

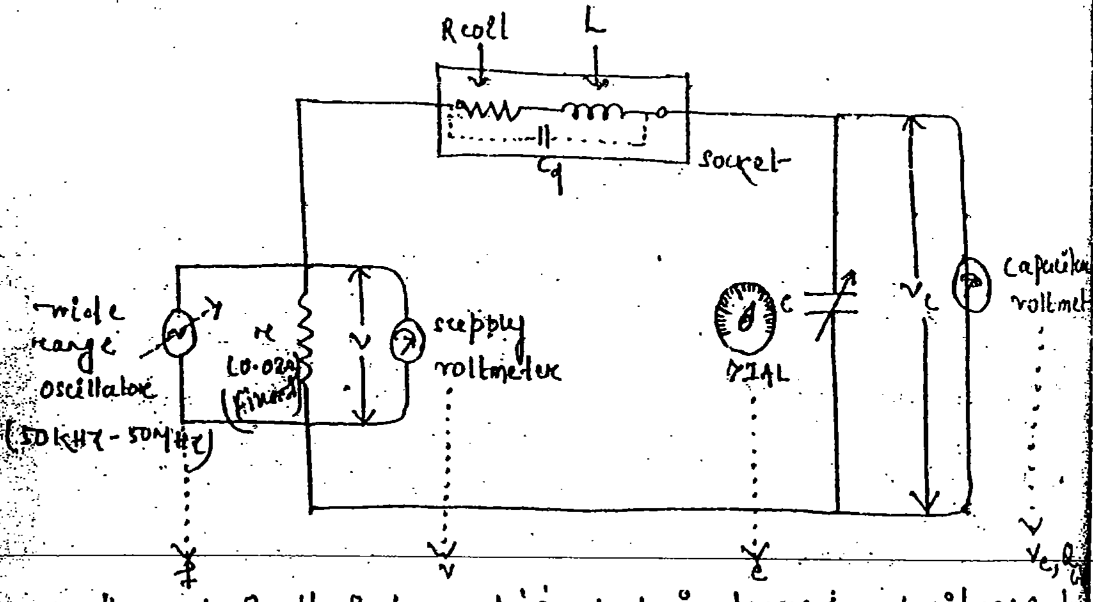
In series R-L-C ckt 1st fixed the i/p and vary the capacitance value, then a volt. at the i/p side that we can track is nothing but applied volt and the volt. devloped at capacitance is the max voltage that we can track.

$$\boxed{Q = \frac{\text{Reactance}}{\text{Resistance}}}$$

$$Q_{true} = \frac{X_L}{R} = \frac{\omega L}{R}$$

Again $Q_{true} = \frac{X_C}{R}$ (or) $= \frac{1}{\omega C R}$.

Direct connection of Q-meter (or) Direct msmt mode



the scale is n't in terms of 'Q', but in terms of capacitance.

n't true Q of coil

Tunning Process :

↳ ~~Introduce the given test coil into socket.~~

↳ Q-meter resembels series R-L-C ckt

∴ 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.

↳ Note down readings.

Then Q value = $\dfrac{\text{capacitor voltmeter rdg}}{\text{supply voltmeter rdg.}}$

$$\boxed{Q = \frac{V_{cmax}}{V}}$$

↳ Here on paper we are showing one capacitor, but exactly there are two capacitor i.e. the ~~capacitance~~ of coil, i.e. introduce into the ckt has a it's own capacitance.

↳ In true case the inductive capacitance

↳ Here the error is due to two parameter i.e.

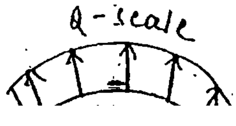
a) Cd

b) r

↳ To overcome such calculation of 'Q' the manufacturer provide a scale caliberated in terms of 'Q' from voltage scale of capacitor voltmeter.

$$Q = \frac{V_c}{} \times \frac{1}{V}.$$

Q-scale



∴ capacitor volt-meter is known as 'Q-volt-meter'.

↳ The Q-voltmeter indicate doesn't indicate true Q of coil, it indicates ckt 'Q' only. becoz of 2 errors

a) insertion resistance (r)

b) distributing capacitance (Cd).

∴ Q-voltmeter is also called as "ckt-Q-meter".

Measured - Q Vs True - Q :-

$$\underline{Q_{ckt}} < \underline{Q_{coil}}$$

$$\frac{\omega L}{R_{coil} + r} < \frac{\omega L}{R_{coil}}$$

$$\frac{1}{\omega (C + C_d)(R_{coil} + r)} < \frac{1}{\omega C R_{coil}}$$

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-msmt due to r (0.02 Ω):

↳ Error = $Q_{msmt} - Q_{true}$

$= Q_{ckt} - Q_{coil}$

$= \frac{\omega L}{R_{coil} + r} - \frac{\omega L}{R_{coil}}$

↳ $\% \text{ Error} = \dfrac{\frac{\omega L}{R_{coil}+r} - \frac{\omega L}{R_{coil}}}{\frac{\omega L}{R_{coil}}} \times 100\%$

case
Ideal
case
(Rare
case-I
(General

meter'.

true

of x

$$\boxed{\left.\begin{array}{l}\text{\% Error in Q measmt} \\ \text{due to 'r'}\end{array}\right\} = \frac{-r}{r+R_{coil}} \times 100\%}$$

<u>Correction factor to be applied on Q-measured</u> :

$$\frac{Q_{true}}{Q_{measured}} = \frac{\frac{\omega L}{R_{coil}}}{\frac{\omega L}{R_{coil}+r}}$$

$$\frac{Q_{true}}{Q_{measured}} = \frac{R_{coil}+r}{R_{coil}}$$

$$\boxed{Q_{true} = \underbrace{\left(1+\frac{r}{R_{coil}}\right)}_{\text{correction factor}} Q_{meas}}$$

10 Ω, 20 Ω ... indication of Q-voltmeter.

<u>case - I</u> :- if $r=0$,
(Ideal)

$$\boxed{Q_{true} = Q_{measured}}$$ (Ideal case)

and % Error is NILL

<u>case - II</u> : if $r \cong R_{coil}$,
(Rare)

$$Q_{true} = 2\, Q_{measured}.$$

$$\boxed{Q_{true} >> Q_{measured}}$$

Again, $Q_{measured} << Q_{true}$

$$Q_{measure} = \frac{1}{2} Q_{true}.$$

⇒ % Error is high.

<u>case-III</u> : if $r << R_{coil}$, $Q_{measure} \cong Q_{true}$.
(general)

% Error is very small i.e. it can be neglected.

n of

te

—①

ckt 'Q'
—②

ckt 'Q'

↳ In general insertion resistance is very low compared to coil resistance. As such error introduced into Q-msmt due to 'r' can be neglected.

b) Error in Q-msmt due to 'cd':

$$\text{Error} = Q_{measured} - Q_{true}$$

$$= Q_{ckt} - Q_{coil}$$

$$= \frac{1}{\omega(C+C_d)(r+R_{coil})} - \frac{1}{\omega C R_{coil}}$$

$$\cong \frac{1}{\omega(C+C_d)R_{coil}} - \frac{1}{\omega C R_{coil}} \quad (\because r \ll R_{coil} \text{ case-iii})$$

$$\text{\% Error in Q-msmt due to } C_d = \frac{\frac{1}{\omega(C+C_d)R_{coil}} - \frac{1}{\omega C R_{coil}}}{\frac{1}{\omega C R_{coil}}} \times 100\%.$$

$$\boxed{\text{\% Error in Q-msmt due to } C_d = \frac{-C_d}{C+C_d} \times 100\%}$$

Correction factor:

$$\frac{Q_{true}}{Q_{measured}} = \frac{\frac{1}{\omega C R_{coil}}}{\frac{1}{\omega(C+C_d)R_{coil}}}.$$

$$\boxed{\frac{Q_{true}}{Q_{measured}} = \frac{C+C_d}{C}} \quad \text{Ratio of Q's.}$$

$$\boxed{Q_{true} = \left[1+\frac{C_d}{C}\right] Q_{measured}}$$

— we can't compare 'c' and 'cd', becoz although 'cd' is fixed but 'c' isn't fixed. it is varying within the experiment itself.

↳ To apply the correction factor the value of 'cd' must be known as such the 1st msmt ie carried out using Q-meter will always be msmt of 'cd'.

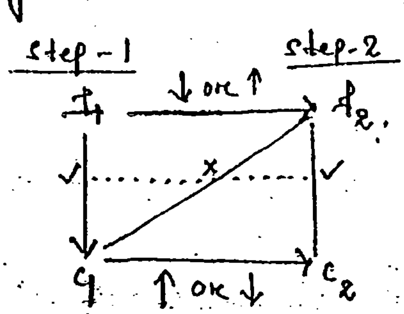
16/10/10

<u>Measurement of 'cd' of coil using direct connection of Q-meter :-</u>

<u>tuning process</u> :

↳ Introduce given test coil into socket and resonate twice at f_1 and f_2 where $\boxed{f_2 = n f_1}$ → $n<1$, → $n>1$.

↳ 1st set the frequency 'f_1' with the corresponding value of 'c_1'. at 'c_1' we are geting the value of resonance.



$$f_1 = \frac{1}{2\pi\sqrt{L(c_1+c_d)}} \quad \text{—①}$$

readgs of step-1 →

$f_1, v, c_1, v_{c_1}, Q_1$ ↳ ckt 'Q'

Again, $$f_2 = \frac{1}{2\pi\sqrt{L(c_2+c_d)}} \quad \text{—②}$$

readgs of step-2 →

$f_2, v, c_2, v_{c_2}, Q_2$ ↳ ckt 'Q'

* coil 'Q' isn't going to change, but ckt 'Q' is changing frequently.

$$\cancel{f_1 + f_2 = \frac{1}{2\pi\sqrt{L(c_1+c_d)}} + \frac{1}{2\pi\sqrt{L(c_2+c_d)}}}$$

The ratio of $\frac{V_{C_2}}{V}$ (max^n volt.) $= Q_2$

$$\boxed{\frac{\text{o/p volt / final volt}}{\text{i/p volt}} = Q}$$

$\frac{V_{C_1}}{V} = Q_1$.

Now devide eqn '1' and eqn '2'

$$\frac{f_1}{f_2} = \frac{\frac{1}{2\pi\sqrt{L(C_1+C_d)}}}{\frac{1}{2\pi\sqrt{L(C_2+C_d)}}}$$

$$\frac{f_1}{f_2} = \frac{\frac{1}{\sqrt{L(C_1+C_d)}}}{\frac{1}{\sqrt{L(C_2+C_d)}}}$$

$$\frac{f_1}{f_2} = \frac{\sqrt{L(C_2+C_d)}}{\sqrt{L(C_1+C_d)}}$$

$$\frac{f_1}{n f_1} = \frac{C_2+C_d}{C_1+C_d}$$

$$\frac{1}{n^2} = \frac{C_2+C_d}{C_1+C_d}$$

$$n^2 C_2 + n^2 C_d = C_1 + C_d$$

$$\boxed{C_d = \frac{C_1 - n^2 C_2}{n^2 - 1}}$$

Measurement of true 'Q' of coil using direct msmt mode of Q-meter:

- First measure 'C_d' of coil by resonating twice.
- Use the reading of 'C_d' to get Q-coil.

$$\boxed{Q_{coil} = \left[1 + \frac{C_d}{C}\right] Q_{ckt}}$$

$\Rightarrow$ $\boxed{Q_{coil} = \left(1 + \frac{C_d}{C_1}\right) Q_1}$, (or) $\boxed{Q_{coil} = \left(1 + \frac{C_d}{C_2}\right) Q_2}$

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 'C_d' of coil by resonating twice.

↳ Use readings of 'C_d' to measure 'L'.

$$f_x = \frac{1}{2\pi\sqrt{L(C_x + C_d)}}$$

$$L = \frac{1}{4\pi^2 f_x^2 (C_x + C_d)}$$

$$\boxed{L = \frac{1}{4\pi^2 f_1^2 (C_1 + C_d)}} \quad \text{(or)} \quad \boxed{L = \frac{1}{4\pi^2 f_2^2 (C_2 + C_d)}}$$

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 it's inductance and not on it's resistance.

ste-2003

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 300 PF. A lossless capacitor 'C_x' 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 C_x is ____

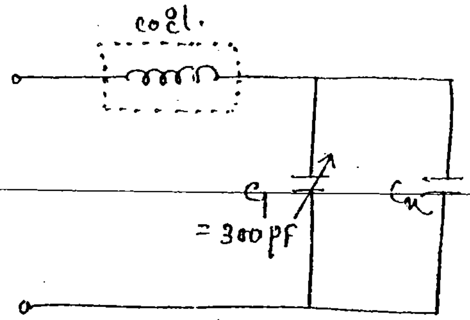
C_1 = 300 pF. Q_1 = 120

C_2 = 200 pF.

$Q_1 = Q_2 = 120.$

$\downarrow \quad \downarrow$

$$\frac{1}{\omega C_1 R} = \frac{1}{\omega (C_2 + C_x) R}$$



$\Rightarrow C_1 = C_2 + C_x$

$\Rightarrow 300 = 200 + C_x$

$\Rightarrow C_x = 100$ pF.

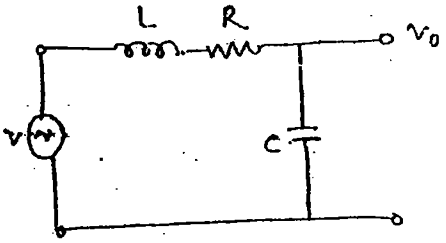
JTO Q: Q-meter works on the principle of ________

Ans: series resonance.

Q: A Q-meter with ea 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 ________.

sol^n:

$$\frac{V_0}{V} = Q = \frac{10}{500\,\text{mV}} = 20.$$



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 ________.

$$L = \frac{1}{4\pi^2 f^2 C} \qquad \omega = 10^6 \text{ rad/sec.}$$

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1 + C_d)}}$$

$$10^6 = \frac{1}{2\pi\sqrt{L(820\times10^{-12} + 9.18\times10^{-9})}}$$

$$\Rightarrow 10^{6} \times 2 \times \pi = \frac{1}{\sqrt{L(820\times10^{-12} + 9.18\times10^{-9})}}$$

$$\Rightarrow L = \frac{1}{4\pi^2 f^2 (c + c_q)}$$

$$\Rightarrow L = \frac{1}{4\pi^2 (10^6)^2 (820\times10^{-12} + 9.18\times10^{-9})}$$

$$\Rightarrow L = \frac{1}{(10^6)^2 (820\times10^{-12} + 9.18\times10^{-9})}$$

$$\Rightarrow L = 100\,\mu H.$$

Pb: A coil is tuned to resonance a 500 KHz with a resonating capacitance . A frequency is rise to 1 MHz. The resonance is obtained at 72 pF. The self capacitance of coil is ______ .

IES Pb: A coil is tuned to resonant 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^n:

$$L = \frac{1}{4\pi^2 f^2 (c + c_q)}.$$

$$\begin{array}{ccc} 500 & \longrightarrow & 1\,MHz \\ \downarrow & & \downarrow \\ 360 & \text{———} & 72\,pF \end{array}$$

$$c_q = \frac{360 - 2^2 \times 72}{2^2 - 1}$$

$$= \frac{360 - 4\times72}{4-1} = \frac{360 - 288}{3}$$

$$= \frac{72}{3} = 24\ PF.$$

note: After deviding c_q, msmt of 'L' also can be carried out.

$$L = \frac{1}{4\pi^2 (500\times10^3)^2 [360+24]}$$

$$L = \frac{1}{4\pi^2 (1000\times10^3) [72+24]}$$

Pb: 2 $f_1 = 500KHz$ $C_1 = 36PF$

$f_2 = 250KHz.$ $C_2 = 160\,PF.$

$n = \frac{1}{2} = 0.5$

$$C_d = \frac{36-(0.5)^2 160}{(0.5)^2-1} = 5.33PF.$$

Pb: A coil with a resistance of 10Ω is connected in direct msmt mode of Q-meter. Resonance occurs when the oscillator frequency is 1MHz and the resonating capacitance is set as 65 PF. Then the magnitude of % error introduced in Q-msmt due to insertion resistance value 0.02Ω is ______.

sol^n:

$R = 10\Omega$

$f = 1MHz.$

$r = 0.02\Omega.$

$$Q_{true} = \frac{1}{\omega CR}.$$

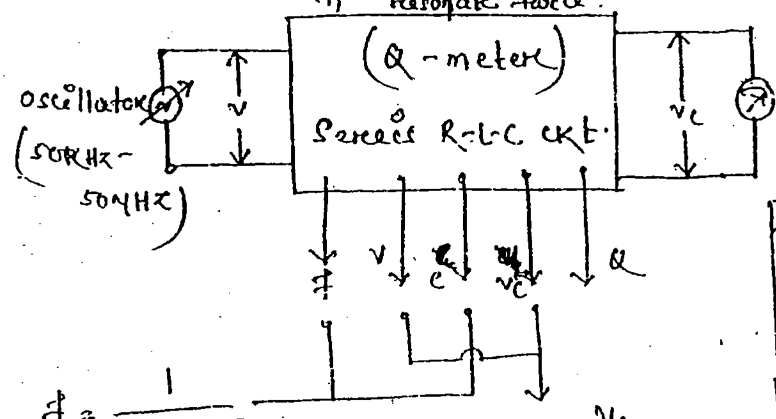
$$= \frac{1}{2\pi (C+C_d)(R+r)}$$ this isn't required.

$$= \frac{-r}{r+R_{coil}} \times 100$$

$$= \frac{-0.02}{10.02} \times 100$$

$C_d = \frac{f_1 - n^2 f_2}{n^2 - 1}$ $\quad n = \frac{f_2}{f_1}$ $\quad Q_{true} = \left(1 + \frac{C_d}{C}\right) Q$ $\quad L = \frac{1}{4\pi^2 f^2 (C + C_d)}$

resonate twice



$f = \frac{1}{2\pi\sqrt{L(C + C_d)}}$ $\quad Q = \frac{V_C}{V}$

→ Provides indication of ckt-Q but not coil-Q
→ becoz of 2 error: $r = 0.02$, C_d

due to r:
→ $C_{fr} = 1 + \frac{r}{R_{coil}}$

$\%\ error = \frac{-r}{r + R_{coil}} \times 100$

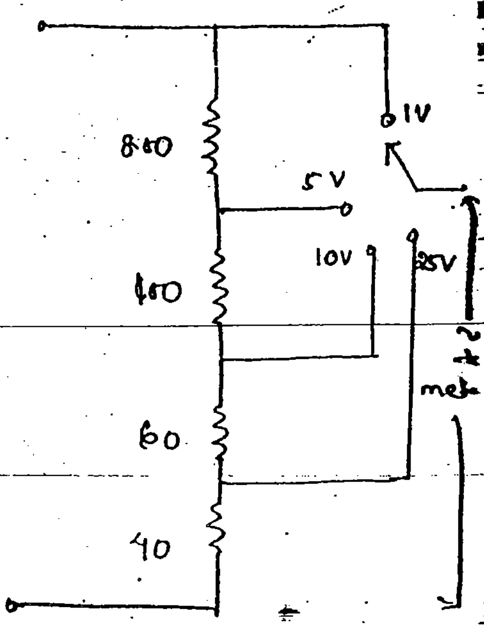
due to C_d:
→ $C_{fd} = 1 + \frac{C_d}{C}$

$\%\ error = \frac{-C_d}{C + C_d} \times 100$

Digital volt-meter :-

→ A digital measuring unit is a volt measuring unit.

The attenuator shown in below fig is the i/p stage of a FET i/p voltmeter. The PMMC instrument use has a fsD of 1mA and resistance of 1kΩ. If used to measure 7.5V in 10V DC range then the current through the meter is ____.



$V_{ys} = 7.5\ e|V_p|$.

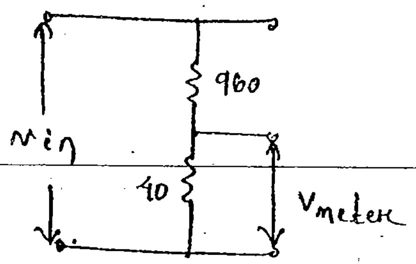
$R = 1k\Omega$.

At $\underline{25V}$:

$$V = \frac{1}{25} \times V_{in}.$$

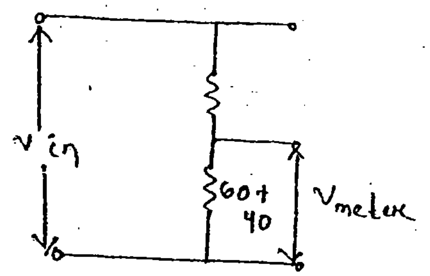
$$= \frac{40K\Omega}{1000K\Omega} \times V_{in}$$

$$= \frac{1}{25} \times V_{in}.$$



at $\underline{sw\ 10V}$:

$$V = \frac{V_{in}}{10}.$$



At the i/p side we'll get max^m 1 volt, but in o/p side we'll never get ~~ma~~ the volt. range more than (0–1)V.

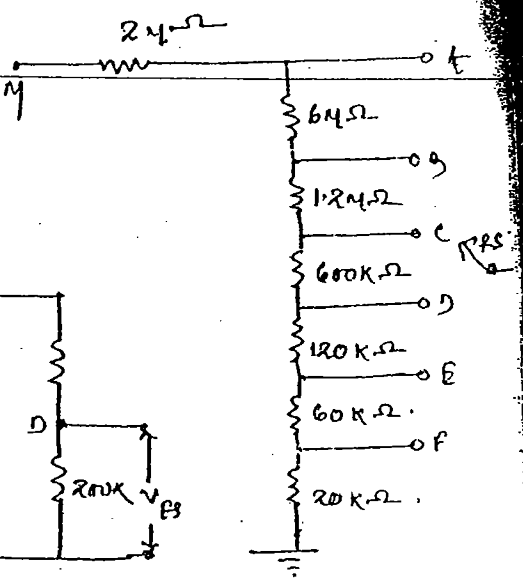
$$I_{in} = \frac{10}{0.7.5} \quad \frac{7.5}{1\times10^3} = \frac{75}{10\times10^3} = 0.75. \quad \frac{7.5}{10} = .75.$$

This can be posible only by zero adjustment

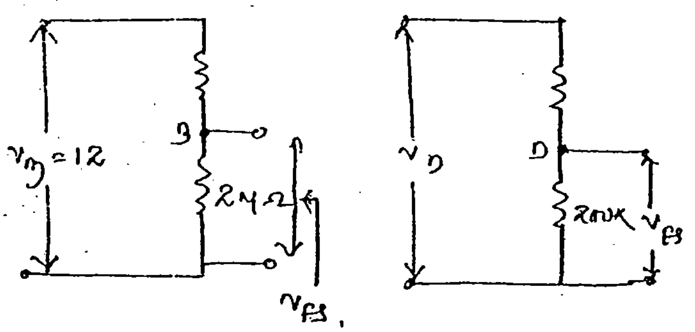
$$I_m = \frac{V_m}{R_m} = \frac{0.75}{1\times10^3} = 0.75\,mA.$$

Pb! The below fig shows i/p attenuator of an analog multimeter. The meter reads full scale with 12V at 'N'. with the range switch at position 'B'. what is the required voltage at 'N' to obtain fsd with the range switch pos^n at 'D'.

$V_{in} = 12V = V_{GS}$.



SW - B SW - D



$\Sigma R = (6+2+1.2+0.8) M\Omega$
$= 10 M\Omega$.

$V_{FS} = 12V \times \frac{2M\Omega}{10M\Omega}$ —①
$= 12 \times \frac{1}{5}$
$= 2.4 M\Omega$.

$V_{FS} = V_{M_2} \times \frac{200 \times 10^3}{10 \times 10^6}$ —②

$\Rightarrow 12 \times \frac{2}{10} = \frac{200 \times 10^3}{10 \times 10^6} \times V_{M_2}$

$\Rightarrow V_{M_2} = 120V$.

Pb: Identify the increasing order of analog voltmeter in terms of their sensitivity.
(i) moving coil voltmeter (ii) FET voltmeter (iii) Rectifier A/C voltmeter

Ans: 3, 1, 2.

Pb: Identify the voltmeter which can be used across $100K\Omega$ with minm loading error.
(i) A $10\frac{K\Omega}{V}$ DC voltmeter
(ii) Electronic A/C voltmeter
(iii) ~~Electronic DC voltmeter~~
(iv) None.

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 volt-meter. 3, 1, 2

(iii) Differential type voltmeter.

Pb: Loading effect is primarily due to instrument having ________.

(i) High i/p resistance ✓(ii) Low sensitivity

(iii) High 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 ✓FET).

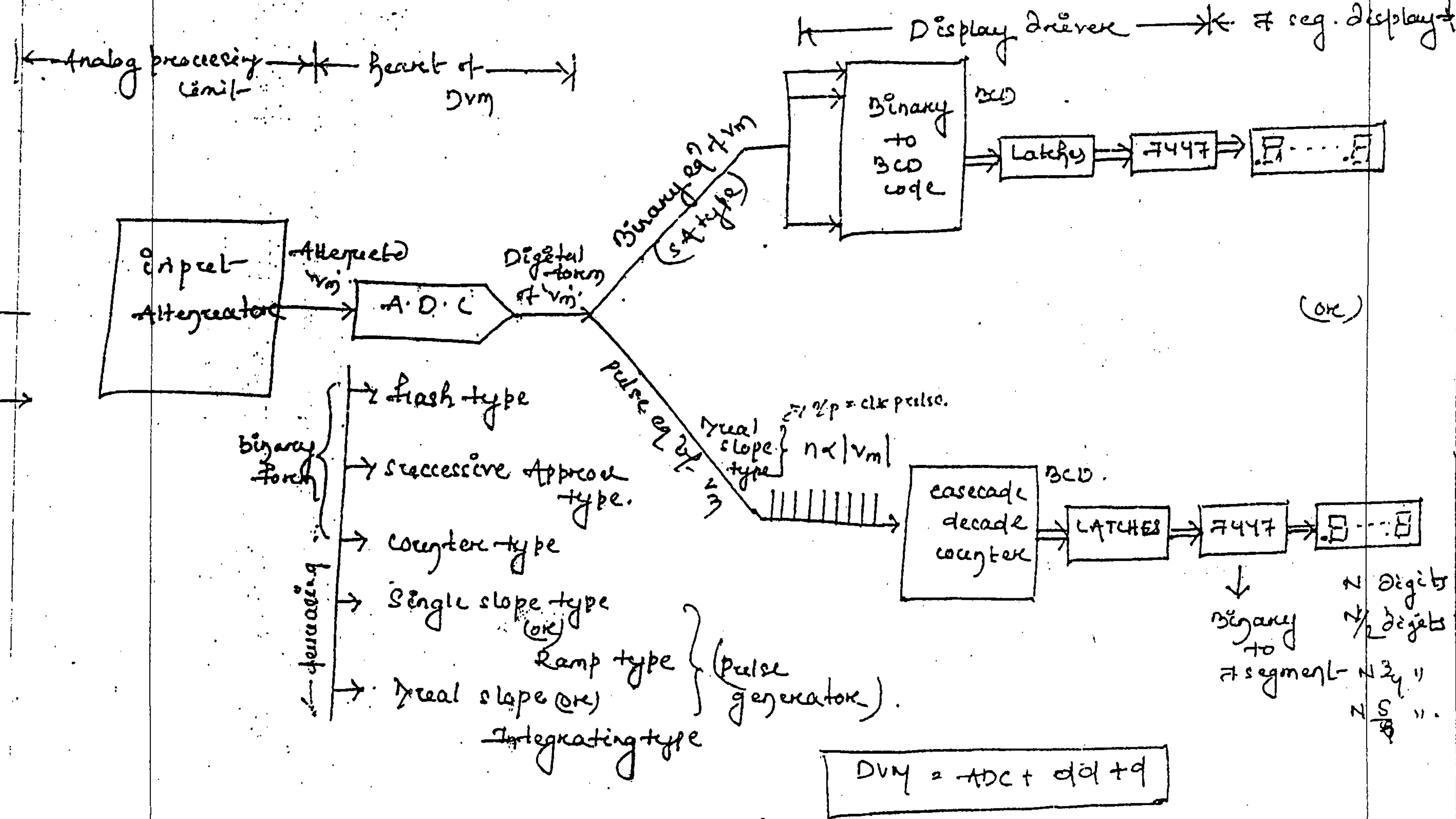
Pb: Identify the voltmeter that required external supply for it's operation

✓(i) Electronic DC voltmeter.

(ii) Electronic A/C voltmeter.

(iii) Electrodynamo meter.

(iv) moving coil meter


Analog processing unit
Heart of DVM
Display driver
7 seg. display
Input Attenuator
Attenuated 'vm'
A.D.C
Digital form of 'vm'
Binary eq of vm
(SA type)
Binary to BCD code
BCD
Latches
7447
(or)
pulse eq of vm
Dual slope type
o/p = clk pulse.
n ∝ |vm|
cascade decade counter
BCD.
LATCHES
7447
Binary to 7 segment
N digits
N½ digits
N¾ "
N 5/8 "
Flash type
Successive Approx type.
counter type
Single slope type (or) Ramp type
Dual slope (or) Integrating type
(Pulse generator).
Binary form
decreasing
DVM = ADC + o/p + o

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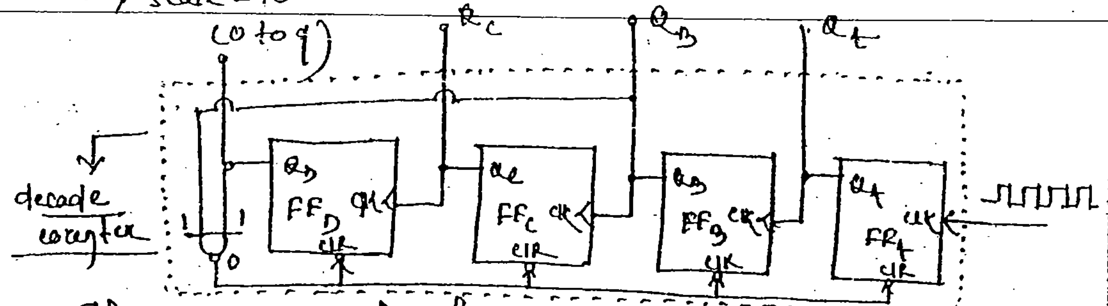
24/10/10

Decade counter :

There are four flip flop in decade counter.

→ state = 10 (0 to 9)



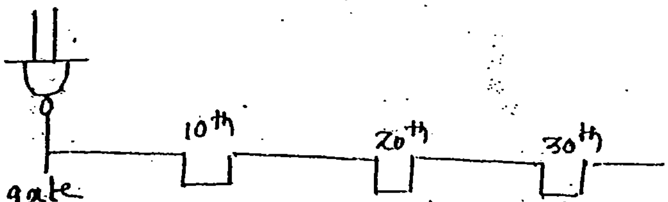
The o/p of the flip flop are based on the pulses that are given to the flipflop.

At i/p →

Q_D	Q_C	Q_B	Q_A
0	0	0	0
0	0	0	1
0	0	1	0
⋮			
9th: 1	0	0	1
10th: $\boxed{1}$	0	$\boxed{1}$	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)



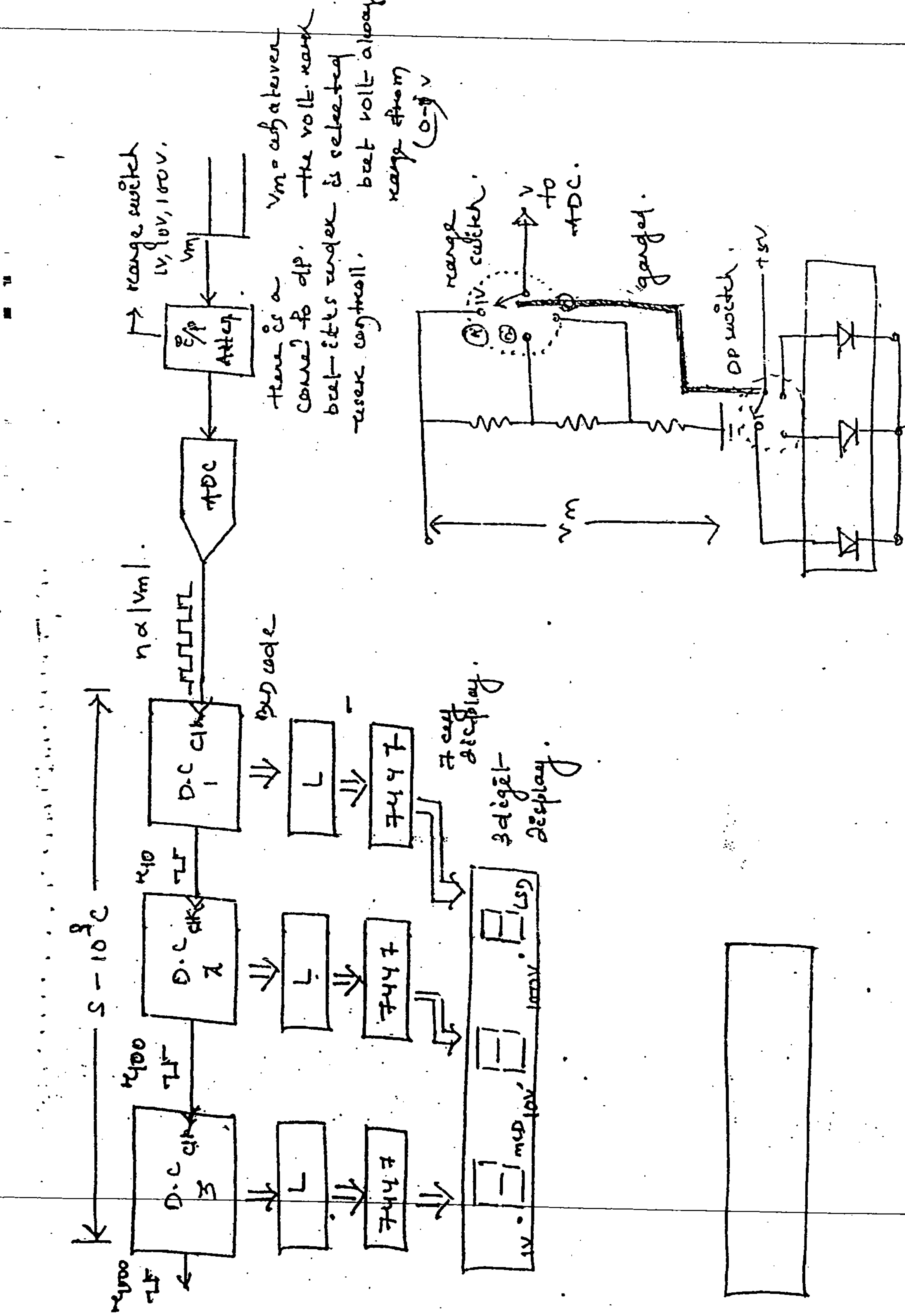
the o/p of nand gate is active low for every 10th clk pulse.

If we cascade one decade counter to another decade counter then the o/p are n't based on the o/p of f.f it is depend upon the nand gate o/p.

state (or) counts

$= 10^3$ state = total states

Here no dp ie pulse for dp.



$\frac{3}{4}$ digit :—

Digit	
Full digit	. 8 → 0, 1, ..., 9 .
$\frac{1}{2}$ digit	FSR = 1, scale = 2 ⇒ 0, 1 ⇒ 8
$\frac{3}{4}$ digit	FSR = 3, scale = 4 ⇒ 0, 1, .. 3 ⇒ 8 no dp ($\leftarrow 4 \rightarrow$)
$\frac{5}{6}$ digit	FSR = 5, scale = 6 ⇒ 0, 1 .... 5 ⇒ 8 no dp ($\leftarrow 6 \rightarrow$)

Note: The $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{6}$ digits are used for extending count range of a N-digit DVM.

** $\boxed{\text{Resolution of a DVM} = \frac{1}{10^N}}$ N = no. of full digits.

** $\boxed{\begin{array}{c}\text{Sensitivity of DVM} = \text{Resolution} \times \text{Range} \\ (S = R \times R)\end{array}}$ → 1V, 10V, 100V

3-digit DVM :—

Roll over :—

$$\left.\begin{array}{ccc} 0 & 0 & 0 \\ 0 & 0 & 1 \\ & \vdots & \\ 0 & 0 & 9 \end{array}\right] DC_1 \qquad \left.\begin{array}{ccc} 0 & 1 & 0 \\ 0 & 1 & 1 \\ & \vdots & \\ 0 & 9 & 9 \end{array}\right] DC_2 \qquad \left.\begin{array}{ccc} 1 & 0 & 0 \\ 1 & 0 & 1 \end{array}\right] DC...$$

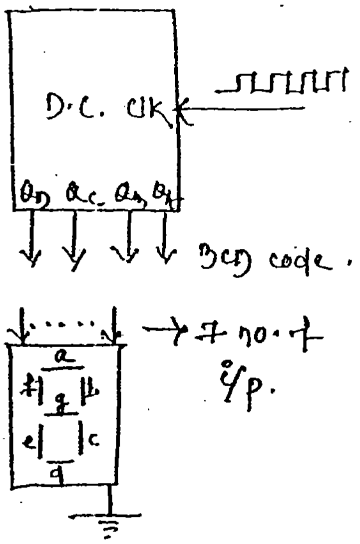
000 = reset
001 = min
⋮
999 = FSR

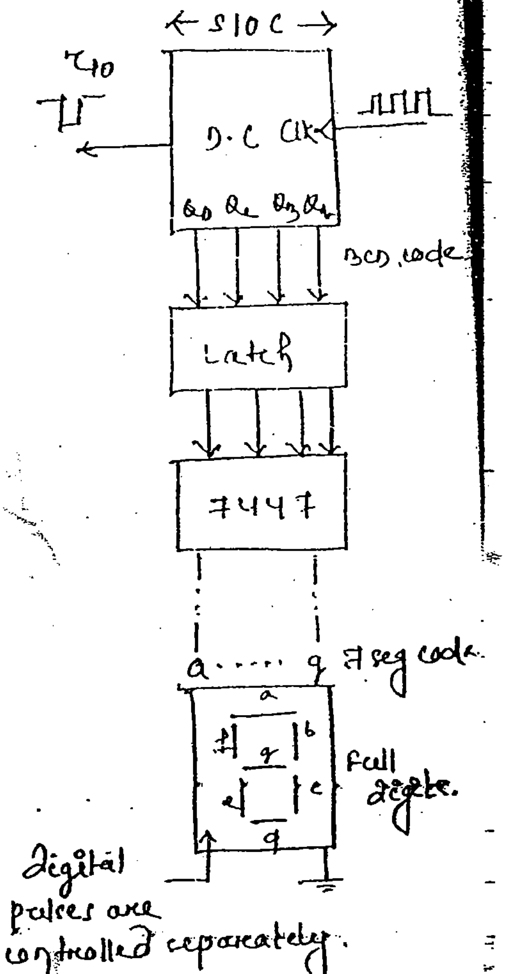
→ counter range of a 3 digit dvm is = 0 to 999.

→ scale = 001 + 999 = 1000 state (readings)

1000 can be display only in $3\frac{1}{2}$ digit

A full digit is internally driven within decade counter.





<u>Roll over</u> : i.e. the states of decade counter is displayed by the full digit.

state (or) counts $\left[\begin{array}{c} 0 \\ \vdots \\ 9 \end{array}\right]$ ← when the decade counter is reset the full digit is also reset.

counter range of full digit $\Big\}$ = 0 to 9.

0 = reset state

1 = min^m state

9 = max^m state / full scale reading.

(becoz it can't show any no. more than '9'.)

$$\boxed{\text{total no. of state} = \text{min}^m + \text{FSR}}$$

$= 1 + 9$

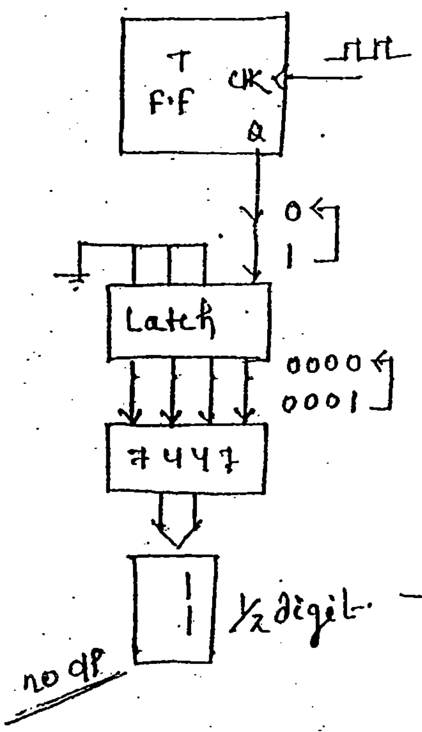
$= 10$ = scale

This 7 g segment display is displayed/controlled by turning off/on by some of these 7 segment.

For specification of 7 segment the roll over is very usefull. This specification means minm or maxm range of full digit value.

½ digit :–

↳ A ½ digit is internally driven with a toggle flipflop. It is nothing but showing the state of '1' design.



↳ For display the digit '1' we have to ground all other terminal. Here we don't get any decimal pt (becoz we getting decimal pt only at full digit)

↳ There is no decimal point for ½ digit.

Roll over : 0 → 1

↳ reset state = 0
minm state = 1
maxm state = 1

count range of ½ digit = 0 to 1.

$\frac{1}{2}$ digit → Full scale reading

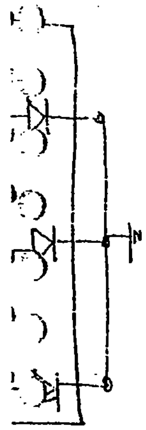
↳ scale / scale of two counter scale = 1+1 = 2.

note

**

**

3-digit dvm	SW-A	SW-B	SW-C
Minimum (001)	.00 1V	0.01 V	00.1V
FSR (999)	.999v	9.99v	99.9V
	0-1V range	0-10V range	0-100V range



↳ Resolution of 3 digit dvm $\Rightarrow r_{3q} = \frac{1}{10^3}$

$= \frac{1}{1000}$

= 1 part in 1000 parts

= 1:1000

= 0.001

= .1%

↳ sensitivity $\Rightarrow S = \underline{FCR}$

$\frac{1}{10^3}$

$\rightarrow 1V \times \frac{1}{10^3} = 0.001V \; (S_{1V})$

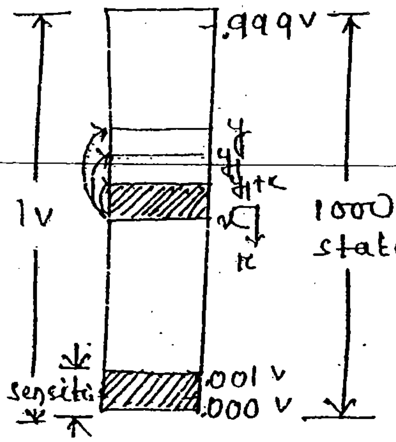
$\rightarrow 10V \times \frac{1}{10^3} = 0.01V \; (S_{10V})$

$\rightarrow 100V \times \frac{1}{10^3} = 0.1V \; (S_{100V})$

∴ Sensitivity of a DVM is the min^m reading that can display by the ~~design~~ dvm. It is the min^m volt. that it can measure.

thus "the min^n i/p volt. that can be sensed and displayed by the DVM is called as it's sensitivity"

(The 1st i/p that the DVM can sense is known as sensitivity.)

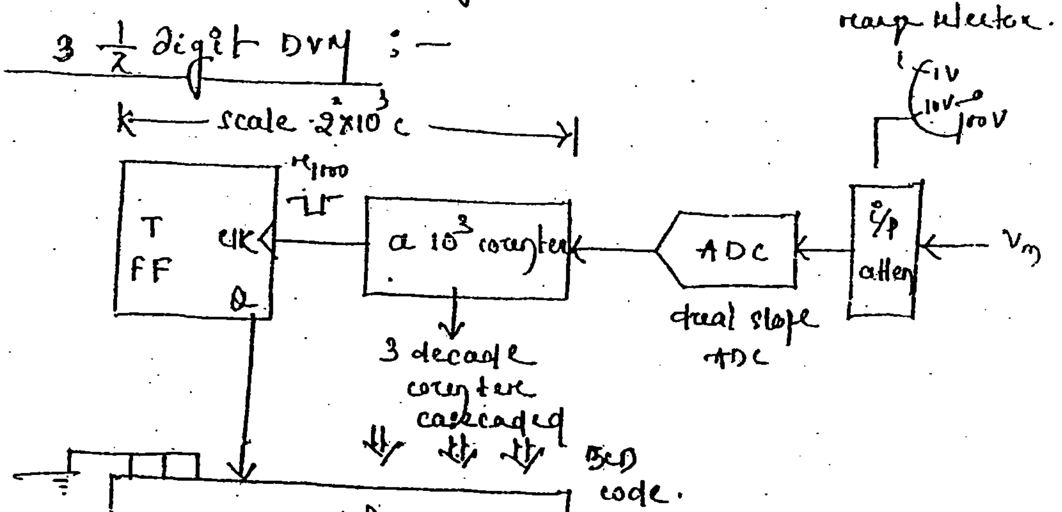


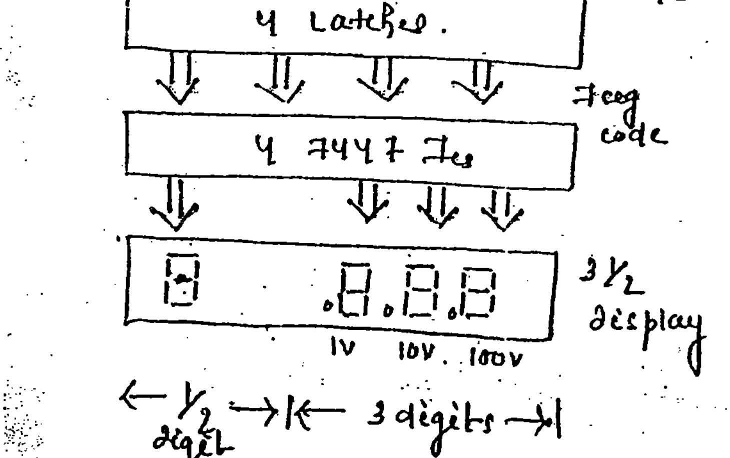
"The min^m difference beyond which we can't detect is known as resolution."

"The smallest possible increamental change allowed at i/p is known as resolution".

** sensitivity and resolution are going to be same at 1V range.

3 ½ digit DVM :–





Here one more ½ digit we can add by cascading a toggle flipflop.

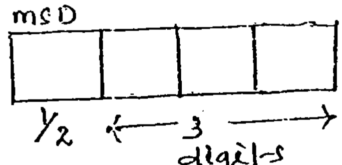
Roll over :

0 000 → reset
0 001 → min^m
⋮
0 999 — Basic range of 3 digit DVM
1 000 — ½ digit is turned ON
⋮
1 999 → FSR.

counter range of 3½ digit of DVM = 0 to 1999

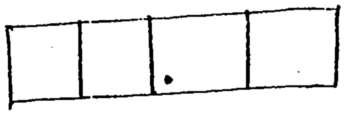
Scale = 000 to 1999
= 2000 states
= 2×10^3 states.

(counter range is extended)

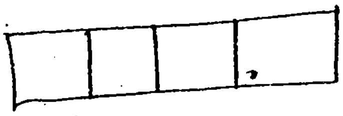
↳ (0–1)V range : 

$\left.\begin{aligned} min^m &= 0.001\,V \\ FSR &= 1.999\,V. \end{aligned}\right\} \Rightarrow$ 2 V range.

Overranging ⇒ when it is 2V i.e. 1.999 V.

↳ (0–100)V range : 

$\left.\begin{aligned} MIN &= 00.01V \\ FSR &= 19.99V \end{aligned}\right\} \Rightarrow$ 20 V range.

↳ (0–1000) V range 

$\left.\begin{aligned} MIN &= 000.1\,V \\ FSR &= 199.9\,V \end{aligned}\right\} \Rightarrow$ 200 V range

↳ over ranging : ~~measuring~~ 1.999V in 1V range.
measuring 19.99V in 10 range.
measuring 199.9V in 100V range.

** overranging is due to 1/2 digit switch ~~turned~~ switched ON.

↳ $\boxed{\text{Resolution} \Rightarrow r_{3\frac{1}{2}d} = \frac{1}{10^3}}$

$= \frac{1}{1000}$

$= 01:1000$

$= 0.001$

$= 0.1\%$ so $\boxed{r_3 = r_{3\frac{1}{2}}}$

↳ Sensitivity ⇒ $S_{1V} = \frac{1}{10^3} \times 1V = 0.001V$

$S_{10V} = \frac{1}{10^3} \times 10V = 00.01V$

$S_{100V} = \frac{1}{10^3} \times 100V = 0.1V$

So $\boxed{S_{3\frac{1}{2}} = S_3 \text{ in a selected range of DVM}}$

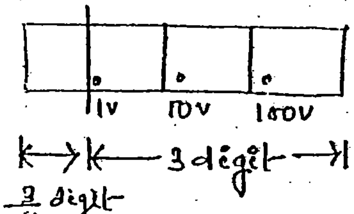
$n_{N-n} = n_N$

$S_{N-n} = S_N$ in same range

$\boxed{\text{counter range}_{N-n} \neq \text{counter range}_N}$

In every $\frac{1}{2}$ digit dvm the denominator represent the multiplying factor.

$3\frac{3}{4}$ digit DVM :-



It'll having a counter to count upto 3 digit.

Roll over :

0 000 → Reset
0 001 → min
⋮
counter range
+ 3 999 → FSR
scale 4000
4×10^3

	min^m volt	sensitivity
1V range	0.001 V	0.001V
10V range	00.01 V	0.01 V
100V range	000.1 V	0.1 V

	max^m volt	sensitivity
1V range	3.999 V	3.999V
10V range	39.99V	39.40V
100V range	399.9V	400V.

over ranging

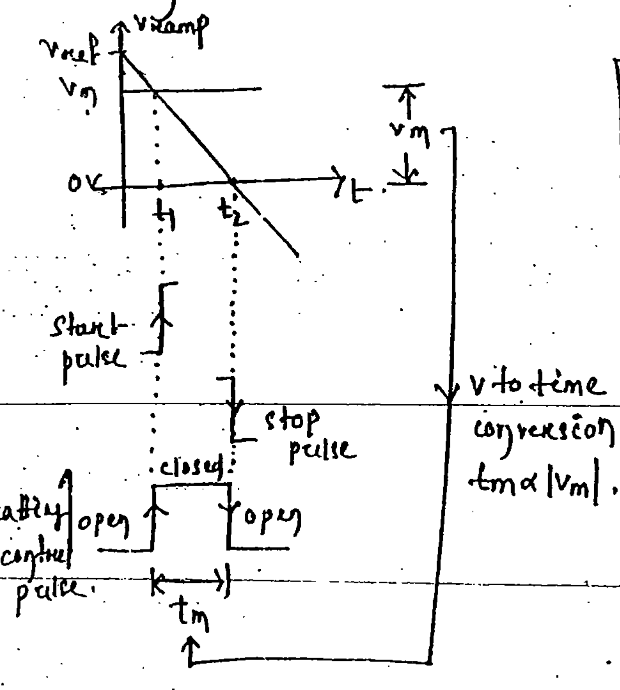
- ~~In ADC the FSR = $2^N - 1$~~
- Built in Electronic counter / timer = $10^N - 1$. (For any DVM)

The i/p comparator compares V_{ramp} with V_m, where as the ground comparator compares V_{ramp} with ground.

- ~~At t_1 ramp volt coincides~~
- The 1st crossover detected by i/p comparator. The 2nd crossover detected by ground comparator.
- At t_1, the i/p comparator generates start pulse which closes the switch of gating and in devices counting starts.
- counting is continued till 't_2', where the ZCD produces a stop pulse, which opens the switch of gatting.

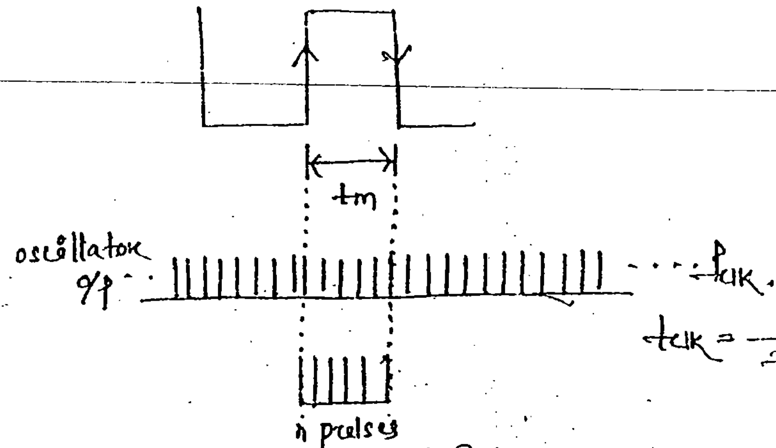
voltage to time conversion :-

Here the magnitude of voltage is converted into time interval.



$$\boxed{V_m = \frac{V_{ref}}{t_r} \times t_m} \quad \text{--- (i)}$$

Time period measurement :



$$t_{clk} = \frac{1}{f_{clk}}$$

n pulses are generated by counter during 'tm'.

$$\boxed{t_m = n \times t_{clk}} \quad \text{——} (2)$$

Substituting eqn (2) in (1).

$$\boxed{V_m = \frac{V_{ref}}{t_r} \times n \times t_{clk}} \qquad \left[\frac{V_{ref}}{t_r} = \text{slope.}\right]$$

unknown volt. analog voltage to be measured = slope × final count × 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) $\boxed{\text{fixed}}$ — t_r: $\boxed{\text{fixed}}$ — n: variable $n \propto |V_m|$ — t_{clk}: fixed.

ii) conversion time :

t_{conv} = start to stop

t_1 to t_2

$= t_2 - t_1$

$= t_m$

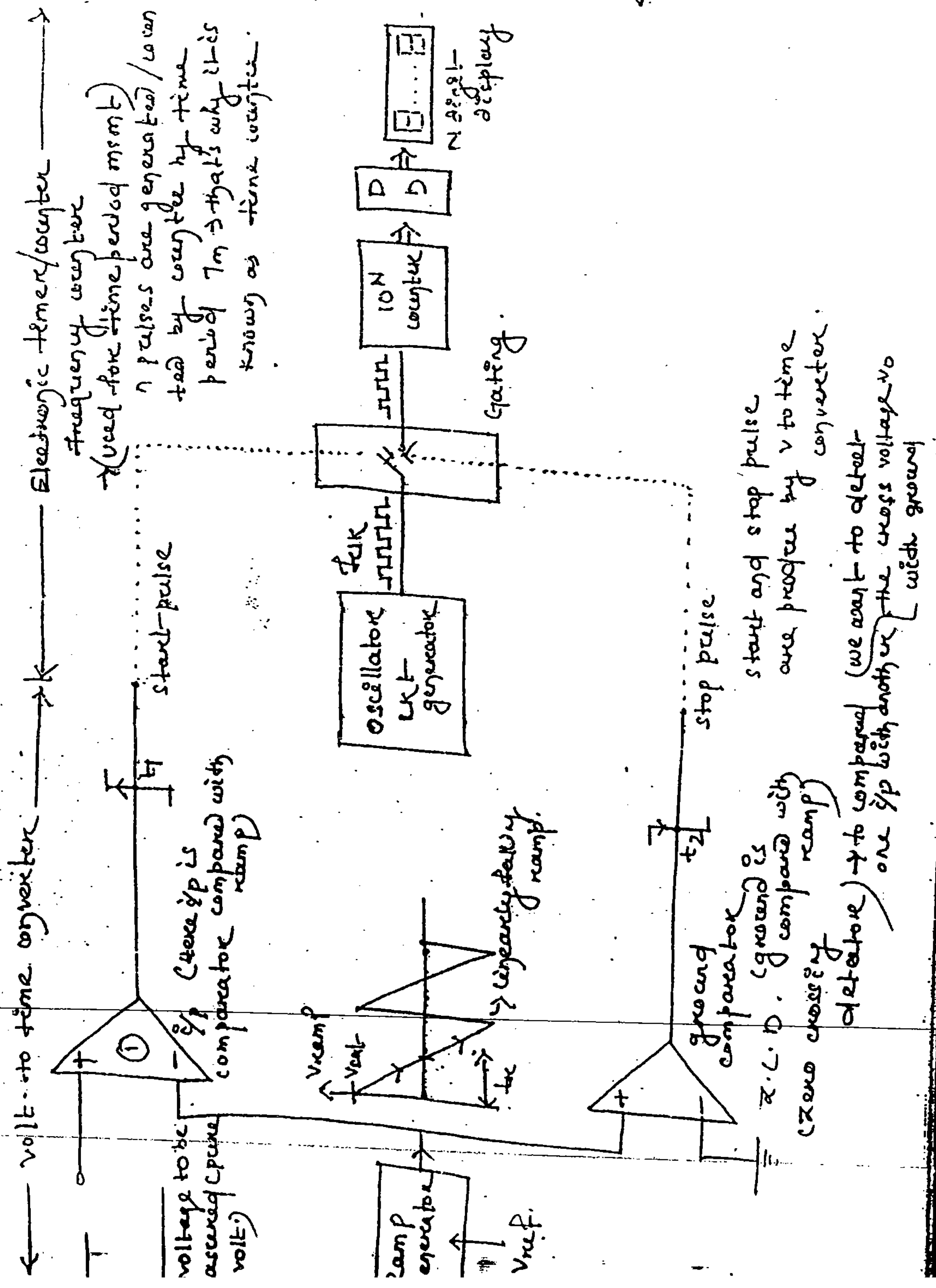
$$\boxed{t_{conv} = n\, t_{clk}.}$$

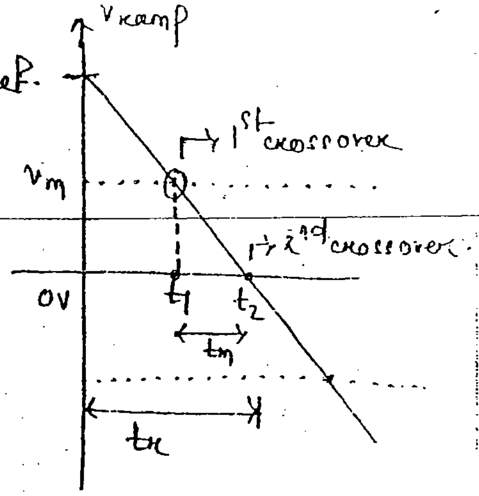
99

Ramp - Type Digital Voltmeter : - (magnitude of voltage convert into the interval)

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.

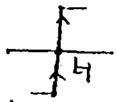




↳ i/p comparator compare ramp with V_m untill ramp voltage is coincide with (V_m) unknown volt. when ramp volt. cross the unknown volt. is known as 1^{st} cross over at time t_1. After t_1 the ramp voltage is less then 'V_m' and become zero.

So
0 to $t_1 \rightarrow V_{ramp} > V_m \rightarrow$ −ve
$t = t_1 \rightarrow V_{ramp} = V_m \rightarrow 0V$
$t > t_1 \rightarrow V_{ram} < V_m \rightarrow$ +ve

o/p of i/p comparator

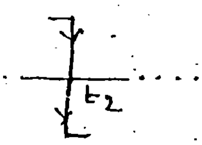


rising pulse is produced.

↳ 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 2^{nd} crossover. The time b/w t_1 and t_2 is the time to be measured.

o/p of 2nd comparator.

0 to $t_2 \rightarrow V_{ramp} > 0V \rightarrow$ +ve
$t_1 = t_2 \rightarrow V_{ramp} = 0V \rightarrow 0V$
$t_1 > t_2 \rightarrow V_{ramp} < 0V \rightarrow$ −ve



falling pulse is produced.

$$\boxed{\frac{V_m}{t_m} = \frac{V_{ref}}{t_r}}$$

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'.

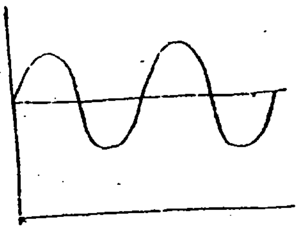
$$\boxed{t_m = t_2 - t_1}$$

gatting control pulse

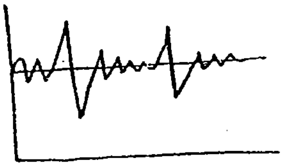
∴ Ramp type DVM (or ADC) has variable conversion time.

$$\boxed{t_{conv} \propto |V_m|}$$

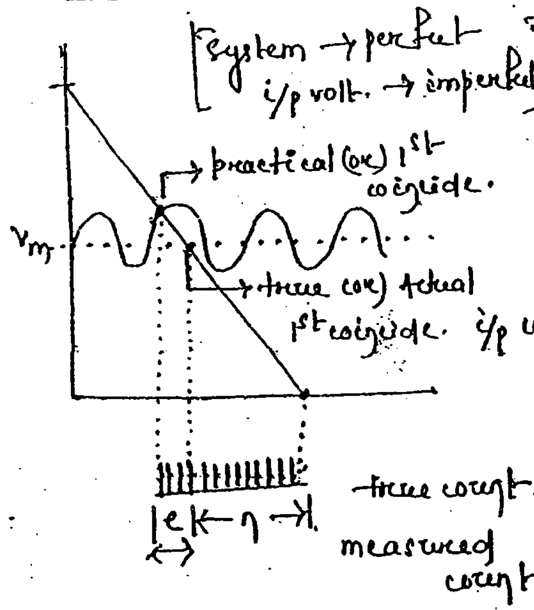
(ii) Stability :



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 measurand i.e. in the volt. which is given to be measured. So the i/p comparator doesn't avoid this error and add this error with no. of pulses.

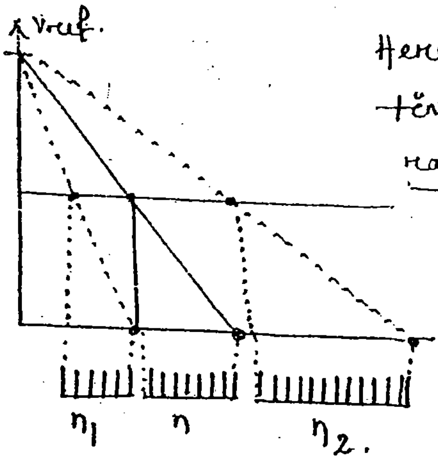
∴ If either A/C signal or noise superimposed on DC voltage to be measured then error is introduced into measurement.

Effect of noise on msmt → Highest
noise opposition → Lowest

Stability of Ramp type DVM in noisy cond^n } lowest (poor).

(iii) **Measurement Accuracy :-**

If R, L, C value are changed due to aging then linearity of the ramp is effected and in turn errors will be introduced into msmt.

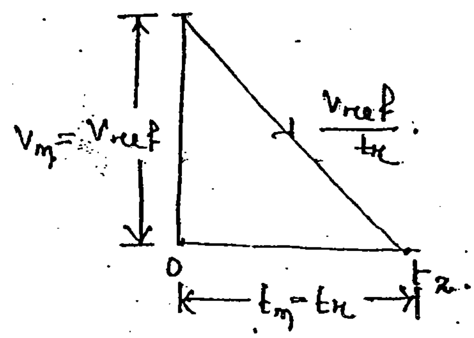


Here the error is due to the time that depend upon the ramp generator (basic error source)

In a single slope adc we are getting an error that's why we devlop dual slop or ADC.

measurement accuracy of Ramp type DVM } → lowest (∵ depending on RLC values)

Note : occurrance 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 (gatting close time) $= t_r$.

$\underline{\eta_{max} = ?}$

we know, $V_{in} = \dfrac{V_{ref}}{t_r} \times \eta \times t_{clk}$.

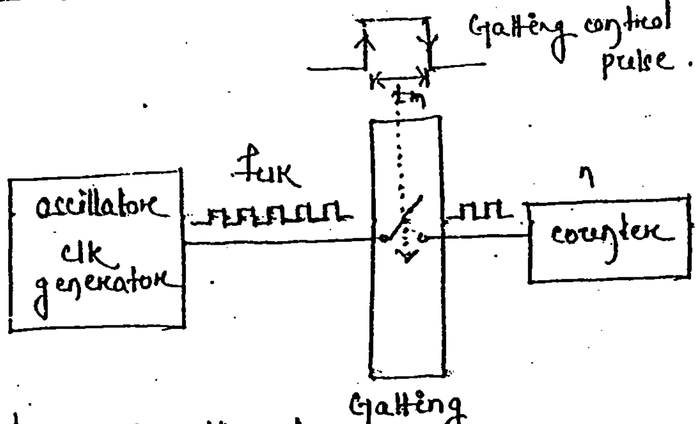
for $\eta_{max} \Rightarrow V_{in} = V_{ref}$.

$\therefore V_{ref} = \dfrac{V_{ref}}{t_r} \times \eta_{max} \times t_{clk}$.

$$\boxed{\eta_{max} = \frac{t_r}{t_{clk}}}$$

Note: A ramp type digital voltmeter is also known as single slope type DVM.

Electronic timer / counter : (frequency counter)



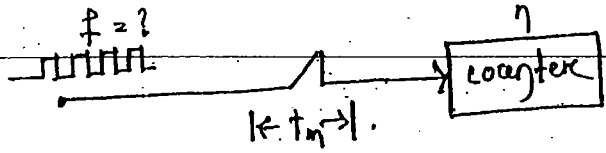
t_{clk} = duration of pulse

$t_{clk} = \dfrac{1}{f_{clk}}$.

t_m = gate closing time. $= \eta\, t_{clk}$.

η = final count.

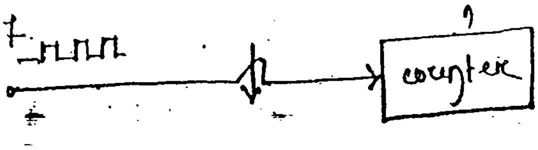
(i) Frequency msmt



$\boxed{f_{clk} = \dfrac{\eta}{t_m}}$

calculation is going for a known time period.

(ii) Time period msmt

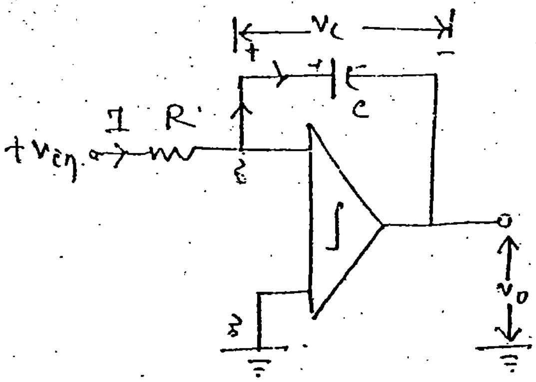


$\boxed{t_m = \dfrac{\eta}{f_{clk}}}$

calculation is going for a unknown time period.

Accumulator	Program counter
Special fun^n register.	Special purpose register. It is a pointer register i.e. the pointer is a ROM pointer.

Integrator :-



↳ $I = \frac{V_{in}}{R}$

↳ $V_0 = -V_c$

$V_c = \frac{1}{C}\int_{-\infty}^{t_1} i \cdot dt$.

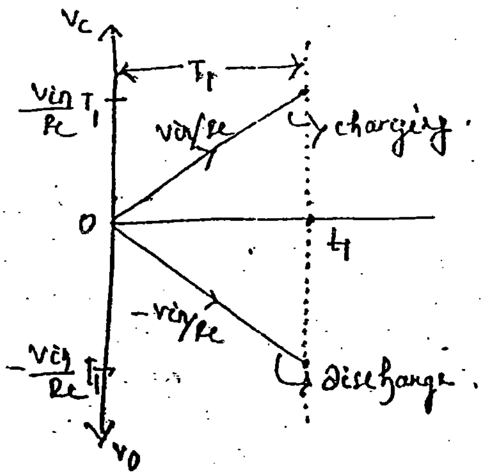
$$\boxed{V_0 = \frac{V_{in}}{RC}\int_0^{t_1} dt}$$ ($\because$ no initial cond^q voltage.)

At $t = t_1$

$V_{c_1} = \frac{V_{in}}{RC}(t_0)_0^{t_1}$

$= \frac{V_{in}}{RC}(t_1 - 0)$

$$\boxed{V_{c_1} = \frac{V_{in}}{RC}T_1}$$



during T_1

↳ $V_0 = -\frac{V_{in}}{RC}\int_0^{t_1} dt$

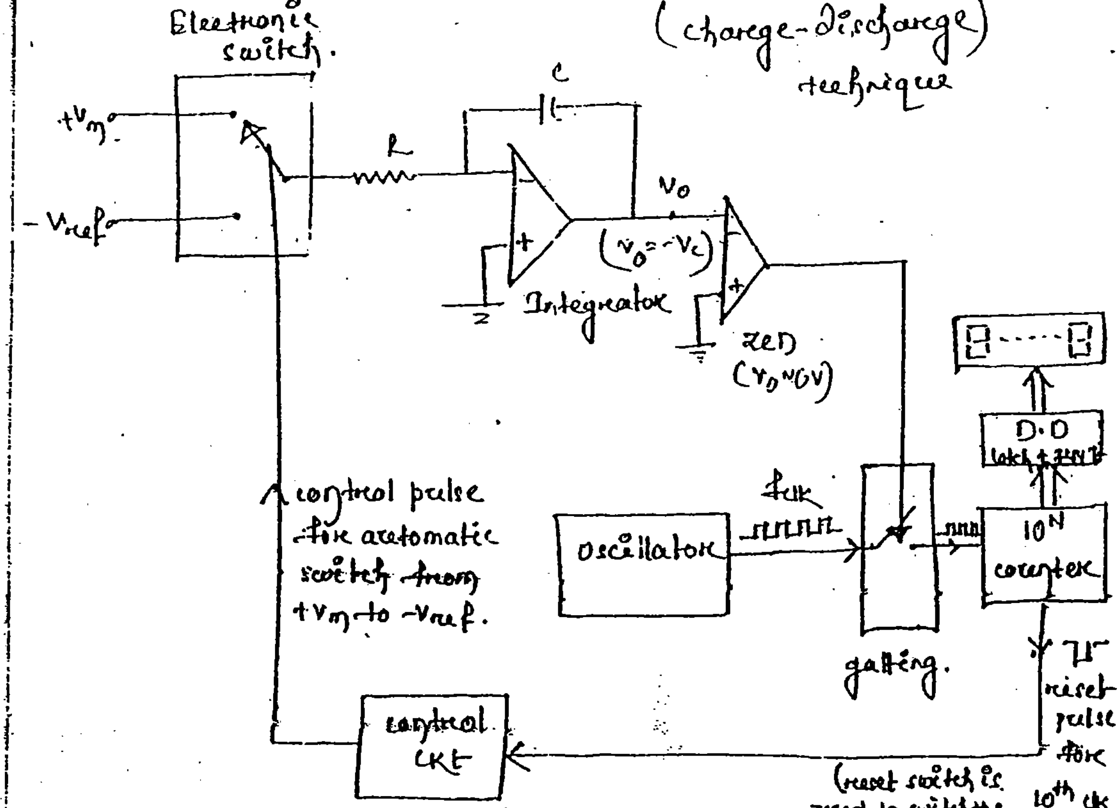
At T_1

$V_{0_1} = -\frac{V_{in}}{RC}T_1$

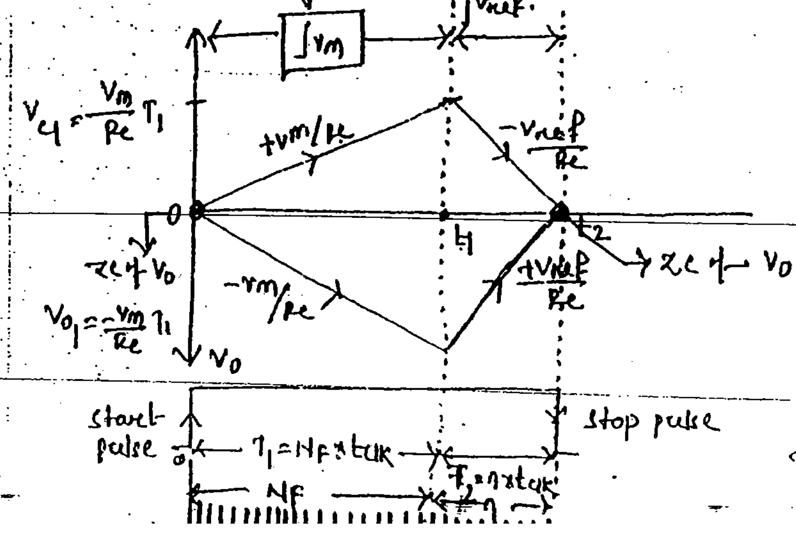
28/10/10

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 here two of slope acting i.e. we are using two phase one is unknown voltage V_m $\int V_{ref}$.



dual slope decode dvm give highest detecting time so it is a slow process, but this is the most widely used ADC.

the conversion time $= t_2 - t_0$

$T_1 = 1^{st}$ Integration time period (fixed = max^m each pulse counted × T_{clk}).

$T_2 = 2^{nd}$ integration time period } (variable)
= De-integration time period } ↳ $\alpha\ |V_m|$

$$\boxed{T_2 = n\, t_{clk}}$$

1st slope $= \frac{V_m}{RC}$ ⇒ variable (due to V_m)

charging current $= \frac{V_m}{R}$ ⇒ variable.

2nd slope $= \frac{V_{ref}}{RC}$ ⇒ fixed. (Here all the parameters are fixed).

discharging current $= \frac{V_{ref}}{R}$ ⇒ fixed.

During T_1	During T_2
(V_m is connected as i/p to integrator)	(V_{ref} is connected as i/p to integrator)
$V_0 = -\frac{1}{RC}\int V_m \cdot dt$	$V_0 = -\frac{1}{RC}\int V_{ref} \cdot dt$
$\boxed{V_{0_0} = 0V}$ at z.c (in time t_0)	$\boxed{V_{0_2} = 0V}$ at z.c. (in time t_2)
$\boxed{V_{0_1} = \frac{-V_m}{RC} T_1}$	$V_0 = +\frac{V_{ref}}{RC}\int_{t_1}^{t_2} dt + V_{01}$.
no initial voltage	$V_0 = +\frac{V_{ref}}{RC}(t)_{t_1}^{t_2} - \frac{V_m}{RC} T_1$
∴ $V_0 = -\frac{V_m}{RC}\int_0^{t_1} dt$.	at t_2, $V_{0_2} = 0V$.
($-\infty$ to 0 → zero work done so neglected)	$0 = \frac{V_{ref}}{RC} T_2 - \frac{V_m}{RC} T_1$
	$\frac{V_m}{RC} T_1 = \frac{V_{ref}}{RC} T_2$

$$\frac{V_m}{RC} N_f \times t_{clk} = \frac{V_{ref}}{RC} n \cdot t_{clk}$$

$$\Rightarrow \boxed{V_m = \frac{V_{ref}}{N_f}\, n}$$

Here 'n' variable is multiplied with const $K = \frac{V_{ref}}{N_f}$.

~~Measurement accuracy~~ in dual slope dvm is high.

$$\boxed{V_m T_1 = V_{ref} T_2}$$

(i) conversion time :

$$t_{conv} = \text{start to stop}$$
$$= 0 \text{ to } t_2$$
$$= t_2 - 0$$
$$= t_1 + t_2$$

$$\boxed{t_{conv} = (\underbrace{N_F}_{\text{fixed}} + \underbrace{n}_{\text{varriable}})\underbrace{t_{ck}}_{\text{fixed}}}$$

$N_F = 10^N - 1$ for N digit DVM.
$= 2^N - 1$ for n bit ADC.

∴ conversion time of dual slope DVM is highest (or) longest.

$$\Rightarrow \text{Slope speed} \downarrow \propto \frac{1}{t_{conv}\uparrow}$$

$$\boxed{\text{Dual slope DVM is slowest DVM}}$$

Measured value :-
In dual slope dvm we get true avg value of i/p becaue we integrate the i/p valtage value for a fixed time interval. ~~that why~~

'V_m' integrated for a long fixed time period,

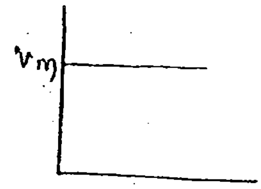
$$V_0 = -\frac{1}{RC}\int_0^{t_1} V_m \, dt$$

where 0 to $t_1 = T_1$
if $T_1 = RC$

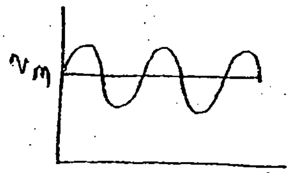
$$\frac{1}{\ldots}\int^{T_1} \ldots dt \quad \text{(these are value of } V_m\text{)}.$$

(iii) <u>Stability</u> :

<u>i/p being measured.</u> | <u>msmt</u> (Avg. value of i/p)



$\int_0^{t_1} \rightarrow v_m$



$\int_0^{t_1} \rightarrow v_m$.

If either the signal or noise as present on dc voltage to be measured then it'll avg out to be zero, becoz of integration during 'T_1'.

Effect of noise on msmt ⟶ Lowest

noise rejection ⟶ Highest

stability ⟶ Highest

(iv) <u>Measurement Accuracy</u> :

msmt accuracy of dual slope DVM is highest since there is no dependency on R, C & temp.

08/11/10 4 digit dvm with 100 mV lowest full scale range have a sensitivity of how much value, the resolution of dvm is 0.0001 ?

a) 0.1mV ~~b)~~ 0.01mV c) 1.0mV d) 10mV.

PB: The i/p resistance of dvm is of the range of ...

a) K.Ω b) ohms c) M.Ω.s d) Hundreds of Ω.s.

Pb: The resolution of a 6 digit dvm is <u>0.000001</u>

sol^n-①:

PB: The sensitivity of 4 digit digital multimeter in 1V range is 0.0001.

PB: The min^m voltage ie that can be read by a $4\frac{1}{2}$ digit DVM is ~~1999.001~~ 00.001 10V range.

PB: The resolution of a 0-1V 4 digit dual slope DVM is 0.001(same) to resolution of a 0-2V, $4\frac{1}{2}$ digit dual slope DVM.

PB: The count range of a ~~10-V~~ 0-1V, 4 digit Dual slope DVM is half of counter range of a 0-2V, $4\frac{1}{2}$ digit dual slope DVM.

Note:

	N digit DVM	$N\frac{1}{2}$ digit DVM.	$N\frac{3}{4}$ digit DVM	$N\frac{5}{6}$ digit DVM.
Resolution	$\frac{1}{10^N}$	$\frac{1}{10^N}$	$\frac{1}{10^N}$	$\frac{1}{10^N}$
sensitivity	$R/10^N$	$R/10^N$	$R/10^N$	$R/10^N$
Total status (scale)	10^N	2×10^N	4×10^N	6×10^N
Counter Range	0 to 10^N-1 ↑ FSR	0 to $2\times10^N-1$ ↑ FSR	0 to $4\times10^N-1$ ↑ FSR	0 to $6\times10^N-1$ ↑ FSR

Eg: 4 digit DVM = 0000 to 9999 = 10,000

$4\frac{1}{2}$ digit DVM = 00000 to 19999 = 20,000

$4\frac{3}{4}$ digit DVM = 00000 to 39999 = 40,000

$4\frac{5}{6}$ digit DVM = 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 type.

b) Flash conversion type (L·C·T)

c) dual slope converter (4·C·T). type

d) the correct sequence in the increasing order of conversion type key is 2 - 1 - 3.

Pb: A dual slope integrating type DVM has an integrating capacitance of 0.1µF and resistance of 100 kΩ. The reference volt is 2V and the o/p of integrator not to exceed 10V. Then the max time for which reference volt can be integrated is

---

$C = 0.1\mu F$

$V_{ref} = 2V$

$R_i = 100 k\Omega$

$V_{o_{max}} = 10V$

$R_i = \text{slope}$

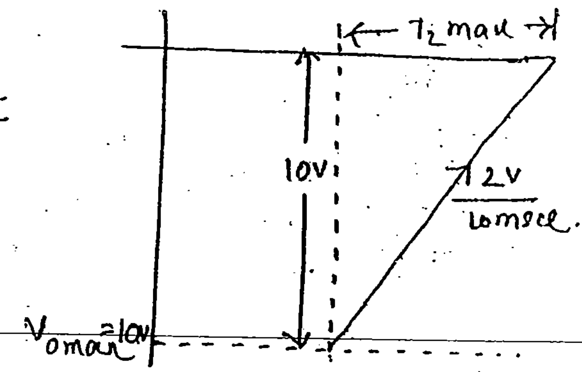
$$\frac{V_{ref}}{R_i} = \frac{2}{100\times10^3 \times \frac{1}{10}\times 10^{-6}}$$

$$= \frac{2}{10\,msec}$$

$2V \longrightarrow 10msec$

$10V \longrightarrow \dfrac{10V \times 10msec}{2V}$

$= 50\,msec$



Pb: The count range of a $4\frac{1}{2}$ digit DVM is from 0 to ....? Ans: 19999

I.E.S Pb: In a digital voltmeter, the oscillation frequency is 400 KHZ. The ramp volt falls from 8 V to 0V in 20 ms. The max^m no. of pulses that can be counted by the DVM is ....

Sol^n ①

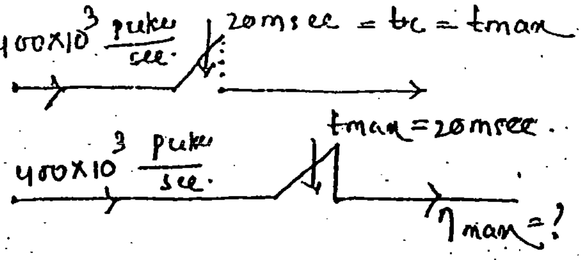
$$\text{sensitivity} = \text{Resolution} \times \text{Range}.$$
$$= \frac{1}{10^4} \times 100\,mV$$
$$= 0.0001 \times 100\,mV$$
$$= 0.01\,mV.$$

Sol ÷ ③

$$R = \frac{1}{10^6} = 0.000001 \simeq 0.$$

Sol: 4:

$$\eta_{max} = \frac{t_c}{t_{ck}} = \frac{20\,msec}{\left(\frac{1}{400\,KHZ}\right)}$$
$$= 400\,KHZ \times 20\,msec$$
$$= 8000\,pulses.$$



$1\,sec \longrightarrow 400 \times 10^3$ pulses

$20\,msec \longrightarrow 20\,msec \times 400 \times 10^3 \frac{pulse}{sec}$.

Pb: The max^r voltage that can be measured by 4 digits DVM is 99.99V in 100 V range.

Pb: A 0-2V, $4\frac{1}{2}$ digit Dual slope integrating DVM can measure upto 1.999V.

Pb: Full scale voltage of a $4\frac{3}{4}$ digit DVM in 1V range of operation <u>3.9999V</u> ?

sol -

Pb: Resolution of DVM is a func^n of <u>digits</u>

Pb: Overranging in DVM implies ______

a) All full digit are turned on

b) $\frac{1}{2}$ digit is switched ON

c) $\frac{1}{2}$ digit is switched off

d) All full digit are turned 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 i/p voltage of 1V is ______?

sol^n:

$$V_{in} = 1V$$

$$V_{ref} = 2V.$$

$$f_1 = 50 Hz. = \frac{1}{50} = T_1$$

$$T_1 = 10 \times \frac{1}{50} = \frac{1}{5}$$

$$V_{in} T_1 = V_{ref} T_2$$

$$\frac{1}{5} \times 1 = 2 \times T_2$$

$$\Rightarrow \frac{1}{5} \times \frac{1}{2} = T_2$$

$$\Rightarrow \frac{1}{10} = T_2$$

$$T_2 = T_1 + T_2 = \frac{1}{10} + \frac{1}{5} = \frac{1+2}{10} = \frac{3}{10} sec.$$

Pb: A frequency ......

of 50 msec counts 1254 cycles of an i/p square wave. Then frequency of the i/p wave is ____ 99

$t_m = n\, t_{clk}$

$t_m = \dfrac{n}{f_{clk}}$

$f_{clk} = \dfrac{n}{t_m} = \dfrac{1254}{50} = 25.08\ \text{KHz}.$

Pb: Pulses from the clk 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 ______.

$f_s = 100\,\text{KHz},\ t_m = 7.75\ \text{msec}.$

$t_m = n\, t_{clk}$

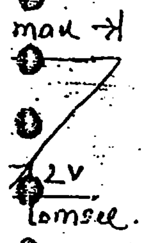
$n = \dfrac{t_{clk}}{t_m} = \dfrac{7.75}{100} = 775$ pulses.

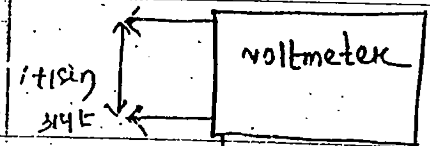
Pb: A dual slope A/D uses a n bit counter. When the i/p signal V_a is being integrated, the counter allow to count upto a value upto $2^{N-1} - 1$.

Pb: A three and half digit, 2V full scale dual slope ADC has an i/p as $1 + 1\sin 314t$ V. Then the o/p of this ADC will be ______ $3\frac{1}{2}$ (2)

a) 1.999V c) 0.001

b) 1.000V d) 0.707





→ A DC voltmeter ---- $V_{DC} = 1V$

→ 0–10V moving iron ---- $V_{rms} \Rightarrow \sqrt{1^2 + \left(\frac{1}{\sqrt{2}}\right)^2}\ V$

→ 0–20V, 3½ digit ..... $V_{DC} \Rightarrow 1V$

± 0.5% of reading

±5 counts. When the meter reads 100 mv, the volt being measured is ______

a) Any value b/w 99.5 mv & 100.5 mv

b) Any value b/w 99.0 mv & 101.0 mv ✓

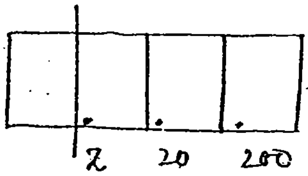
c) Exactly 99.5 mv

d) Exactly 100 mv

$V_{fsv} = 200mV$.

$L = \pm 0.5 + 5$ counts

$V_m = 100$ mv.



½ digit. (1 count)

(2mv) 1 mv range ⟶ 0.001 mv

(20mv) 10 mv range ⟶ 00.01 mv

(200mv) 100 mv range ⟶ 000.1 mv.

range = ±0.5% of reading pulse 5 counts

range $= \pm\left[\frac{0.5}{100} \times 100mv + 5 \times 0.1 mv\right]$.

range $= \pm[1mv]$

⇒ 100 mv ± 1mv

99.0 mv to 101.0 mv //

Pb! A galvanometer ((dc ammeter) with internal resistance of 100 Ω and full scale current of 1 mA is used to realize a dc voltmeter with full scale range of 1V. The full scale range of this voltmeter can be extended to 10 V by connecting an external resistance of value ______

a) 9.1 k ✓   c) 10 K Ω.
b) 9.9 K Ω ✓.   d) 11 K Ω.

$R_i = 100\,k\Omega$ 0 – 1V DC voltmeter ← 0-1mA, 100Ω

$I = 1mA$ $R_{se} = \frac{1V}{1mA} - 100\Omega$ = 0.9 kΩ   DC ameter.

$V_{fsv} = 1V$.   9kΩ ↓

0 -10V DC voltmeter. ←

$R_{se} = \frac{10V}{1mA} - 100\Omega = 9.9\,k\Omega$.

Pb: A 2-Amp full scale PMMC 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 ______

soln: $2A \xrightarrow{\times 5} 10A$ → multiplying factor.

at f.s. volt. drop is 100mV

$R_{sh} = ?$

$= \frac{R_m}{m-1}$

$\therefore R_m = \frac{100mV}{2A}$

$= 50m\Omega$

$\therefore R_{sh} = \frac{50m\Omega}{4} = 12.5\,m\Omega$ (so it is connected in parallal with the ammeter)

~~Advantages of digital voltmeter over analog voltmeter.~~

(i) DVM offers very high i/p resistance in the range of MΩ.

adv: As such loading under the ckt under test become reduce.

(ii) Dvm ~~is~~ gives / offers supperior (to analog) resolution, $1:10^6$.

~~(iii) Dvm offer 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 content of range

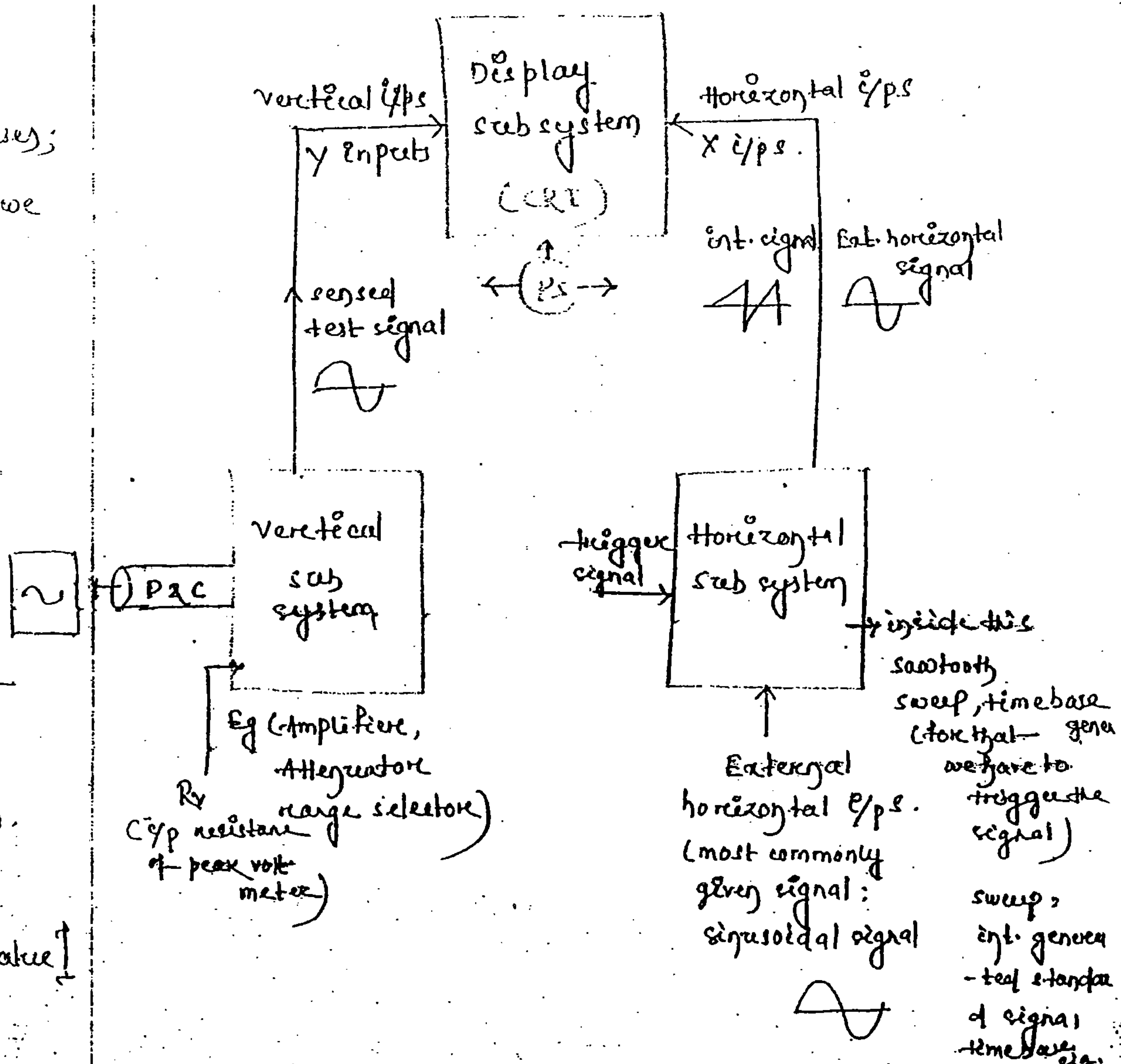
c) Reading errors are nullified while using Dvm.

d) They offer ~~the~~ superior resolution.

KK [no dvm can present it's in full scale division value]

CRO

A CRO is an Electronic peak voltmeter which work for both a/c and dc i/p signal.



internally generated signal is known as reference signal ~~becoz it is the signal which we want to be examined.~~

we sense the signal by the help of probe is transmitted to vertical sub system and o/p of vertical subsys. is known as sensensed test signal.

CRO is an image plotter
↳ Y-t plot
↳ X-Y plot

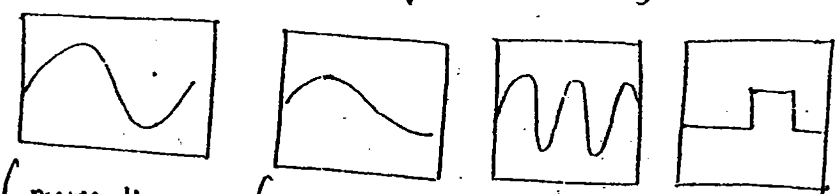
Y-t plot :-

Y = sensed test signal (is nothing but amplitude w.r.t. reference variation)
signal.

t = reference signal.

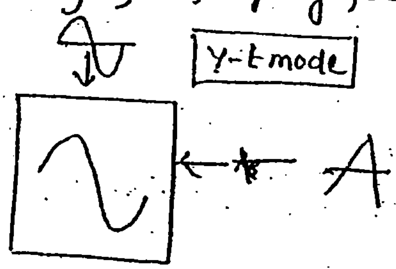
Y-t plot means : Amplitude variation of sensed test signal displayed w.r.t time is a Y-t plot i.e., test signal displayed on screen.

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/ps are driven with sensed test signal & X i/ps are driven with internally generated sawtooth.



Y-t plot

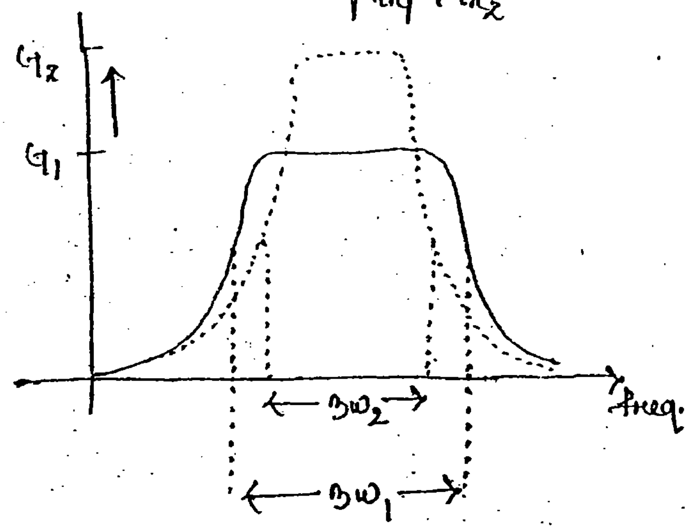
↳ measurements using Y-t plot :

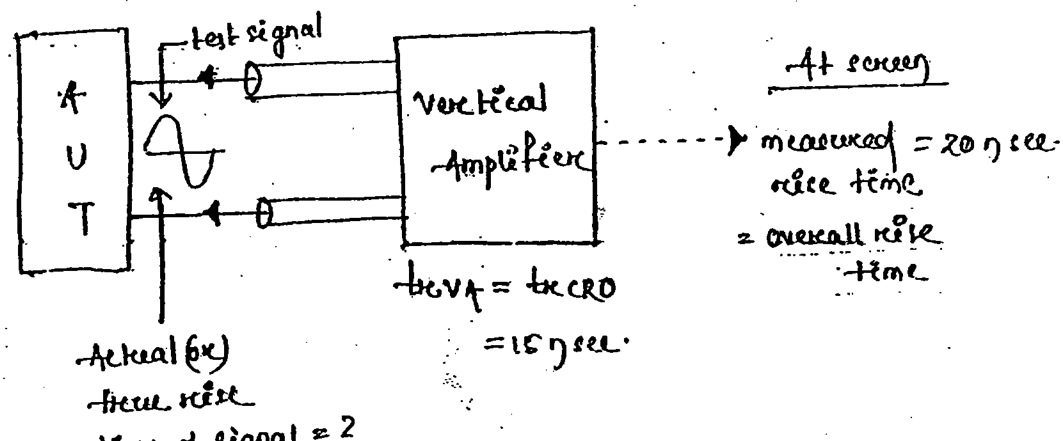
(i) msmt of peak to peak volt of signal (V_{pp})

→ overall gain $= G_1 \times G_2$

→ overall risetime $= \sqrt{t_{r1}^2 + t_{r2}^2}$

→ overall B.W. $= \dfrac{0.35}{\sqrt{t_{r1}^2 + t_{r2}^2}}$





$$\boxed{\text{measured rise time} = \sqrt{t_{rA}^2 + t_{rVA}^2}}$$

So.
$$20\ n\,sec = \sqrt{t_{rA}^2 + (15\,sec)^2}$$

$$t_{rA} = \sqrt{(20\ n\,sec)^2 - (15\ n\,sec)^2}$$

$$t_{rA} = 13.23\ n\,sec.$$

B.W. of CRO = B.W. of V.A. } Frequency range of operation.
Rise time of CRO = Rise time of V.A.

↳ Primary stage of V.A. consist of a FET.
∴ I/p resistance of CRO is in M-Ω which causes less on AUT (amp. under test)

Pb: If the B.W. of an oscilloscope is driven as 0-10 MHz. what is the fastest rise time a sinwave 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'.

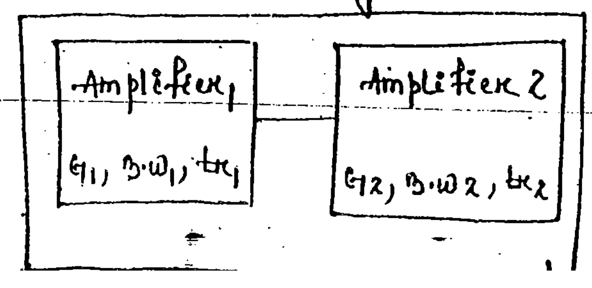
Amplifier → B.W × rise time = 0.35
→ Gain × B.W = const.

Sol^n: ⇒ $\dfrac{10\times10^{6}}{0.35}$ = risetime

⇒ rise time = $\dfrac{0.35}{10\times10^{6}}$ = 35 nsec.

Sol^n: ⇒ rise time = $\dfrac{0.35}{20\times10^{6}}$ = 17.5 nsec.

Pb: A CRO with a risetime of 15 nsec. measures the rise time of a signal as 20 nsec. Then the actual rise time of signal is ______



→ Gain × B.W = K
→ t_r × B.W = 0.35.

11/11/10

A vertical subsystem drives the

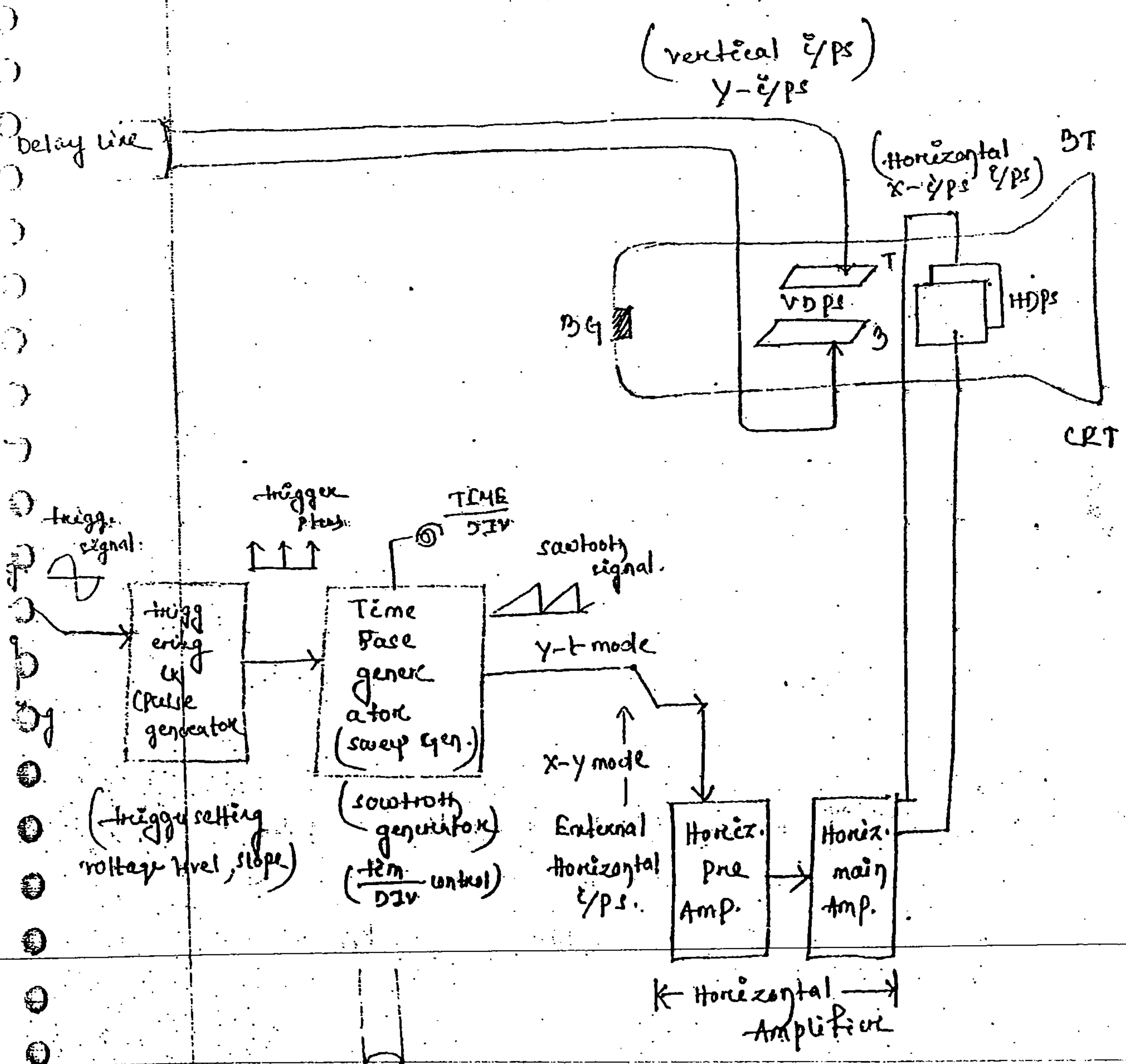
CRO = test signal path + sweep/ext. horizontal path + e^- beam path.

Power path

- 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 it's target (screen)
- The test signal is sensed using probe of the oscilloscope and transmitted to vertical i/p terminal via a cable.
- By adjusting $\frac{\text{Volt}}{\text{DIV}}$ 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 of push pull configuration otherwise n't required.
- i/p resistance of CRO = i/p resistance of V.A.

both
when the vertical plate having same voltage then there is we required push pull amp. it is required to give same peak amp. of both of plates. but in case of oppositive phase volt. we need n't require any push pull amp. (i.e. the bottom & R plate).
gain, rise time of CRO is nothing but the gain & rise time of V.A.
In CRO the i/p resistance is less than DVM.

ables mod
an be

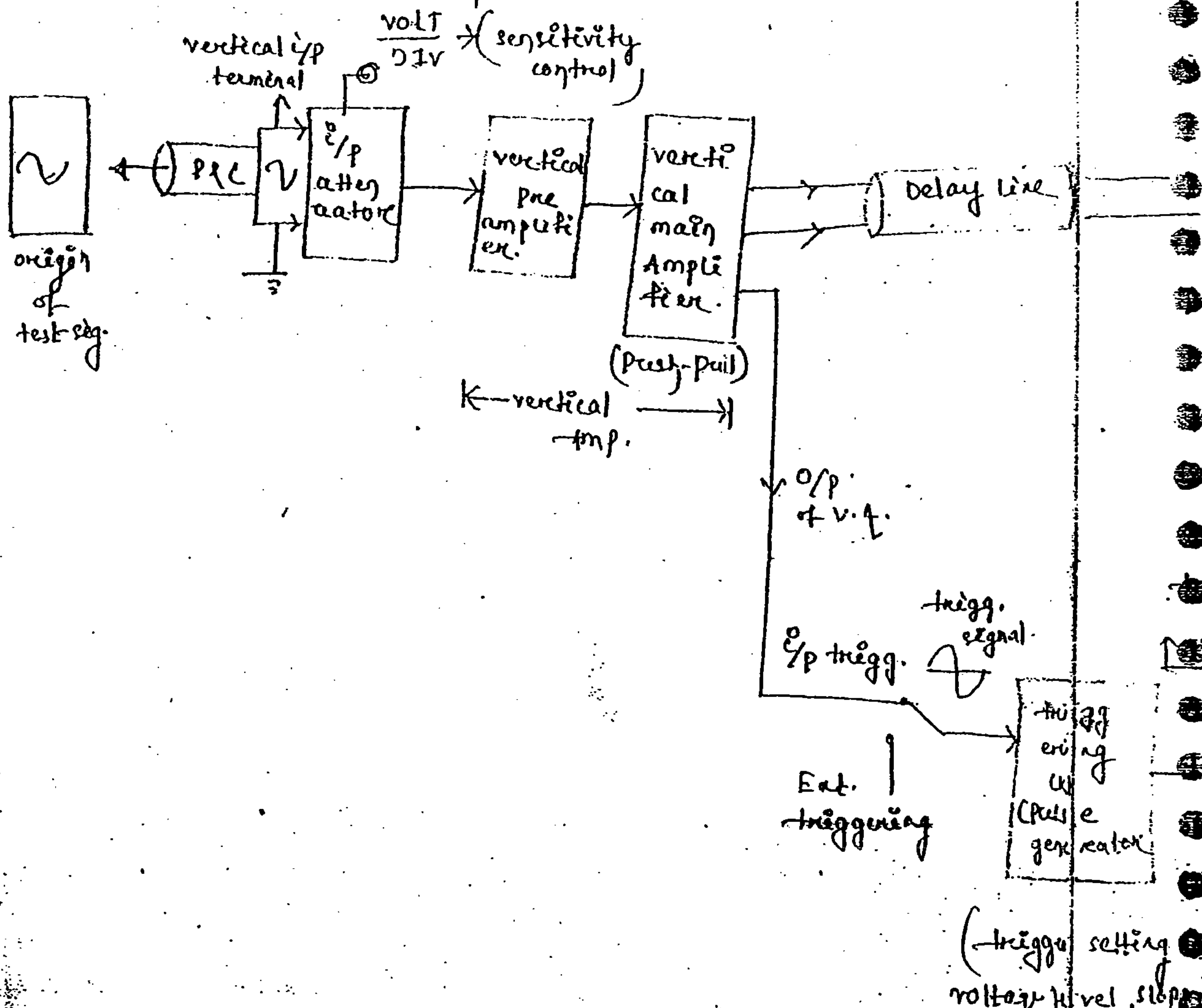


↳ Measurements using C.R.S. :

(i) msmt of frequency

(ii) msmt of phase.

Note : Using a special technique known as Z-axis mod or intensity modulation a X, Y, Z plot can be produce on the screen.



(ii) msmt of Amplitude of signal (V_p)

(iii) msmt of dc value & rms value of signal (V_{avg}, V_{rms})

(iv) msmt of time period of signal (T)

(v) msmt of frequency of signal (f).

(vi) msmt of risetime, fall time etc.

(2) x-y plot :—

x-y plot is nothing but a "Lissajious figure/pattern"

There are 3 types of Lissajious figure :

(i) closed loop L.Fs : (there is no break in the figure /no free arms)

Eg :

(ii) Open loop L.Fs : (It has free arms)

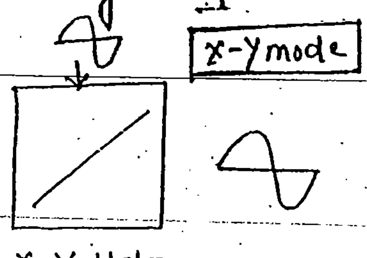
Eg : C / S

(iii) Mixed / Hybrid L.Fs : (one closed loop followed by an open loop)

Eg :

→ A x-y plot is produced when XY - i/ps are driven with sinusoidal* signal.

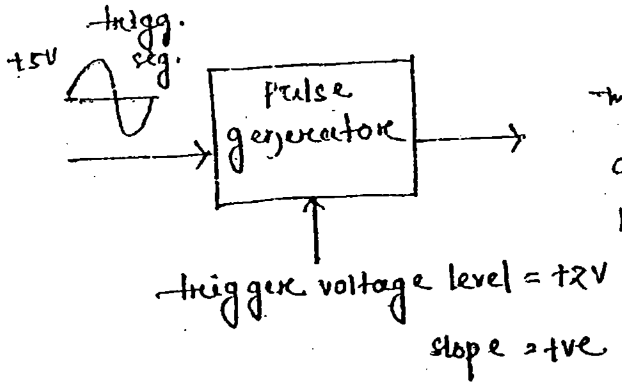
[* → it can be both sinusoidal signal or with rectangular or can be a dc signal.]



X-Y plot

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.

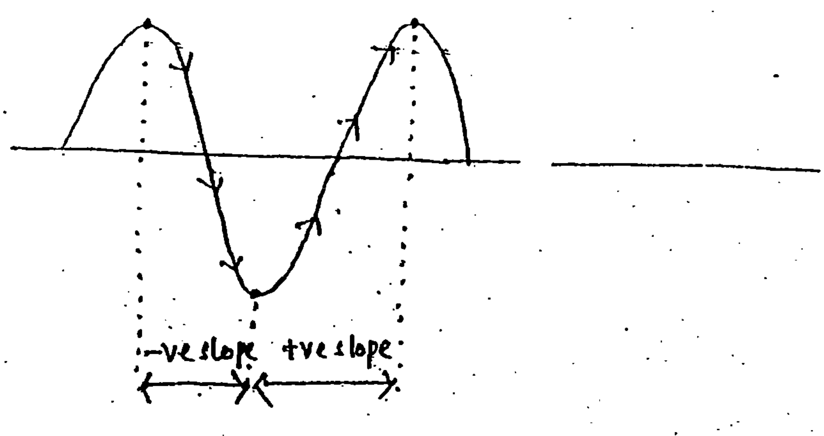


whenever the trigger signal cross the trigger volt. level then only it is going to produce a pulse.

20 nsec

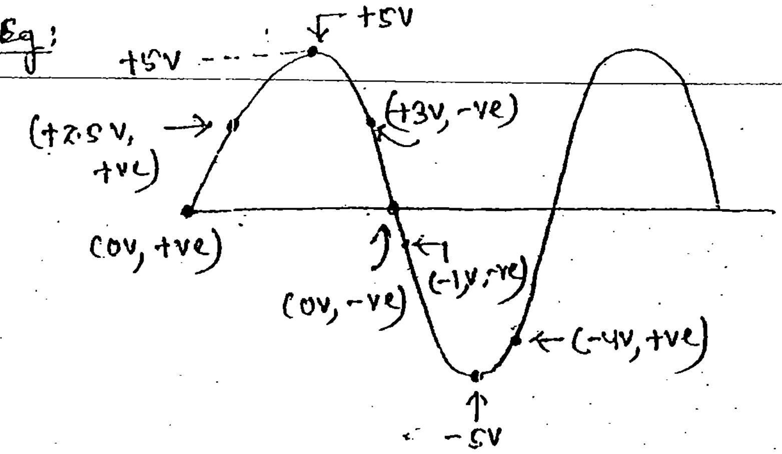
Horizontal Subsystem :

- 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 cond^n. (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 side of cycle of sweep signal for every each one trigger pulse.
- The sweep frequency can be varried by user by adjusting (time/div) control.



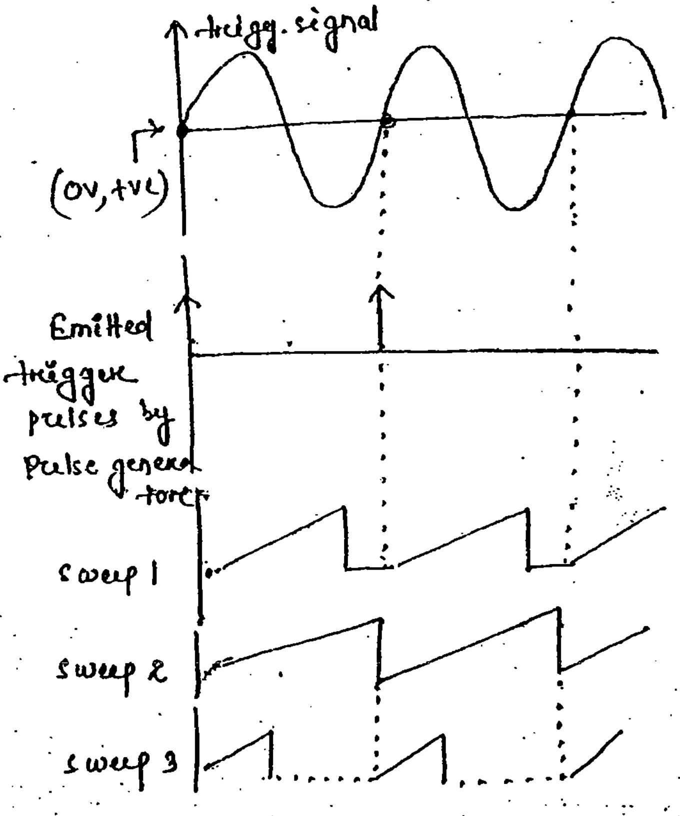
- trigger volt. level can either be +ve or -ve or '0'.
- trigger slope can either be '-ve' or '+ve'.

Eg:



Eg: triggering signal $= 5 \sin 314t$ V.

trigger setting → 0V, +ve.

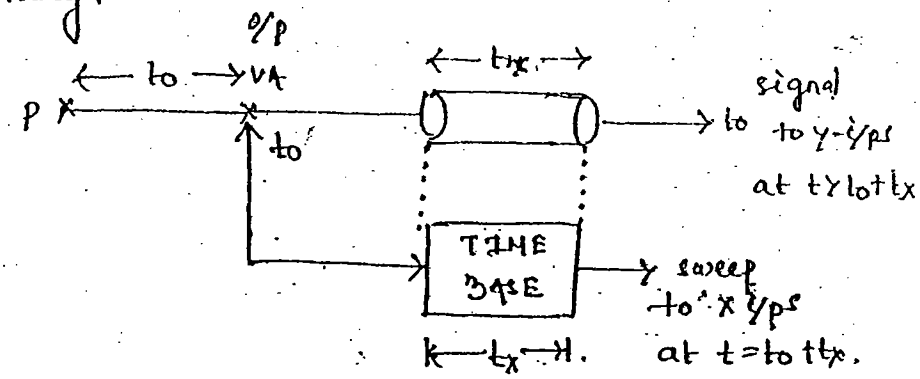


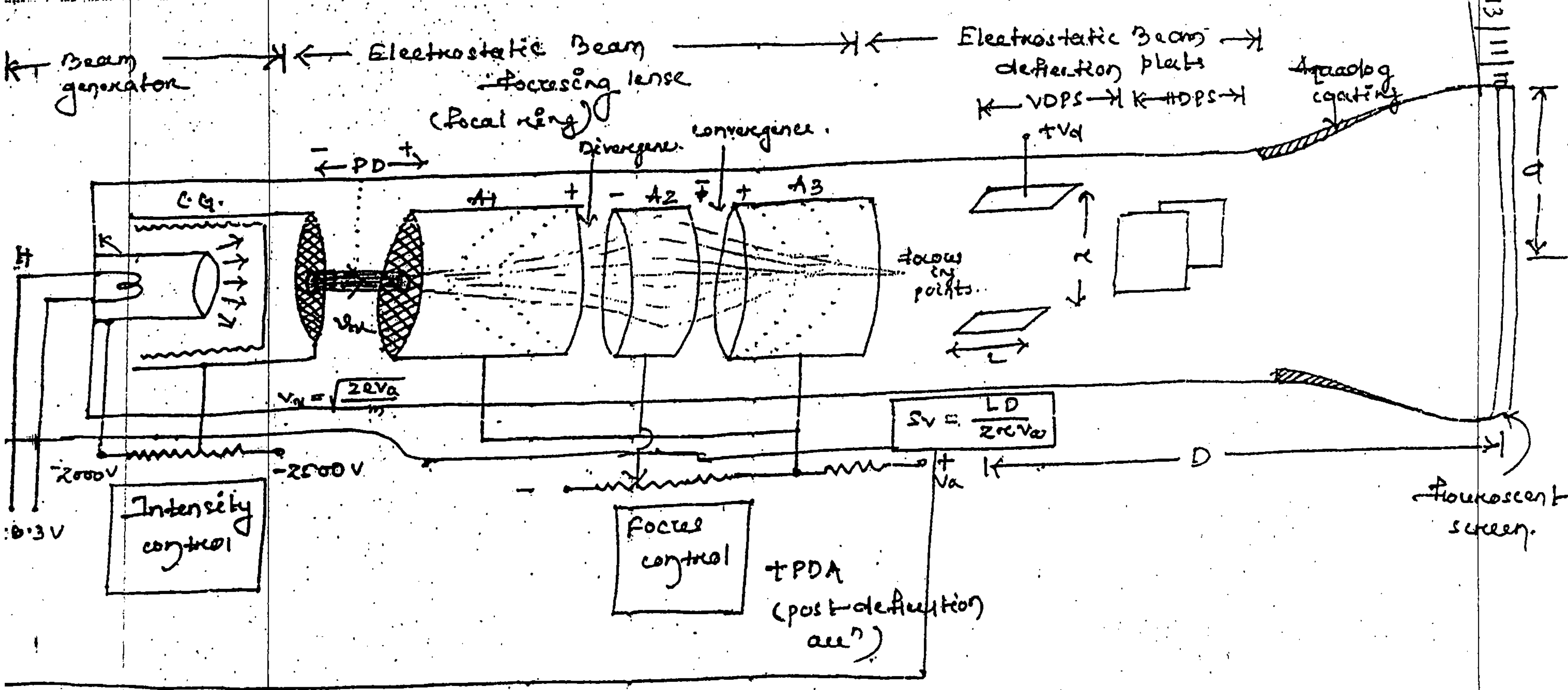
sweep generated by time base generator with diff. $\frac{\text{Time}}{\text{DIV}}$ control values.

→ In Y-T mode the internally generated / 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-i/ps. (vdps) to delay the test signal by time amount slightly greater than time consumed in time base circuitary.




Beam generator
Electrostatic Beam focussing lense (focal ring)
Electrostatic Beam deflection plats
VDPS
HDPS
Aquadog coating
convergence.
Divergence.
PD
C.G.
K
H
A1
A2
A3
focussing points.
+Vd
r
L
d
13
11
Va = √(2eVa/m)
Sv = LD/2reVa
D
+ Va
2000 V
-2500 V
6.3 V
Intensity control
Focus control
+PDA (post deflection acc^n)
flourescent screen.

Def^n: "CRT is an evacuated glass tube with beam generator at one end and beam target at other end."

① Beam Generator

- H → + Heater fillament
- K → -ve cathode
- CG → -ve Control grid.

cathod is a ~~cy~~ nickel cylinder whose surface is coated with oxide matterial (for high emission).

↳ Control grid is a nickel cup which hold coated.

↳ When the cathod is indirectly heated by heater fillament e^- are evapourated from it's metalic surface (thermioinic emission).

↳ Since grid volt is -ve the emitted e^- experience a repulsion from the inner cylindrical sidewalls of grid.

↳ As such the repuled e^-lectrodes try to comeout of grid and steam out of pin hole on the ~~the~~ ~~tt~~ 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 florescent screen (fixed)

(ii) Speed of the ~~ep~~ beam: with which it strike 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 accelating anode.

A_2 = focusing anode.

② Beam Focusing Lense

- A_1 (1st accelarating anode)
- A_2 (focusing anode)
- A_3 (2nd accelarating anode)

↳ 'A_1' and 'A_3' are applied with a typical potential 'V_a'

V_a = accelarating 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 lense.

↳ whenever an e^- crosses equipotential surface, it experience a force that changes it's direcⁿ of travel, but n't speed.

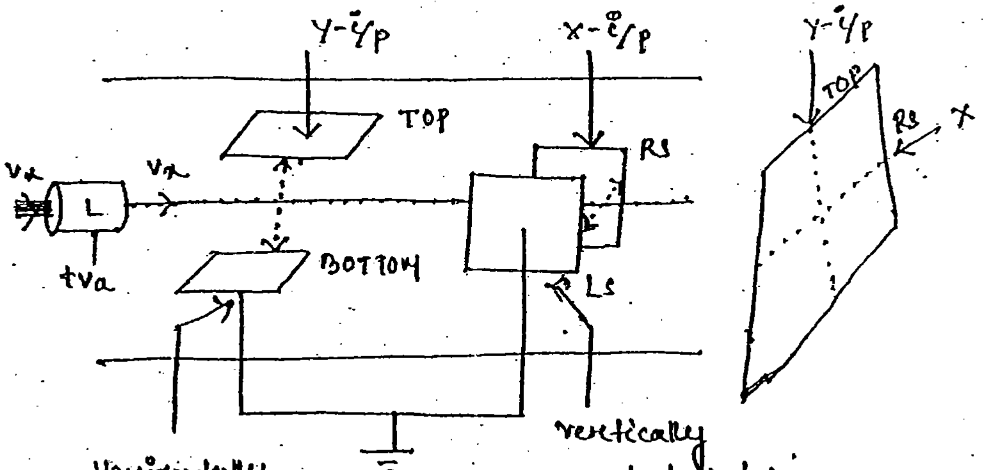
↳ ~~It change the direcⁿ of tra~~

↳ Due to high potential difference, A_1 and C_4, the e^- beam is attracted and accelarate towards 'A_1' and enters into lense via the pinhole of lense 'A_1', with the velocity 'V_x'.

4 The beam is then diverged and converged into a sharp beam.

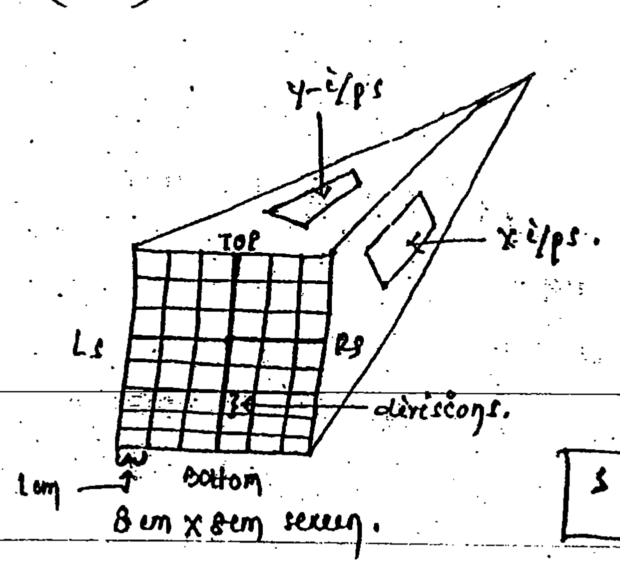
4 The velocity with which the beam enters the lense will be the velocity with which the beam leaves the vet lense. This is known as narrowing the e⁻ beam or sharpening or focusing beam.

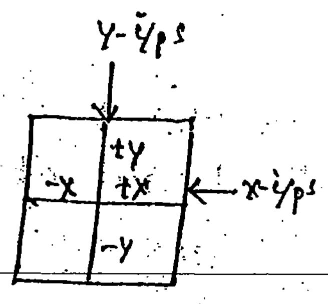
③ Beam deflection plates :-



~~Horizontally~~ mounted plates deflect e⁻ beam vertically (up-down) (VDPS)

vertically mounted plates which deflect e⁻ beam Horizontally (left-right) (H.D.PS)





$$\boxed{S = \frac{d}{V_d}} \quad \frac{\text{div}}{\text{volts}}$$

d = amt of vertical deflection.

V_d = deflecting vertical signal.

Deflection Sensitivity :-

It is represented as 's'

$$\boxed{S = \text{Deflection per unit voltage}}$$

S = amount of distance travelled by e^- beam per unit voltage

units : $\frac{\text{cms}}{\text{volt}}$ (or) $\frac{\text{divs}}{\text{volt}}$

$$\boxed{\text{sensitivity} = \frac{\text{Deflection}}{\text{voltage}}}$$

Deflection factor :

Df = reciprocal of sensitivity

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

units : $\frac{\text{volts}}{\text{cm}}$ (or) $\frac{\text{volts}}{\text{div}}$

2 sensitivits

- 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 florescence 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.

↳ Florosience 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 phosphoscence exist is called as persistance of phosphorous.

Need for PDA:

$$\boxed{S_V = \frac{LD}{2SV_a}}$$

($S = r$)

($\uparrow$ spread = $\uparrow$ brightness)

S_V = vertical deflecting plate.

L = length of each VDP

D = Distance b/w VDPs and screen.

$r = S$ = separation distance b/w both VDPS.

V_a = accelarating anode volt.

To offer 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 &placed to one another.

$\uparrow S_V \propto \frac{1}{V_a\downarrow} \Rightarrow$ Accelarating anode volt. must be kept low.

$$\downarrow$$

$\downarrow V_x \propto \sqrt{V_a}\downarrow$.

↳ If 'V_a' is kept low, then speed of 'V_a' will a low. since $V_x \propto \sqrt{V_a}$, but the slowly moving e^- beam gives rise to high sensitivity.

↳ ~~Whereas once the~~ beam crosses deflection plates assembly. It will be accelarated once again by a very high +ve volt attached to the screen, know as 'PDA'.

↳ e^- beam is accelarated twice

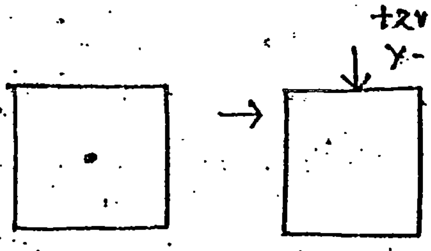
→ 1st time, prior to focusing due to 'A'.

→ final time, post to deflection due to PDA.

↳ 'A1' is known as 1st accelarating anode
(or)
Pre accelarating anode.

↳ 'PDA' is known as final accelarating anode.
(or)
Post deflection accelarating anode.

DC ~~to~~ Y & X inputs of CRO :-

↳ 

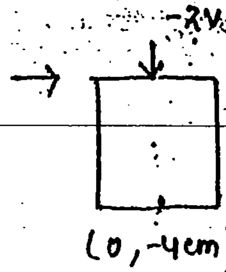
+2V dc Y-i/p

$S_V = 2\frac{cm}{V}$

$Y = V_y \times S_V$

$= (+2V) \times 2cm$

$= 4cm$



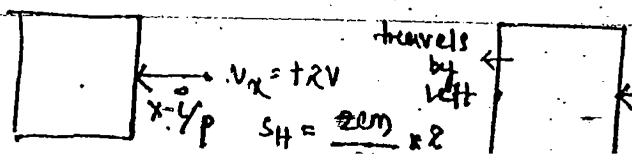
-2V

$S_V = \frac{-2cm}{V}$

$= -2V \times 2cm$

$= -4\ cm.$

(0, -4cm)

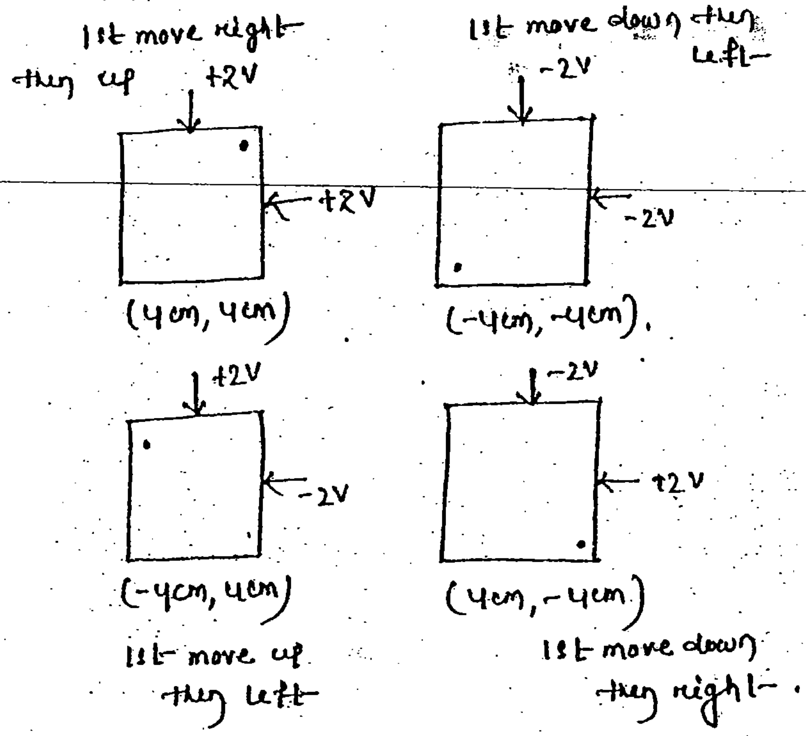
↳ 

$V_x = +2V$ X-i/p

$S_H = \frac{2cm}{} \times 2$

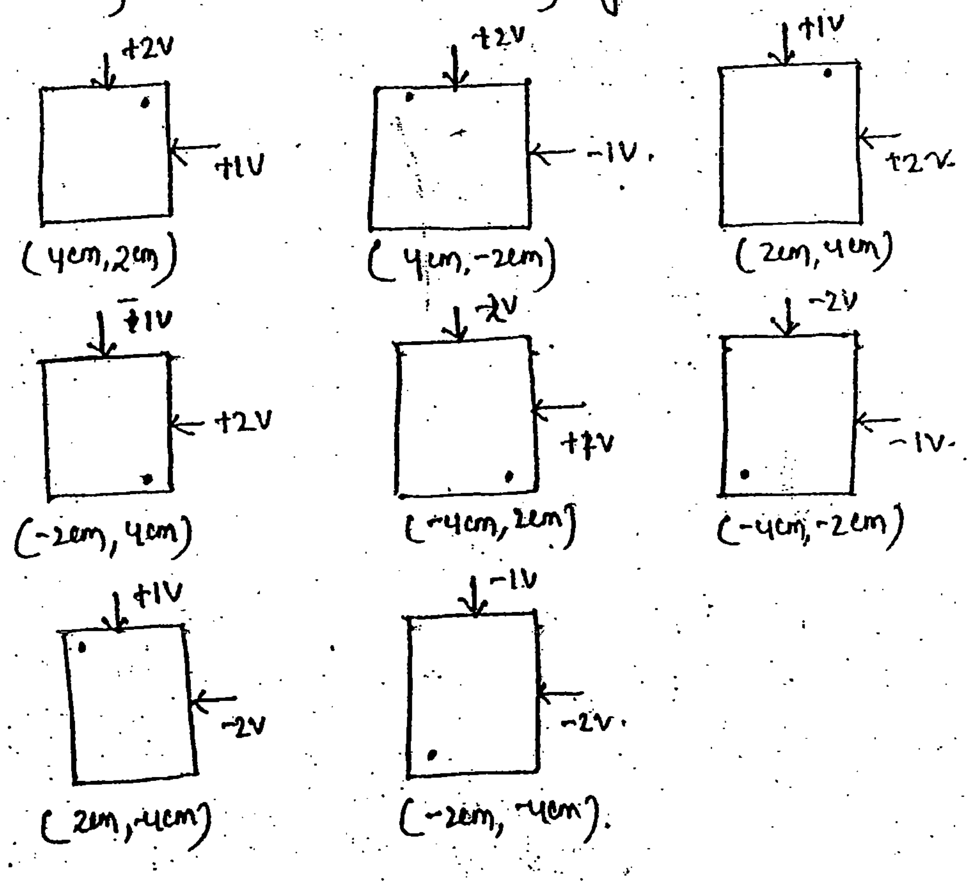
travels by left

$V_x = -2V$ X-i/p



1st move right then up
+2V
+2V
(4cm, 4cm)
1st move down then left
-2V
-2V
(-4cm, -4cm).
+2V
-2V
(-4cm, 4cm)
1st move up then left
-2V
+2V
(4cm, -4cm)
1st move down then right.

Eg:



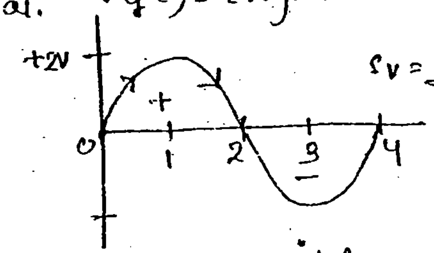
+2V
+1V
(4cm, 2cm)
+2V
-1V.
(4cm, -2cm)
+1V
+2V.
(2cm, 4cm)
+1V
+2V
(-2cm, 4cm)
-2V
+1V
(-4cm, 2cm)
-2V
-1V.
(-4cm, -2cm)
+1V
-2V
(2cm, -4cm)
-1V
-2V.
(-2cm, -4cm).

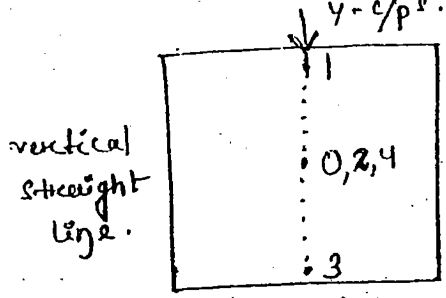
15/10/10

Sinusoidal signal applied to y inputs :-

↳ Desired test signal. $v_y(t) = 2\sin 314t$ V

The y-T plot is nothing but the signal in the screen.



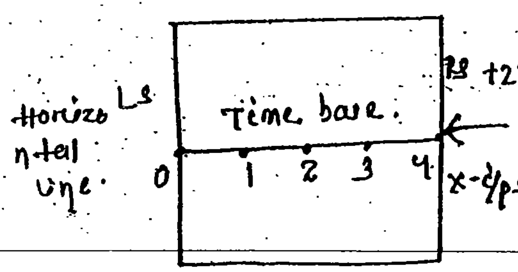


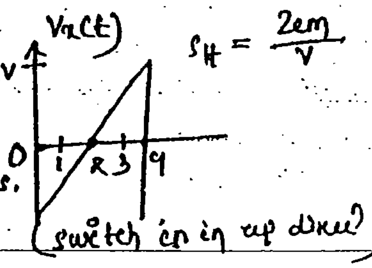
t	$v_y \xrightarrow{\times S_v} y$
0	0 ⟶ 0
1	+2V ⟶ +4 cm
2	0 ⟶ 0
3	-2V ⟶ -4 cm
4	0 ⟶ 0

Saw tooth signal applied to x-i/ps :-

↳ standard, int. generated sweep signal.

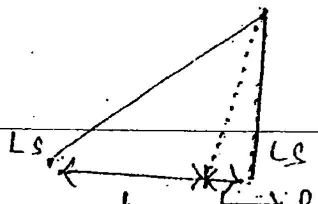
This i/p is an alternating sweep signal becoz it is going to





this is an free running sweep. This free running sweep is generated ~~by trigger~~ pulse.

t	$V_x \xrightarrow{\times S_H} x$
0	$-2V \longrightarrow -4cm$.
1	$-1V \longrightarrow -2cm$
2	$0V \longrightarrow 0$
3	$+1V \longrightarrow +2cm$.
4	$+2V \longrightarrow +4cm$.



~~trace~~ periode → Retrace

(it is always from left to right.

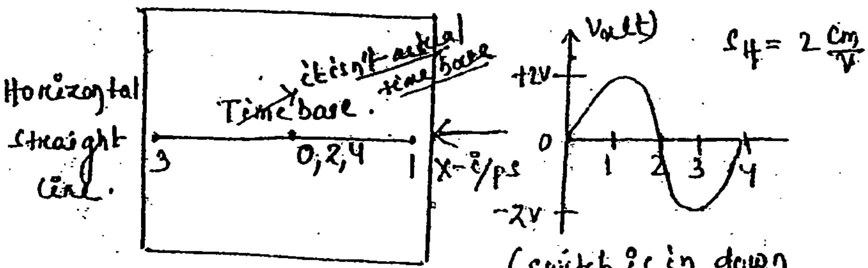
Right → left. In this the screen is left as blank.

It is also known as flyback.

This horizontal line is nothing but the beam that moving from left to right ~~or~~ and right to left within no time.

Retrace period << trace period.

Sinusoidal signal applied to x-i/ps :-
→ Externally applied horizontal signal.



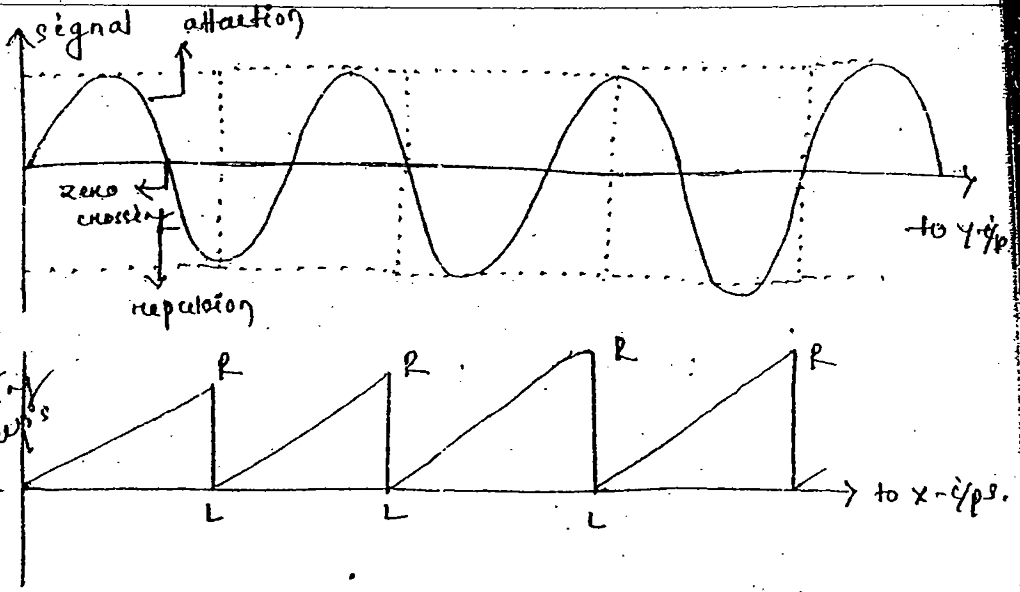
$S_H = 2\frac{cm}{V}$.

(switch is in down direcⁿ)

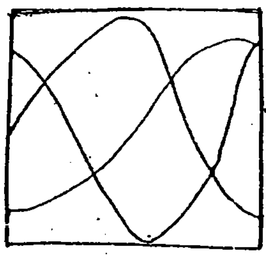
t	$V_x \longrightarrow x$.
0	$0V \longrightarrow 0$
1	$+2V \longrightarrow +4cm$
2	$0V \longrightarrow 0$
3	$-2V \longrightarrow -4cm$
4	$0V \longrightarrow 0$

center ~~to~~ right → center → left center.

to adjust
setting
given
signal
as
by
sweep.



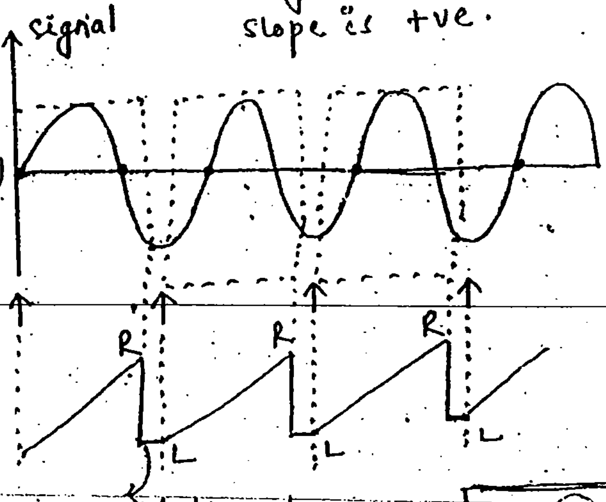
Jumble



0V = voltage level.

+ve = slope.

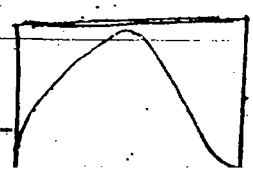
case ② trigger settings are made
↳ voltage level is 0V.
slope is +ve.



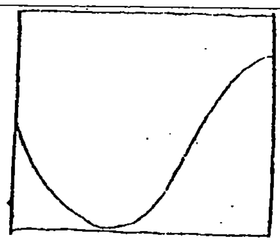
↑ trigger pulse
↓
applied to sawtooth signal.

same portion of signal is repeatedly displayed on screen (∵ trigg)

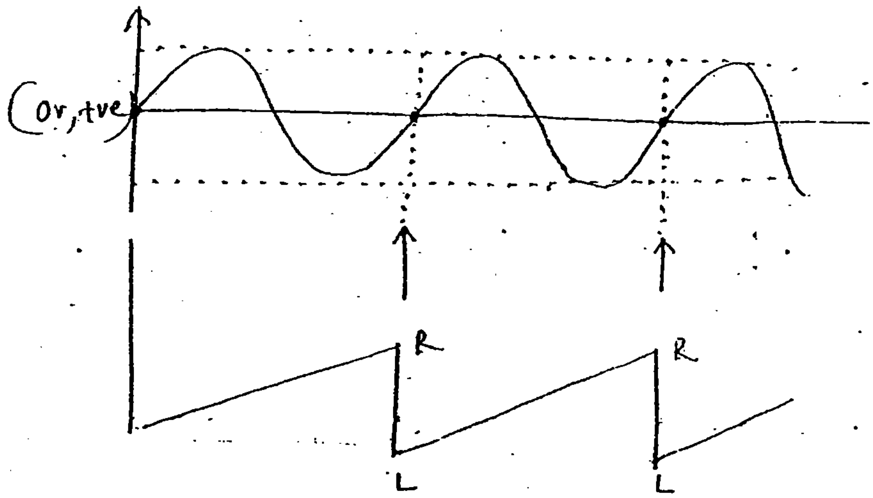
steady display

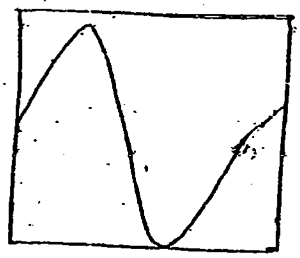


Note-1 If trigger voltage level is 0V and trigger slope = -ve.



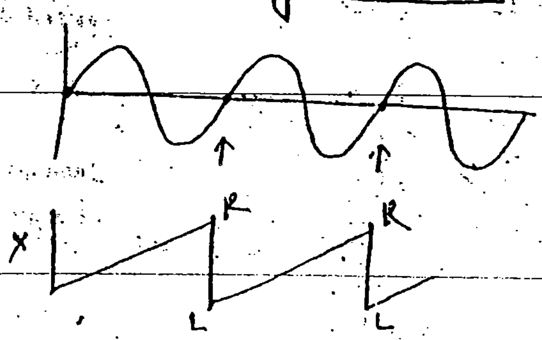
case-3 Along with trigger settings and Adjust $\frac{\text{Time}}{\text{DIV}}$ to make $f_{sweep} = f_{signal}$.



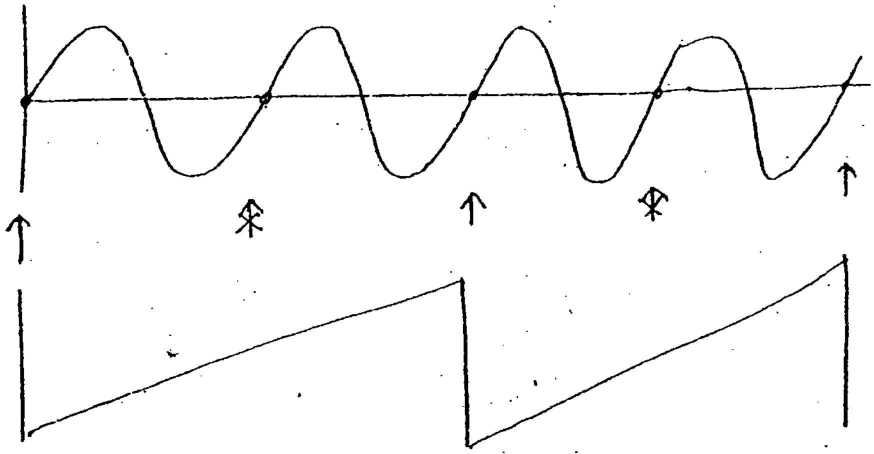


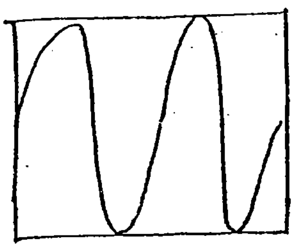
→ Proper triggering
→ Steady display of 1 cycle of signal
↓
∴ $f_{sweep} = f_{signal}$.
synchronisation

case-4 If $f_{signal} > f_{sweep}$



test





↳ If $f_{signal} < f_{sweep}$, then less than 1 cycle of signal will be displayed on screen.

↳ If $f_{signal} = f_{sweep}$, then 1 cycle of signal will be displayed on screen.

Triggering

play of signal

↳ If $f_{signal} > f_{sweep}$, then more than 1 cycle of signal displayed on screen.

signal synchronisat?

↳ $\boxed{f_{signal} \geq f_{sweep}}$ ↳ locking cond?.

(for proper synchronisat?)

↳ $f_{signal\,(min)} = f_{sweep}$

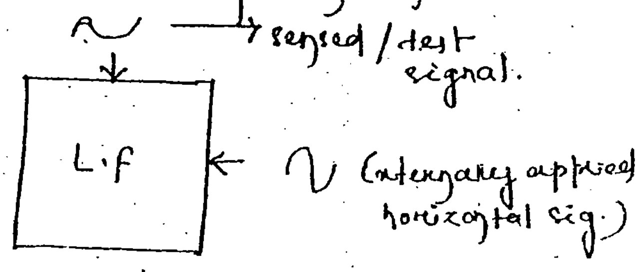
$\boxed{f_{signal} = \underbrace{n}_{\geq 1} f_{sweep}}$

(improper signal is nothing but jumble).

16/11/10

x-y plot :-

A x-y plot is produced on the screen of CRO when both x and y - i/ps are driven with sinusoidal signals.



↳ This mode of operation is known as x-y mode of operation.

↳ x-y plot are called as "Lissagieous figure / pattern".

↳ 3 types of Lissagious 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.fs. namely frequency msmt and phase msmt.

① <u>Unknown frequency msmt using L.F. :-</u>

there are two methods :

Tangent Method (touch technique)	Intersection Method (cut technique)
↳ Draw Horizontal & vertical tangent lines touching the peaks of L.F.	↳ Draw Horizontal and vertical lines passing through L.Fs. <u>RULE</u> : Never Draw via preexisting intersection
↳ Then apply the formula: $$\boxed{\frac{f_y}{f_x} = \frac{n_x}{n_y}}$$ freq. ratio	↳ then apply the formula : $$\boxed{\frac{f_y}{f_x} = \frac{n_x}{n_y}}$$
n_x = no. of peaks as touch by Horizontal line tangent n_y = no. of peaks as touch by vertical tangent.	n_x = no. of cuts as made by horizontal lines. n_y = no. of cuts as made by vertical lines.

now

↳ $$\boxed{f_y = \underbrace{\left(\frac{n_x}{n_y}\right)}_{\text{ratio}} f_x}$$

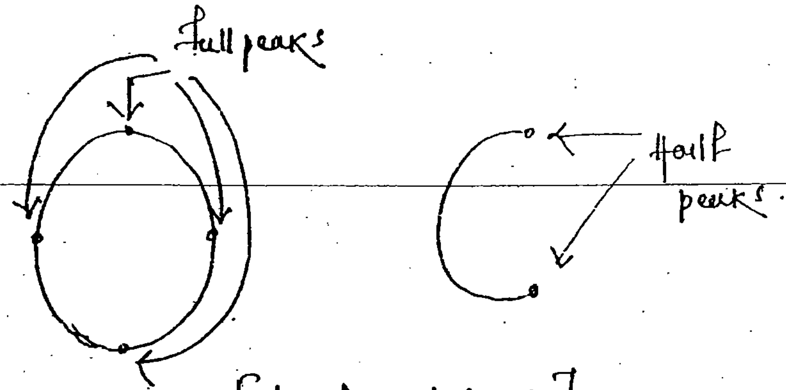
f_y → unknown frequency

f_x → known frequency

'unknown' measured by 'known' interms of 'ratio'

this principle is known as '<u>Bridge principle</u>'.

Note :



[Focus technique]

② Phase measurement using L.Fs :—

↳ One typical condⁿ is made here to understand the analysis

cond : Equal amplitudes : $V_y = V_x = V$

Equal frequency : $f_x = f_y = f$

Equal sensitive : $S_V = S_H = S$.

↳ ∴ $V_y(t) = V \sin(2\pi f t + \phi)$

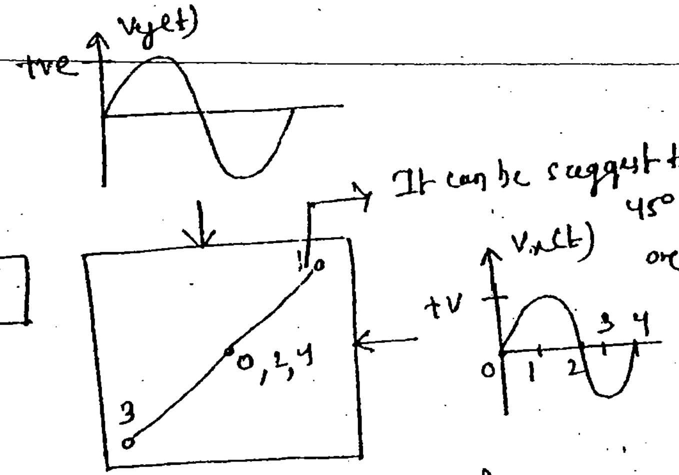
$V_x(t) = V \sin(2\pi f t)$ ⟶ $(0^\circ$ to $360^\circ)$

↳ As the horizontal and vertical beams are maintaing the same frequency and amplitude then it is obvious that they should maintain the same distance. For this there are 3 cases:

case ① : 2 sinusoidal signal with equal amplitude and equal frequencies with no phase difference are applied to both i/ps of CRO :

Inphase

$\boxed{0° \text{ or } 360°}$



→ It can be suggest that it is 45° with +ve x-axis or 135° with −ve x-axis.

$(v_x, v_y) \rightarrow (0,0) - (+v,+v) - (0,0)$

$(-v,-ve) - (0,0)$ → 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 upword/toword vertical lines and vice versa.

<u>Note :</u> if $v_x = v_y$, $f_x = f_y$ & $\phi = 0$

A diagonal line observed on the screen made exactly 45° with +ve 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 +ve x-axis.

if $v_y < v_x$, $f_x = f_y$, $\phi = 0$

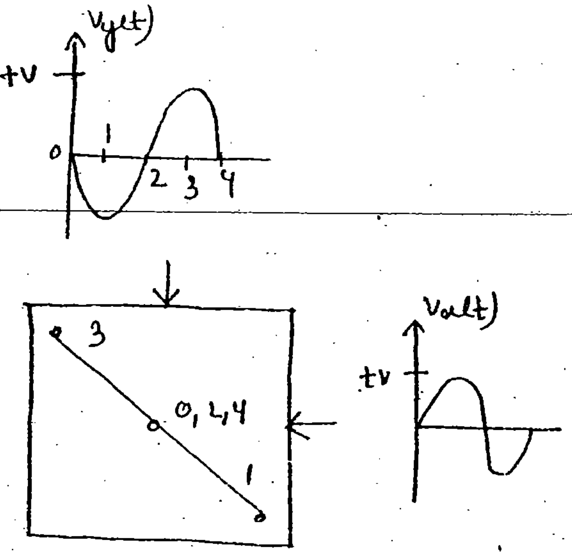
A diagonal line observed on the screen made ~~gr~~ less than 45° with +ve x-axis.

<u>case (2)</u> : 2 sinusoidal signals <u>with equal amplitude</u> and <u>equal frequencies</u> with <u>having phase difference</u> of 180° are applied to both i/ps of CRO.

of ... peaks. ... stand ... main ... are then ... in ... cases: amplitude ... ference.

out of phase

$\boxed{\phi = 180^\circ}$



$(v_x, v_y) \to (0,0) - (+v,-v) - (0,0)$

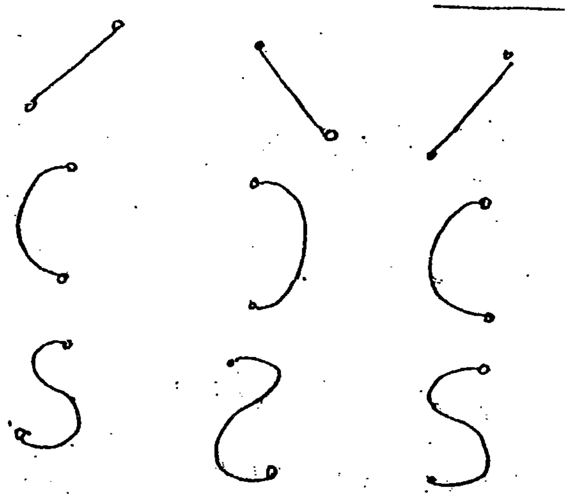
$(-v,+v) - (0,0)$

↳ Here diagonal straight line making 135° with +ve ~~axis~~ x-axis and with quadrant (2, 4).

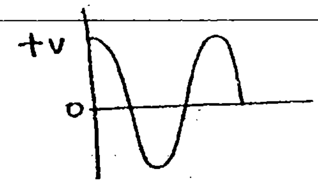
Note:

same

$0^\circ \leftrightarrow 180^\circ \leftrightarrow 360^\circ$

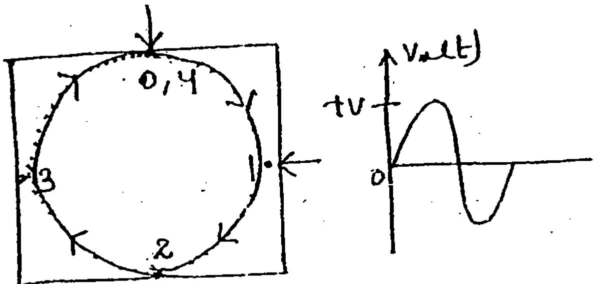


case ③ : 2 sinusoidal signal with equal amplitude and equal frequencies, but having a phase difference of 90° are applied to both i/ps of CRO



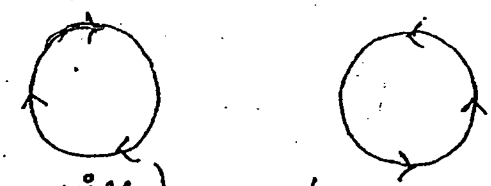
$\boxed{\phi = 90^\circ}$

clockwise rotating circle.



$(V_x, V_y) \to (0, +V) - (+V, 0) - (0, -V)$
$(-V, 0) - (0, +V)$

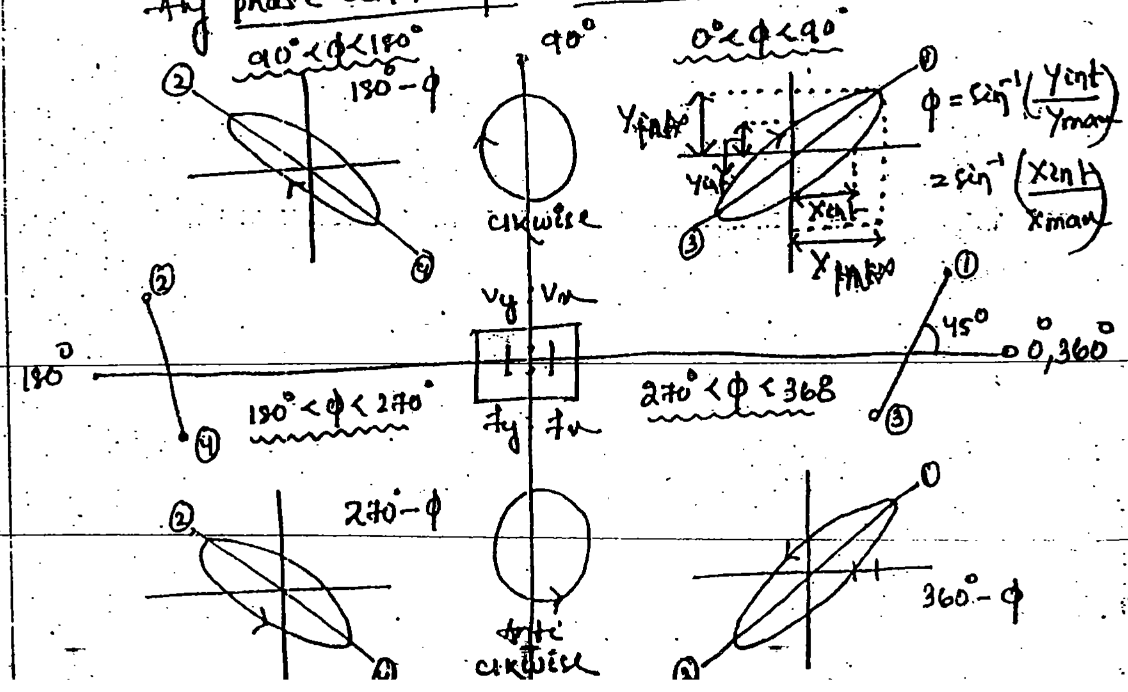
Note : 90° 270° (i.e. 360° − 90°).



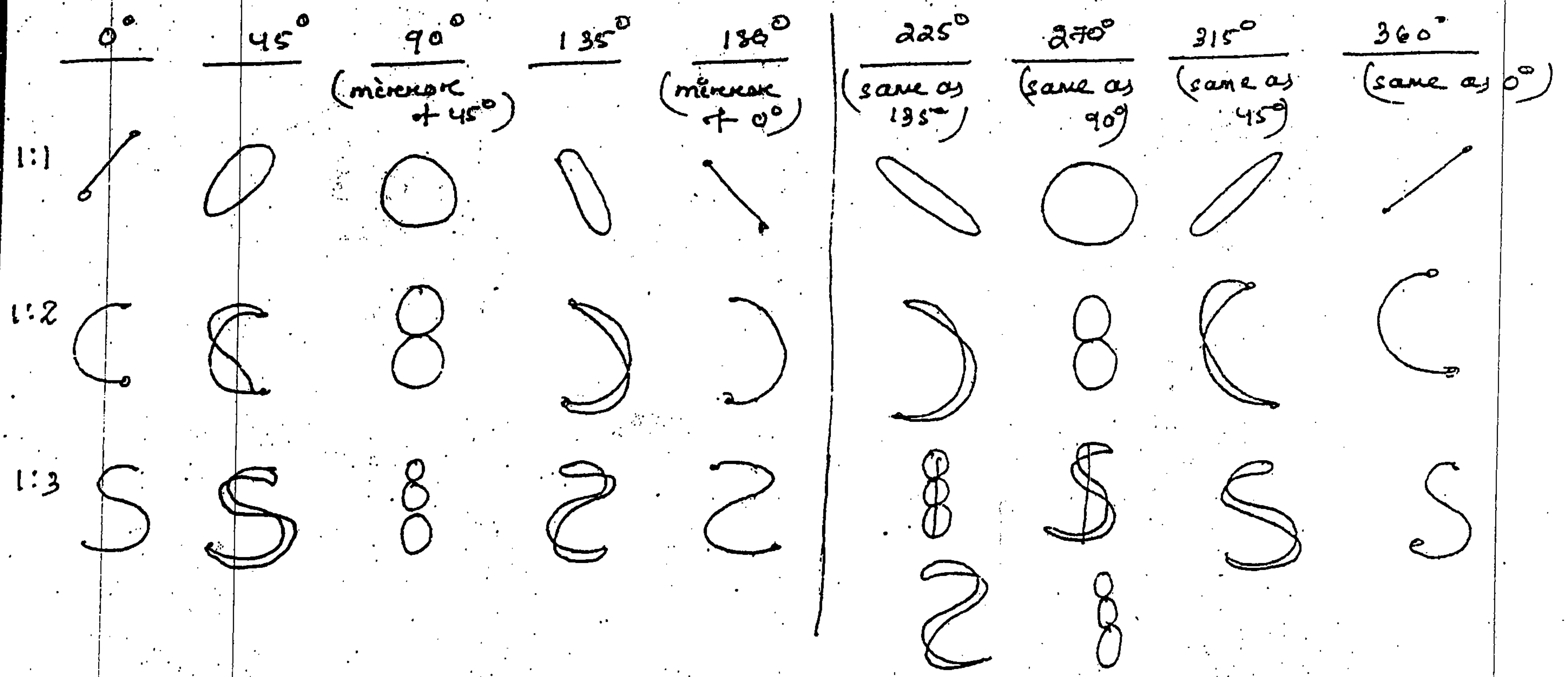
(clockwise) (Anti-clkwise)

↳ Any other phase difference b/w two i/ps we are going to get an elipse on the CRO.

Any phase difference (0°, 90°, 180°, 270°, & 360°)



Sample phase of CRO


0°
45°
90° (mirror of 45°)
135°
180° (mirror of 0°)
225° (same as 135°)
270° (same as 90°)
315° (same as 45°)
360° (same as 0°)
1:1
1:2
1:3

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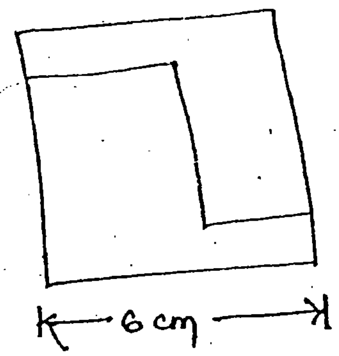
20/11/10

2006 IES : one cycle of square wave signal is observed on oscilloscope found to occupy 6 cm at a scale setting of 30 μsec./cm. what is the scale frequency.



sol^n: time period = $N_H X$

$X = 30\, \mu s/cm$.

$f_{square} = ?$

$T = 30 \frac{\mu s}{cm} \times 6\, cm$

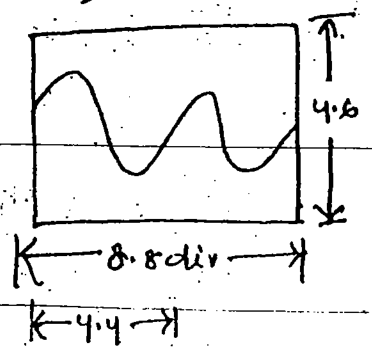
$T = 180\, \mu s$.

$f = \frac{1}{180\, \mu s} = 5.55\, kHz$.

Pb: An oscilloscope is operated with scale setting of 0.5 msec/div and vertical setting of 100 mV/Div. Hence two cycle of sinewave 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 ——

sol^n: Horizontal division = 8.8. (N_H = 4.4).

vertical division = 4.6. (N_V)



$X = 0.5 \frac{mV}{div}$

$Y = 100 \frac{mV}{div}$.

$V_{pp} = N_V\, Y$	$T = N_H \cdot X$
$V_{pp} = 4.6$ $= 460\, mV$	$T = 4.4\, div \times 0.5\, msec/div$ $= 2.2\, msec$

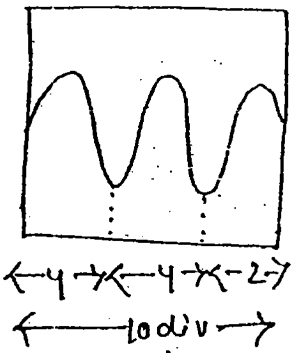
$$V_{rms} = \frac{230}{\sqrt{2}} \text{ mV}$$

~~Pb: The CRO screen has 10 div on the horizontal~~ scale if a voltage signal $5\sin(314t + 45^\circ)$ is examined with a time base setting of 5msec/div. then the no. of the cycle of signal displayed on the ~~si~~ screen will be ______ .

$v_y(t)\cancel{N_H} = 5\sin(314t + 45^\circ)$.

$x = \frac{5\text{ msec}}{\text{div}}$.

no. of cycle displayed = ?



$T = N_H x$

$5 \sin(314t + 45^\circ)$.

V_p ← ; $f = 50\text{Hz}$; → ϕ.

$$\frac{1}{50\text{Hz}} = N_H \times \frac{5\text{msec}}{\text{div}}$$

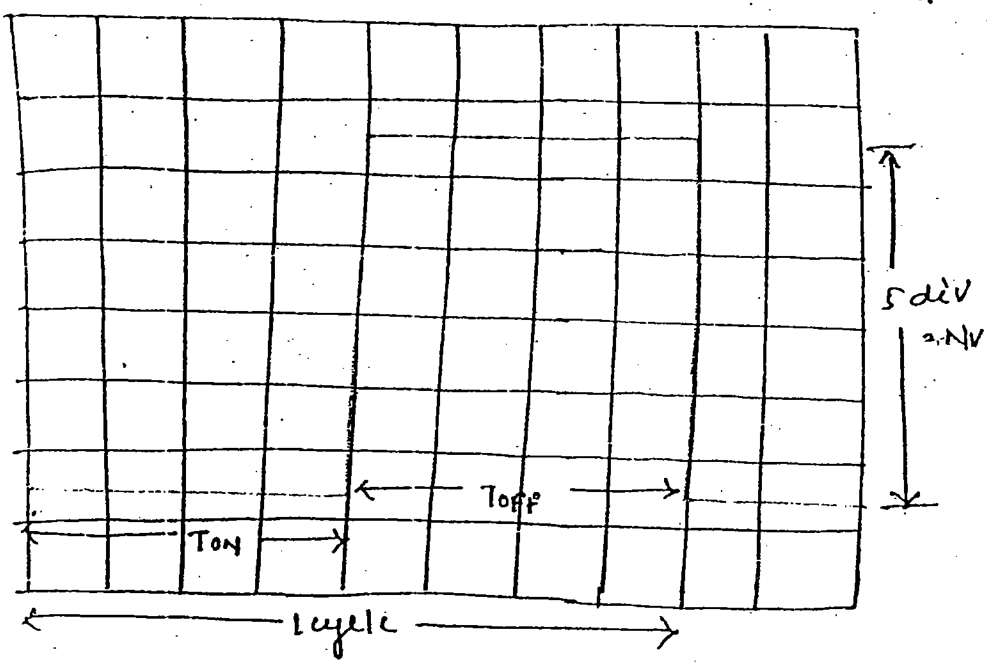
$$N_H = \frac{20\text{msec}}{5\text{msec}} = 4 \text{ div}.$$

1cycle occupy 4 div,

∴ 10 div occupy ~~4×~~ 2.5 cycles.

Pb: A symmetrical squarewave of frequency 25KHz on peak to peak amplitude of 10V is fed to the y-i/p of an oscilloscope. The screen appears as shown in below fig. Then the vertical setting and time setting ~~values~~ & slope values are ______

Symmetrical square wave → $T_{ON} = T_{OFF}$
→ 4 div = 4 div = 8 div = N_H

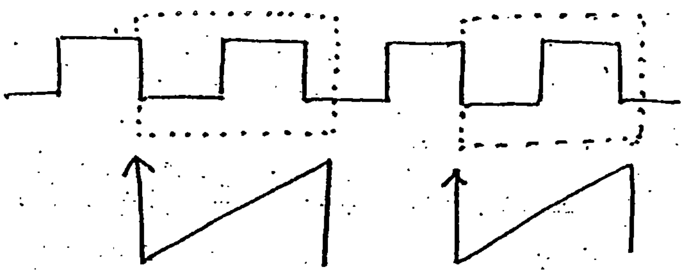


$V_{pp} = 10V$. $N_V = 5\,div$.

$f = 25\,KH$

$T = \frac{1}{25} = 4\,msec$.

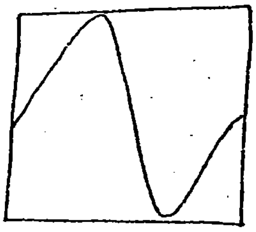
$V_{pp} = N_V \times Y$	$T = N_H \times X$
$10V = 5\,div \times Y$	$4\,msec = 8\,div \times X$
$Y = 2\,V/div$.	$X = 5\,\frac{usec}{div}$.

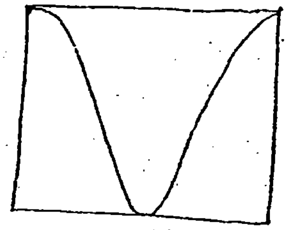


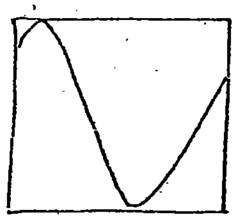
slope = -ve always.

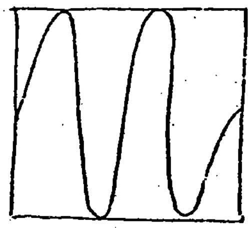
Pb: In a cathod ray oscilloscope the x and y sensitivity are set as 1 msec/div and 1 V/div respectively. The y-i/p is connected to a voltage is internal and the level source is zero. and slope is +ve. The display on the screen is ____. (a)

~~[no. of horiz div = 10, vertical div = 8~~

a) 

b) 

c) 

d) 

(c)

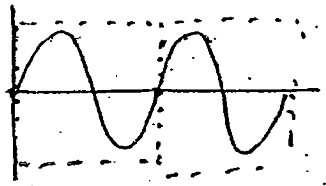
$X = 1\,ms/div.$ | Internal trigger source
$Y = 1\ volt/div.$ | trigger level = ±0V
trigger slope = +ve.

IES Pb.

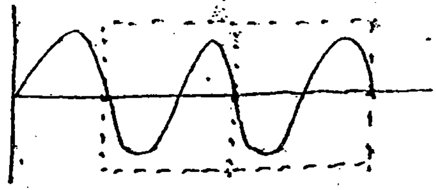
sol^n: $4\cos(200\pi t - 45^\circ)\,v$

$V_p = 4$ $f = 100\,Hz$

$T = 10\,msec.$

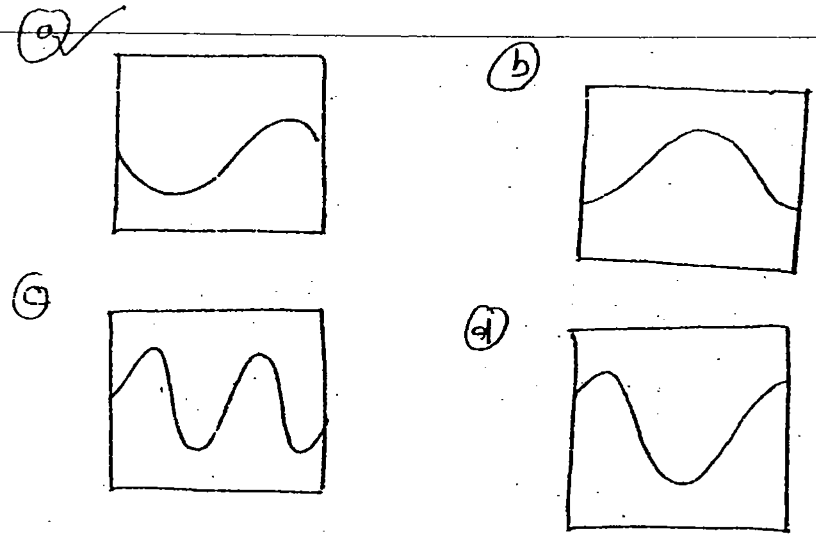


(0V, +ve)



(0V, -ve).

Pb: The x and y sensitivities of an analog oscilloscope are set as 2msec/cm. and 1volt/cm respectively. The trigger is setted 0 volts and -ve slope ~~and~~. An i/p of $2\cos(100\pi t + 30^\circ)$ volts is fed to Y-i/p. of oscilloscope. The waveform seen on the scope will be ____. (b)



$X = \cancel{2\,cm/sec}\; 2\ sec/cm.$

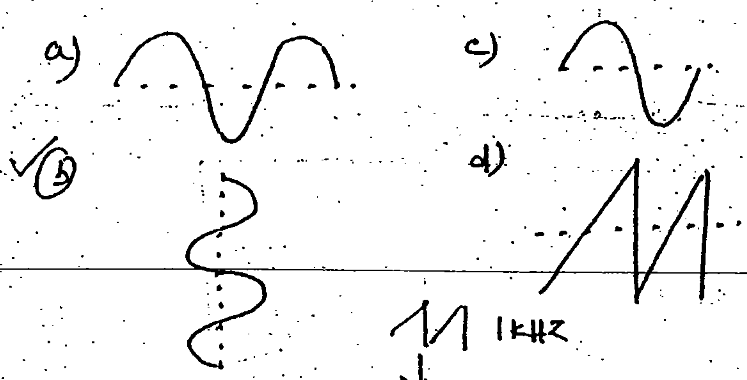
$Y = 1\ volt/cm.$

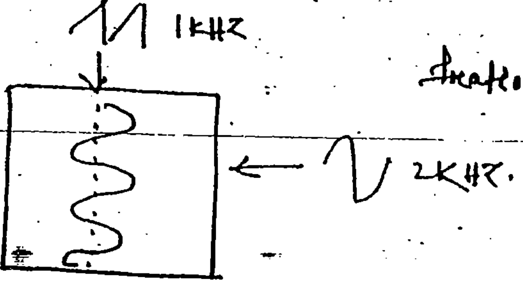
$2\cos(100\pi t + 30)$

$\rightarrow f = 50Hz.$

$T =$

IES P5: A sinusoidal signal of ~~frequency~~ 2kHz is applied to the x-diffleetion plate and a saw tooth frequency of 1kHz is applied to the y-diffleetion plate (vertical) of CRO. The wave form shown in the screen is





Ratio = $\frac{2\ time}{1}$ = 2 times.

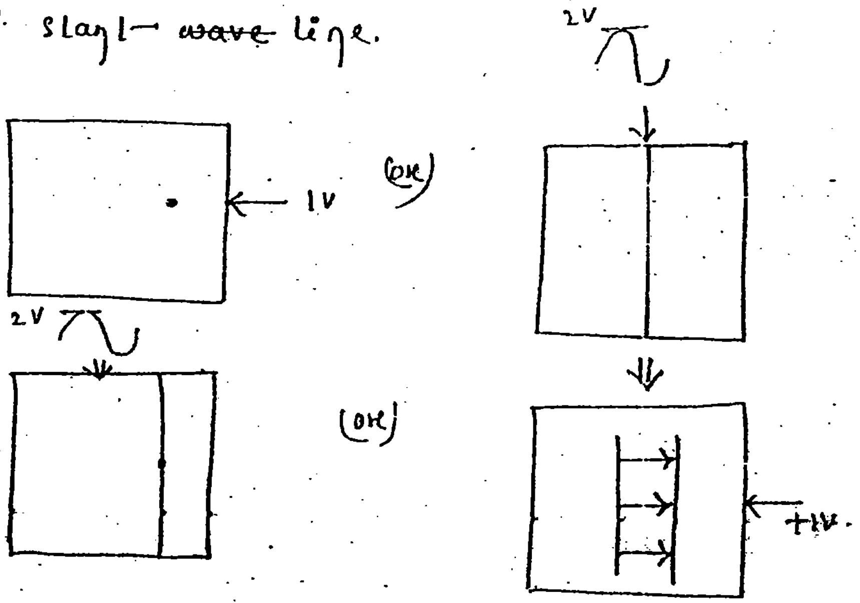
Pb: A dc voltage of 1 volt is applied to the X-plate of CRO and an ac volt. of $2 \sin 100t$ is applied to y-plates. The resulting display on the screen will be

a) vertical st. line

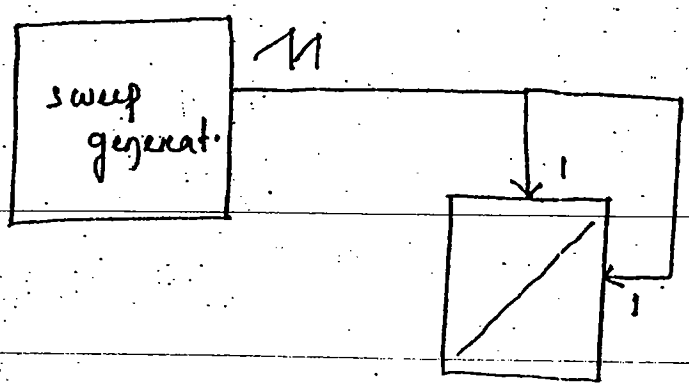
b) Horizontal st. line.

c) Sinewave.

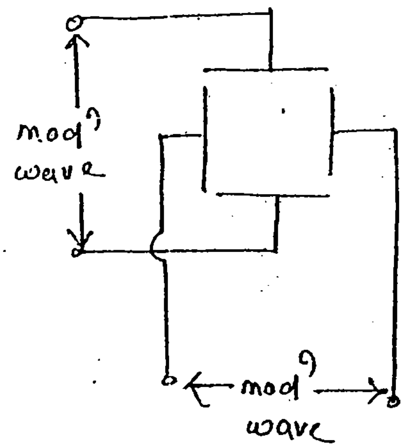
d) slant ~~wave~~ line.



Pb: A certain oscilloscope with 4cm x 4cm screen has it's own sweep o/p fed to it's i/p. If the x & y sensitivities are same, the oscilloscope will display a ______. (diagonal line)



Pb: ~~For msmt 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'.



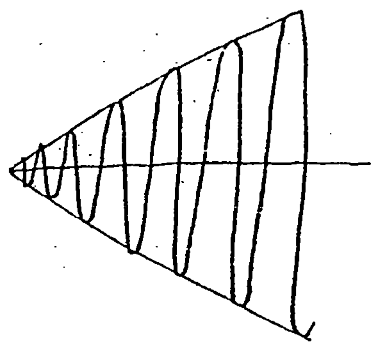
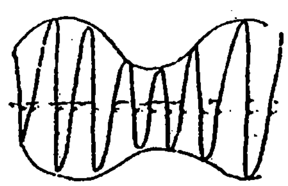


fig-(b)



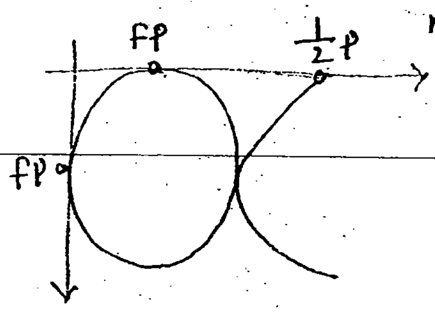
$$\boxed{m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}}$$

Pb: 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 ____

$$T_q = \sqrt{T_s^2 + T_q^2}$$

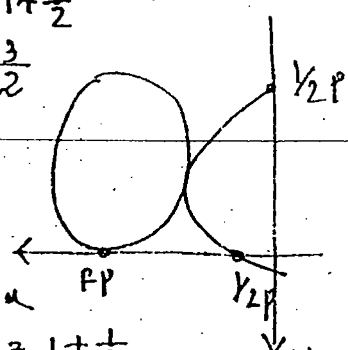
Pb: An oscilloscope is operated in x-y mode. The below lissajeous fig is displayed on the screen. If the frequency of signal is applied to x-i/p is 1KHZ. then the frequency of signal applied to y-i/p is

____



$n_x = 1 + \frac{1}{2} = \frac{3}{2}$

$n_y = 1.$



$n_x = 1 + \frac{1}{2} = \frac{3}{2}p.$

$n_y = \frac{1}{2} + \frac{1}{2} = 1.$

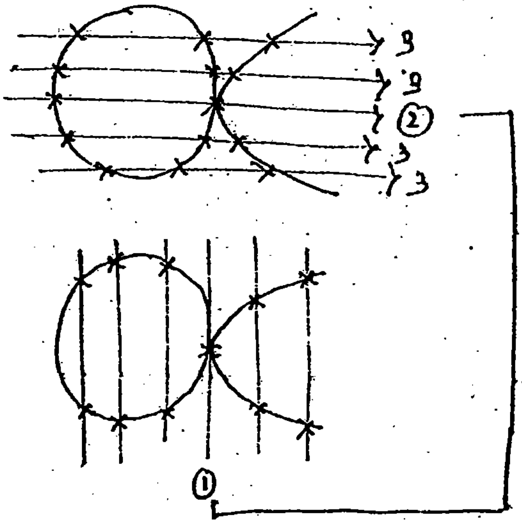
$$\frac{f_y}{f_x} = \frac{3/2}{1}$$

$$\boxed{\frac{f_y}{f_x} = 3:2.}$$

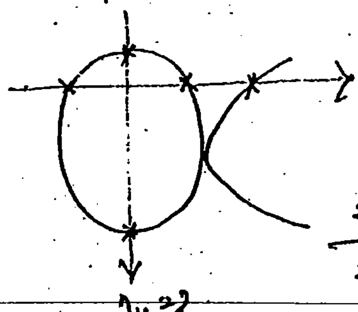
$$\frac{f_y}{f_x} = \frac{3/2}{1}$$

$$\boxed{\frac{f_y}{f_x} = 3:2.}$$

cut method :



Rule is violated.



$n_x = 3.$

$n_y = 2$

$$\frac{f_y}{f_x} = \frac{3}{2}.$$

The cut method is efficient where the no. of intersection is simple / or it is a trace method.

The touch method is efficient where the peak point are given in the fig.

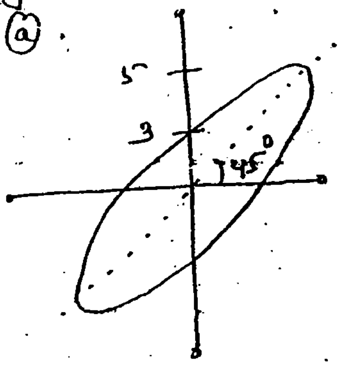
Pb: Two sinusoidal voltage of equal amp. and equal frequency are applied to the x- and y i/ps of CRO. and ellipse is examined on the screen. The peak y-deflection is at 5 div and it's intercept is at 3 div. Then the value of phase difference b/w the signals ______

(i) If the major axis of ellipse is inclined with x-axis at 45° (ii) If the major axis is inclined with x-axis at 135°.

$= \frac{1}{2} + \frac{1}{2}$

$= 1.$

(a).



$Y_{deflection} = 5\,div.$

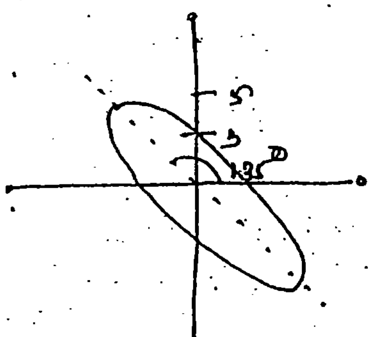
$Y_{intercept} = 3\,div.$

$\phi = \sin^{-1}\left(\frac{Y_{int}}{Y_{def}}\right) = 36.8^\circ.$

(b) $\phi = 180^\circ - \sin^{-1}\left(\frac{Y_{int}}{Y_{def.}}\right)$

$= 180^\circ - 36.8^\circ$

$= 36.86$



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 signal are ______ respectively.

Q no.

Examined.

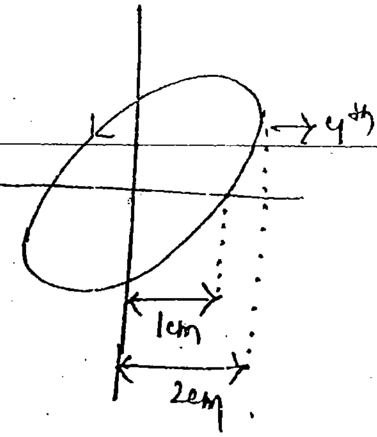
$\phi = \sin^{-1}\left(\frac{1}{2}\right)$

$= 30^\circ$.

$\rightarrow \phi = 360^\circ - \sin^{-1}(1/2)$

$= 360^\circ - 30^\circ$

$= 330^\circ$.

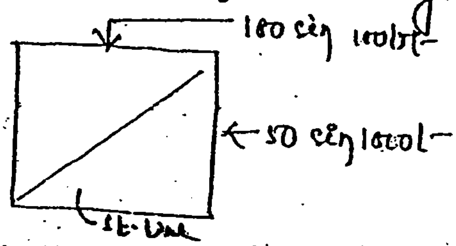


Pb: While measuring the phase difference b/w the signals $\eta \sin \omega t$ and $\eta \sin(\omega t + \phi)$, the Lissajous fig. observed in the screen is a circle, the value of $\phi = ?$ ($90^\circ \rightarrow$ clockwise

$270^\circ \rightarrow$ anticlockwise)

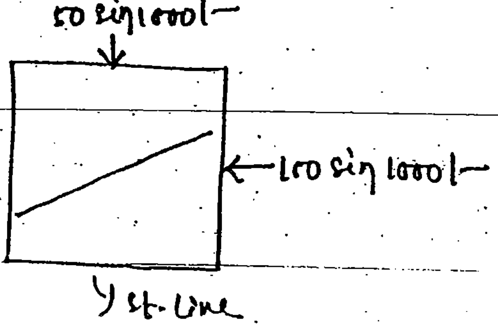
Pb: Voltages $100 \sin 1000t$ and $50 \sin 1000t$ are connected to vertical or Horizontal terminals of 'CRO'. Then the resulting Lissajous fig is ____.

sol:



st. line making an angle greater than 45° with (+ve) 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 (+ve) X-axis.

Pb: The x- and y i/ps to a CRO are $10\cos(100t+\pi)$ and $10\sin(100t+\pi)$. The resulting lissajious pattern on the screen is ______.

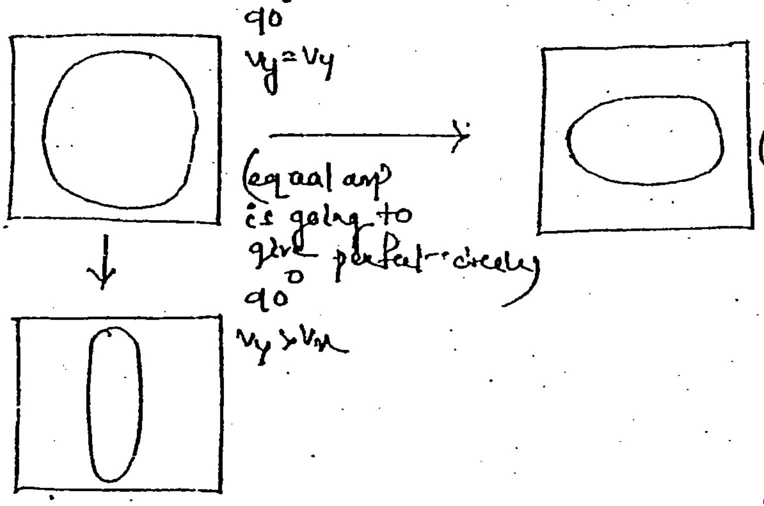
sol:

90°
$V_x = V_y$

(equal amp is going to give perfect circle)

90°
$V_x > V_y$
(more amp.)

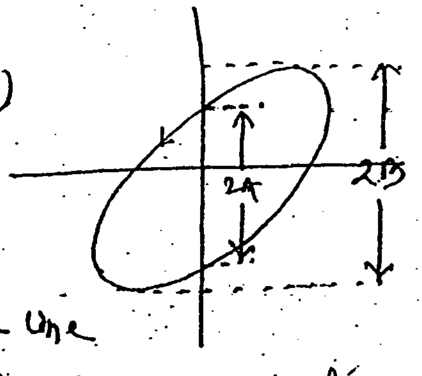
90°
$V_y > V_x$



Pb: The eliptical lissajious pattern shown in below fig was observed from 2 sinusoidal signal sources of same frequency on a 'CRO'. The phase angle b/w the signal is = ?

a) $\cos^{-1}(A/B)$ ✓ c) $\sin^{-1}(A/B)$

b) $\tan^{-1}(A/B)$ d) A/B.



Pb:
An oscilloscope screen displays a line inclined at 45°. It's y-i/p is a sinwave of frequency 'f'. Then the x-i/p should be ______.

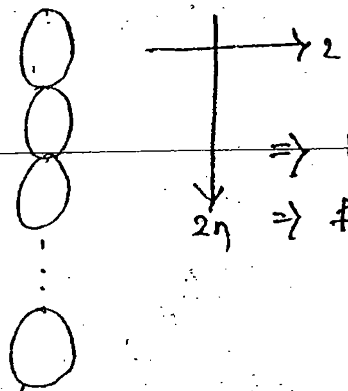
a) sawtooth wave of freq. 'f'.

b) sinwave of frequency 'f' and 90° phase shift with y-

✓ c) Sinewave of freq. 'f' and '0' phase shift with y-i/p

248 124

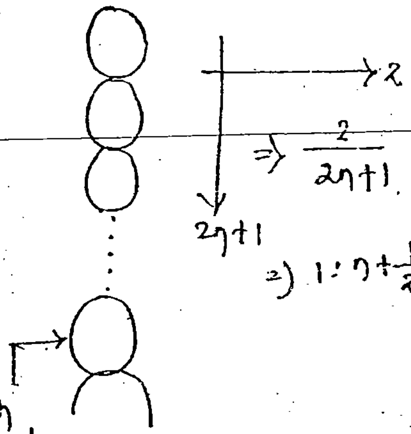
79



$\Rightarrow 1:n$

$\Rightarrow f_y = \frac{f_x}{n}$

nth circle



$\Rightarrow \frac{2}{2n+1}$

$\Rightarrow 1:n+\frac{1}{2}$

nth circle.

Amit Kumar