17/sept/2017 Measurement

Analog meters

- Indicating meters
  - Ⓥ
  - Ⓐ
  - Ⓦ
  - (PF)
- Energy meter
- Null Detector
  - Potentiometer

Indicating meter

order :- 2nd order

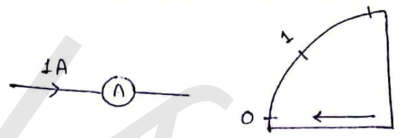
$$\frac{C(s)}{R(s)} = \frac{\omega n^2}{s^2 + 2\xi\omega n s + \omega n^2}$$

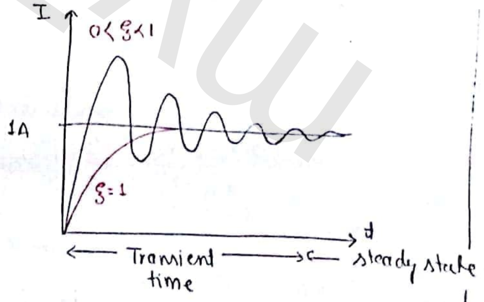
$0 < \xi < 1$ underdamped case

$\xi = 1$ Critical

For practical indicating meter

$$\boxed{\xi = 0.6 \text{ to } 0.8}$$





Torque

1) Damping Torque : To stop/damp oscillations at final steady state position so that response time is reduced.

Instrument	Damping
MI, EMMC	Air friction
Electrostatic	fluid friction
PMMC	Eddy current
Galvanometer	Electromagnetic

Controlling torque (T_c):

Spring control : $T_c = K\theta \Rightarrow$ Linear response

Graving " : $T_c \propto \sin\theta \Rightarrow$ Non-liner response

$T_c =$ N-m

$K =$ N-m/rad or N-m/degree

$\theta =$ Rad or degree

Deflecting torque.

$T_d \propto$ (Quantity to be measured)

At balance :

$$\boxed{T_d = T_c}$$

Electromagnetic instruments	T_d	T_c	$T_d = T_c$	Application
PMMC	$NBIA$	$K\theta$	$NBIA = K\theta$ $\boxed{\theta \propto I}$	Measures Idc, Vdc Rectifier meter, Thermal meter
MI	$\frac{1}{2} I^2 \frac{dL}{d\theta}$	$K\theta$	$K\theta = \frac{I^2}{2}\frac{dL}{d\theta}$ $\boxed{\theta \propto I^2}$	Measure AC & DC current voltage AC → RMS
EMMC/ ED (Electrodynamometer)	$I^2 \frac{dM}{d\theta}$	$K\theta$	$K\theta = I^2\frac{dM}{d\theta}$ $\boxed{\theta \propto I^2}$	measure ac & dc Transfer Instrument → calibrated for dc same is used for measurement of ac without recalibration

Q1 A PMMC instrument has a coil of dimensions 10mm x 8mm the flux density B in the air gap is 0.15 wb/m² if the coil is wound for 100 turns carrying a current of 5mA calc ① deflecting torque
② deflection if the spring contl is 0.2×10^{-6} N-m/degree

Sol

Solⁿ ① $T_d = NBIA$

$= 100 \times 0.15 \times 5\times10^{-3} \times 10 \times 8 \times 10^{-6}$

$= \frac{\cancel{100} \times 15}{\cancel{100}} \times 5 \times 10 \times 8 \times 10^{-9}$ ~~1000~~

$750 \times 8 \times 10^{-9} = 6000 \times 10^{-9} = 6 \times 10^{-6}$ N-m

② $T_d = T_c = K\theta$

$6 \times 10^{-6} = 0.2 \times 10^{-6} \times \theta$

$\theta = 30$ degree

Note :

- If pure AC signal is send to PMMC like $I = I_m \sin\omega t$ and the pointer vibrates near to zero because of inertia of the instrument. The avg value of $\sin\omega t$ is 0.
- If spring is broken or snapped then the pointer will come to zero initial position in case of PMMC b/c current is passing through the spring { in all other case pointer move to max^m posⁿ }.

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$= \frac{100 \times 15}{100} \times \frac{5 \times 10 \times 8 \times 10^{-9}}{1000}$

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Q2 Due to Temp^r Variat^n from 20°c Spring tension is reduced by 20%. and magnetic field is reduced by

① 20%.
② 10%.

then the error in the instrument is

Sol^n ① $K \longrightarrow$ ~~0.98K~~ 0.8K & $B \longrightarrow 0.8B$

~~0.8~~ $K\theta \longrightarrow N$ ~~0.8~~ $B I A$

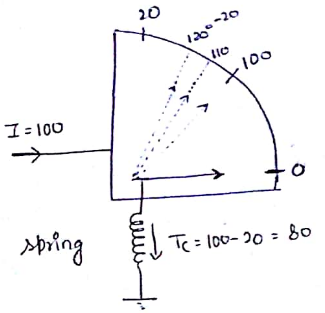
so no error

② $K \longrightarrow 0.8K$ $B \longrightarrow 0.9B$

$0.8K\theta \longrightarrow N\,0.9B\,I\,A$

~~$K\theta$~~ error = $T_d - T_c$ = $0.9 - 0.8 = 0.1 = 10\%$.

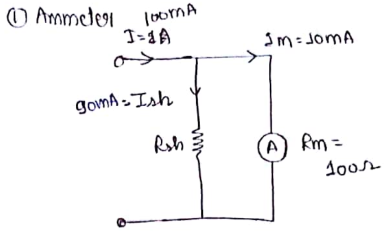
error in the instrument is 10%

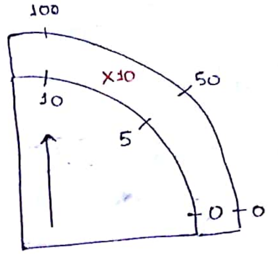


$T_2 = 40°c$
$\uparrow \Delta T = 20°c$
$T_1 = 20°c$

voltage
50

Enhancement of meters





$$Im = I \times \frac{Rsh}{Rsh+Rm}$$

$$Rsh = \frac{Rm}{\left(\frac{I}{Im} - 1\right)}$$

$$\boxed{Rsh = \frac{Rm}{m-1}}$$

$$\boxed{V_m = Im\,Rm = Ish \cdot Rsh}$$

$$\boxed{m = \frac{I}{Im} = \text{multiplication Factor}}$$

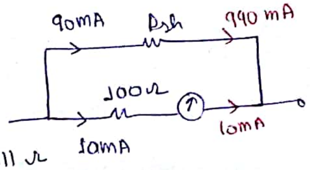
Rsh << Rm

~~Finding R~~

Q.3 A pmmc ammeter has meter resistance of 100Ω measures max^m current of 10mA. Calc^c voltage drop across the meter and shunt resistance required for measurement of

① 100mA
② 1 A.

Sol^n 3



① $100 \times 10\,mA = Rsh \times 90\,mA$

$Rsh = \frac{1000}{90}\,\Omega = \frac{100}{9}\,\Omega = 11.111\,\Omega$

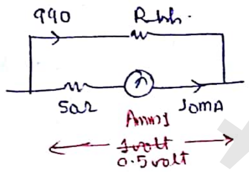
Voltag drop across the meter
$= 100 \times 10mA = 1volt$

Red ② $100 \times 10mA = Rsh \times 990\,mA$

$Rsh = \frac{1000}{990} = \frac{100}{99}\,\Omega$
$= 1.0101\,\Omega$

Q2 Du · mmeter has meter resistance of 50Ω measures FS current 10 mA
ch shunt resistance is required for measurement of 1 amp.
nother ammeter having meter resistance of 100Ω carrying FS curnt 10 mA find the shunt resistance required for measuring 1 amp of current
If these two meters are connected in parallel what is the maxm curnt able to measure through the ∥ combination.

Soln ①

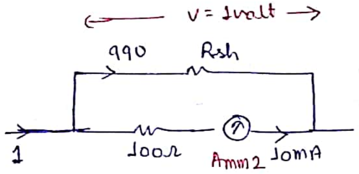


Amm 1 can bear 0.5volt, more than 0.5 volt will damage the insulation

$50 \times 10 = R_{sh} \times 990$

$R_{sh} = \frac{500}{990} = .505\Omega$

②

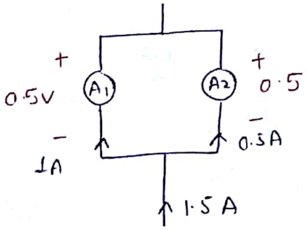


Ammeter 2 can bear maxm 1volt,

$100 \times 10 = 990 \times R_{sh}$

$R_{sh} = 1.01 \ \Omega$

③

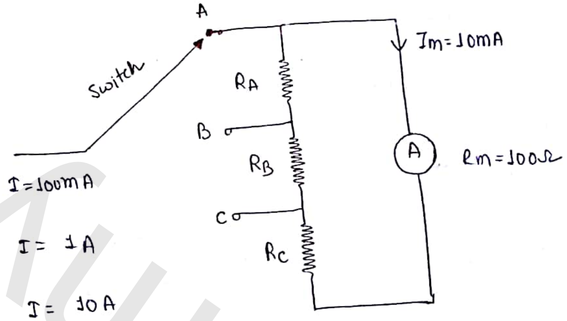


For A2

$0.5 = I \times 100$

Note: If the ammeters are to be connected in parallel then the minm voltage among all the meters is applicable to all the parallel meters. So that withstanding the insulation level of the meter.

Ayrton shunt :—



when current measured is high shunt resistance should low.

Switch at A:

$m = \frac{I}{I_m} = \frac{100}{10} = 10$

$(R_A+R_B+R_C) = \frac{R_m}{m-1} = \frac{100}{9}$ —①

Switch at B:

$$m = \frac{I}{I_m} = \frac{1000}{10} = 100$$

$$R_B + R_C = \frac{R_A + R_m}{m-1} = \frac{R_A + 100}{100-1} \quad — ②$$

Switch at C:

$$m = \frac{I}{I_m} = \frac{10000}{10} = 1000$$

$$R_C = \frac{R_A + R_B + R_m}{m-1} = \frac{R_A + R_B + 100}{1000-1} \quad — ③$$

eq^n

$$(R_A + R_B + R_C) = \frac{100}{9} \quad — ①$$

① - ②

$$R_A = \frac{11 \times 100}{11 \times 9} - \frac{R_A + 100}{99}$$

$$99 R_A = \underline{1100 - R_A - 100}$$

$$99 R_A + R_A = 1000$$

$$100 R_A = 1000$$

$$\boxed{R_A = 10\Omega}$$

① - ③

$$R_A + R_B = \frac{100}{9} - \frac{(110 + R_B)}{999}$$

$$10 + R_B = \frac{11100 - 110 - R_B}{999}$$

$$9990 + 999 R_B + R_B = 10990$$

$$1000 R_B = \frac{10990}{9990}$$

$$R_B = \underline{1.1} \times 10^{-3} = 1.1 mA$$

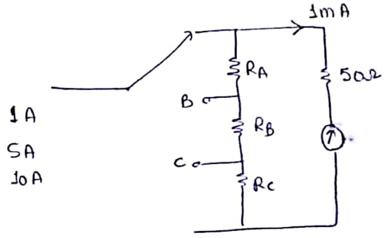
Put in ①

$$10 + 1.1 \times 10^{-3} + R_C = 100/9$$

$$R_C = 1.11\Omega$$

Q.6. Design a Ayrton shunt to provide an ammeter with current range of 1A, 5A, 10 A with basic meter resistance of 50Ω and full scale deflection current of 1 mA

Sol^n



①
$$m = \frac{I}{I_m} = \frac{1000}{1} = 1000$$

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

$$R_A + R_B + R_C = \frac{50}{1000-1} \quad — ①$$

②
$$m = \frac{5000}{1} = 5000$$

$$R_B + R_C = \frac{R_A + 50}{5000 - 1} \quad — ②$$

③
$$m = \frac{10000}{1}$$

$$R_C = \frac{R_A + R_B + 50}{10000 - 1} \quad — ③$$

$$R_A = \frac{50}{999} - \frac{(R_A + 50)}{4999}$$

$R_A = 0.04\Omega$
$R_B = 5 m\Omega$
$R_C = 5 m\Omega$

Effect of Temperature on ammeter

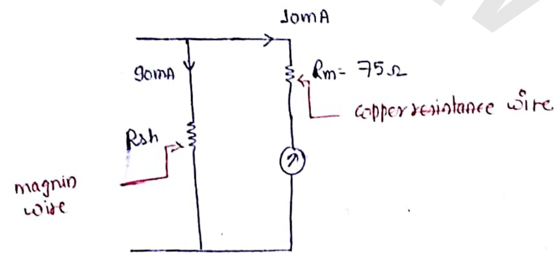
By the addition of $\boxed{\text{Swamp resistance}}$ in series with the meter Effect of temp^r is reduced.

Q7 An ammeter has meter Resistance of 75Ω measures current up to 10mA the a meter is made of copper $\alpha = 0.0004/°C$

① How much of shunt is required for measurement of 100mA.

② Find the error in the meter if the temp^r raise of 25°C the α for magnin shunt is 0.00015/°C

③ If a swamp resistance of 35 Ω is connected in series to the meter Finding the error for temp^r Range of 25 °C swamp is made of magnin.



① $$90 \times Rsh = 10 \times 75$$

$$Rsh = \frac{750}{90} = \frac{75}{9} = 8.3\ \Omega$$

② $\Delta T = 25$

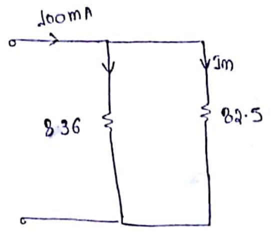
$$Rm_2 = Rm_1 [1 + \alpha \Delta T]$$

$$= 75 [1 + 0.004 \times 25]$$

$$Rm_2 = \cancel{75}\ 82.5\ \Omega$$

$$Rsh_2 = \cancel{\frac{10 \times 82.5}{90}} = \cancel{\frac{82.5}{9}}$$

$$Rsh_2 = 8.3 [1 + 0.0015 \times 25] = 8.36$$



$$Im = \frac{100 \times 8.36}{8.36 + 82.5}$$

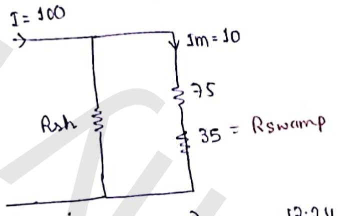
$= 9.205\text{mA}$ [measured value]

$$\% Er = \frac{MV - TV}{TV} \times 100$$

$$= \frac{9.205 - 10}{10}$$

$$\% Er = -7.98\ \%$$

③



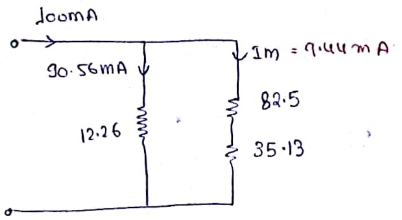
$$Rsh = \frac{Rm}{(m-1)} = \frac{(75+35)}{(10-1)} = 12.24\ \Omega$$

$\Delta T = 25°C$

$$Rsh_2 = 12.24 [1 + 0.00015 \times 25] = 12.26\ \Omega$$

$$R_{sw_2} = 35 [1 + 0.00015 \times 25] = 35.13\ \Omega$$

$$Rm_2 = 82.5\ \Omega$$



$$Im = \frac{100 \times 12.26}{82.5 + 35.13 + 12.26}$$

$= 9.44 mA$ = measured

$$\% Gr = \frac{9.44 - 10}{10} \times 100$$

$= -5.5\%$

Note: ammeter which has minimum full scale value has higher sensitivity

Ex three amm A, B, & C are having a full scale values of 5A, 2A, & 1A then ~~when~~ the sensitivity of the meter in ↑ing order.

Sol^n A B C

Note: In case of AC ammeter like MI, EMMC etc the shunt time constant and meter time constant are to be maintained equal for making the instrument independent of frequency.

Q A MI ammeter has meter resistance of 100Ω and inductance of 20 mH is designed to work independent of frq^c then the time const of shunt is ______ sec.

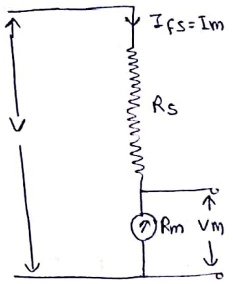
$$\tau = \frac{L}{R} = \frac{\cancel{100}}{\cancel{20}} \frac{20}{100} \times 10^{-3} = 0.2 m sec$$

Enhancement of Voltmeters

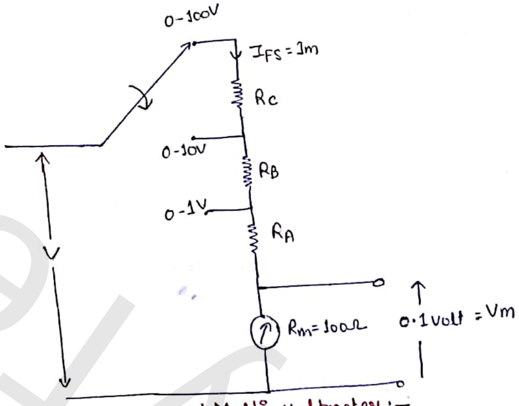
$$m = \frac{V}{V_m}$$

$$\boxed{R_s = R_m [m-1]}$$

$$\boxed{S_v = \frac{1}{I_{FS}} = \frac{(R_s + R_m)}{V}} \ldots \Omega/V$$



$R_s >> R_m$



–: Multi voltmeter :–

0-1 volt $m = \frac{1}{0.1} = 10$

$R_A =$

$R_A = R_m[m-1] = 100[10-1] = 900\Omega = 0.9 K\Omega$

$R_A + R_B = 100\left[\frac{10}{0.1} - 1\right]$

$100[99] = 9900 \Omega = 9.9 K\Omega$

$$\boxed{R_B = 9900 - 900 = 9K\Omega}$$

$R_A + R_B + R_C = 100[1000-1] = 99900 \Omega$

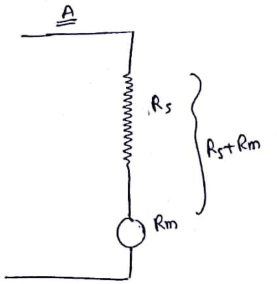
$R_C = 99900 - 9900 = 90000 = 90 K\Omega$

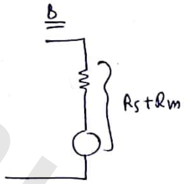
O=IV

m =

3Q. two voltmeter A and B having sensitivies of 1kΩ/volt and 2kΩ/volt and each has a range of 0–100 volts are connected in series. what is the maximum voltage is able to measure by the series combination.

Solⁿ.





$S_v = 1k\Omega/V$

$I_{FS} = 1mA$

$V = 0-100V$

$(R_s + R_m) = \frac{100}{1} = 100k\Omega$

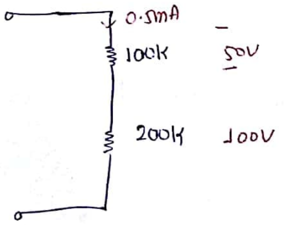
$S_v = 2k\Omega/V$

$I_{fs} = 0.5\,mA$

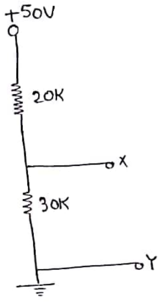
$V = 0 — 100V$

$(R_s + R_m) = \frac{100}{.5} = 200K\Omega$

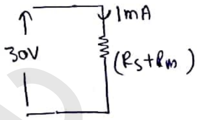
$Min^m\ I = 0.5\,mA$



Q. Two voltmeters having a range of (0-30)volt and sensitivities of 1kΩ/volt and 1MΩ/volt are used to measure voltage across 30KΩ. the ckt shown in fig find the reading of each meter and error in each meter

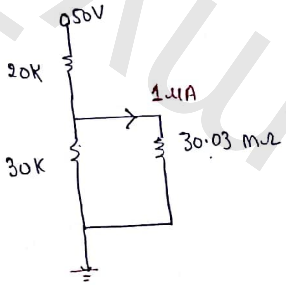


$I_{FS1} = 1mA$

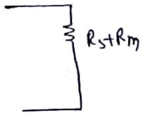


$30 = 1\,mA(R_s+R_m)$

$R_s + R_m = 30K\Omega$



$I_{FS2} = 1\,\mu A$



$R_s + R_m = 30\,M\Omega$

$TV = \frac{50 \times 30}{50} = 30V$

$mV = 30.03\ Volt$

$\%\ er = \frac{.03}{30} = 0.1\%$

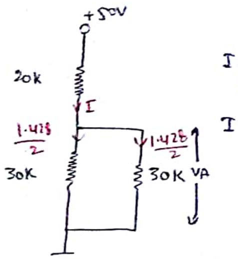
By Sm

$V_{True} = TV = \frac{50 \times 30}{30+20} = 30V$

① A : $S_V = 1K\Omega/V$, $I_{fs} = 1mA$

0-30 V

$R_s + R_m = V \cdot S_V = 30K\Omega$



$I = \frac{50}{(20+15)}$

$I = 1.428mA$

$V_A = \frac{1.428}{2} \times 30$

$= 21.428V$

$=$ Measured

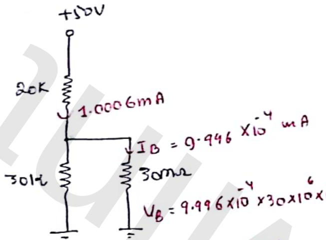
$\% Gr = \frac{21.428 - 30}{30}$

$\boxed{\% Gr = -28.56\%}$

① B : $S_V = 1M\Omega/V$

0-30 V

$R_i + R_m = 30M\Omega$



$I_B = 9.946 \times 10^{-4}$ mA

$V_B = 9.996 \times 10^{-4} \times 30 \times 10^{6} \times 10^{-3}$

$= 29.983V$

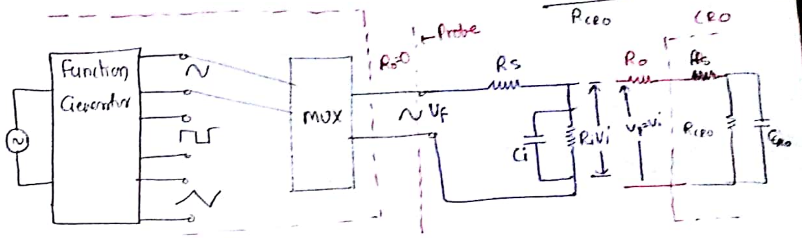
$R_s + R_m =$

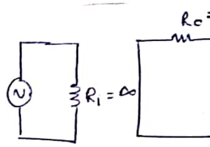
$\% Gr = \frac{29.988 - 30}{30} \times 100$

$\boxed{\% Gr = -0.04\%}$

- voltmeter having High resistance, have high sensitivity
- A voltmeter must have high i/p resistance, ideal cond^n is ∞ and low o/p Resistance
- voltmtr with higher sensitivity has high resistance so that loading effect is less and accuracy is higher.
- If any connecting channel is used to transfer the voltage s/g must have High i/p resistance and low o/p Resistance so that loading effect is less
- A Buffer amp^r (CC), op amp has $R_i = \infty$ and, $R_o = 0$ so that there is no attenuation of sampled signal i.e gain = 1 (in CC)

$\frac{R_i + R_{CRO}}{R_{CRO}} = 10$, $R_i = 9 R_{CRO}$





$V_i = \frac{V_F \, R_i}{R_s + R_i}$

if $R_i = \infty$, $V_i = V_F$

$V_p = \frac{V_i \times R_L}{R_L + R_o}$

$R_o \to 0$ $V_p = V_i \Rightarrow V_F$

Note

Probe is used to transfer function generator o/p signal to the CRO

the o/p Resistance of func gen^r must be of low value [practical value : 50Ω]

To avoid loading effect the ~~[illegible]~~ 10x probe is used i.e $\frac{R_{probe} + R_{CRO}}{R_{CRO}} = 10$;

Function gen^r is delivering different signal with wide range of frq^c from Hz to MHz these signals must pass thorough the probe i.e probe must be independent of frq^c by maintaining time const of the probe and CRO are to be equal.

$\boxed{R_{probe} \, C_{probe} = R_{CRO} \cdot C_{CRO}}$

A CRO has i/p resistance of 1 MΩ and i/p capacitance of 25 pF parallel to the Resistance

Q Design a 10x probe which is connected b/w Function Gen^r and CRO if a CRO has i/p Resistance of 1 mΩ and ~~O/p Resistance~~ i/p capacitance of 25 pF parallel to the Resistance

Sol^n

$9 \times C_{probe} = 25pF \times 1 m\Omega$

$C_{probe} = 2.77 pF$

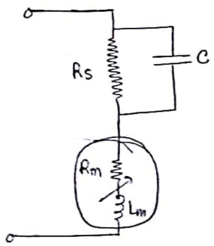
$R_{probe} = 9 R_{CRO}$

Note* Digital multimeter uses operational Amplifiers, Buffer amp^r which has higher i/p resistance so that loading effect is very less bcz sensitivity is higher, compared to analog multimeters

an AC voltmeter is made independent of supply frequency by connecting capacitance in parallel to the ~~Rest~~ series multiplier resistance

$C \simeq 0.41 \frac{L_m}{R_s^2}$

$R_s C \simeq 0.41 \frac{L_m}{R_s}$



Q An ac voltmeter has meter resistance of 100Ω and inductance of 10 mH is connected with series multiplier resistance of 10kΩ How much of compensating capacitance is required for making meter independent of freq^c

$C = \frac{0.41 \times (10 \times 10^{-3})}{100 \times 10^{6}}$

$C = \frac{41 \times 10^{-3} \times 10^{-6} \times 10^{-8} \times 10^{-1}}{} = 41 \times 10^{-18}$ F

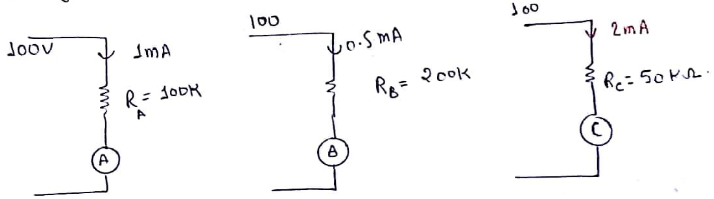
Q three voltmeters having ABC are specified

A: 0–100V , 1KΩ/V

B: 0.5mA , 0–100V

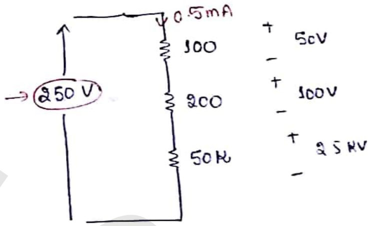
C: 50KΩ , 0–100V

what is the reading of meters A, B, C if a i/p voltage is 250volts if they are connected in series.



We cont send more than 0.5 mA.

we applied → 250 V



but 50+100+25 = 175V so we can't apply more than 175 V

Vmax = 175 V

Maximum measurable voltage is 175 volts

MI meters

Q Inductance of moving iron instrument is given by $L = (12 + 6\theta - \theta^2)\,\mu H$ where θ (deflection in radian) from zero posn. spring coil is $12 \times 10^{-6}\ \frac{N\text{-}m}{rad}$ calculate deflection in radians and degrees for a current of 8 amps.

Soln

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

$$12 \times \cancel{10^{-6}} \times \theta = \frac{(8)^2}{2}\left[6 - 2\theta\right] \times \cancel{10^{-6}}$$

$$\frac{24}{64}\theta = 6 - 2\theta$$

$$\theta\left(\frac{24}{64} + 2\right) = 6$$

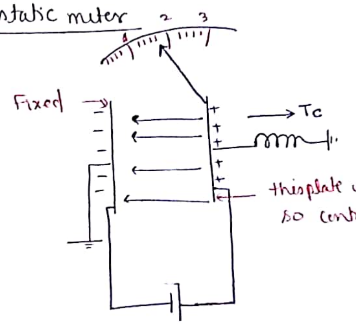
$$\theta\ \frac{\cancel{12}}{\cancel{32}}\ \frac{\cancel{6}}{16}\left(\frac{3}{8} + \frac{2\cdot 8}{8}\right) = 6$$

$$\theta\ \frac{19}{8} = 6$$

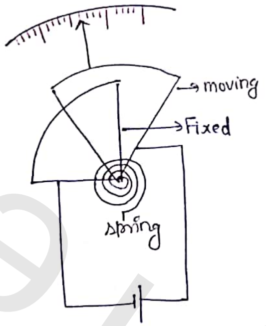
$$\theta = \frac{8 \times 6}{19} = \frac{48}{19} = 2.53\ rad^n$$

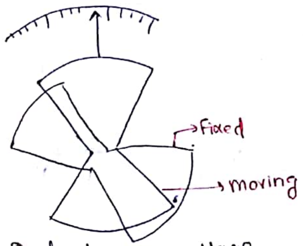
$$\theta = 144.74^0$$

Electrostatic meter



this plate will move toward fixed plate so controlling torque $T_c = K\theta$ will be applied



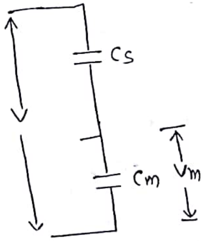


Quadrant + ES voltage

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

$$\boxed{\begin{array}{l} T_d = \frac{1}{2}\ V^2 \cdot \frac{dc}{d\theta} \Rightarrow ES \\ T_c = K\theta \end{array}}$$

$$\boxed{T_d = T_c}$$



$$V_m = \frac{V \cdot C_s}{(C_s + C_m)}$$

$$\frac{C_s + C_m}{C_s} = \frac{V}{V_m} = m$$

$$1 + \frac{C_m}{C_s} = m$$

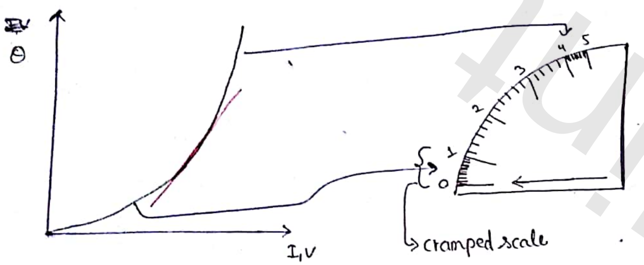
$$\boxed{C_s = \frac{C_m}{(m-1)}}$$

Condition for linearity

MI ⇒ $\theta \cdot \frac{dL}{d\theta}$ = constant

EMMC ⇒ $\theta \frac{dM}{d\theta}$ = constant

ES ⇒ $\theta \cdot \frac{dC}{dV}$ = const



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

Q In Electrostatic voltmeter controlled by a spring a spring const of 4×10^{-6} $\frac{Nm}{rad}$ and has a full scale deflection of 90° when voltage of 1500 voltag is applied to it, the capacitance at zero voltage is 10 pF. find the capacitance when the pointer indicates 1500 volts

$0V \longrightarrow 10\,pF$

$\theta = \pi/2 \longrightarrow 1500$

Soln

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

$$4\times10^{-6}\,\theta = \frac{1}{2}\times 1500^2 \times$$

$$4\times10^{-6}\times\frac{\pi}{2} = \frac{1}{2}\times1500^2\times\frac{dc}{d\theta}$$

$$2\frac{4\times10^{-6}}{(1500)^2}\times\frac{\pi}{2} = \frac{dc}{d\theta} = 5.585\times10^{-12}$$

$$dC = 5.585\,d\theta$$

$$C = 5.585 + \text{Const}$$ ↳ cap at θ=0

$$C = 5.585\theta + 10$$

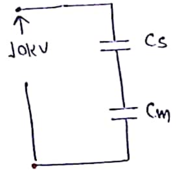
$$C = 5.585\times\frac{\pi}{2} + 10$$

$$= 18.77\ pF$$

Q capacitance of 0–1000V, electrostatic voltmeter Tes uniformly from 36 to 42 pf. from 0 to full scale deflection if is required to extend the range of voltmeter to 10kV by using an external series capacitor calc the value of series capacitor.

$$m = \frac{10000}{1000} = 10$$

before we could measure 1000V by adding $C_s = 4.66\,pF$ we can measure 10kV.



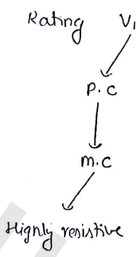
$$C_s = \frac{C_m}{(m-1)} = \frac{36}{9} = 4\ pF$$

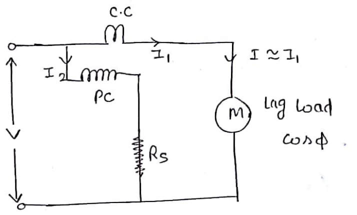
$$C_s = \frac{C_m}{m-1} = \frac{42}{9} = 4.667\ pF$$ // Answer

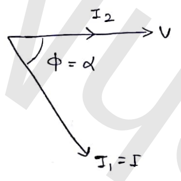
bcz we need to take higher value

capacitive voltage Xmer [CVT] is working on the principle of electrostatic voltmeter used for measurement of large bus bar or feeder voltages. Ig in the 11, 33, 132 kV substation etc

Wattmeter







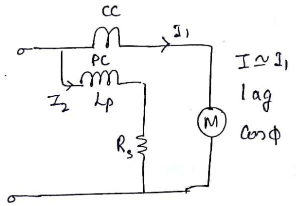
$$T_d = I_1 I_2 \cos\alpha \cdot \frac{dM}{d\theta} = k\theta$$

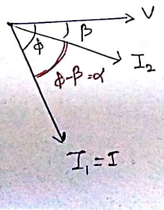
$$= I \cdot \frac{V}{R_s} \cos\phi \frac{dM}{d\theta}$$

$$T_d = \frac{P_{avg}}{R_s} \cdot \frac{dM}{d\theta} = k\theta$$

$$\boxed{\theta \propto P_{avg}}$$

P.C containing Inductance (L_p):





$P_T = VI\cos\phi$

$P_m = VI\cos\beta\cos(\phi-\beta)$

$$\boxed{\text{Correction Factor } [C_F] = \frac{\cos\phi}{\cos\beta\cos(\phi-\beta)} = \frac{P_T}{P_m}}$$

$$\boxed{\%Er = \frac{P_m-P_T}{P_T}\times 100 \approx \tan\phi\tan\beta\times 100}$$

Error due to potential coil inductance

$$\boxed{\text{absolute error} = P_m-P_T = \tan\phi\tan\beta\times P_T}$$

$$\boxed{C_F = \frac{1}{1+\tan\phi\tan\beta}}$$

ϕ = p.f angle of Load

error in watts due to L_p

Error in watts :

ⓐ Lag Load : ϕ = +ve

$P_e = P_m - P_T = \boxed{VI\sin\phi\tan\beta}$

$\boxed{P_m = (P_T + VI\sin\phi\tan\beta)}$

$\boxed{P_m > P_T}$ $\%Er$ = +ve

ⓑ Lead Load ϕ = -ve

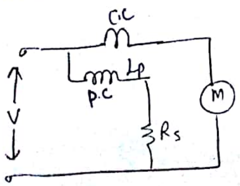
$P_e = P_m - P_T = -VI\sin\phi\tan\beta$

$\boxed{P_m = P_T - (VI\sin\phi\tan\beta)}$

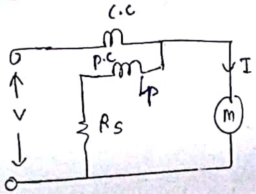
$\boxed{P_m < P_T}$ Er = -ve

Error due to Connection :-

① P.C on source side



② PC on Load side



)

$P_m = P_T + I^2 r_c$

$\% Er = \frac{I^2 r_c}{P_T}\times 100$

r_c = C.C resistance

** when asked total error on source side

= error due to L_p + error due to current coil

$VI\sin\phi\tan\beta + I^2 r_c$

$P_m = P_T + \frac{V^2}{R_s}$

$\% Er = \frac{V^2}{R_s P_T} \times 100$

when asked total error on load side

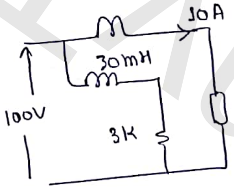
= error due to L_p + error due to P.C

Q: An electrodynamometer is used for measurement of Power in a Single phase ckt the load voltage is 100 volts and the load current is 10 amps. at a pf of 0.2 wattmtr voltage ckt has a resistance of 3 kΩ and a inductance of 30 mH calc the % error in the wattmtr reading when pressure coil is connected

① on the. supply side

② on the Load side

The current coil has a resistance of 0.1 Ω and negligible inductance the freq is 50Hz.



$\cos\phi = 0.2$

$Pf = 0.2$

$\phi = 78.46°$

$\beta = \tan^{-1}\frac{2\times 50\times\pi\times 30}{1000\times 3000}$

$\beta = 0.179°$

① error when PC at supply side

$= (10)^2 \times (10)^2 \times r_c = 100\times 0.1 + VI\tan\beta\sin\phi$

$= 10 + 100\times 10\times 3.14\times 10^{-3}\times 0.9797$

$= \frac{~~11.11~~\ 13.077}{100\times 10\times 0.2} = ~~7.05\%~~ \quad 6.538\%$

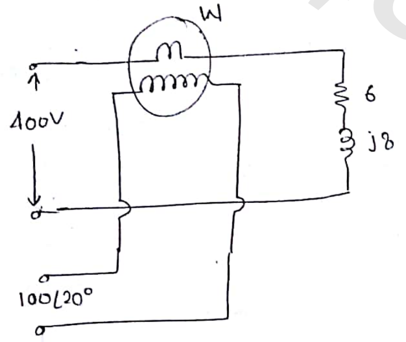
on load side

$$= \frac{V^2}{R_s} + \quad VI \sin\phi \tan\beta$$

$$= \frac{(100)^2}{3000} + \quad 3.076$$

$$= \frac{6.333 \times 100}{VI \cos\phi} = \frac{\cancel{6.33.}\ 6.33 \times \cancel{10}}{\cancel{100} \times 10 \times 0.2} = 3.166\%$$

Q For a following ckt calculate reading of wattmeter

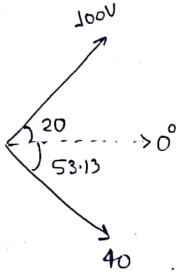


$P = VI \cos\phi$

$$I = \frac{400}{(6+j8)} = \frac{400}{\sqrt{64+36}\ \angle \tan^{-1}\frac{8}{6}} = 40\angle -53.13^\circ$$

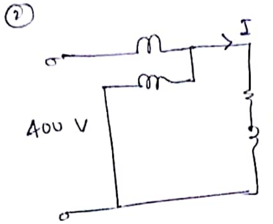
$P = 100 \times 40 \times \cos(73.13^\circ)$

$= 1160.80$ watt



Q find out wattmeter reading

②



~~VI =~~ 100 ×

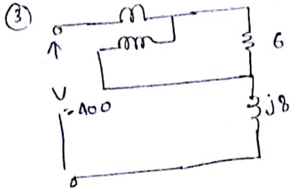
$$I = \frac{400}{6+j8} = 40\angle -53.10$$

$P = 400 \times 40 \times \cos 53.10$

$\boxed{P = 4 \times 2401.68 \text{ W}}$

$= 9600$ watt

③



$$I = \frac{400}{6+j8} = 40\angle -53.10$$

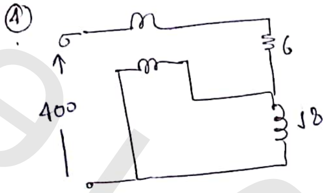
$V = 6 \times 40\angle -53.10$

$= 240\angle -53.10$

$P = 240 \times 40 \times \cos 0$

$\boxed{P = 9600 \text{ W}}$

④



$I = 40\angle -53.10$

$V = 40\angle -53.10 \times 8\angle 90^\circ$

$V = 320\angle 36.9^\circ$

$P = 40 \times 320 \times \cos 90^\circ$

$\boxed{P = 0 \text{ watt}}$

Q

PC ⇒ $V = V_0 + V_{m1}\sin(\omega t + \alpha_1) + V_{m2}\sin(2\omega t + \alpha_2) + \ldots$

CC ⇒ $i = I_0 + I_{m1}\sin(\omega t + \beta_1) + I_{m2}\sin(2\omega t + \beta_2 t)$

Wattmeter Reading = P_{avg}

$$= V_0 I_0 + \frac{1}{2}\left[V_{m1} I_{m1}\cos(\alpha_1 - \beta_1) + V_{m2} I_{m2}\cos(\alpha_2 - \beta_2) + \ldots\right]$$

Ex:- $V = 10 + 5\sin(\omega t + 45^\circ) + 2\sin(2\omega t + 30^\circ)$

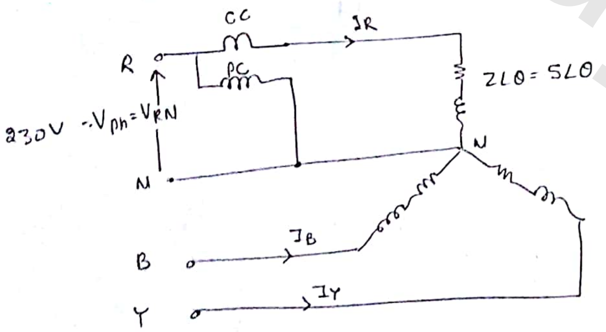
$i = 8 + 4\sin(2\omega t - 15^\circ)$

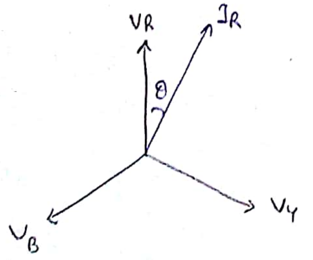
$$P = 10\times 8 + \frac{5\ 2\times 4}{\sqrt{2}\ \sqrt{2}} \times \cos 45^\circ$$

$$80 + 4 \times \frac{1}{\sqrt{2}}$$

$$P = 82.828W$$

3ϕ wattmeters



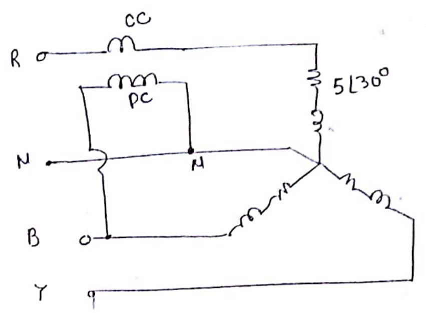


$$W = V_{pc} \times I_{cc} \times \cos \angle V_{pc} - I_{cc}$$

$$= |V_{RN}||I_R| \cos\angle\theta$$

$$= 230 \times \frac{230}{5} \times \cos 30^\circ$$

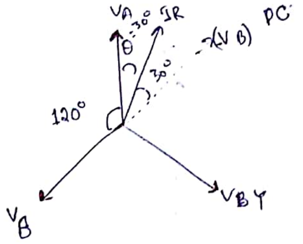
$$= 9162.55 \text{ watt}.$$

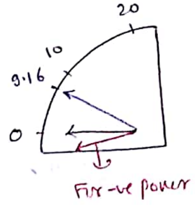


$$W = \frac{230 \times 230}{5} \times \cos(120 + 30^\circ)$$

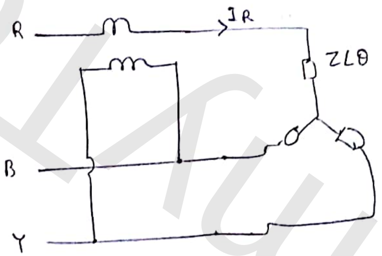
$$= -9.16kW$$

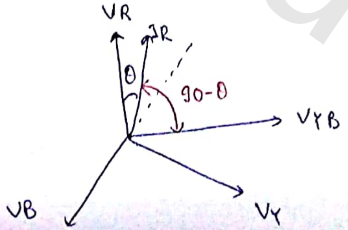
If wattmtr reads −ve value reverse either Pc or cc terminals for measurement of the power & Record with −ve sign.





For −ve power it try to go down



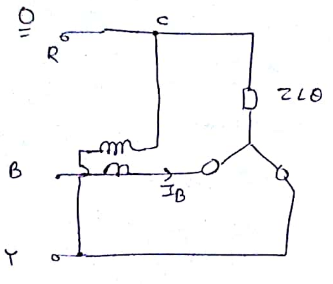


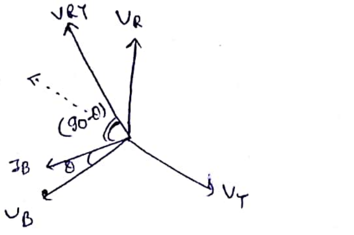
$$W = V_{YB} I_R \cos(90 - \theta)$$

$$\boxed{W = V_L I_L \sin\phi}$$

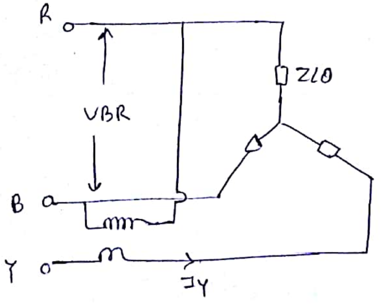
↳ wattmtr measuring reactive power.

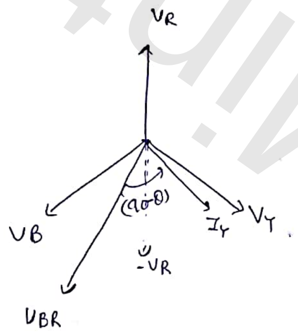
Q





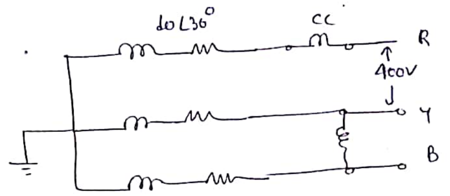
$W = I_B \times V_{RY} \times \cos(90 \pm \theta)$

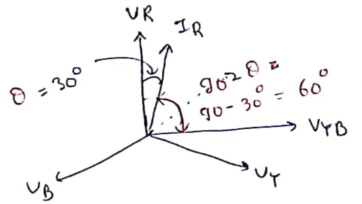




○ if current coil is connected to one phase or potential coil is connected to remaining two phases then the wattmeter measures reactive power

? For the ckt shown in the figure find the wattmeter reading





$I = \frac{400}{\sqrt{3}\ 10\angle 30} = \frac{40}{\sqrt{3}}\angle -30° = 23.1\angle -30°$

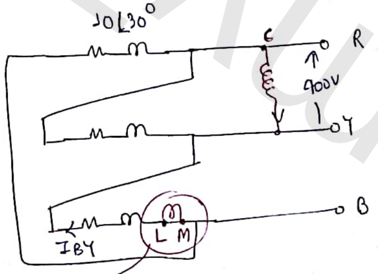
$V_{YB} \times I_R \times \cos(90-\theta)$

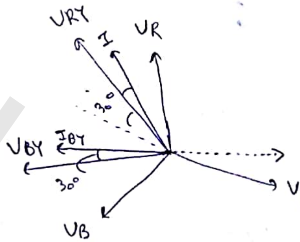
$V_{YB} \times I_R \sin\theta$

$= 400 \times \frac{40}{\sqrt{3}} \times \sin 30° \cdot \frac{400 \times 40}{\sqrt{3}} \times \frac{1}{2}$ watt

=

Q



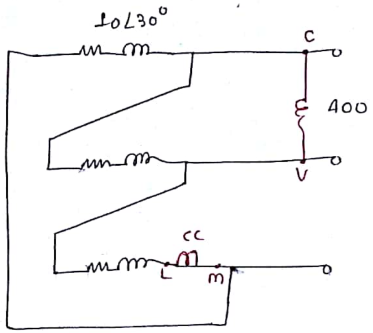


take care of sense L and m.

$I_{BY} = \frac{V_{BY}}{10\angle 30} = \frac{400}{10} = 40\angle -30°$

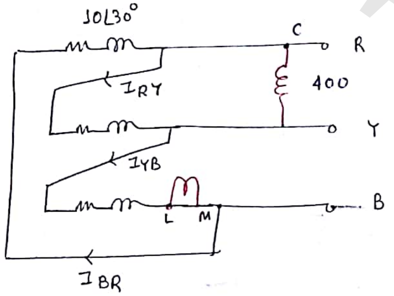
$W = 400 \times 40 \times \cos 30° = 400 \times 40 \times \frac{\sqrt{3}}{2} = 13856.4$ watt

Q

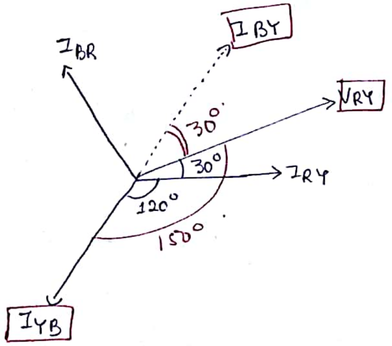


Find loading of wattmeter

Solⁿ



$|I_{RY}| = \left|\frac{400}{10}\right| = 40$



$P = V_{RY}\, I_{YB} \cos 150^\circ = -ve$ power.

$P = 400 \times 40 \times (-0.866) = -13.85$ KW

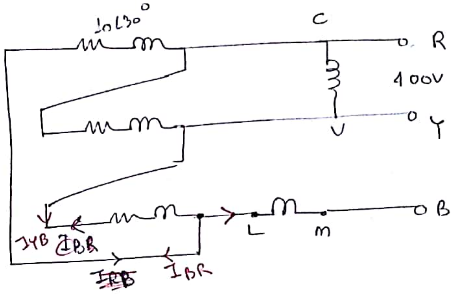
{-ve power, so take reading by either interchange current CC terminal or PC terminals}.

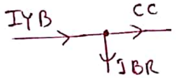
$V_{RY} \quad I_{BY}$

$P = 400 \times 40 \times \cos 30^\circ$

$= 13.85$ KW

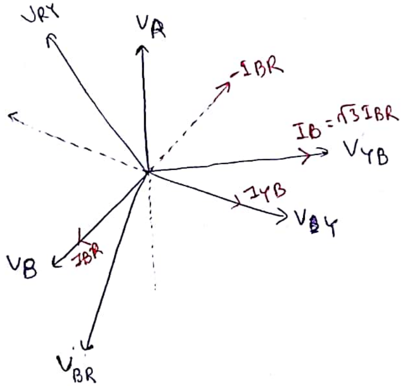
Q





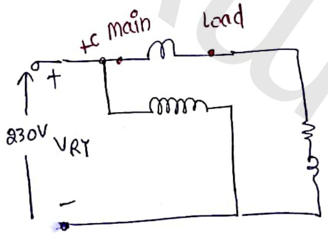
$I_{YB} = CC + I_{BR}$

$I_{YB} - I_{BR}$



$= V_{RY} \cdot \sqrt{3} I_{BR} \times \cos 120^\circ$

$400 \times \sqrt{3} \times$



***

In current coil

main = +ve terminal

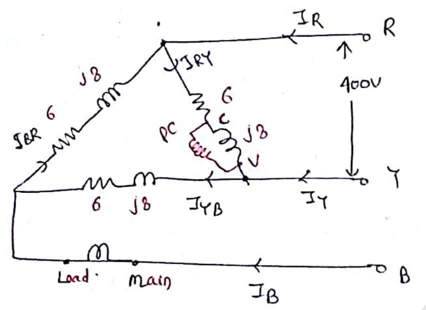
Load = -ve terminal

In pressure coil

C = +ve terminal

V = -ve terminal

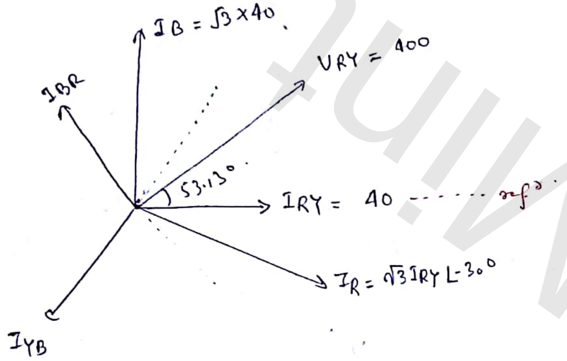
Q



Soln

6+j8

$\phi = \tan^{-1}\frac{8}{6} = 53 \cdot 13^{\circ}$



$I_{RY} = \frac{400}{10\angle 53.13} = 40\angle -53.13^{\circ}$

$V_{p.c} = j8 \times 40 = 320\angle 90^{\circ}$

$W = \cancel{3} \times 320 \times 40 \cancel{\times \cos} 0$ ×r

$W = 320 \times 40 \times \sqrt{3}$

$$\boxed{W = 22.17 \text{ kW}}$$

Instrument Transformer

CT

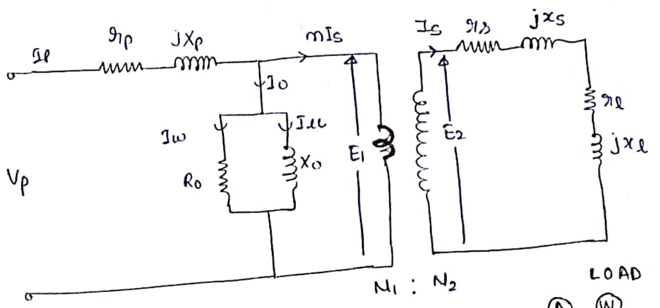
PT

E_1 is in phase with I_w.

I_w.

I_s lag E_2 by γ

① CT



Ⓐ Ⓦ

Ⓡ Relay

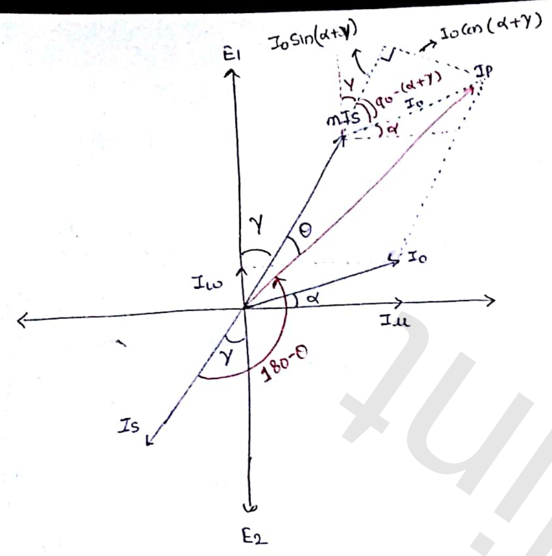
(EM) Energy meter/Ⓦ cc of ~~cc of~~

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

Nominal ratio $= K_n = \frac{I_p}{I_s} = \frac{\vec{I_o} + mI_s}{I_s}$

Actual / Transformation ratio $= R = \frac{\vec{I_p}}{\vec{I_s}}$

γ = secondary Burden angle $\Big\} = \tan^{-1}\left(\frac{x_l + x_s}{r_l + r_s}\right)$



Transformation ratio (R)

① If $\gamma \neq 0$

$$R = \frac{I_p}{I_S} = n + \frac{I_0 \sin(\alpha+\gamma)}{I_S} \quad \text{or} \quad \frac{nI_S + I_0 \sin(\alpha+\gamma)}{I_S}$$

$$= n + \frac{I_0 \sin\alpha \cos\gamma + I_0 \cos\alpha \sin\gamma}{I_S}$$

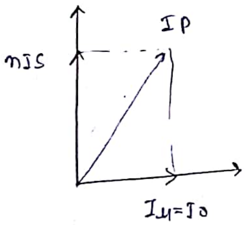
$$\boxed{R = n + \frac{I_w \cos\gamma + I_u \sin\gamma}{I_S}}$$ ← valid for all γ except γ=0

② If $\gamma = 0$

(purely resistive branch)

Assume $I_w \ll nI_S$

$$\boxed{R = \frac{I_p}{I_S} = \frac{\sqrt{(nI_S)^2 + I_u^2}}{I_S}}$$



③ phase angle error (θ)

assuming $I_0(\sin(\alpha+\gamma))$ is very small

$$\tan\theta \simeq \theta \approx \frac{I_0 \cos(\alpha+\gamma)}{nI_S} \ldots \text{Radians}$$

$$\theta \approx \frac{I_0 \cos\alpha \cos\gamma - I_0 \sin\alpha \sin\gamma}{nI_S}$$

$$\boxed{\theta \approx \frac{I_u \cos\gamma - I_w \sin\gamma}{nI_S}}$$ ← valid for all values of γ ..... Radian

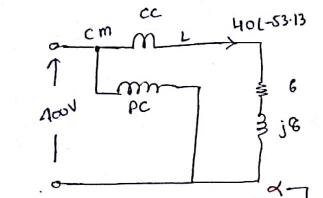
Phase angle b/w I_p & I_S ⇒ $(180-\theta) \times \frac{180}{\pi}$ degree

④ Ratio error (σ) :

$$\boxed{\% \sigma = \frac{K_n - R}{R} \times 100}$$

⑤ Ratio correction factor

$$\boxed{RCF = \frac{R}{K_n}}$$ R → Actual ratio, Kn → Nominal ratio

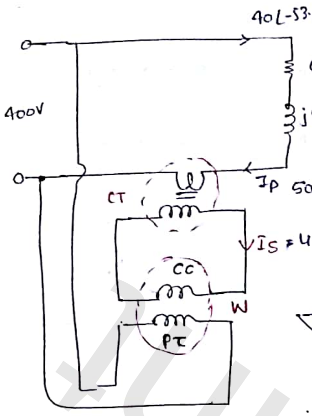


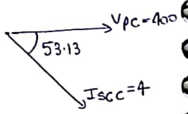
α

$W = V_{pc} I_{cc} \cos \angle (V_{pc} - I_{cc})$

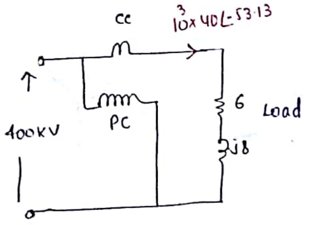
$400 \times 40 \times \cos 53.13$

ये हमेशा जरूरी नहीं है कि ये angle load angle के बराबर होगा

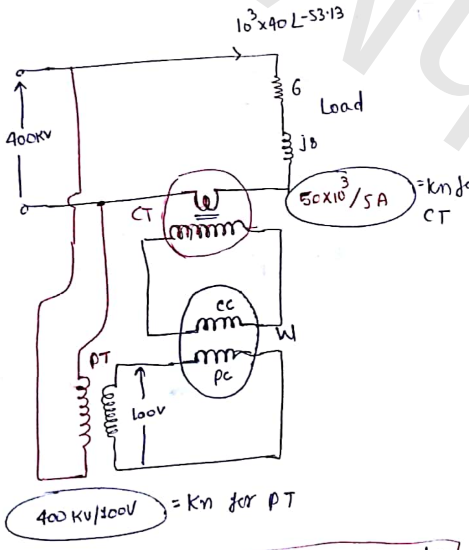




$W = 400 \times 4 \times \cos 53.13 \times \boxed{\text{CT ratio}}$



we can't apply 400kV across PC coil, it will damage



$50 \times 10^3 / 5A$ = Kn for CT

400 kV/100V = Kn for PT

$W = 100 \times 4 \times \cos 53.13 \times \boxed{\text{CT ratio} \times \text{PT ratio}}$

adding errors ① ratio error

For CT (σ) ratio error

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

$R = \frac{\bar{I_p}}{\bar{I_s}}$

$RCF = \frac{R}{K_n}$

$R = (RCF) \times K_n$

$$\underset{\substack{\uparrow \\ \text{True}}}{\frac{\bar{I_p}}{\bar{I_s}}} = \underset{\substack{\uparrow \\ \text{correction}}}{(RCF)} \times \underset{\substack{\uparrow \\ \text{Measured}}}{\left(\frac{I_p}{I_s}\right)}$$

For PT (σ)

$\frac{\bar{V_p}}{\bar{V_s}} = R = RCF \times \frac{V_p}{V_s} = K_n$

Power Measurement using wattmeter including errors in CT PT and Potential coil inductance

V_p = Voltage across the load

I_p = load current

ϕ = pf angle of load {angle b/w V_p and I_p}

V_s = voltage across secondary of PT = wattmtr PC voltage

I_s = Current in the second of CT = wattmtr CC current

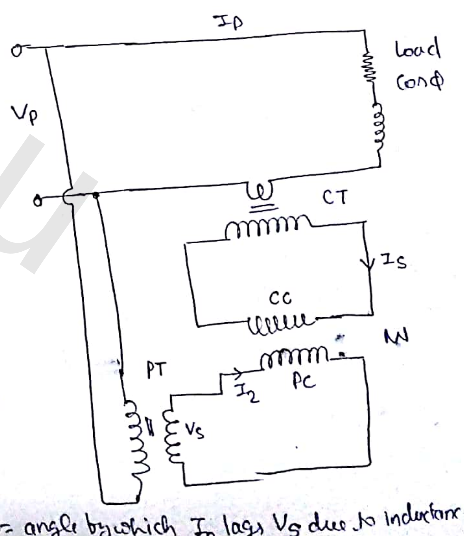
I_2 = current in the pressure coil of wattmtr

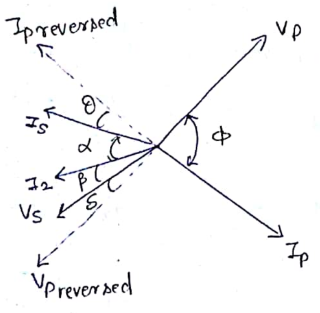
α = phase angle b/w CC current & PC voltage of wattmeter.

δ = phase angle error of PT

θ = phase angle error of CT

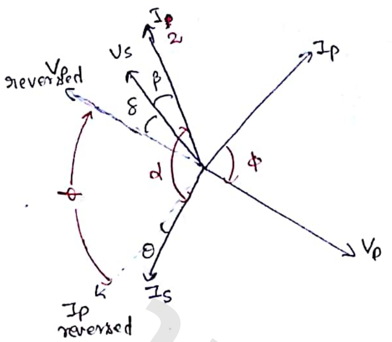
β = angle by which I_2 lags V_s due to inductance of P.C





$\phi = \alpha + \beta \pm \delta + \theta$

a) Lagging pf



$\phi = \alpha - \theta \pm \delta - \beta$

b) Leading pf

$\phi = \alpha + \beta + \delta + \theta$ ..... $\delta(-ve)$ } Lagging pf

$\phi = \alpha + \beta - \delta + \theta$ ...... $\delta(+ve)$ }

$\phi = \alpha - \beta - \delta - \theta$ ...... $\delta(-ve)$ } Leading pf

$\phi = \alpha - \beta + \delta - \theta$ ...... $\delta(+ve)$ }

C_f = Correction factor = $K = \dfrac{\cos\phi}{\cos\beta \cos\alpha}$

$\alpha = \phi - \beta - \delta - \theta$ .... lagging pf (with $\delta(-ve)$)

$\alpha = \phi + \beta + \delta + \theta$ .... leading pf (with $\delta(+ve)$)

∴ True Power = K × actual ratio of CT × actual ratio of PT × wattmeter reading

$$\text{True Power} = K \times \begin{bmatrix}\text{RCF}\\ \text{of CT}\end{bmatrix} \times \begin{bmatrix}\text{R.C.F}\\ \text{of P.T}\end{bmatrix} \times \begin{bmatrix}\text{nominal}\\ \text{ratio}\\ \text{of CT}\end{bmatrix} \times \begin{bmatrix}\text{nominal}\\ \text{ratio}\\ \text{of PT}\end{bmatrix} \times \begin{bmatrix}\text{wattmtr}\\ \text{reading}\end{bmatrix}$$

$$\begin{bmatrix}\text{True}\\ \text{Power}\end{bmatrix} = K \times \begin{bmatrix}\text{RCF}\\ \text{of}\\ \text{PT}\end{bmatrix} \times \begin{bmatrix}\text{R.C.F}\\ \text{of}\\ \text{CT}\end{bmatrix} \times \begin{bmatrix}\text{Kn of}\\ \text{CT}\end{bmatrix} \times \begin{bmatrix}\text{Kn of}\\ \text{PT}\end{bmatrix} \times \begin{bmatrix}\text{wattmtr}\\ \text{reading}\end{bmatrix}$$

Q. Reading of 400 watts is indicated on a 100 volt, 5 amps wattmeter used in connection with PT and CT of nominal ratio $\frac{100}{1}$ and $\frac{20}{1}$ respectively if wattmtr pressure coil has resist. of 400Ω and inductan of 20mH the ratio and phase angle errors of PT is +1% and 50' $\left\{\left(\frac{50}{60}\right)^\circ\right\}$ and ratio " " " " " CT is −0.5% & 100' $\left\{\left(\frac{100}{60}\right)^\circ\right\}$ respectively calculate true value of the power measured the load phase angle is 60° lagging; and frq is 50 Hz.

Soln Wattmtr reading = 400 W

Kn = of CT = 20

Kn of PT = 100

σ = for PT = 1%

$\sigma = \dfrac{Kn - R}{R} \Rightarrow R\,0.01 = \overset{100}{\cancel{20}} - R$

$R\,1.01 = 20$

$R = 20/1.01$

$R = 99.0099$

$\text{RCF for PT} = \dfrac{R}{Kn} = \dfrac{99.0099}{100} = .990099$

σ for PT = 1%

$\sigma = \frac{Kn-R}{R} \Rightarrow 0.01 = \left(\frac{100-R}{R}\right)$ $R = 99.0099$

$(RCT)_{PT} = \frac{R}{Kn} = \frac{99.0099}{100} = 0.9900$

$\sigma_{CT} = -\frac{.5}{100} = \frac{20-R}{R}$

$-.5R = 2000 - 100R$

$2000 = 100.5R$

$R = 19.90$

$\tan\beta = \frac{2\pi f L_p}{R_s}$

$\phi = 60^\circ$

$\beta = 0.89^\circ$

$\delta = 0.83^\circ$

$\theta = 1.667^\circ$

$\phi = \alpha + \beta - \delta + \theta$

$\alpha = 58.276^\circ$

$(RCF)_{CF} = 0.99$

$K = C_f = \frac{\cos\phi}{\cos\alpha \cdot \cos\beta} = 0.9506$

$W_m = W_T \times (Kn)_{CT} \times (Kn)_{PT} \times (RCF)_{CT} \times (RCF)_{PT} \times C_f$

$= 400 \times \frac{20}{1} \times \frac{100}{1} \times \underbrace{.990099 \times 1.005 \times 0.9507}_{\text{these are errors}}$

$\boxed{W_m = 756.879 \text{ Kw}}$ ✓

If errors not present

$W_T = 400 \times 20 \times 100 = 800 \text{ KW}$

$\%\ Er = \frac{756.879 - 800}{800} = -5.4\%$

Q A PT Nominal ratio of $\frac{2000}{100}$ volts ratio correction factor of 0.995 Phase angle error of $-22'$ (-22 minutes) $= \left\{\left(-\frac{22}{60}\right)^\circ\right\}$ is used with a CT of nominal ratio $\frac{100}{5}$ amp ratio correction factor of 1.005 and a phase angle error of 10°. if we measure the power (I_s leads I_p) to a single phase inductive load. a wattmeter connected read correct readings of 102 V, 4 A and 375 watts determine the power consumed by the load.

Soln $\beta = 0^\circ$ (Here)

RCF of PT = 0.995

Kn of PT = $\frac{2000}{100} = 20$

(-ve) value $\delta = -22$ minutes $= \left(-\frac{22}{60}\right)^\circ = 0.366^\circ$

$\theta = 10^\circ$

Kn of CT = $\frac{100}{5} = 20$

$\phi = \alpha + \overset{=0}{\beta} + \overset{✓}{\delta} + \overset{✓}{\theta}$ ... δ(-ve) } lagging pf

$W = V_{pc} \times I_{cc} \times \cos\alpha$]← take care.

$375 = 102 \times 4 \times \cos\alpha$

$\frac{375}{408} = \cos\alpha$

$\alpha = 23.20^\circ$

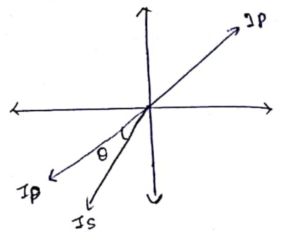
$\phi = \alpha + \beta + \delta + \theta$

$\phi = 23.20 + 0 + 0.366^\circ + 10^\circ$

$\phi = 33.566^\circ$

$$Cf = \frac{\cos\phi}{\cos\beta \cdot \cos\alpha}$$

$$K = Cf = \frac{\cos 33.566^\circ}{\cos 0^\circ \cdot \cos 23.20} = 0.9065$$



$$W_m = 375 \times 20 \times 20 \times 0.955 \times 1.005 \times 0.9065$$
$$= 135.98 \text{ kW}$$

Digital Multimeter & [DMM]
Digital voltmeter [DVM]

Advantages:

→ No parallax error
→ Single meter used for multiple appl^n
→ High accuracy
→ High resolution
→ Higher sensitivity
→ Easily compatable with computers.
→ Easily adjustable scale
→ Less effected by electromagnetic and electrostatic effect
→ Less maintenance.
→ Low power consumption
→ Higher speed
→ compact in size

Disadvantages:

→ Effected by surrounding temp^r due to electronic equipment (or) temp^r dependency.
→ External battery source is required.
→ If the battery is discharged then errors are produced.

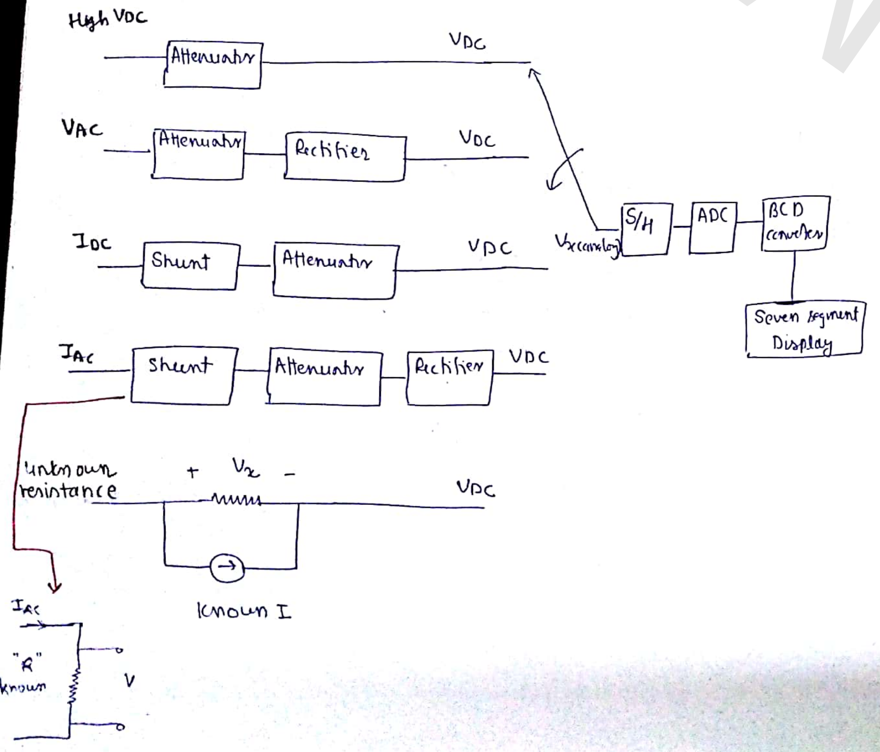
Ckt of DVM:→

→ The Basic measurable quantity of DVM is DC Voltage, i.e any quantity to be measured like DC voltage, AC voltage, DC & AC currents and unknown resistances are initially converted in terms of DC voltage which is of analog sigs.

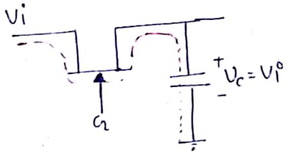
→ During measurement the i/p is assumed constant for this purpose a sample & hold sig ckt is used for sampling of i/p data and holding this data until it is measured.

→ This analog sampled data is converted into digital using ADC and this digital data is processed through the BCD converter and displayed on a 7 segment display unit.

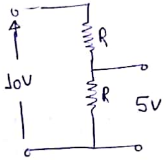
→ Dual slope ADC is practically used method in DVM bcz accuracy is higher and less affected by external noise.



→ S/H ckt



→ Attenuator



→ ADC

Types	Data conversion time
1) Flash	1 clock cycle.
(2) SAR	n x Tclk
(3) Counter	$(2^n - 1)$ Tclk
** (4) Dual slope ↳ (DVM uses) →	$2^{(n+1)}$ Tclk

Tclk = Time period of clock sig

n = no. of Digital bits of ADC

Significance of DVM

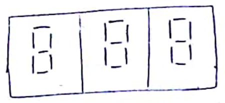
① **Resolution :** Smallest change in input able to detect by the instrument is called resolution.

→ In DVM by ↑ing the no of digits resolution is ↑ed.

Resolution = $\boxed{R = \frac{1}{10^n}}$

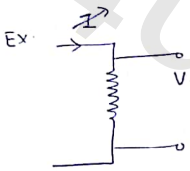
n = no. of full digit
↳ which can display all no. from 0 to 9.

Seven segment display :-


n = 3

$R = \frac{1}{10^3} = 0.001$

Ex.


V = 0.235V
= 0.236V
0.001 V

② Sensitivity Smallest value of the i/p that can be displayed by the meter in the given range is called sensitivity

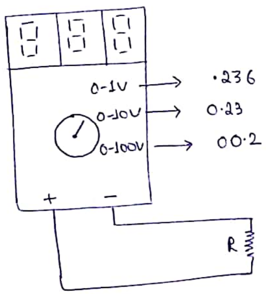
sensitivity = S = min^m full scale value × Resolution
(f.S)min × R

$\boxed{S = \text{Range} \times \text{Resolution}}$

Ex.

Range	$R = \frac{1}{10^n}$	S	min	max^m Display
~~0-1V~~ 0-1V	0.001	0.001 × 1 = 0.001	.000	.999
0-10V	0.001	0.001 × 10 = 0.01	0.00	9.99
0 - 100V	0.001	.001 × 100 = 0.1	00.0	99.9

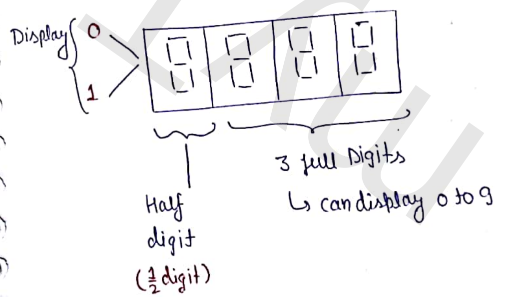
Ex. .236



(.236V)

③ Over Ranging :-

→ If Extra ½ digit is switch on is called over ranging.



3½ Digit Display ∴ $R = \frac{1}{10^3} = 0.001$

n½ Digit Display ⇒ $R = \frac{1}{10^n}$

but sensitivity will change.

Ex

Range	$R = \frac{1}{10^n}$	S	min	max. Display
0 – 1 V	.001	.001 × 1 = .001	0.000	1.999
0 – 10V	.001	.001 × 10 = .01	00.00	19.99
0 – 100V	.001	.001 × 100 = .1	000.0	199.9
			0000	1999

Here in overanging, range is doubled

④ % Total Error (% Er)

$$\%E_r = \pm\left[\%\text{ Error at reading value} \times \text{Reading value} + \frac{\text{No. of counts}}{(\text{max. scale range})} \times \text{full scale reading}\right]$$

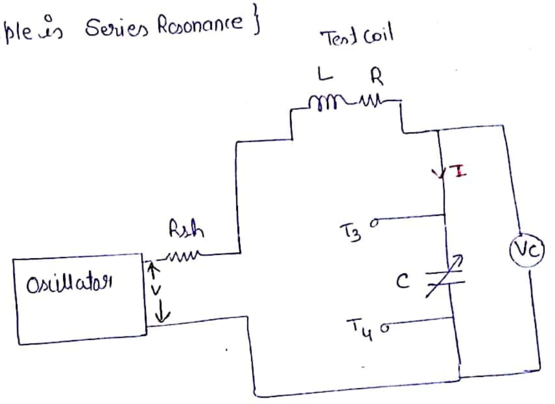
(max^m over ranging)

$$\text{Error} = (\%\text{ error in reading}) \times \text{reading} + (\text{No. of counts}) \times \frac{\text{Full scale}}{\text{Range of meter}}$$

23rd September

Q-meter [Quality factor meter or voltage magnifier] :-

{Principle is Series Resonance}



$$Q_T = \frac{\omega L}{R} = \frac{X_L}{R} = \text{True Value}$$

$V_c = I \cdot X_C$

Series resonance $X_L = X_C$

$$I = \frac{V}{(R+R_{sh})}$$

$$V_c = \frac{V X_C}{(R+R_{sh})} = \frac{V \cdot X_L}{(R+R_{sh})}$$

$$V_c = \frac{V \cdot X_L}{R\left[1+\frac{R_{sh}}{R}\right]}$$

$$= \frac{V \cdot Q_T}{\left(1+\frac{R_{sh}}{R}\right)}$$

$$\boxed{V_c = V \cdot Q_m}$$

$$\boxed{V_c \propto Q_m}$$

$$Q_m = \frac{Q_T}{\left(1+\frac{R_{sh}}{R}\right)}$$

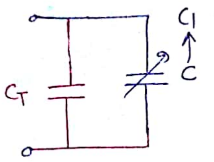
$$\%E_r = \frac{Q_m - Q_T}{Q_T} \times 100$$

$$\%E_r = -\left(\frac{R_{sh}}{R_{sh}+R}\right)$$

Er is Low if Rsh is Low value

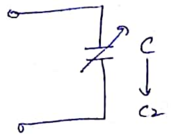
so Rsh = mΩ

Application ①
If we want to measure Test capacitance.



$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_T)}}$$

we are tuning so we will make
$f_1 = f_2$



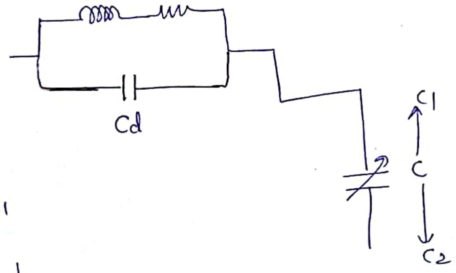
$$f_2 = \frac{1}{2\pi\sqrt{LC_2}}$$

$f_1 = f_2$

$$\boxed{C_T = C_2 - C_1}$$

Appl^n ②

How to measure self capacitance of the coil.



$C \longrightarrow C_1$

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_d)}}$$

$C \to C_2$ $\quad f = f_2$ $\quad$ tune f_2 such that $f_2 = nf_1$

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2+C_d)}} = nf_1 = n \cdot \frac{1}{2\pi\sqrt{L(C_1+C_d)}}$$

$$\boxed{C_d = \frac{C_1 - n^2 C_2}{(n^2-1)}}$$

self / distributed capacitance of coil = C_d

Q Qmeter cap^c is set to 400μF with oscillator frq^c of 2kHz now by varying the oscillator frq^c to 4kHz. the new value of capacitance is 20μF. Find the self or distributed capacitance of the test coil

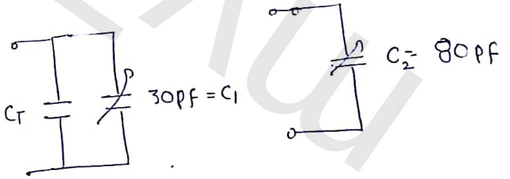
$$C_d = \frac{C_1 - n^2 C_2}{n^2-1}$$

$f_1 = 2kHz$ $\quad f_2 = 4kHz$

$f_2 = nf_1 = \quad \Rightarrow n = 2$

$$C_d = \frac{400-(2)^2 \times 20}{2^2-1} = \frac{400-80}{4-1} = \frac{320}{3}μF$$

Q An unknown cap^c is measured using a Q meter by connecting a test capacitance across cap^c of Q meter the ckt is resonated with a cap^c of 30 pF and the reading of 50 observed across the voltmeter capacitor connected By removing the capacitance the ckt is resonated at a freq^c of same value and same reading of 50 is observed with cap^c of 80 pF. Find the unknown capacitance.

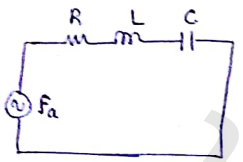


$C_T = C_2 - C_1 = 80 - 30 = 50pF$

Note* Qmeter is also used for the measurement of L from known Q and R and measures R from known Q and L

- In the measurement of low impedance Q meter is connected in series and for the measurmt of high impedance Q mtr is " " parrel to the coil

A.K? ~~किसी~~ RLC ckt में



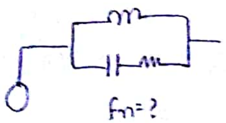
$f = \frac{1}{2\pi\sqrt{LC}}$

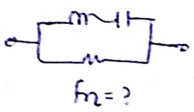
ये जो fnq^c होती है

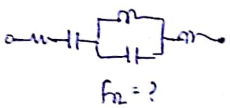
fa= applied fnq^c ` fn= natural fnq^c

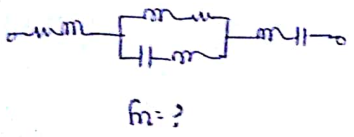
If i make $f_a = f_n$ then $X_L = X_C$ and system will behave as a Resistive N/w.

asks ?









Cathode Ray Oscilloscope [CRO] :→

No. of cycles visible on the screen

$$n = \frac{\text{Time period of Screen}}{\text{Time period of Signal}} = \frac{T_{screen}}{T_{signal}}$$

Q1 A CRO has 10cm x 8cm in the x and y scale the time per division is 20msec is set. a sig of $V = V_m \sin 2\pi 100t$ is applied calc no. of cycle visible on the screen.

So $20m sec \times 10 = 200m sec = T_{screen}$

$2\pi 100 = \omega m$ $f = T = \frac{1}{100} = 0.01 = 10 m sec = T_{signal}$

$\frac{T_{screen}}{T_{signal}} = \frac{200m sec}{10 m se} = 20$ cycles are visible.

Q2 In the above CRO 2volts/div is set to the y scale if a sig of

① $4 \sin 2\pi 50t$

⑪ a Ac rms voltage of 10V magnitude & fnq^c of 200Hz. is applied find no. of cycles and visibility of waveform on the screen. i.e clipper or unclipped

Soln peak to peak of CRO = 16 volts bcz 8 div in y scale.

① $f = 50\,Hz$ $T = \frac{1}{50} = 20 m sec$

$n = \frac{T_{screen}}{T_{sig}} = \frac{200}{20} = 10$ cycle.

Peak to p of Sig = 8 volt so unclipped

② $f = 200 Hz \Rightarrow T = \frac{1}{200} = 5 m sec$

$n = \frac{200 m}{5 m} = 40$ cycle.

$V_{rms} = 10$

$V_m = 10 \times \sqrt{2} =$

$V_{pp} = 20 \times \sqrt{2} = >$ than 16 V

So clipped sig.

Preaccelerating and Accelerating Anode potential are used to ↑ the speed of the e^-.

$$K.E = P.E$$

$$\frac{1}{2}mv^2 = q.V_a$$

$$v = \sqrt{\frac{2q.V_a}{m}}$$

$$\boxed{V_a = \text{anode potential}}$$

$$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}} \sqrt{V_a}$$

$$= \cancel{0.775}\ 0.59 \times 10^6 \sqrt{V_a}$$

$$\boxed{v \approx 0.6 \times 10^6 \sqrt{V_a}}$$

if Va ~~doubles~~ 4 times , v becomes twice.

Q The anode potential applied to the CRO is 25 volts find the velocity of the electron beam

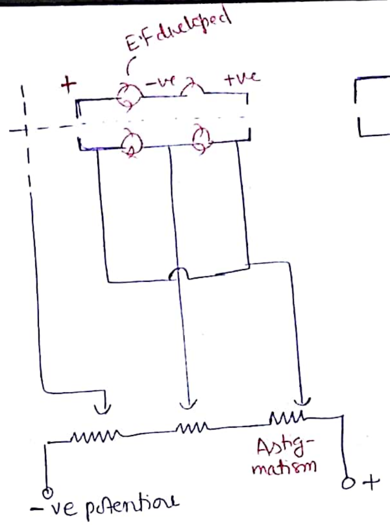
S.O $v \simeq 0.6 \times 10^6 \sqrt{25}$

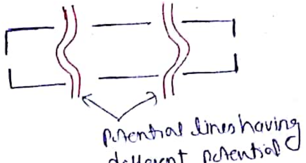
$$\boxed{v \simeq 3 \times 10^6 \ m/sec}$$

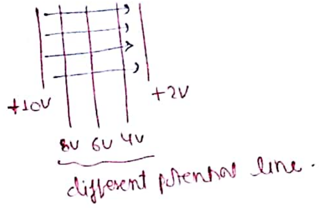
Intensity :-

Note* By changing the control grid potential, intensity or brightness of the beam is changed.

if i apply -ve potential at control grid no. of e^- will be stopped



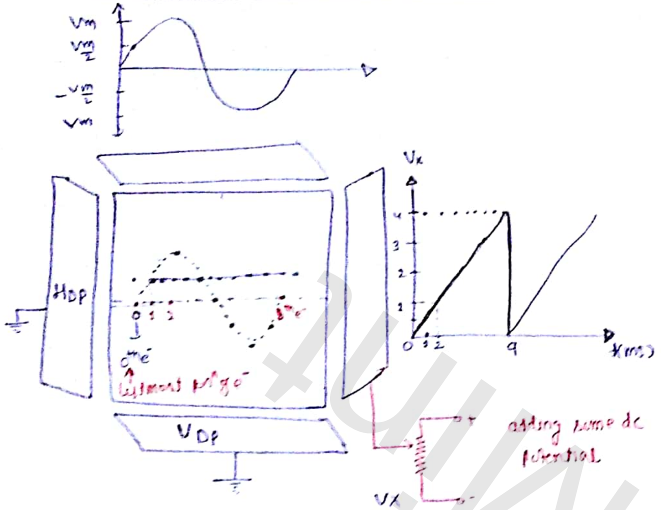


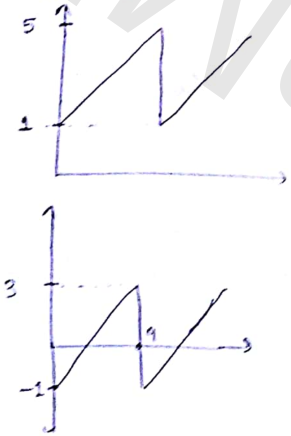


Focus control :

Electrostatic Focus control is used in laboratory CRO's which is working on the principle of Double concave electron lens

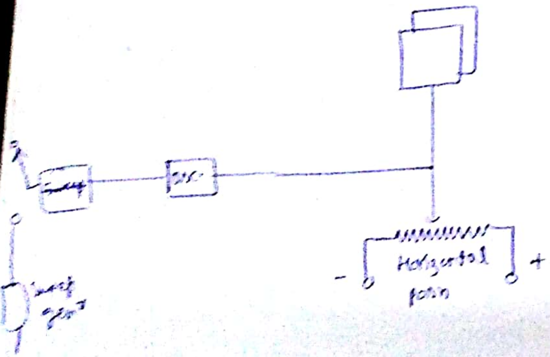
For Fine Focus control Astigmatism is used by applying a potential to pre and accelerating anode

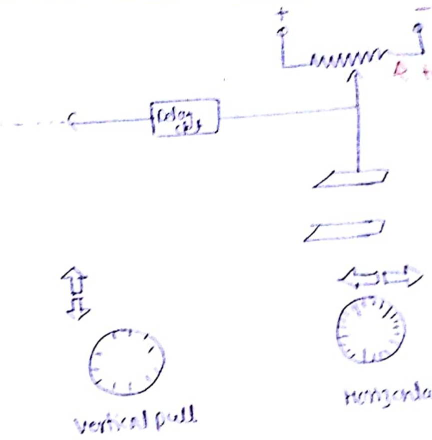




If i want to pull the Horizontal wave toward right or left dc potential is required.

apply + dc → Right side
" - dc → left side

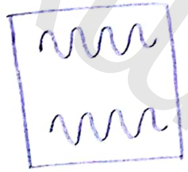




& to pull the waveform upward & downward adding dc

- Horizontal Deflecting plate HDP applied with a Sawtooth used to move the beam along Horizontal line.
- Vertical deflecting plate is applied with a test signal to move the beam up and down in vertical posn.
- The dc potential +ve or -V is applied to both HDP or VDP for Horizontal and vertical pull of the beam.

Sometime we need to center the waveform hence need to adjust vertical pull properly.

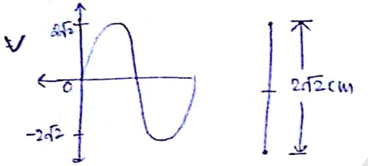


Q Vpp is applied with 10 volt DC produces a displacement of 1cm on a screen if a AC sig having rms value of 10V is applied what is the max^m distance occupied on the screen.

10V = 1 cm

1V = 0.1cm

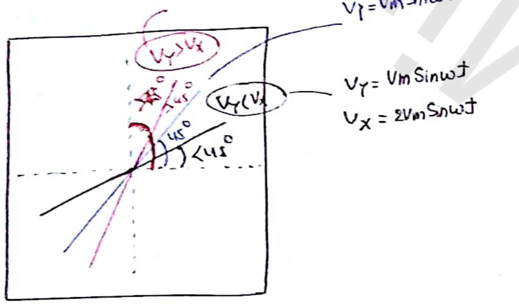
$10\sqrt{2}$ V



$2\sqrt{2}$ cm = 2.818 cm

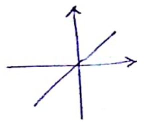
★★★ concept :-

$V_Y = 2V_m \sin\omega t$ $V_x = V_m \sin\omega t$



LP

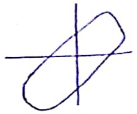
$\phi = 0^\circ$ or 360°



$0^\circ < \phi < 90^\circ$

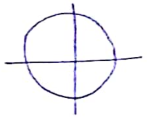
or

$270 < \phi < 360^\circ$



$\phi = 90^\circ$ or

270°

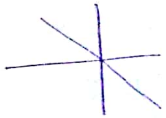


$90 < \phi < 180^\circ$

or

$180 < \phi < 270$

$\phi = 180^\circ$

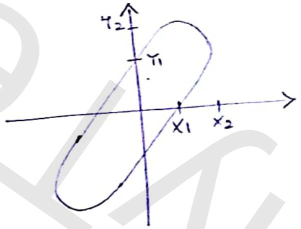


$V_x = V_m \sin\omega t$

$V_Y = V_m \sin(\omega t + \phi)$

ϕ = phase angle b/w V_x & V_Y

① LP in I & III Quadrant

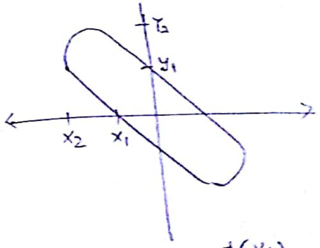


$\phi = \cancel{\phi}\ \sin^{-1}\left(\frac{X_1}{X_2}\right)$ or

$= \sin^{-1}\left(\frac{Y_1}{Y_2}\right)$

Second probability = $(360 - \phi)$

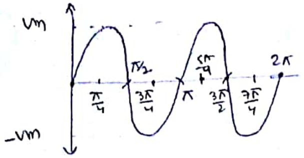
⑪ LP in II^nd & IV^th Quad



$\phi = 180^\circ - \sin^{-1}\left(\frac{X_1}{X_2}\right)$

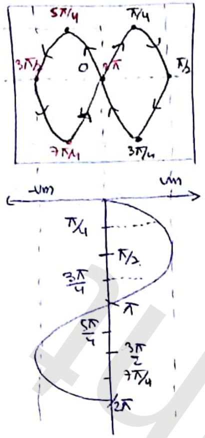
$= 180 - \sin^{-1}\left(\frac{Y_1}{Y_2}\right)$

Second prob = $(360 - \phi)$

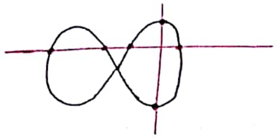


$V_y = V_m \sin 2\omega t$

$V_Y = V_m \sin \omega_y t$

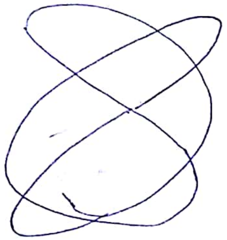


$V_x = V_m \sin \omega_x t$



$\frac{f_y}{f_x} = \frac{\text{No. of Horizontal touch}}{\text{No. of vertical touch}} = \frac{4}{2} = 2$

$\boxed{f_y = 2f_x}$

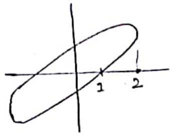


$y = \sin 2t$

$x = \sin 3t$

Q From the following Lissa - Pattern find phase angle difference b/w horizontal and vertical deflecting AC voltages.

①

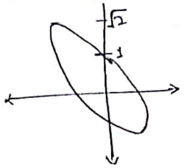


$\phi = \sin^{-1}\left(\frac{1}{2}\right)$ $\frac{f_y}{f_x} = \frac{2}{2} = 1$

$\phi = 30°$

or $(360 - \phi) = 330°$

②



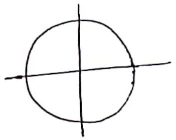
$\phi =$ ~~ϕ~~ ~~$\sin^{-1}\left(\frac{-1}{\sqrt{2}}\right)$~~ $180 - \sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$ $\frac{f_y}{f_x} = 1$

$\phi =$ ~~$45°$~~ $135°$

(or)

$(360 - 135°) = 225°$

③



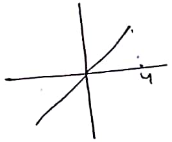
$\frac{f_y}{f_x} = 1$

~~$\phi = 90°$~~ or

$\phi = \sin^{-1}\frac{5}{5} = 90°$

or

$270°$



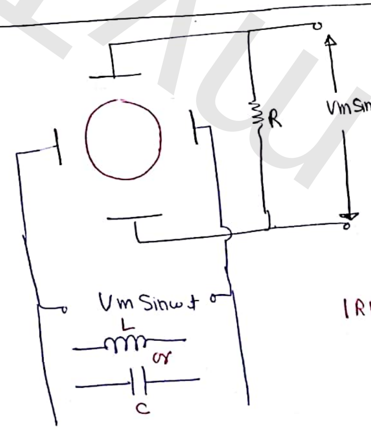
$\frac{f_y}{f_x} = 1$

$\phi = \sin^{-1}\frac{0}{4} = 0°$

or

$360°$

Concept



$|R| = |X_C|$

Q CRO Vpp applied with $V = V_m \sin 2\pi 1000 t$ volts through a Resistance of 1kΩ How much of capacitance required if $V = V_m \sin 2\pi 1000 t$ is applied to the Hpp so that circle is formed on the screen

Sol^n =

$|R| = |X_c|$

$1000 = \frac{1}{2\pi 1000 C}$

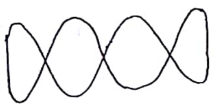
$\boxed{C = \frac{1}{2\pi} \mu F}$

$|R| = |X_L|$

$1000 = 2\pi 1000 L$

$\boxed{L = \frac{1}{2\pi} \text{ Henry}}$

Q Voltage $V_x = V_m \sin 1000 t$ is applied to the CRO ~~on~~ along with $V_y = V_m \sin 2\pi f t$ to the Vpp produces Liss. pattern shown in the figure find the freq^c of ~~[illegible]~~ Vpp.



Sol^n

$\frac{f_y}{f_x} = \frac{8}{2}$

$f_y = 4 f_x$

$f_y = 4 \times f_x$

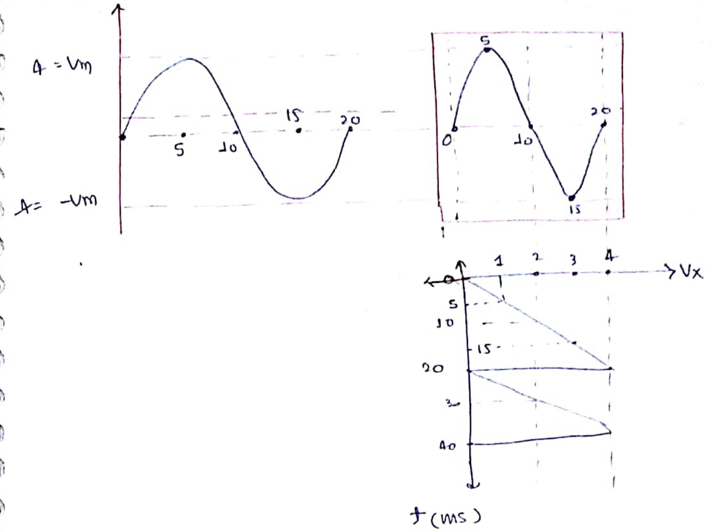
$\omega_y = 4000$

$\omega_y = 4000$

$\boxed{f_y = \frac{4000}{2\pi} = \frac{2000}{\pi} \text{ Hz}}$

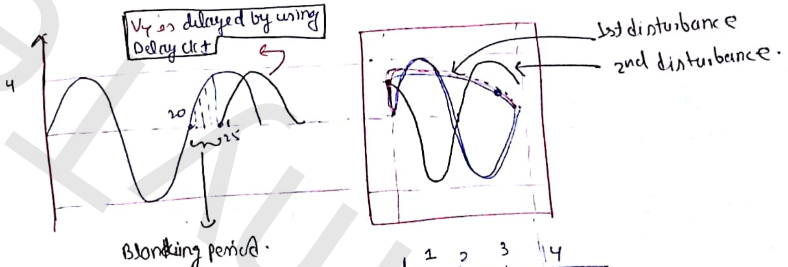
Concept

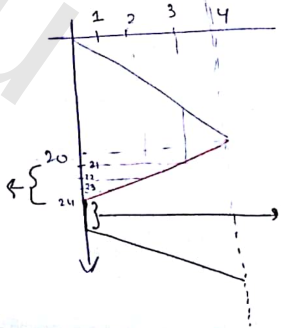
Problems with Sawtooth wave



Sawtooth/Sweep

Sawtooth don't have 0 falling time practically
UJT contain RCN/w so some time Delay is there.





Retrace time of Sawtooth
||
Time delay
||
Falling time

suppose Sawtooth wave-form itself delay by some time (t)

* **Balanking ckt** is used to stop the e^-s entering into the CRO during falling or retrace time of the sawtooth signal applied to the Hop.

Time delay line crckt is connected to the VDP for delaying the test sig for synchronising b/w sawtooth and test sig

$$\boxed{\text{Total time Delay } V_{DP} = \text{Falling time of Sweep gen}^r + \text{Initial starting time delay of the sweep sig.}}$$

Blanking ckt connected to control grid, makes control grid more −ve so no e^- flow for falling time

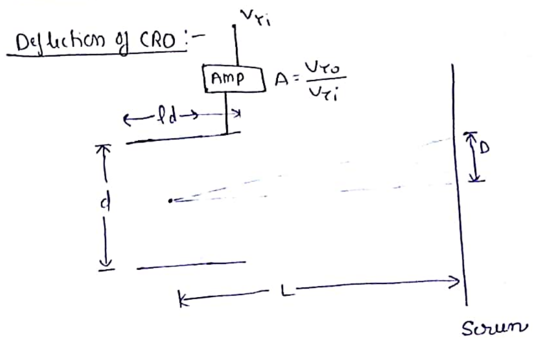
** **Concept** UJT is inbuilt inside CRO

V_Y we need to apply from outside fun^c gen^r

Trigger input is used in the CRO to bring the initial starting point of the test sig which is supposed to be synchronise with the horizontal deflecting plate initial sawtooth signal. depending on the initial magnitude from +ve to −ve of the test sig corresponding compensation is added using the trigger and bring the waveform to the initial pos^n so that smooth o/p is available repeatedly displaying similar waveform of test sig.

Edge triggering is the most basic type used in all the digital and analog oscilloscope both the +ve and −ve slope are added depending on slope of the incoming sig.

Deflection of CRO :-



$$\boxed{D = \frac{L l d V_Y}{2 d V_a}}$$

Va = anode voltage

$$\boxed{\text{Deflection Sensitivity } S = \frac{D}{V_Y} = \frac{L l d}{2 d V_a} \; \ldots \frac{mm}{V}}$$

$$\boxed{\text{Deflection Factor } G = \frac{1}{S} \; \ldots\ldots V/mm}$$

Q An electron beam having a velocity of 6×10^6 m/sec is passing through the vertical deflecting plate seperated by 10mm and a length of 20mm and L = 25mm produces a D = 10mm Find the voltage applied to the VDP if the gain of the amp^r is 100.

Sol^n.

$$\frac{1}{2} m v^2 = q V_a$$

$$\frac{1}{2} \times 9.1 \times 10^{-31} \times 6 \times 10^{12} = 1.6 \times 10^{-19} \times V_a$$

$$V_a \simeq 102.335$$

$$D = \frac{L l d V_Y}{2 d V_a}$$

$$10\,mm = \frac{25\,mm \times 20\,mm}{2 \times 10\,mm \times 102.335} \times V_Y$$

$$\boxed{V_Y = 40.95}$$

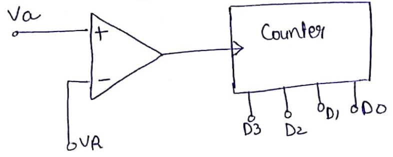
V_i —$\boxed{100}$— $V_o = 40.95$

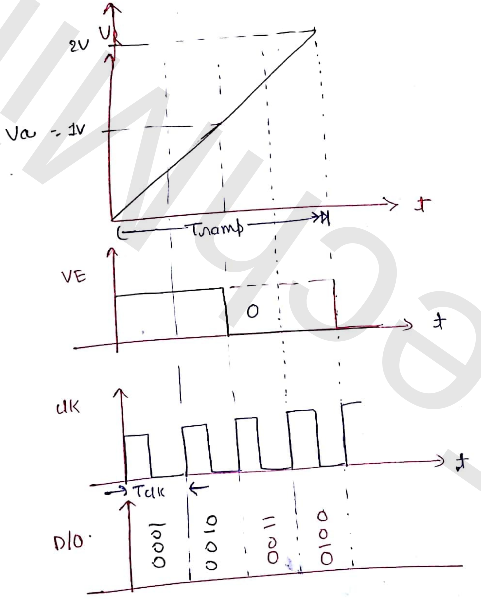
$$V_i = \frac{40.95}{100} = .40 \text{ volt}$$

DVM

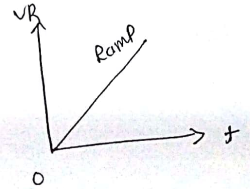
Continious Ramp type DVM

$\boxed{V_E = V_a - V_R}$





Data conversion time is high which is a problem.



$T_{max} = 2^n \times T_{clk}$

No. of clock pulses $= P = \frac{T_{ramp}}{T_{clk}} = \frac{f_{clk}}{f_{ramp}}$

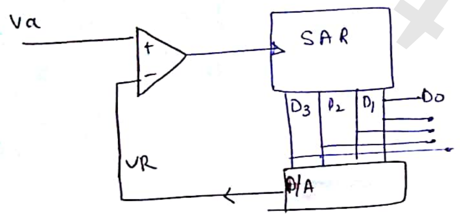
Q A continuous ramp DVM has a ramp sig with a -ve slope drops voltage from 6 V to 0V, in 10msec. clock sig has a frq of 1MHz calculate ~~Time~~ no of pulses, required for this ramp type.

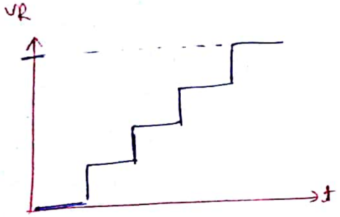
$T_{clk} = 1\ \mu sec$

$T_{Ramp} = 10msec.$

$P = \frac{10\ m\ sec}{1\ \mu sec} = \frac{10 \times 10^{-3}}{1 \times 10^{-6}} = 10000$ Pulses required.

Staircase Ramp





Successive Approximation

Advantages

- Capable of High speed and Reliable
- Medium accuracy ~~accurately~~ compared to other ADC types
- Good trade-off between ~~basis~~ speed and cost
- Capable of outputting the binary no. in serial (one bit at a time) Format.

$\boxed{T_{max} = n \times T_{clk}}$

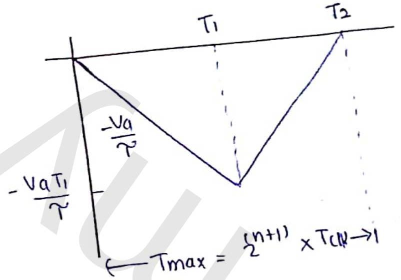
max^m conversion time

$n =$ no. of digital o/p bits.

Disadvantages

- Higher resolution Successive approximation ADC's will be slower.
- speed limited to ~5 Msps

Dual slope Approximation:



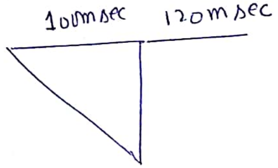
Data conversion occur at $t = T_2$

$V_a T_1 = V_R\ (\underbrace{T_2 - T_1}) \rightarrow$ Discharging time.

Advantage	Disadvantage
○ I/p sig is averaged	○ slow
○ Greater noise immunity than other ADC type	○ High precision external components required to achieve accuracy.
○ High accuracy	

Speed		Data conversion time	Accuracy
Flash	–	1 clock.	↑
SAR	–	n "	
Single slope/Ramp	–	2^n "	
Dual slope.		$2^{(n+1)}$ "	Most accurate

Q. A Dual slope ADC DVM has charging time of 100 msec dintegrat in period of 120msec with reference voltage of 2volts. Find the analog i/p voltage.



$V_R = 2V$

$V_a \cdot T_1 = V_R (T_2 - T_1)$

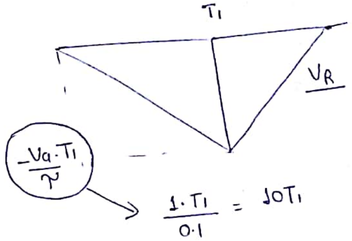
$V_a \cdot 100 = 2 \cdot 120$

$$\boxed{V_a = \frac{240}{100} = 2.4 \text{ volt}}$$

Q A Dual slope DVM consisting of an integrator of Resistance=100kΩ & 1μF capacitance the voltage applied to the integrator i/p is 1V . now if a reference voltage is applied to integrator at time T_1 to 5V in amplitude what time interval of T_2.

$\tau = RC = 100 \times 10^3 \times 1 \times 10^{-6} = \frac{1}{10} = 0.1$

$V_a = 1V$; $V_R = 5V$



$\frac{-V_a \cdot T_1}{\tau} \rightarrow \frac{1 \cdot T_1}{0.1} = 10T_1$

$\frac{V_a}{V_R} T_1 = (T_2 - T_1)$

$\frac{1}{5} T_1 + T_1 = T_2$

$T_1 (1 + \frac{1}{5}) = T_2$

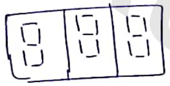
$\boxed{\frac{6}{5} T_1 = T_2}$ —①

$\boxed{T_2 = 1.2 T_1}$ —① answer

Specification :- of DVM

① $R = \frac{1}{10^n}$ = Resolution ⑪ ~~Resol~~ Semitivity.

n = no. of full digit



Ex $n=3$

$R = \frac{1}{10^3} = 0.001$

Problem :- A $3\frac{1}{2}$ voltmeter used for voltage measurement

① find its resolution

② How would 11.52 volts will be displayed on the 10 V range.

③ " " 0.2345 volts " " " " " 1V-~~10~~ and 10V range.

Sol^n :- ① $R = \frac{1}{10^3} = 0.001$

② 0- 10V

$S = 0.001 \times 10$

$= 00.01$

display: 11.52

③ (i) ~~S= 00.01~~

0- 1V Range

$S = 0.001 \times 1$

$= 0.001$

$\boxed{\text{display} \quad 0.234}$ //

(ii) 0-10V

$S = 0.001 \times 10$

$S = 00.01$

$\boxed{\text{display} = 00.23}$ //

Transducer

① Potentiometer T/D

② LVDT T/D

③ Hall Effect T/D

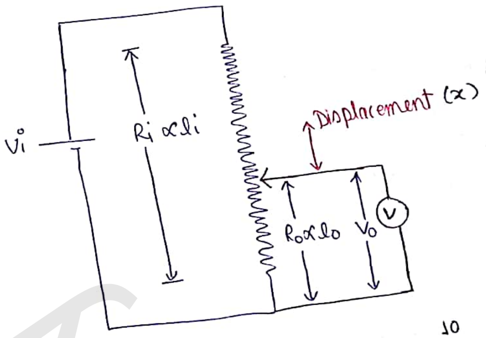
Q1 A potentiometer has a stroke of 20 cm applied with voltage of 1v.

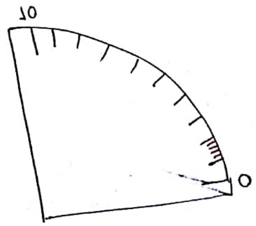
Find ① sensitivity

② Displacement in the o/p voltage is 0.25 V

③ if the o/p voltmeter has 20 divisions. b/w 0 to 1 volt range and scale can be read upto 1/5th of division find the resolution of the potentiometer

Sol^n





l_i = stroke

= max Displacement measured by PoT

$V_o = V_i \frac{R_o}{R_i}$

$= V_i \frac{l_o}{l_i} = \frac{V_i x}{l_i}$

$\boxed{S = \frac{V_o}{x} = \frac{V_i}{l_i}}$ V/mm

S= sensitivity

① $S = \frac{V_i}{x_i} = \frac{1}{20} = 0.05\ V/cm$. sensitivity $= \frac{o/p}{i/p}$

② $\frac{V_o}{x} = S \Rightarrow x = \frac{V_o}{S} = \frac{0.25}{0.05} = 5cm$

③ 20 division = 1V

$1\ \text{division} = \frac{1}{20}V = 0.05V$

Read upto $\frac{1}{5}$ division $= \frac{0.05}{5} = 0.01V$

$\text{Resolution} = \frac{\text{Min}^m\ \text{Read value}}{S}$

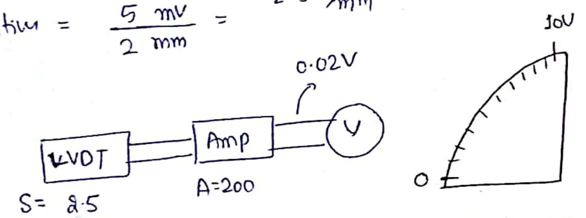
$= \frac{0.01}{0.05V/cm}$

$\boxed{R = 0.2cm}$

Q An LVDT has o/p of 5 mvolts across its terminals when the core moves through a distance of 2mm the o/p of LVDT is connected to ~~through~~ a 10V voltmeter through an ampr of gain 200. if the mili voltmeter scale has 100 divisions and scale can be read up to 1/5th of the division find the

① Resolution for the overall instrument in mm.

$\text{Sensitivity} = \frac{5\ mV}{2\ mm} = 2.5 mV/mm$



$\frac{0.02}{200} =$
$= 0.1mV$

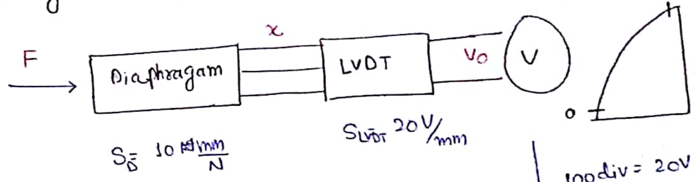
100div = 10V
1 div = 0.1V
$\text{Readability} = \frac{0.1}{5} = 0.02V$

$R \Rightarrow \frac{0.1\ mV}{2.5\frac{mV}{mm}}$

$= 0.04\ mm$

$= 40\ \mu m$

Q A diaphragm and LVDT combination are used to measure force in terms of voltage diaphragm has sensitivity of 10 µm/N, LVDT has sensitivity of 20V/mm the o/p of LVDT voltmeter has 100 divisions measures upto 1/10th of division find the minm force able to measure by the setup



$S_D = 10\ \frac{\mu m}{N}$ $S_{LVDT}\ 20 V/mm$

100div = 20V
1 div = 0.2V
$\frac{1}{10}$ div ⇒ Readibility = 0.02

$\text{overall sensitivity} \to S_o = \frac{V_o}{F} = \frac{V_o}{x} \times \frac{x}{F}$

$= S_D \times S_{LVDT}$

$= 10 \times 20 = 200\ V/N$

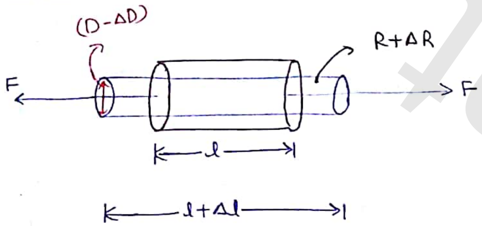
$\text{Min Force} = \text{Resolution} \Rightarrow \frac{0.02V}{200V/N} = 0.1mN$

Stress/ strain/ pressure/ Force :-

① Piezo Resistive / strain Gauge / Load cell

② Piezo Electric

Strain Gauge :-



confirm

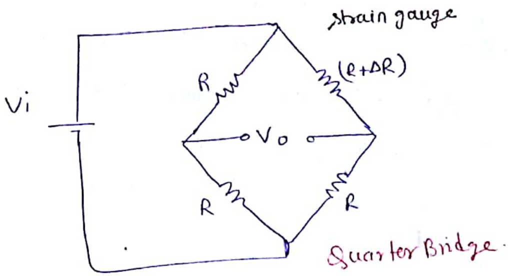
$$\text{Gauge Factor} = \boxed{G_F = \frac{\frac{\Delta R}{R}}{\frac{\Delta l}{l}} = 1 + 2\gamma + \frac{\partial \rho/\rho}{\partial l/l}}$$

$Y = \frac{\text{stress}}{\text{strain}}$ = Young modulus

$\frac{\Delta l}{l} = \epsilon_l$ = Longitudinal strain

$-\frac{\Delta D}{D} = \epsilon_D$ = Lateral strain

$\gamma = \frac{\epsilon_D}{\epsilon_l}$ = Poissions Ratio



Quarter Bridge.

$$V_o = V_i\left[\frac{R}{2R} - \frac{R}{2R+\Delta R}\right]$$

$$= V_i\left[\frac{(2R+\Delta R)R - 2R^2}{2R(2R+\Delta R)}\right]$$

$$= \frac{V_i}{2}\,\frac{\Delta R}{(2R+\Delta R)}$$

$$= \frac{V_i}{2}\,\frac{\Delta R/R}{(2+\Delta R/R)}$$

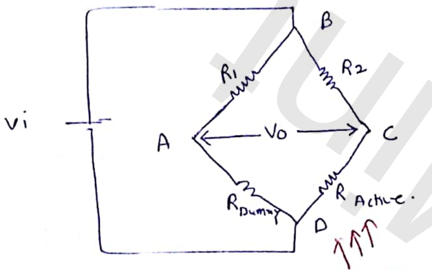
$$\boxed{V_o = \frac{V_i}{2}\cdot\frac{G_F\cdot\epsilon_l}{(2+G_F\cdot\epsilon_l)}}$$

Q semicond^c strain gauge has a nominal resistance of 1000Ω and Gauge factor of +200 at 25°C calculate the resistance of strain gauge in ohms when subjected to a strain of 10^{-4} at the same temp^r

1020 Ans

Q a wheatstone bridge ABCD has resistors R_1 in arm R_{AB}, R_2 in arm R_{BC}, dummy gage R_{AD} and active gauge in arm AC if a strain 1250 unit/meter is applied find the bridge offset voltage across AC the bridge is applied with a voltage of 12 Volt across BD assume $R_1 = R_2 =$ ~~350~~ R dummy gage = 350Ω and Resistance of active straingage = 350Ω with Gauge factor of 2

Sol^n



strain = $\epsilon_s = 1250 \times 10^{-6}$

$G_f = 2$

$$\boxed{V_o = \frac{V_i}{2} \times \frac{G_f \cdot \epsilon_l}{2 + G_f \cdot \epsilon_l}}$$

$$V_o = \frac{12}{2} \times \left(\frac{2 \times 1250 \times 10^{-6}}{2 + 1250 \times 10^{-6} \times 2} \right)$$

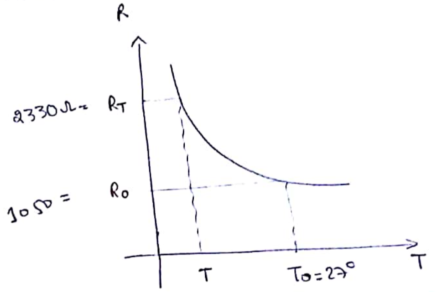
$$\boxed{V_o = 7.49 \text{ mV}}$$

Q Resistance at temp^r T_0 kelvin of a Thermistor is given by

$$R_T = R_0 \, e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

where $R_0 = 1050\ \Omega$ at 27° Ω $\beta = 3140$ what is the temp^r with the thermistor resistance is 2330 Ω

$T = \boxed{5.77°}$



→ small change in temp^r but large change in resistor {advantage of thermistor}

I/p Temp^r O/p Resistance.