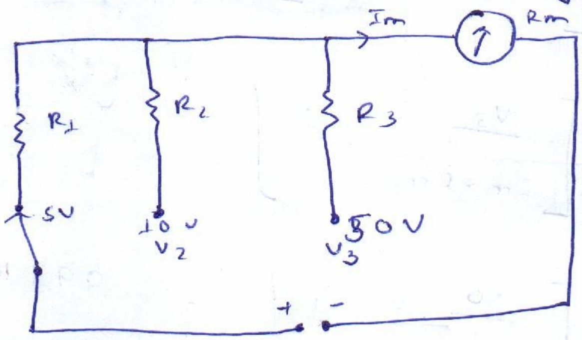
Q1. A multi-range voltmeter is shown in the figure with full scale deflection current of $50\mu A$ and meter resistance of $1 k\Omega$. what are the value of resistance R_1, R_2 and R_3 respectively ?



Solution : Using KVL

$$V_1 = I_m R_1 + I_m R_m$$

$$V_1 = I_m R_1 + V_m \quad (\because V_m = I_m R_m)$$

$$I_m R_1 = (V_1 - V_m)$$

$$I_m R_1 = V_m \left[\frac{V_1}{V_m} - 1 \right]$$

$$I_m R_1 = I_m R_m \left[\frac{V_1}{I_m R_m} - 1 \right]$$

$$R_1 = R_m \left[\frac{V_1}{I_m R_m} - 1 \right]$$

$$R_1 = 1 k\Omega \left[\frac{5}{50\mu \times 1k\Omega} - 1 \right] = 99 k\Omega$$

similarly for R_2 & R_3

$$R_2 = R_m \left[\frac{V_2}{I_m \times R_m} - 1 \right]$$

$$R_2 = 1K \left[\frac{10}{50\mu \times 1K} - 1 \right] = 199 \, K\Omega$$

$$R_3 = R_m \left[\frac{V_3}{I_m \times R_m} - 1 \right]$$

$$R_3 = 1K \left[\frac{50}{50\mu \times 1K} - 1 \right] = 999 \, K\Omega$$

Q2 The current i(t) passing through 10Ω resistor is shown in fig 2(a) or a waveform as shown in fig 2(b). ~~That~~ What is the reading of the D.C. voltmeter connected across 10Ω resistor?

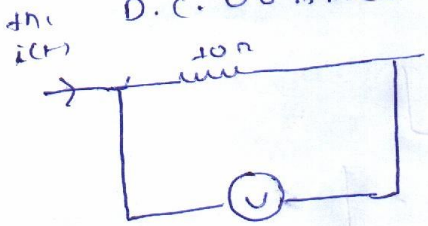


fig 2(a)

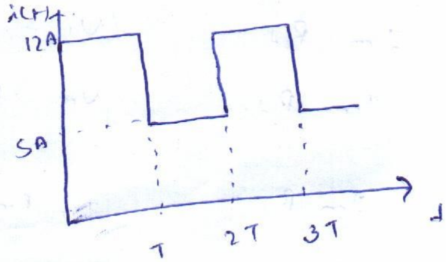


fig 2(b)

Solution. Here DC voltmeter is used which measured average voltage across the resistance.

$$V = \cancel{i(t)} \; i_{avg} \times R$$

i_{avg} can be found in fig 2(b),

$$i_{avg} = \frac{1}{2T} \int_0^{2T} i(t)\, dt$$

$$= \frac{1}{2T} \left[\int_0^{T} i(t)\, dt + \int_T^{2T} i(t)\, dt \right]$$

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

$$= \frac{1}{2T} \left[5 (t)_0^{T} + 12 (t)_T^{2T} \right]$$

$$= \frac{1}{2T} \left[5T + 12T \right]$$

$$= \frac{17T}{2T}$$

$$i_{avg} = 8.5\ A$$

$$V = i_{avg} \times R$$

$$= 8.5\ A \times 10\ \Omega$$

$$V = 85\ V$$

Q3. A D.C. Voltmeter has a sensitivity of 1000Ω/volt when it measures half full scale in 100 V range, the current through the voltmeter is what value?

Solution

~~Sensitivity = Full scale~~

$$\text{Sensitivity} = \frac{\text{Meter Resistance}}{\text{Full scale voltage}}$$

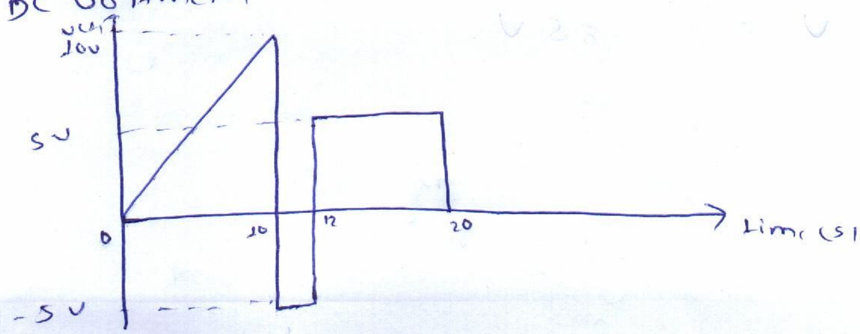
$$= \frac{R_m}{I_{fs} R_m}$$

$$\text{Sensitivity} = \frac{1}{I_{fs}} = \frac{1000\,\Omega}{\text{volt}}$$

$$I_{fs} = \frac{1}{1000} = 1\,mA$$

$$\text{Half full scale current} = \frac{I_{fs}}{2} = 0.5\,mA$$

Q4. A periodic voltage waveform observed on an oscilloscope across a load as shown in fig. what is the reading in ~~voltmeter~~ (~~RMS~~) DC voltmeter connected across the same load



Solution. DC voltmeter measure the average value of voltage.

We measure the average value of the waveform obtained from oscilloscope.

$$V_{D.C} = V_{avg}$$

$$= \frac{1}{20}\int_0^{20} v(t)\, dt$$

$$= \frac{1}{20}\left[\int_0^{10} \frac{(10-0)}{(10-0)} t \,.\, dt + \int_{10}^{12} -5 \,. dt + \int_{12}^{20} 5\, dt\right]$$

$$= \frac{1}{20}\left[\int_0^{10} t \,. dt - \int_{10}^{12} 5 \,. dt + \int_{12}^{20} 5\, dt\right]$$

$$= \frac{1}{20}\left(\left[\frac{t^2}{2}\right]_0^{10} - 5\left[t\right]_{10}^{12} + 5\left[t\right]_{12}^{20}\right)$$

$$= \frac{1}{20}\left(\frac{10 \times 10}{2} - 5 \times 2 + 5 \times 8\right)$$

$$= \frac{1}{20} \times 80 = 4V$$

Alternate method.

$$V_{D.C} = \frac{\text{Area Under Curve}}{\text{Base length}}$$

$$= \frac{\text{Positive Area} - (\text{Negative Area})}{\text{Base length}}$$

$$= \frac{\frac{1}{2} \times 10 \times 10 + 5 \times 8 - (5 \times 2)}{20}$$

$$= \frac{50 + 40 - 10}{20}$$

$$= \frac{80}{20}$$

$$V_{D.C.} = 4\,V$$

Energy Meter

Q.1 A correctly adjusted single phase 240V induction watt hour meter has a meter constant of 600 revolutions per kwh. Determine the speed of the disc, for a current of 10A at a power factor of 0.8 lagging. If the lag adjustment is altered so that phase angle between voltage coil flux and applied voltage is 86°, calculate the error introduced at 0.5 pf lagging.

Solⁿ:- Energy consumed in one minute with rated current and 0.8 pf lagging is

$$240 \times 10 \times 0.8 \times \left(\frac{1}{60}\right) \times 10^{-3} = 0.032\ kWh$$

$\therefore$ Revolutions made in one minute $= 0.032 \times \underbrace{600}_{\text{Meter constant}}$

$= 19.2$ rpm

$\therefore$ Speed of the Disc $= 19.2$ rpm

$$\text{Error introduced} = \frac{\sin(\Delta - \phi) - \cos\phi}{\cos\phi} \times 100$$

We have $\Delta = 86°$

p.f. $= 0.5$ lagging

$\Rightarrow \phi = 60°$

$$\therefore \text{error} = \frac{\sin(86° - 60°) - \cos 60°}{\cos 60°} \times 100 = -12.3\%$$

Q.2 In the measurement of power on balanced load by two-Wattmeter method in a 3-phase circuit, the readings of the Wattmeters are 3kW and 1kW respectively, the latter being obtained after reversing the connections of the current coil. The power factor of the load is?

Sol^n:- $W_1 = 3\,kW$

$W_2 = -1\,kW$

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

$= 0.277$

Q.3 Find the error in measurement of power using L-C short wattmeter having pressure coil resistance of $6\,k\Omega$, for a load with power factor 0.6 and drawing 20A at 220V.

Ans. $P_t = V_L I_L \cos\phi$

$= 220 \times 20 \times 0.6$

$= 2640\,W$

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

$= 2640 + \frac{(220)^2}{6000}$

$= 2648.6067\,W$

% error $= \frac{P_m - P_t}{P_t} \times 100 = 0.305\,\%$

Q.4 The voltage - flux adjustment of a certain 1-phase 220V induction watt-hour meter is altered so that the phase angle between the applied voltage and flux ~~are~~ due to it is 85° (instead of 90°). The errors introduced in the reading of this meter when the current is 5A at power factors of unity and 0.5 lagging are respectively?

Sol^n:- $\%\ \text{error} = \dfrac{P_m - P_t}{P_t} \times 100$

$\text{error} = P_m - P_t$

$P_t = V_L I_L \sin(90° - \phi)$

$P_m = V_L I_L \sin(85° - \phi)$

$\text{error} = V_L I_L (\sin(85° - \phi) - \sin(90° - \phi))$

$\cos\phi = 1$

$\Rightarrow \phi = 0°$

$\Rightarrow \text{error}_1 = 220 \times 5 (\sin 85° - \sin 90°)$

$= -4.18W$

$\cos\phi = 0.5$

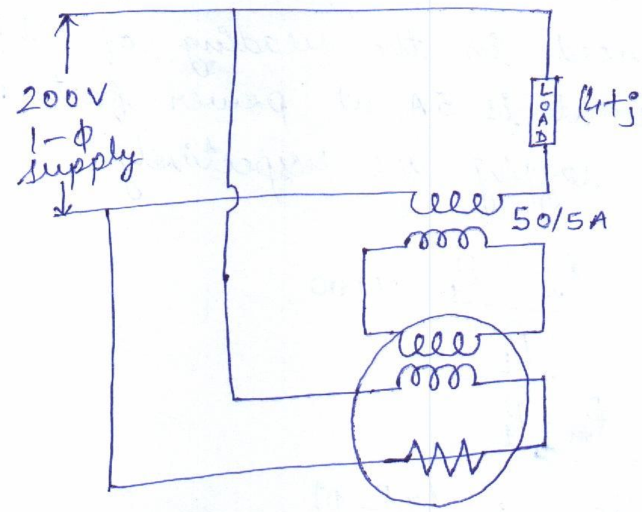
$\phi = 60°$

$\Rightarrow \text{error}_2 = 220 \times 5 [\sin 25° - \sin 30°]$

$= -85.1W$

Wattmeter

Q.1 In the circuit shown in the given figure, the wattmeter reading will be?



Current Transformer

Sol^n:- $Z = 4+3j$

$= \sqrt{4^2+3^2}$

$= 5\,\Omega$

$I_L = \frac{V}{Z} = \frac{200}{5} = 40\,A$

Step down current

$\Rightarrow \frac{40}{10} = 4\,A$

$P = V_L I_L \cos\phi$

$= 200 \times 4 \times 0.8$ $\qquad \cos\phi = \frac{R}{Z}$

$= 640\,W$

Q.2 A single phase kwh meter makes 500 revolutions per kwh. It is found on testing as making 40 revolutions in 58.1 seconds as 5kw full load. The percentage error in the meter is?

Solⁿ:- Energy consumed $(E.C.)_t = 5 \times \frac{58.1}{3600} = 0.0807$ kwh

$$(E.C.)_m = \frac{\text{revolutions}}{\text{Meter Constant}} = \frac{40}{500} = 0.08 \text{ kwh}$$

$$\% \text{ error} = \frac{0.08 - 0.0807}{0.0807} \times 100$$

$$= -0.86\%$$

Q.3 A 230V, 1-ϕ watt hour meter has a constant load of 4A passing ~~the~~ through it for 6 hours at unity p.f. if the meter disc makes 2208 revolutions during this period. Calculate the power factor of the load if the number of revolutions made by the meter are 1472 when operating at 230V and 5A for 4 hours.

Solⁿ:- No. of revolutions $= KVI\cos\phi \times t$

$$\therefore k = \frac{2208}{230 \times 4 \times 1 \times 6} = 400 \text{ rev/kwh}$$

$\therefore$ for 1472 revolutions $\cos\phi = ?$

$$\Rightarrow 1472 = (400 \times 230 \times 5 \times \cos\phi) \times 4 \times 10^{-3}$$

$$\Rightarrow \cos\phi = 0.8$$

Q.4 Find which coil connection should be chosen based on the error produced in the readings for wattmeter measuring ~~a too~~ power drawn by a load with the p.f. of unity at 30 V and current drawn being 20A. The pressure coil and current coil resistances are 1kΩ and 0.01 Ω respectively.

Ans. $P_t = V_L I_L \cos\phi$

$= 30 \times 20 \times 1$

$= 600\ W$

For M-C short

$$P_m = P_t + I_L^2 R_{cc}$$

$$= 600 + (20)^2 \times 0.01$$

$$= 604\ W$$

For L-C short

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

$$= 600 + \frac{30^2}{1000}$$

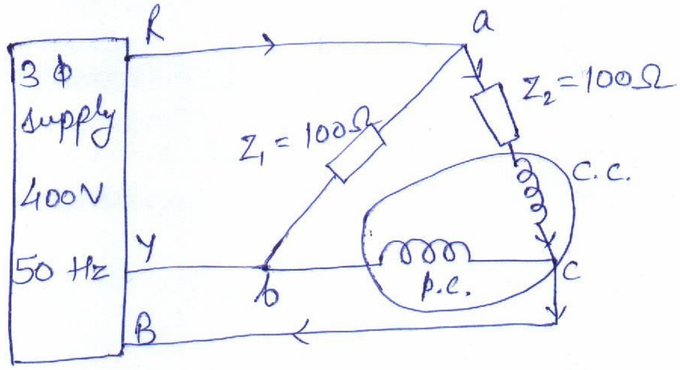
$$= 600.9 W$$

% error in MC short $e_1 = \frac{4}{600} \times 100 = 0.67\%$

% error in L-C short $e_2 = \frac{0.9}{600} \times 100 = 0.15\%$

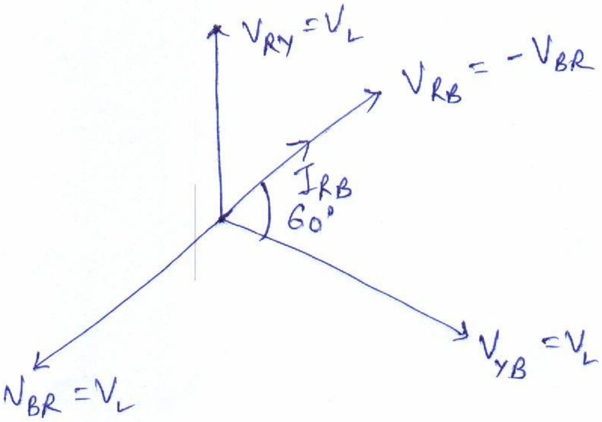
∴ L-C short wattmeter should be used here.

Q.5 The figure shows a three phase delta connected load supplied from a 400V, 50Hz, 3ϕ balanced source. The pressure coil and current coil of a wattmeter are connected to the load as shown. With the coil polarities suitably selected to ensure a positive deflection. The wattmeter reading will be?



Sol^n:- $P = I_{c.c.} \times V_{p.c.} \cos(I_{cc} \& V_{pc})$

$= I_{RB} \times V_{YB} \times \cos(I_{RB} \& V_{YB})$



$= \frac{V_L}{Z_2} \times V_L \times \cos(60°) = \frac{400}{100} \times 400 \times \frac{1}{2} = 800\,W$