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Modern Electrical & Electronics Technologies

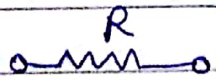
Google group: MEET_2017

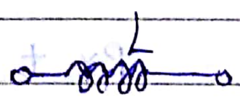
Topics:-
(i) Electrical Measuring Instruments
(ii) Transformers
(iii) Induction Motors
(iv) Special motors
(v) Electrical drives
(vi) Electrical heating
(vii) Digital Electronics + Intro to Mechatronics

mid-term

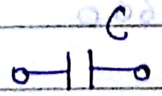
★ Electrical engineering: Quantities to be measured

(i) Voltage (Volts)
(ii) Current (Ampere)
(iii) Power (Watts)
(iv) Energy (Joules)
(v) Resistance (ohm (Ω))
(vi) Reactance
(vii) Inductance (Henry (H))
(viii) Capacitance (F)
(ix) Frequency (Hz) or (c/s)
(x) Angular frequency [$\omega = 2\pi f$]





$X_L = 2\pi f L$ — ①



$X_C = \dfrac{1}{2\pi f C}$ — ②

$\omega = 2\pi f$ — ③

$X_L = \omega L$ — ④ $\quad X_C = \dfrac{1}{\omega C}$ — ⑤

$f = \dfrac{1}{T}$ — ⑥ $\quad \omega = \dfrac{2\pi}{T}$ — ⑦

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$$R.P.M. = 1000$$

$$R.P.S. = \frac{1000}{60}$$

Electrical Parameters

- Direct Current (D.C.) type ⇓ No time dependence
- Alternating Current (A.C.) type ⇓ Time dependence

Q1. A 220 V D.C. supply is connected across a water-heater (geyser) and draws 4.4 A current. Calculate the resistance of heating element inside the heater.

Ans

$$R = \frac{220}{4.4} = 50\ \Omega$$

Q2. For the heater in Prob 4, Calculate amount of power dissipated in ~~the~~ the element. Also, calculate energy consumed in 1 hour

Ans

$$P = VI = 220 \times 4.4 = \quad Watts$$

$$E = P \times t$$

$$= 220 \times 4.4 \times 3600$$

$$= 3484.8\ KJoules$$

$$= \quad Kwh$$

Note:- Energy we pay for is measured in Kwh (Kilo Watt - hour)

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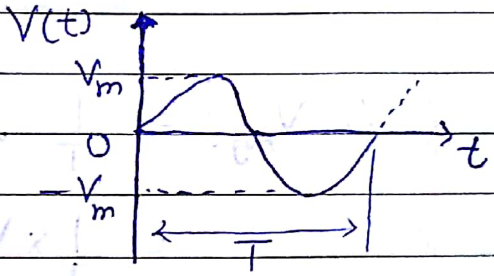
* $1\ KWh = 1000\ watt \times 3600\ sec.$
$= 3.6 \times 10^6\ watt-sec.$
$= 3.6 \times 10^6\ Joule$
[∵ 1 watt-sec = 1 Joule]

∴ $1\ Joule = \frac{1}{3.6 \times 10^6}$

$\simeq 2.77778 \times 10^{-7}\ KWh$

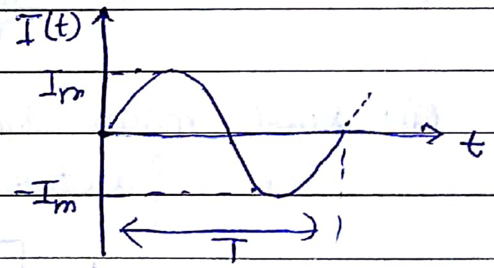
* A.C. signals:-

(i)
T = Time-period (sec)
V_m = Maximum or Peak value of Voltage



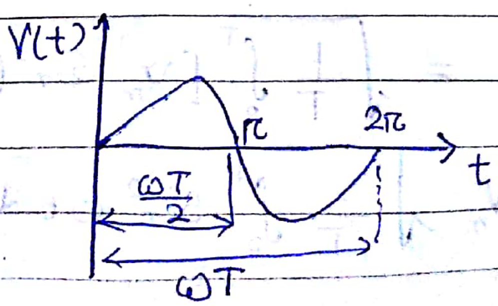
Frequency $(f) = \frac{1}{T}$ — ① ⇒ $T = \frac{1}{f}$ — ②

(ii) I_m = Peak Value for Current



Angular frequency (ω)
$= 2\pi f$ — ③
$\omega = \frac{2\pi}{T}$ — ④

$\Rightarrow \boxed{\omega T = 2\pi}$



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(i) Average Value ($V_{Avg.}$ or V_{DC}) :-

$$V_{DC} = V_{Avg} = \frac{1}{T}\int_0^T v(t)\,dt \quad — ①$$

$$v(t) = V_m \sin \omega t \quad — ②$$ (from first graph with phase diff. = 0)

$\because$ $\omega T = 2\pi$

$$\Rightarrow \omega = \frac{2\pi}{T} \quad — ③$$

$$= 2\pi f \quad — ④$$

$$\therefore V_{Avg.} = \frac{1}{T}\int_0^T V_m \sin(\omega t)\,dt$$

$$= \frac{1}{T} \times V_m \left[-\frac{\cos \omega t}{\omega}\right]_0^T$$

$$= -\frac{V_m}{T}\left[\cos \omega T - \cos 0\right]$$

$$= -\frac{V_m}{T} \times 0 = 0 \quad — ⑤$$

(ii) Root-mean square (RMS) Value or Effective value -

$$V_{RMS} \triangleq \sqrt{\frac{1}{T}\int_0^T [v(t)]^2\,dt} \quad — ⑦$$

For the same graph,

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T [v_m^2 \sin^2(\omega t)]\,dt} \quad — ⑧$$

$$= V_m \sqrt{\frac{1}{T}\int_0^T \sin^2 \omega t\,dt} \quad — ⑨$$

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Note:- Make sure that you mention units of all calculated values.

$$= V_m \cdot \sqrt{\frac{1}{T} \int_0^T \left[\frac{1}{2}(1-\cos 2\omega t)\right] dt} \quad \text{— (10)}$$

$$= V_m \sqrt{\left[\frac{1}{2} - \frac{1}{2T}\left[\frac{\sin 2\omega t}{2\omega}\right]_0^T\right]}$$

$$V_{RMS} = \frac{V_m}{\sqrt{2}} \quad \text{— (11)}$$

Similarly,

For an A.C. current $I(t) = I_m \sin \omega t$ — (12)

It can be shown that

$$I_{Avg} = I_{AC} = 0 \quad \text{— (13)}$$

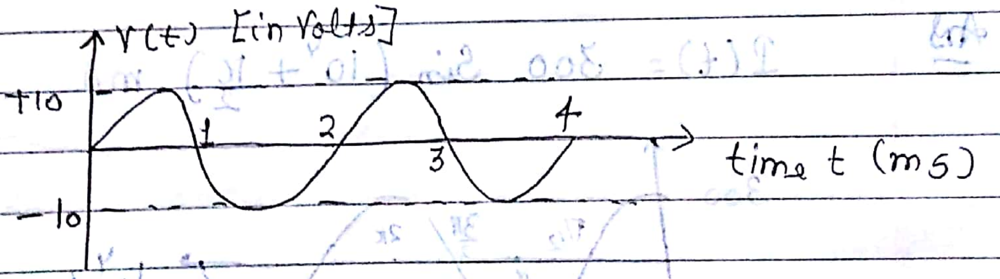
$$\& \quad I_{RMS} = \frac{I_m}{\sqrt{2}} \quad \text{— (14)}$$

Q. For A.C. Voltage waveform shown below, calculate the numerical values of the following:

(a) Frequency (b) Time-period (c) Angular freq.

(d) Peak-Value (e) Peak-to-peak Value

(f) RMS value and, (g) Average Value



Ans (a) $f = \frac{1000}{2} = 500$ Hz (b) $T = 2$ ms

(c) $\omega = 2\pi f = 1000\pi$ Hz $\simeq 3140$ Hz

(d) Peak Value = 10 Volts

(e) Peak-to-peak Value = 10+10 = 20 Volts

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(f) $V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{10}{\sqrt{2}} \simeq 7.07\ V$

(g) $V_{Avg.} = 0\ V$

Q. Repeat problem 1, for an A.C. current given by the following equation.

$$I(t) = 300 \sin(10^4 t)\ mA$$

where t is time in seconds.

Ans

$I_p = 300\ mA$

$\omega = 10^4\ rad/sec.$

$f = \frac{10^4}{2\pi} \simeq 1591.55\ c/s.$

$T = \cancel{\ }\ 6.28 \times 10^{-4}\ sec.$

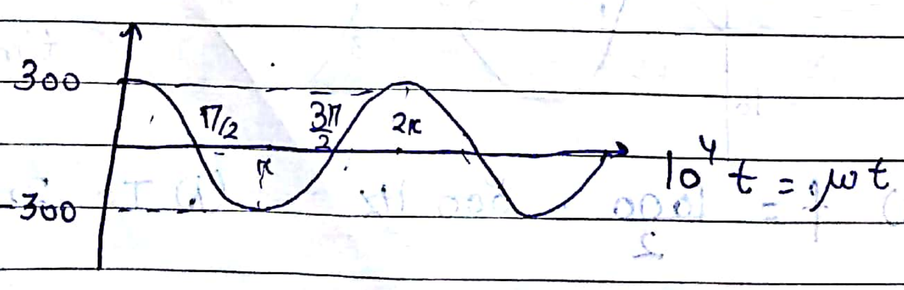
$I_{RMS} = \frac{300}{\sqrt{2}}\ mA$

$I_{p-p} = 600\ mA$

Q. Repeat prob. 2 for $I(t) = 300 \cos(10^4 t)\ mA$

Ans

$I(t) = 300 \sin\left(10^4 + \frac{\pi}{2}\right)\ mA$



$I_{Avg.} = 0$ $\qquad$ $I_{r.m.s.} = \frac{300}{\sqrt{2}}\ mA$

$I_p = 300\ mA$ $\qquad$ $I_{P-P} = 600\ mA$

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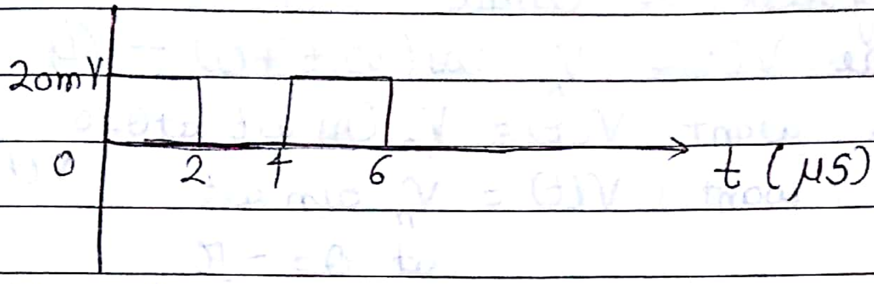
Q. Repeat problem 1 for the Voltage wave form shown below:



Ans

$T = 4\ \mu s$ $\qquad V_p = 20\,mV$

$f = \frac{10^6}{4}$ c/s

$$V_{DC} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{T}\left[\int_0^{T/2} (20\times 10^{-3})\,dt + 0\right]$$

$$= \frac{1}{T} \times 10^{-2} \times T = 10^{-2} = 10\,mV$$

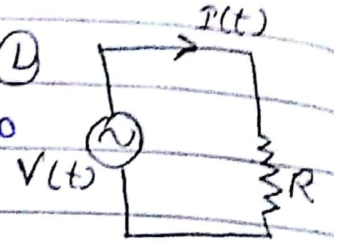
$$V_{rms} = \sqrt{\frac{1}{T}\int_0^{T/2} [v(t)]^2\,dt}$$

$$= \sqrt{\frac{1}{T}\times\frac{T}{2}\times 400\times 10^{-6}}$$

$$= \sqrt{2}\times 10^{-2}\,V = 10\sqrt{2}\ mV$$

★ Power in A.C. circuits:-

1. Purely resistive load:-



Assume $V(t) = V_m \cos(\omega t + \theta)$ — ①

If we want $V(t) = V_m \cos \omega t$ at $\theta = 0$

If we want $V(t) = V_m \sin \omega t$ at $\theta = -\frac{\pi}{2}$

θ is known as the phase-shift or phase-angle and can be measured either in radians or in degrees.

$$I(t) = \frac{V(t)}{R} \quad — ②$$

$$= \frac{V_m}{R} \cos(\omega t + \theta) \quad — ③$$

$$I(t) = I_m \cos(\omega t + \theta) \quad — ④$$

where $I_m \triangleq \frac{V_m}{R}$ — ⑤

Time dependent power can be written as-

$$P(t) \triangleq v(t)\, I(t) \quad — ⑥$$

$$= V_m I_m \cos^2(\omega t + \theta) \quad — ⑦$$

$$= \frac{V_m I_m}{2} \left[1 + \cos\{2(\omega t + \theta)\}\right] \quad — ⑧$$

$$\left[\because V_{rms} = \frac{V_m}{\sqrt{2}},\ I_{Rms} = \frac{I_m}{\sqrt{2}}\right]$$

$$= \underbrace{I_{rms} V_{rms}}_{\text{Real Power}} + \underbrace{V_{rms} I_{rms} \cos\{2(\omega t + \theta)\}}_{\text{Reactive Power}} \quad — ⑨$$

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Average Power -

(Consumed power)

$$P_{Avg} = P_{DC} = \frac{1}{T}\int_0^T p(t)\,dt \quad — (10)$$

$$= V_{rms} I_{rms} + \frac{1}{T}\left[\frac{\sin 2(\omega t + \theta)}{2\omega}\right]_0^T$$

$$= V_{rms} I_{rms} + \frac{1}{2T\omega}\left[\sin(2\omega T + 2\theta) - \sin 2\theta\right]$$

$$= V_{rms} I_{rms}$$

Problem 4:- An A.C. water heater operates at 220V (r.m.s.), 50 Hz input & consumes 1 kW. Calculate the resistance of heating element.

Ans

$$V_{rms} I_{rms} = 1000$$

$$\therefore I_{rms} = \frac{1000}{V_{rms}} = \frac{1000}{220} \text{ Amperes}$$

$$R = \frac{V_{rms}}{I_{RMS}} = \frac{220 \times 220}{1000}\ \Omega = 48.4\ \Omega$$

$$P = V_{rms} I_{rms}$$

$$= I_{rms}^2 R = \frac{V_{rms}^2}{R}$$

Power factor :-

The "Power-factor Angle" is defined as the phase-difference between $V(t)$ & $I(t)$

Power factor is defined to be $\cos\phi$

Note:- Power factor of purely-resistive circuit $= \cos\phi = \cos 0° = 1$

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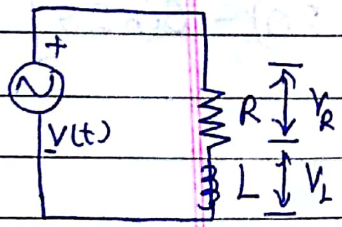
Problem 2:- Load containing .

2. Load containing a resistor & an indicator.

$$V(t) = V_m \cos(\omega t + \theta_v) \quad — (1)$$



$$V_L = L \frac{di}{dt} \quad — (2) \text{ [Faraday's law]}$$

$$V_R = Ri \quad — (3)$$

$$V = V_L + V_R \quad — (4) \quad \text{[Using Kirchoff's Voltage law]}$$

Source Voltage

$$L \frac{di}{dt} + Ri = V \quad — (5)$$

Impedance -

$$Z = R + j\omega L$$

Simplified case - $R = 0$

$$V_R = 0 \quad — (6)$$

$$L \frac{di}{dt} = V = V_m \cos(\omega t + \theta_v)$$

$$i = \frac{1}{L} \int v \, dt \quad — (7)$$

$$i = \frac{1}{L} \left[V_m \frac{\sin(\omega t + \theta_v)}{\omega} \right]$$

Note:- Clearly, i & V of purely indicative circuit have $\frac{\pi}{2}$ phase-difference, hence power-factor = 0 i.e. Power consumed = 0

$$[P = V_{rms} I_{rms} \cos\phi]$$

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$$i = \frac{V_m}{\omega L} \sin(\omega t + \theta_v) \quad — (8)$$

We define the reactance of the Inductor -

$$X_L = \omega L \quad — (9)$$
$$= 2\pi f L \quad — (10)$$

$$i = I_m \sin(\omega t + \theta_v) \quad — (11)$$

$$\Rightarrow i = I_m \cos(\omega t + \theta_v - \frac{\pi}{2})$$

where, $I_m = \frac{V_m}{\omega L}$ — (12)

$$i = I_m \cos(\omega t + \theta_I) \quad — (13)$$

$$\theta_I = \theta_v - \frac{\pi}{2} \quad — (14)$$

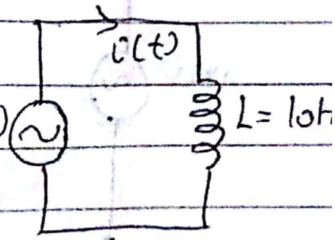
Power Factor Angle

$$\phi = \theta_v - \theta_I \quad — (15)$$
$$= \frac{\pi}{2}$$

$$\therefore \quad P.F. = \cos\phi = 0 \quad — (16)$$

Q// Consider a purely-inductive load connected to an A.C. Voltage source, as shown below:

$v(t) = 311 \cos(314t + 45°)$ Volts
(given)



Calculate the r.m.s. value of current flowing in the load.
Also write mathematical expression depicting the dependence of load current on time.

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$i_m = \frac{V_m}{\omega L}$

Sol. $v_{rms} = \frac{311}{\sqrt{2}}$, $\omega = 314$

$v = L\frac{di}{dt}$

$i = \frac{1}{L}\int v\,dt$

$= \frac{1}{10}\int 311 \cos(314t + 45^\circ)\,dt$

$= \frac{1}{10}\left[\frac{311}{314} \sin(314t + 45^\circ)\right]$

$X_L = 2\pi f L = \omega L$

$= 314 \times 10 = 3140\ \Omega$

$i = \frac{311}{3140} \sin(314t + 45^\circ)$ A

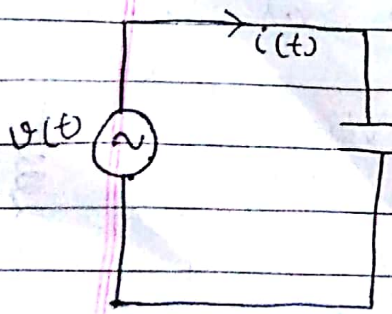
$\simeq 0.1 \cos(314 - \frac{\pi}{4})$ A

$i_{rms} = \frac{311}{3140 \times \sqrt{2}} \simeq 0.07$ A

P. F. angle → $\phi = \theta_V - \theta_I$

$= \frac{\pi}{4} - (-\frac{\pi}{4}) = \frac{\pi}{2}$ $\therefore$ P.F. $= \cos\phi = 0$

Case 3: Purely - Capacitive load :-



$v(t) = V_m \cos(\omega t + \theta_v)$ — ①

$i = C\frac{dv}{dt}$ — ②

$= -C V_m \omega \sin(\omega t + \theta_v)$ — ③

The reactance of capacitor is defined as-

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$ — ④

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$$i(t) = -\frac{V_m}{X_C} \sin(\omega t + \theta_v)$$

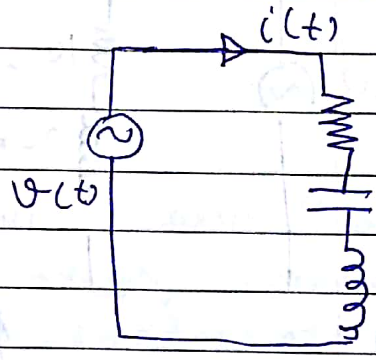
$$= -\frac{V_m}{X_C} \cos\left(\omega t + \theta_v + \frac{\pi}{2}\right)$$

$$\theta_I = \frac{\pi}{2} + \theta_v$$

$$\Rightarrow \phi = \theta_v - \theta_I = -\frac{\pi}{2}$$

Power factor $\rightarrow \cos\left(-\frac{\pi}{2}\right) = 0$

Case 4: Load has R, L & C



$$v(t) = V_m \cos(\omega t + \theta_v) \quad — (1)$$

$$i(t) = I_m \cos(\omega t + \theta_I) \quad — (2)$$

$$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}} \quad — (3)$$

where,

$$X_L = 2\pi f L = \omega L \quad — (4)$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{\omega C} \quad — (5)$$

P. F. Angle: $\phi = \theta_v - \theta_I \quad — (6)$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) \quad — (7)$$

P. F. $= \cos\phi \quad — (8)$

Average Power [True Power]:-

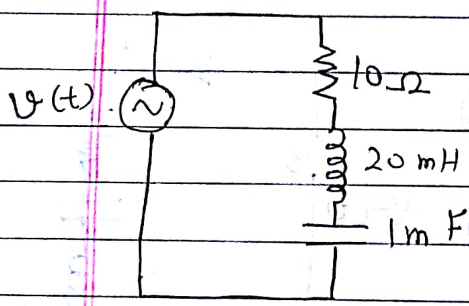
$$P = I_{rms} V_{rms} \cos\phi \quad [\text{Unit : Watts}]$$

Reactive Power [Phantom Power]:-

$$Q = V_{rms} \cdot I_{rms} \sin\phi \quad [\text{Unit : VAR}]$$

Voltage Ampere reactive

Q. Calculate the power factor, the consumed power & reactive power in the load below:-



$v(t) = 220\sqrt{2}\cos(314t)$ Volts

Ans

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$$X_L = 314 \times 20 \times 10^{-3}\,\Omega$$
$$= 6.28\,\Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{\omega C}$$

$$= \frac{1}{3.14 \times 1 \times 10^{-3}} \simeq 3.19\,\Omega$$

$$\phi \simeq \tan^{-1}\left(\frac{6.28 - 3.19}{10}\right)$$

$$\simeq \tan^{-1}(0.309) \simeq 17.17^\circ$$

P.F. → $\cos\phi \simeq \cos(17.17^\circ) \simeq 0.955$

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Consumed power $\rightarrow$ $P = \cancel{\frac{220^2}{10^2 + 3.09^2}}$

$$P = 220 \times \frac{220}{\sqrt{10^2+3.09^2}} \times \cos\phi$$

$$\simeq \frac{220^2}{10.47} \times 0.955$$

$$\simeq 4416 \text{ Watt}$$

Reactive Power $\rightarrow$ $Q = V_{rms} I_{rms} \sin\phi$

$$= 1371.6 \text{ VAR}$$

$$= 1.3716 \text{ KVAR}$$

★ Power Triangle :-

(i) We define the true power (also known as consumed power, average power, real power, actual power, power dissipated etc.) as -

[P → watts]

$$P = V_{rms} I_{rms} \cos\phi \quad — (1)$$

where ϕ is the "power-factor angle" and $\cos\phi$ is Power-factor

(ii) We also define the reactive power (also known as, imaginary power, phantom power etc.) as -

$$Q = V_{rms} I_{rms} \sin\phi \quad — (2)$$

['Q' is measured in VAR]

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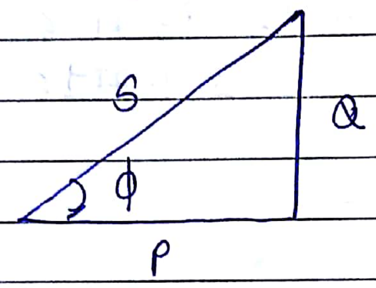
(iii) In addition "Apparent power" is defined as-

$$S = V_{rms} I_{rms} \quad — (3)$$

Note:- 'S' is measured in VA.

$$\therefore P = S \cos\phi \quad — (4)$$
$$Q = S \sin\phi \quad — (5)$$

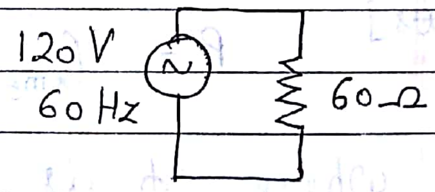


$$S = \sqrt{P^2+Q^2} \quad — (6)$$

$$\phi = \tan^{-1}\left(\frac{Q}{P}\right)$$

Power - Triangle

Q Sketch the power-triangle for the circuit shown below:



Ans

$P = V_{rms} I_{rms} \cos\phi$

$V_{rms} = 120\,V$ (given)

$I_{rms} = \frac{120}{60} = 2A$

$\phi = 0$

$\therefore P = 120 \times 2 = 240$ Watts

Now, $Q = 120 \times 2 \times 0 = 0$ VAR

$S = 240$ VA

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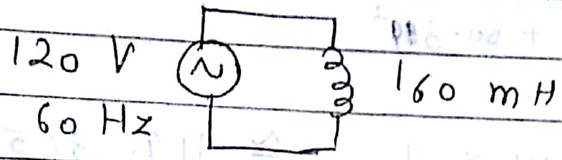
$$\xrightarrow{Q=0,\ \phi=0}$$
$S = P = 240$

Q2. Repeat the problem 1 for the circuit shown bellow:



Ans

$$\phi = \frac{\pi}{2}, \quad V_{rms} = 120$$

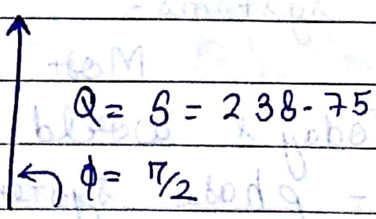
$$X_L = 2\pi f L = 2 \times 3.14 \times 60 \times 160 \times 10^{-3}$$
$$\approx \cancel{60.288\Omega} \simeq 60.319\ \Omega$$

$$I_{rms.} = \frac{120}{60} \simeq 2\ A$$

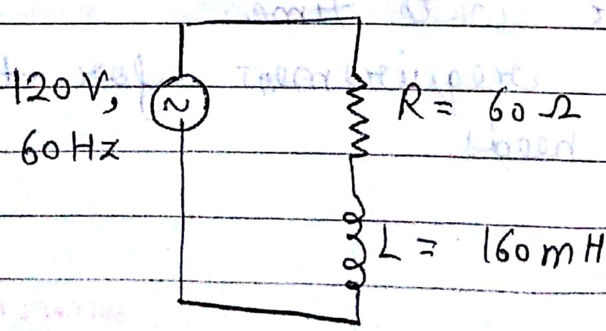
Here, $P = 0$

$$Q \simeq 120 \times 2 = 238.73\ VAR$$

$$S = 238.73\ VA$$



Q Repeat problem 4 for circuit shown below:



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Ans $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{X_L}{R}\right)$

$\simeq 45.15^\circ$

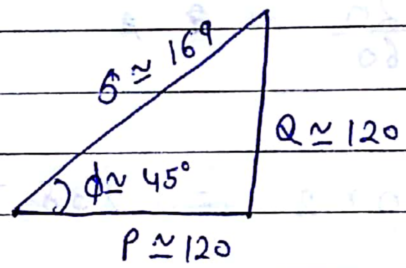
$I_{rms} = \frac{120}{\sqrt{60^2 + 60.3^2}} \simeq 1.41$

$P \simeq 120 \times 1.41 \times \frac{1}{\sqrt{2}} \simeq 119.365$ Watts

$Q \simeq 119.998$ VAR

$S = \sqrt{P^2 + Q^2}$

$\simeq 169.256$ VA



* Three – Phase systems :-

Most of the electrical power in Today's world is generated using three-phase systems. Advantage of a three-phase system over a single-phase system are:

(i) Constant-power with time

(ii) Less material requirement for the same power needs.

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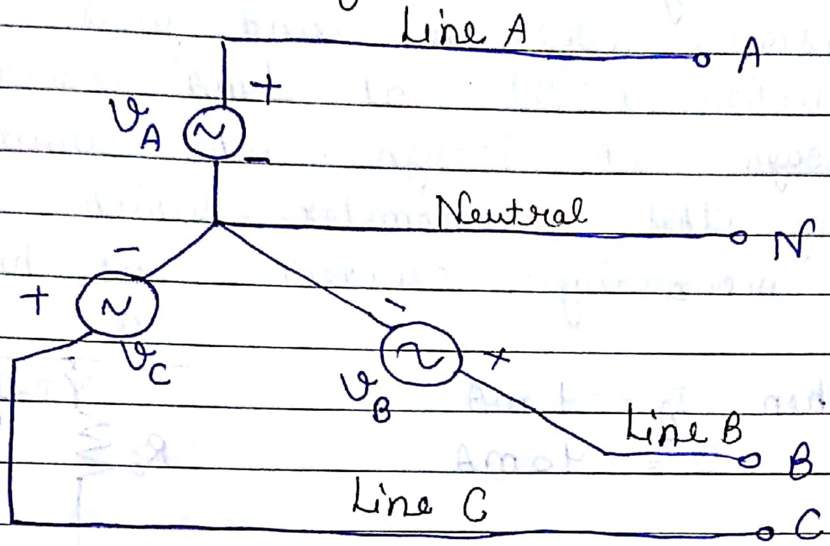
(a) Star - Connected generators :-



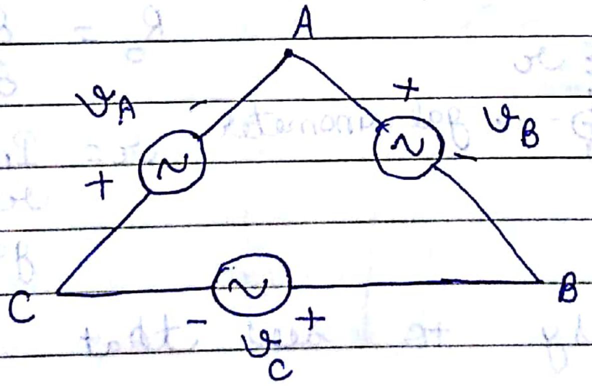
$$v_A = V_m \cos(\omega t) \text{ Volts}$$

$$v_B = V_m \cos(\omega t + 120^\circ) \text{ Volts}$$

$$v_C = V_m \cos(\omega t + 240^\circ) \text{ Volts}$$

Phase Voltages

(b) Delta- Connected systems



Load can also be Δ type or Star type

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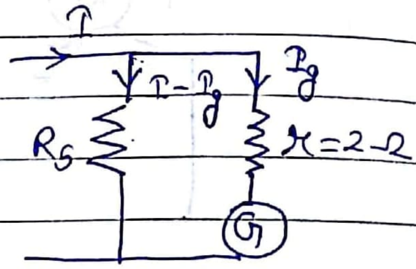
Q. A moving-coil Galvanometer has internal resistance (r) = 2Ω and gives full-scale deflection (FSD) at $1\,mA$ current flowing through it. Design the ammeter circuit (using this galvanometer) which is capable of measuring current as high as $10\,mA$

Sol.



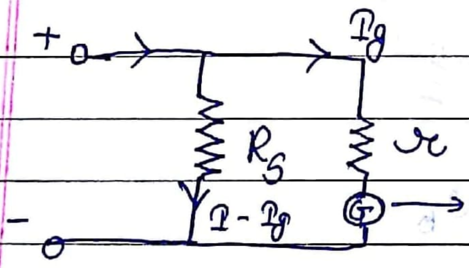
When $I_g = 1\,mA$

$I = 10\,mA$

$$(I - I_g)\, R_s = r \times I_g$$

$$\Rightarrow R_s = \frac{r\, I_g}{I - I_g} = \frac{2 \times 1}{9} = \frac{2}{9}\,\Omega$$

* Equations for analyzing / designing an ammeter (Ampere-meter)



R_s = External Shunt resistance

r = Internal resistance of galvanometer 'G'

It is easy to see that

$$R_s (I - I_g) = r\, I_g \quad \text{— (1)}$$

$$\therefore \; R_s\, I = I_g (r + R_s)$$

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$$\therefore \frac{I_g}{I} = \frac{R_S}{r + R_S} \quad \text{--- (2)}$$

Q You are given the ammeter circuit shown below. It is given that $r = 2\,\Omega$ and $R_S = 10\,\Omega$. It is also known that the galvanometer shows full-scale deflection (FSD) when the galvanometer current $= 100\,\mu A$. Over what range can this ammeter measure current?

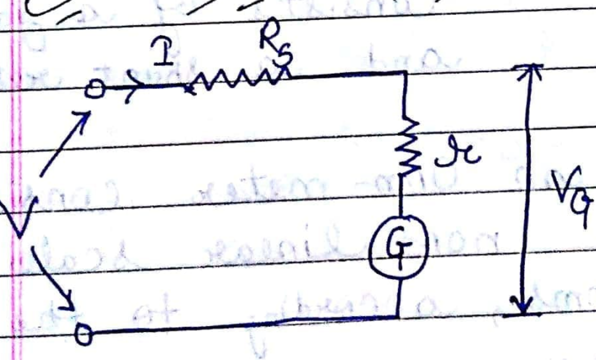
Ans

~~$I_{FSD} = 100\ \mu A$~~ $\quad I_g = 100\,\mu A$

$$\therefore I_{FSD} = I_g \times \frac{R_S + r}{R_S}$$

$$= 100 \times \frac{12}{10} = 120\,\mu A$$

★ **Equations for Analysing / designing a Voltmeter:-**



$$V_G = r\, I_{G(FSD)} \quad \text{--- (1)}$$

$$I = I_G = \frac{V}{R_S + r} \quad \text{--- (2)}$$

$$V_G = \frac{r}{R_S + r} V \quad \text{--- (3)}$$

By KVL,

$$V = I R_S + V_G$$

$$= \frac{V R_S}{R_S + r} + V_G$$

$$\Rightarrow \boxed{V\left[1 - \frac{R_S}{R_S + r}\right] = V_G}$$

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Q. Using a galvanometer with internal resistance = 1 Ω and FSD current = 1 mA. Design a Voltmeter capable of measuring Voltages as high as 50 V.

Ans

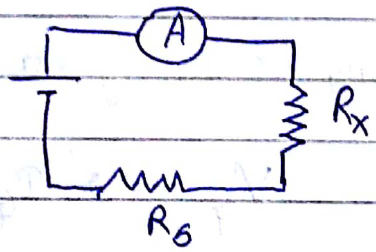
$$V_G = 1\,\Omega \times 1\,mA = 1\,mV$$

$$V_{FSD} = \left(\frac{R_s + r}{r}\right) V_G = 50$$

$$\Rightarrow R_s \simeq 50\,K\Omega$$

✱ Ohm-meter:-

A simple Ohm-meter consists of a battery, an ammeter, and a safety resistance R_s, all connected in series with the resistance being measured.



The ammeter itself consists of a galvanometer and a shunt resistance.

The display of an Ohm-meter consists of an inverted non-linear scale calibrated in ohms, according to the following equation:

$$I = \frac{V}{R_s + R_x} \quad \text{--- (1)}$$

i.e. $$R_x = \frac{V}{I} - R_s \quad \text{--- (2)}$$

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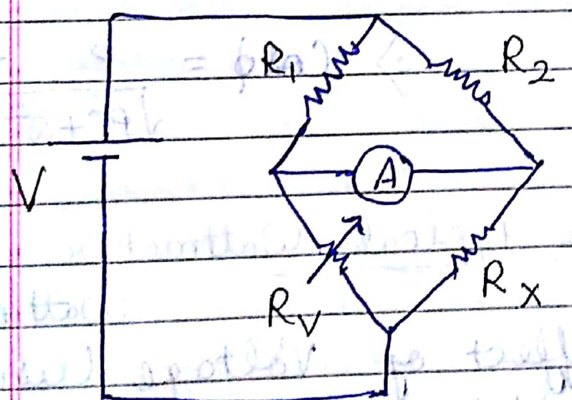
★ Measuring Small resistance Values using Wheatstone Bridge:-

For small resistances, typically less than 1 Ω, moving-coil-based Ohm meter display poor accuracy, since they do not separate the resistance to be measured (R_x) from the resistance of the wires used for making the circuit, internal resistance of the battery, errors in obtaining precise values of the safety resistance (R_S), etc.

In such cases, we use Wheat-stone Bridge which is Null-Type Intrument (not a DEFLECTION-Type instrument)



The ammeter in this circuit should be able to handle currents in both directions. It does not have to be highly-accurate for non-zero current values.

The ammeter must, however, be able to reliably indicate which way the current is flowing through it, and also when ~~when~~ when the current fully vanishes

Null-condition is obtained by varying R_V, the unknown resistance 'R_X' can be calculated using -

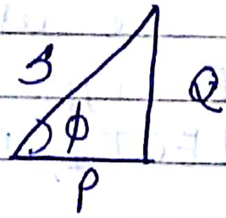
$$R_X = \left(\frac{R_2}{R_1}\right) R_V \quad \text{— (1)}$$

* Watt-meter :-

(i) is used to measure Average Power 'P'

(ii) VAR-meters are used to measure Reactive Power Q.

(iii) Power factor can be measured using Power triangle.



$$\cos\phi = \text{P.F.} = \frac{P}{S} \quad \text{— (1)}$$

$$\Rightarrow \cos\phi = \frac{P}{\sqrt{P^2+Q^2}} \quad \text{— (2)}$$

Construction of a Typical Wattmeter

Watt meter combines the effect of Voltage (using a "Voltage Coil" which is Known as "pressure coil) and current (using a "Current coil)

P.C. ⇒ Pressure Coil
C.C. ⇒ Current coil

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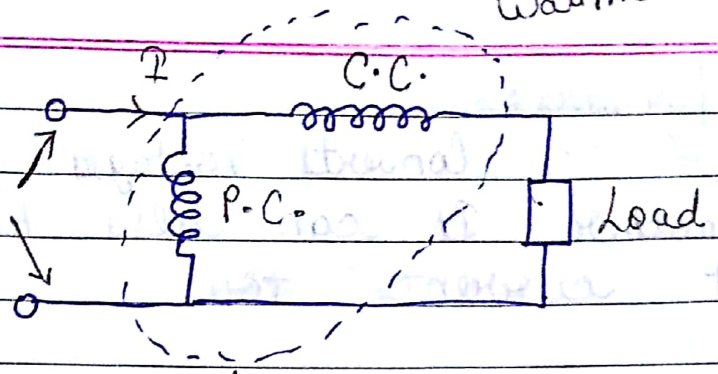
Wattmeter



Schematic

Wattmeter Types:- (i) Dynamomometer type] Commonly used for DC power
(using two coils)
(ii) Induction Type → Commonly used for AC power
(iii) Electrostatic Type] Not much used because Torque/weight ratio is small

(i) Induction Type Wattmeter - (a) works on the principle of torque ~~produced induced~~ production by induced currents in a short - circuited coil which is under the influence of other current - carrying coils.

(b) Induction Type Wattmeters are used only for AC measurements.

(c) The few decisive advantages of the induction type Wattmeter are sturdy construction, very long circular scale, reasonably - low torque/weight ratio, almost maintenance - free operation etc.

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