Basic Electrical Engineering IAT1 Scheme and Solution

1. a) State and explain Ohm's law, List out its limitation.

n's law :-

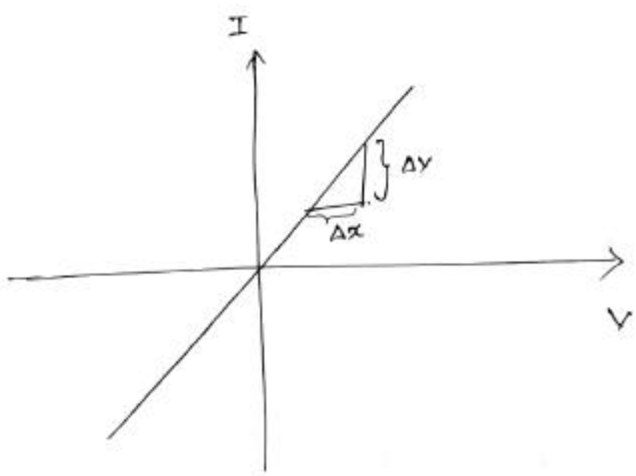
The ratio of potential difference (V) between any two points on a conductor to the current (I) flowing between them is constant, provided the temperature of the conductor doesn't change.

$$\frac{V}{I} = \text{constant}$$
$$= R(\Omega)$$

R - constant of proportionality

- resistance of the conductor.

Graphical representation of Ohm's law:



$$\text{Slope} = \frac{\Delta Y}{\Delta X} = \frac{I}{V} = \frac{1}{R} = G$$

where G is conductance (siemens) (℧).

Limitations - OHM'S LAW

1) It cannot be applied to non-linear devices like diodes, zener diodes, transistors, voltage regulator etc.

2) Ohm's law is applicable as long as tempe- -rature and other physical parameters remains constant

3) It cannot be applied to complicated ckts having more no of branches and emf sources.

4) Not suitable for non-metallic conductors like silicon carbide, graphite etc.

1 b) Derive maximum power transfer theorem applied to the series circuit. Mention its applications

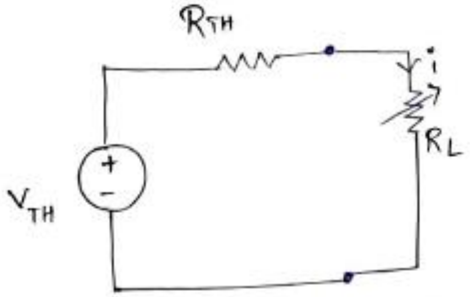
Maximum Power Transfer Theorem

In many situations, a circuit is designed to provide power to a load. There are applications in areas such as communi-cations it is desirable to maximize the power delivered to the load.

Thevenin equivalent is useful in finding the maximum power a linear circuit can deliver to a load.

Thevenin's Theorem

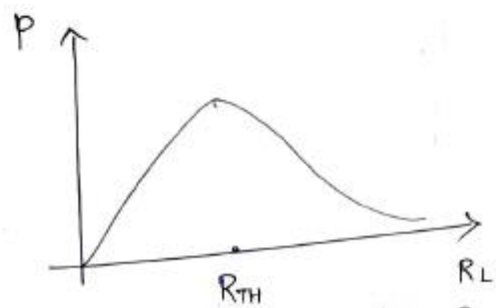
A linear two-terminal ckt can be replaced by an equivalent circuit consisting of a voltage source V_{TH} in series with a resistor R_{TH}, where V_{TH} is the open circuit voltage at the terminals and R_{TH} is the equivalent resistance at the terminals when the independent sources are turned off.



* the entire circuit is replaced by its Thevenin equivalent except for the load.

the power delivered to the load,

$$p = i^2 R_L = \left[\frac{V_{TH}}{R_{TH} + R_L}\right]^2 R_L \quad — ①$$



V_{TH} and R_{TH} are constant

→ By varying R_L, the power delivered to the load varies.

$$p = V_{TH}^2 \left[\frac{R_L}{(R_{TH}+R_L)^2}\right] \quad — ②$$

differentiating p w.r.t R_L,

$$\frac{dp}{dR_L} = V_{TH}^2 \left[\frac{(R_{TH}+R_L)^2 \times 1 - R_L \times 2(R_{TH}+R_L)}{(R_{TH}+R_L)^4}\right] = 0.$$

$R_{TH}^2 + R_L^2 - 2R_{TH}R_L - 2$

$$V_{TH}^2 \left[\frac{(R_{TH}+R_L)\left[(R_{TH}+R_L) - 2R_L\right]}{(R_{TH}+R_L)^4}\right] = 0.$$

$$V_{TH}^2 \left[\frac{R_{TH} + R_L - 2R_L}{(R_{TH}+R_L)^3} \right] = 0.$$

$$R_{TH} - R_L = 0$$

$$\boxed{R_{TH} = R_L} \quad - (3).$$

$\therefore$ Maximum power is transferred when the load resistance equals the Thevenin resistance as seen from the load.

The value of maximum power:

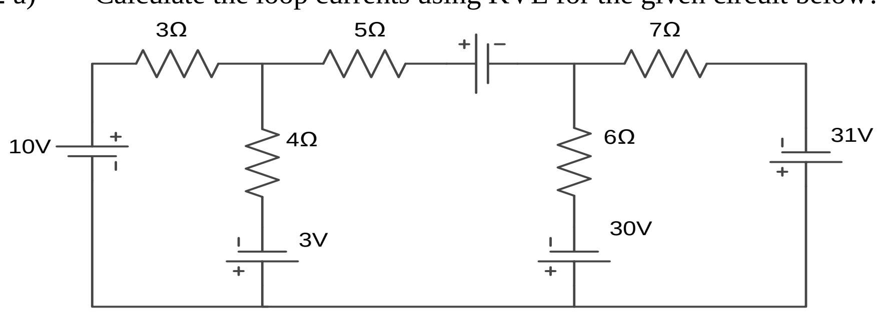
(3) in (1),

$$P_{max} = \frac{V_{TH}^2}{(R_{TH}+R_{TH})^2} \cdot R_{TH} \Rightarrow \frac{V_{TH}^2}{(2R_{TH})^2} R_{TH}$$

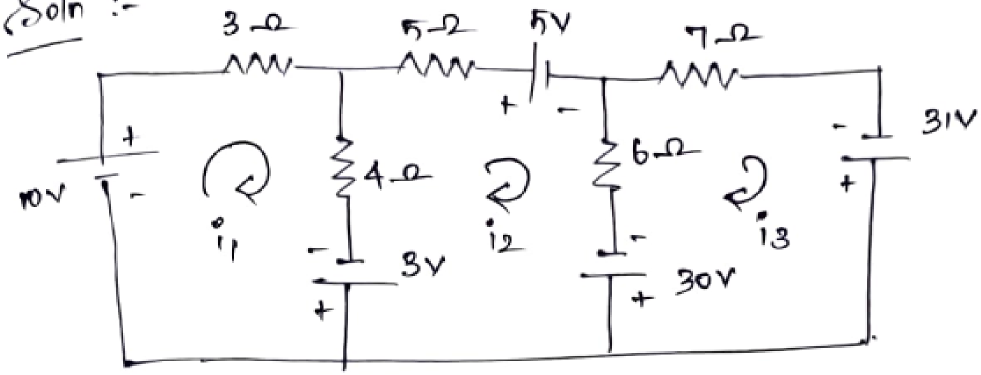
$$= \frac{V_{TH}^2 \cancel{R_{TH}}}{4R_{TH}^{\cancel{2}}}$$

$$\boxed{P_{max} = \frac{V_{TH}^2}{4R_{TH}}} \quad - (4).$$

2 a) Calculate the loop currents using KVL for the given circuit below?



Soln :-



KVL @ loop 1 :-

$$10 - 3i_1 - 4(i_1 - i_2) + 3 = 0$$

$$10 - 3i_1 - 4i_1 + 4i_2 + 3 = 0$$

$$10 - 7i_1 + 4i_2 + 3 = 0$$

$$\boxed{-7i_1 + 4i_2 + 0i_3 = -13} \quad - (1)$$

KVL @ loop 2 :-

$$-5i_2 - 5 - 6(i_2 - i_3) + 30 - 3 - 4(i_2 - i_1) = 0.$$

$$-5i_2 - 5 - 6i_2 + 6i_3 + 27 - 4i_2 + 4i_1 = 0.$$

$$\boxed{4i_1 - 15i_2 + 6i_3 = -22} \quad - (2)$$

KVL @ loop 3 :-

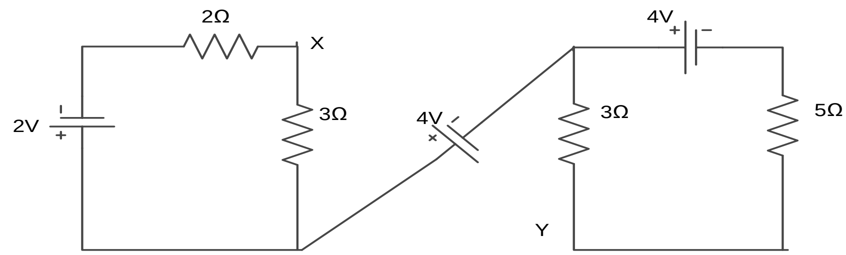
$$-7i_3 + 31 - 30 - 6(i_3 - i_2) = 0.$$

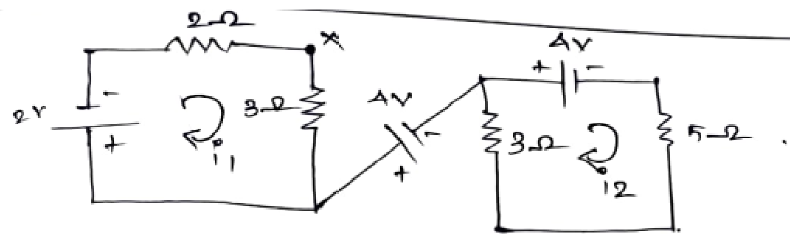
$$-7i_3 + 1 - 6i_3 + 6i_2 = 0.$$

$$\boxed{0i_1 + 6i_2 - 13i_3 = -1} \quad - (3).$$

Solving, $i_1 = 3.57A$; $i_2 = 3.01A$; $i_3 = 1.46A$.

2 b) For the given circuit calculate Vxy





Calculate i_1 using KVL @ loop 1,

$-2i_1 - 3i_1 - 2 = 0.$

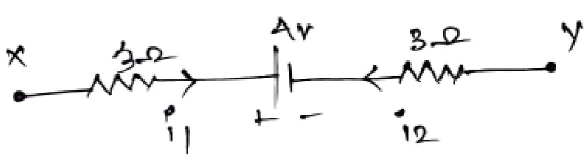
$-5i_1 = 2$; $\boxed{i_1 = -0.4A}$

$i_2 \Rightarrow$ KVL @ loop 2 ;

$-4 - 5i_2 - 3i_2 = 0.$

$-8i_2 = 4$; $\boxed{i_2 = -0.5A}$.

Vxy



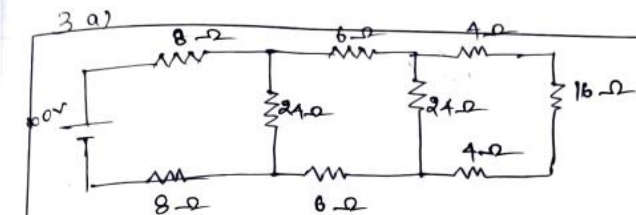
$\therefore V_{xy} = -3i_1 - 4 + 3i_2 \Rightarrow -3(-0.4) - 4 + 3(-0.5)$

$\boxed{V_{xy} = -4.3V}$.

↳ can be +ve or −ve depending on the assumed current direction.

3 a) Find the power dissipated in 16 ohm resistor.

3 a)



$\Rightarrow 16 + 4 + 4 = 24$

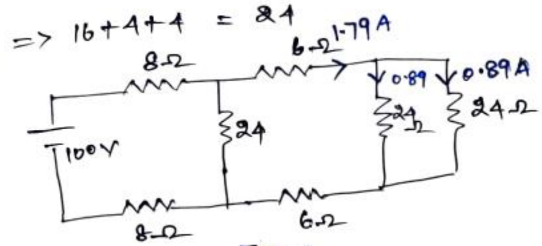


FIG : 1

(2) $24 \parallel 24 = 12\,\Omega$

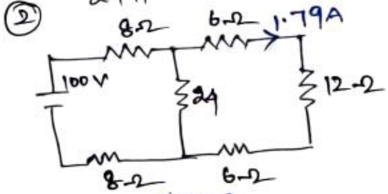


FIG : 2

(4) $24 \parallel 24 = 12\,\Omega$.

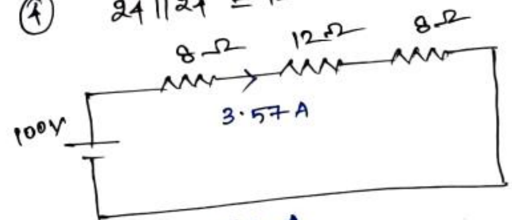


FIG 4

$6 + 12 + 6 = 24\,\Omega$

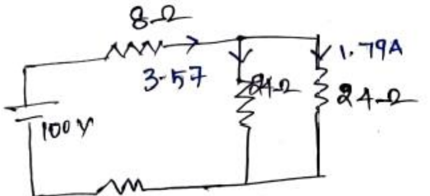


FIG 3

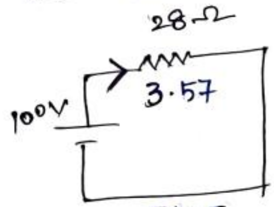


FIG 5

To find P thro 16 Ω,

$\Rightarrow$ Refer fig (5), using current div, current thro 24 Ω resistors $\boxed{1.79\,A}$. $\boxed{\because \frac{3.57}{2}}$

$\Rightarrow$ Same logic apply for remaining figures. the current thro 16 Ω 0.89 A.

$R_{eq} = 28\,\Omega$

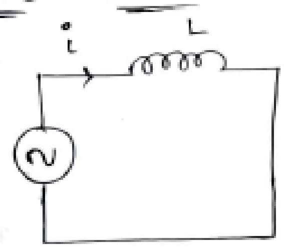
$I = \frac{V}{R} = \frac{100}{28} \Rightarrow 3.57\,A$.

$\therefore P = 0.89^2 \times 16 \Rightarrow 12.67\,W$.

$(I^2 R)$

3 b) For a pure inductor excited by sinusoidal varying AC voltage, show that the average power consumed by inductor is zero with necessary diagrams and waveforms

AC Circuit containing inductance :-



When an alternating current flows thro pure inductive coil, an emf is induced. $e = L\frac{di}{dt}$ ..

$v = V_m \sin\omega t$

∴ Since there is no voltage drop,

applied voltage = back emf

Let L be the inductance of the coil,

$$v = V_m \sin \omega t \quad - ①$$

$$V_m \sin \omega t = L \frac{di}{dt}$$

$$\frac{di}{dt} = \frac{V_m}{L} \sin \omega t$$

$$di = \frac{V_m}{L} \sin \omega t \, dt$$

$$i = \frac{V_m}{L} \int \sin \omega t \, dt$$

$$= \frac{V_m}{L} \frac{(-\cos \omega t)}{\omega}$$

$\because -\cos\theta = \sin(\theta - 90)$.

$$i = \frac{V_m}{\omega L} \sin(\omega t - 90) \quad - ②$$

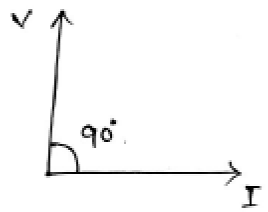
The value of i will be max, when $\sin(\omega t - 90)$ is unity

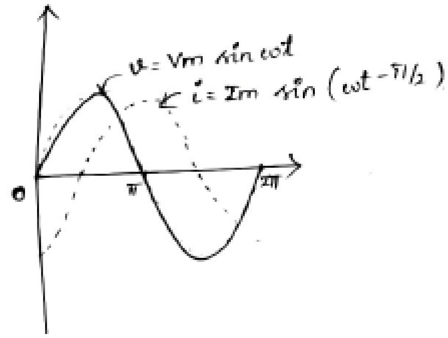
$$\therefore I_m = \frac{V_m}{\omega L} \quad - ③$$

⑤ in ⑤, $i = I_m \sin(\omega t - 90) \quad - ④$

Comparing ① and ④,

$\Rightarrow$ current lags voltage by 90°.





Inductive reactance: $I_m = \frac{V_m}{\omega L}$

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

The opposition offered by the inductance to the current flow is $\omega L = X_L$

X_L - inductive reactance of the coil. (Ω)

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

Power: Instantaneous power $= v \times i$

$$= V_m I_m \sin \omega t \sin(\omega t - 90)$$

$$= -V_m I_m \sin \omega t \cos \omega t.$$

$$p = -\frac{V_m I_m}{2} \sin 2\omega t \quad - ⑤.$$

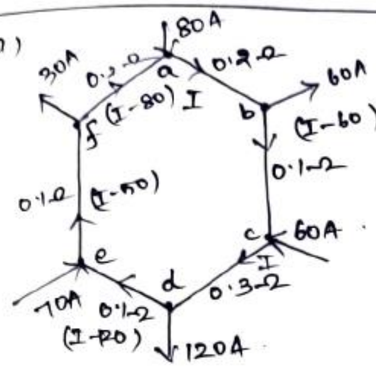
Average power P = average power over one cycle.

$$= \frac{1}{2\pi} \int_0^{2\pi} -\frac{V_m I_m}{2} \sin 2\omega t \; d\omega t.$$

$$P = 0. \quad - ⑥.$$

4 a) For the given circuit , calculate current through all the branches

a)



Let us assume current through branch ab, be I (A).
Applying KCL at remaining nodes, the current through all other branches are written as follows

$I_{ab} = I(A)$; $I_{bc} = (I-60)\,A$; $I_{cd} = I(A)$; $I_{de} = (I-120)\,A$

$I_{ef} = (I-50)\,A$; $I_{fa} = (I-80)\,A$.

Apply KVL for the loop $\underline{abcdefa}$,

$-0.2I - 0.1(I-60) - 0.3I - 0.1(I-120) - 0.1(I-50)$

$- 0.2(I-80) = 0.$

$-0.2I - 0.1I + \cancel{6} - 0.3I - 0.1I + 12 - 0.1I + 5 - 0.2I + 16 =$

$I - 39 = 0$

$\boxed{I = 39\,A}$

$I_{ab} = 39A$; $I_{bc} = \cancel{I}\ 39-60 = -21A$; $I_{cd} = 30A$

$I_{de} = I-120 = 39-120 = -81A$; $I_{ef} = -11A$;

$I_{fa} = -41A$.

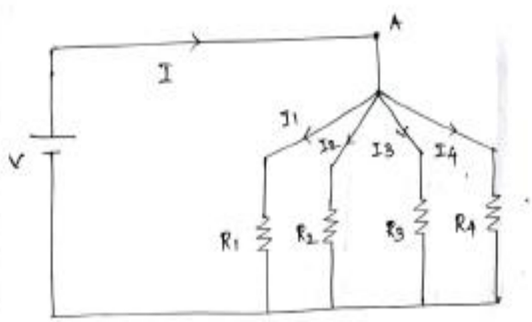
0

4 b) State and explain Kirchhoff's Laws, as applied to D.C. Circuit.

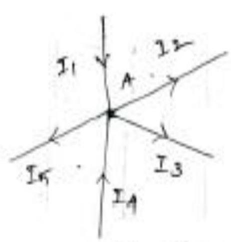
KIRCHHOFF'S CURRENT / POINT LAW: [KCL]

In any electrical network, the algebraic sum of the currents meeting at a point on junction is zero. i.e $\Sigma I = 0$.

i.e total current leaving a junction is equal to the total current entering that junction.



$I = I_1 + I_2 + I_3 + I_4$



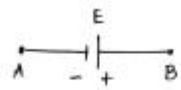
$I_1 + I_4 = I_2 + I_3 + I_5$

KIRCHHOFF'S VOLTAGE / MESH LAW: [KVL]

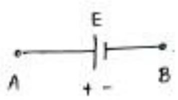
The algebraic sum of voltages [voltage drop + e. around a closed loop or circuit is zero.

$$\sum IR + \sum e.m.f = 0.$$

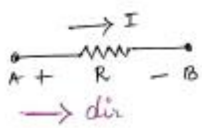
Determination of voltage sign :-



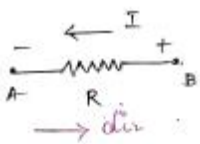
Rise in voltage +ve sign.



Fall in voltage -ve sign.



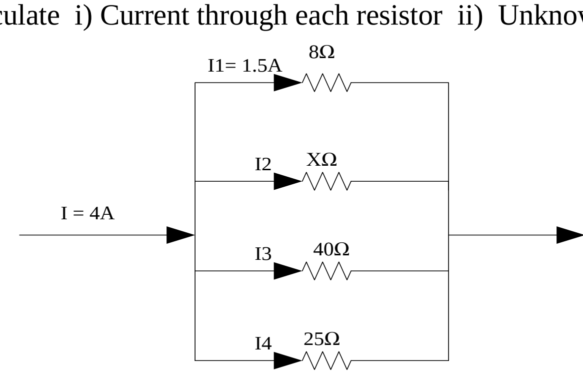
Fall in voltage -ve sign

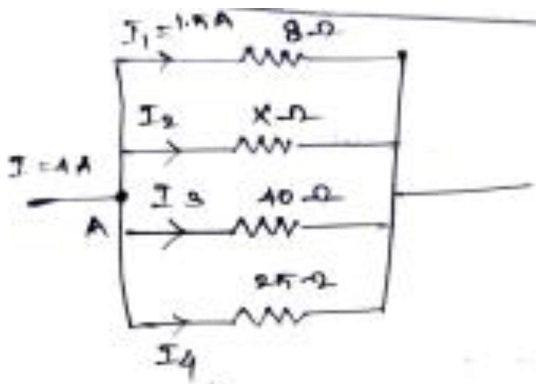


Rise in voltage +ve sign.

x. It should be noted that sign of voltage drop depends on the direction of current and is independent of the polarity of the emf of source in the circuit under consideration.

5 a) Calculate i) Current through each resistor ii) Unknown resistance x? iii) Req. iv) Power consumed.





Voltage across 8Ω, resistor $= I_1 R = 1.5 \times 8 = 12\text{ V}$.

current through 40Ω, $\frac{V}{R} = \frac{12}{40} \Rightarrow 0.3\text{A} \Rightarrow I_3$

current through 25Ω, $\frac{V}{R} = \frac{12}{25} \Rightarrow 0.48\text{A} \Rightarrow I_4$

apply KCL @ node A,

$$I = I_1 + I_2 + I_3 + I_4$$

$$I_2 = I - I_1 - I_3 - I_4 \Rightarrow 4 - 1.5 - 0.3 - 0.48$$

$$\boxed{I_2 = 1.72\text{ A}}$$

$\therefore$ unknown resistance, $x = \frac{V}{I_2} = \frac{12}{1.72} = 6.97$

$$\boxed{x = 6.97\Omega}$$

$$R_{eq} = \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right]^{-1} \Rightarrow \left[\frac{1}{8} + \frac{1}{6.97} + \frac{1}{40} + \frac{1}{25}\right]^{-1}$$

$R_{eq} = 2.998\Omega$ $\boxed{R_{eq} = 3\Omega}$

Power consumed $= I^2 R_{eq}$

$= 4^2 \times 3 \Rightarrow 48\ W$

or

$= I_1^2 R + I_2^2 R + I_3^2 R + I_4^2 R$

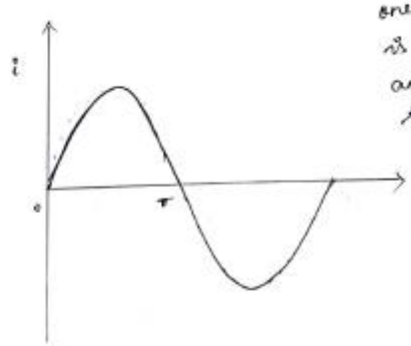
$= (1.5^2 \times 8) + (1.72^2 \times 6.97) + (0.3^2 \times 40)$

$+ (0.48^2 \times 25)$

$= 47.98 \simeq 48\ W.$

6. Derive the RMS, average value, form factor and peak factor for a sinusoidal signal.

Average and R.M.S Values of sinusoidal currents and voltages



* The average value of ac over one cycle is zero, bcoz the waveform is symmetrical about time axis and +ve area exactly cancels the -ve area.

* ∴ average value of ac means half cycle average value unless stated otherwise.

$$\text{Average value} = \frac{\text{area enclosed over half-cycle}}{\text{length of base over half-cycle}}$$

area enclosed

$$= \int_0^{\pi} i \cdot d\theta = \int_0^{\pi} I_m \sin\theta \, d\theta$$

$$= I_m (-\cos\theta)_0^{\pi} \Rightarrow I_m(-\cos\pi + \cos 0)$$

$$= 2 I_m$$

$$\text{average value} = \frac{2I_m}{\pi}$$

$$I_{av} = 0.637 I_m$$

* for +ve half cycle = $0.637 I_m$
for -ve half cycle = $-0.637 I_m$
i.e average value of ac over a complete cycle is zero.

R.M.S value of a sinusoid :-

$$I_{rms}^2 = \frac{\text{area enclosed by } i^2 \text{ curve for half cycle}}{\text{length of base}}$$

$$= \frac{1}{\pi}\int_0^{\pi} i^2\, d\theta$$

$$= \frac{I_m^2}{\pi}\int_0^{\pi} \sin^2\theta\, d\theta$$

$$= \frac{I_m^2}{\pi}\int_0^{\pi} \frac{1-\cos 2\theta}{2}\, d\theta \Rightarrow \frac{I_m^2}{2\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}$$

$$= \frac{I_m^2}{2\pi}(\pi) \Rightarrow \frac{I_m^2}{2}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$$

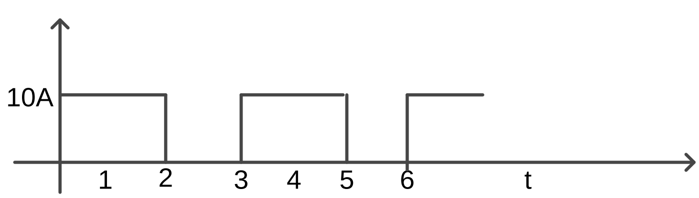
$$\text{Form factor} = \frac{I_{rms}}{I_{av}} = \frac{0.707\, I_m}{0.637\, I_m}$$

$K_f = 1.11$

$$\text{Peak factor} = \frac{\text{max value}}{\text{rms value}} = \frac{I_m}{0.707\, I_m} = 1.414$$

$K_p = 1.414$

7 a) Find the rms, average and form factor for the given current waveform.



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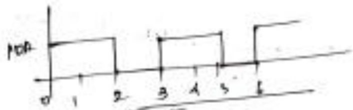

$$RMS = \sqrt{\frac{1}{T}\int_0^T a^2\,dt}$$

$$= \sqrt{\frac{1}{3}\int_0^2 10^2\,dt}$$

$$= \sqrt{\frac{100}{3}\left[(t)_0^2\right]}$$

$$= \sqrt{\frac{100}{3}\times 2} = \sqrt{\frac{200}{3}}$$

$$\text{RMS Value} = \sqrt{200/3}\ A$$

$$\underline{\text{Average}} = \frac{1}{T}\int_0^T a\,dt$$

$$= \frac{1}{3}\int_0^2 10\,dt \Rightarrow \frac{10}{3}\int_0^2 dt$$

$$= \frac{10}{3}(t)_0^2 = \frac{10}{3}\times 2$$

$$= 20/3\ A$$

$$\underline{\text{Form factor}}$$

$$= \frac{RMS}{average} = \frac{\sqrt{200/3}}{20/3} \Rightarrow 1.224$$

7 b) An alternating current of frequency 50Hz has a maximum value of 20A.

i) Write down the equation for its instantaneous value

ii) Find the value of current after 1/360 second

Find the time taken to reach 9.6A for the first time

7) b) $I_m = 20A, \quad f = 50Hz$

i) $i = I_m \sin \omega t$

$= 20 \sin 2\pi f t$

$i = 20 \sin 100\pi t\ A$

ii) $t = 1/360,$

$i = 20 \sin\left(100\pi \times \frac{1}{360}\right)$

$i = 15.32\ A$

iii) $i = 9.6\ A$

$9.6 = 20 \sin(100\pi t)$

$100\pi t = \sin^{-1}\left(\frac{9.6}{20}\right)$

$t = 1.59\,ms$