SECTION-A

1. **Answer following questions in brief.**

a. Define ideal and practical voltage and current sources.

b. State and explain Kirchhoff's voltage law.

c. Define RMS value of any alternating quantity.

d. Write the voltage and current relations between line and phase values for star and delta connected three phase AC systems.

e. Draw the power triangle and define various types of powers.

f. Write the basic working principle of a transformer.

g. What do you understand by an auto-transformer?

h. Define synchronous speed and slip.

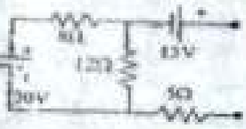
i. Why commutator and brushes are used in DC machines?

j. Define duty ratio of a converter.

02

SECTION-B

2. Calculate the Thevenin equivalent for the shown circuit.



3. Define the average value of alternating current having sine wave and derive its expression.

4. Explain the operation of series RL circuit with single phase AC supply.

5. Derive the EMF equation of a single phase transformer.

SECTION-C

6. Define resonance and derive the relation for resonance condition in a series RLC circuit.

7. Explain the construction of a single-phase transformer with the help of a neat sketch while mentioning the purpose of each component.

8. Explain the operation of a three-phase voltage source inverter with the help of its circuit diagram and associated waveforms.

9. Write short notes on any two of the following :

a) DC buck and boost converters.

b) Generation of rotating magnetic field in a 3-ph Induction Motor.

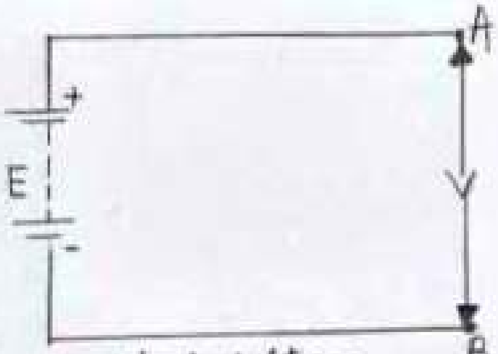
c) Construction and working of a single phase induction motor.

SECTION-A [2 Marks]

Q.1 Answer the following Questions in brief :-

(a). Define ideal and practical voltage and current sources.

→ Ideal Voltage source: A voltage source which has zero internal resistance is called an ideal voltage source.



Ideal Voltage source

In such cases the terminal voltage remains the same, irrespective of the value of load resistance.

(b). Practical Voltage: sources having some amount of internal resistances are known as practical voltage source; due to this internal resistance; voltage drop takes place, and it causes the terminal voltage to reduce.

Practical Voltage source

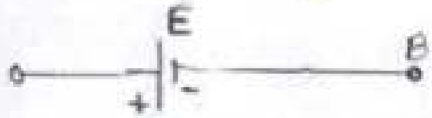
b). State and explain Kirchoff's voltage law?

- Kirchhoff's Secon Law (KVL): since this law relates the voltages in a closed circuit of an electrical network, it is also known as a Kirchhoff's voltage law (KVL) or Kirchhoff's mesh law. this state's that;

In a closed circuit or mesh, the algebraic sum of all emfs. plus the algebraic sum of all the voltage drops (i.e. product of current and resistances) is zero.

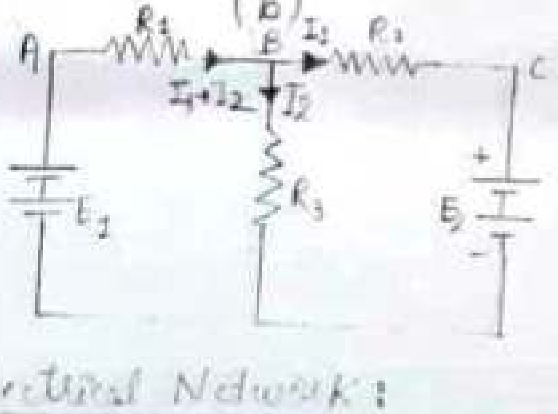
$$\sum E + \sum V = 0 \text{ (algebraic values)}$$

A rise in potential as +ve;
and a fall in potential as -ve.



(a)

(b)

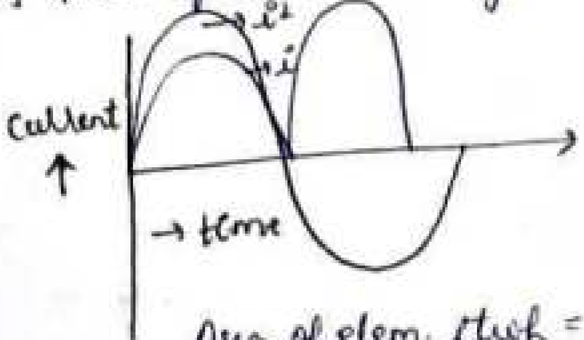


Electrical Network:

Algebraic sum of all the e.m.fs. and voltage drops to be taken.

c) Define RMS value of any alternating quantity.

⇒ That steady current which when flows through a resistor of known resistance for a given time produces the same amount of heat as produced by the alternating current when flows through the same resistor for the same time is called effective or r.m.s value of the alternating current.



$$\text{Area of elem. strip} = i^2\, d\theta = i_m^2 \sin^2\theta\, d\theta$$

$$\text{Area of squared wave} = \int_0^{2\pi} i_m^2 \sin^2\theta\, d\theta$$

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

$$= i_m^2 \int_0^{2\pi} \frac{1-\cos 2\theta}{2}\, d\theta$$

$$= \frac{i_m^2}{2}\int_0^{2\pi} (1-\cos 2\theta)\, d\theta$$

$$= \frac{i_m^2}{2}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{2\pi}$$

$$= \pi i_m^2$$

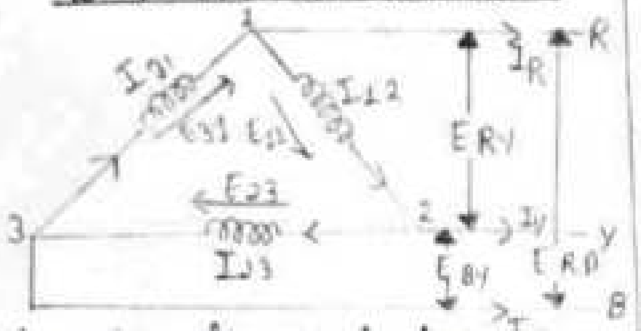
R.M.S value:

$$= \sqrt{\frac{\pi i_m^2}{2\pi}}$$

$$\boxed{\text{RMS value} = \frac{I_m}{\sqrt{2}}}$$

Q. Write the voltage and current relations between line and phase values for star and delta connected three phase AC systems.

Delta or Mesh Connection



Relation b/w line and phase voltage.

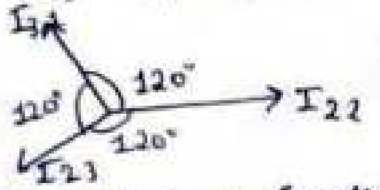
$E_{12} = E_{RY}$, $E_{31} = E_{RB}$

$E_{23} = E_{YB}$

Line voltage = phase voltage

Relation b/w line and phase current:

$I_{12} = I_{23} = I_{31} = I_{phase}$ (in magnitude)



Apply KCL at junction 1.

$\Sigma I = 0$

$I_{31} - I_{12} - I_R = 0$

$(I_R = I_{31} - I_{12})$

$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$I_R = \sqrt{I_{12}^2 + I_{31}^2 + 2I_{12}I_{31}\cos 60°}$

$I_R = \sqrt{I_{12}^2 + I_{31}^2 + 2I_{12}I_{31}}$

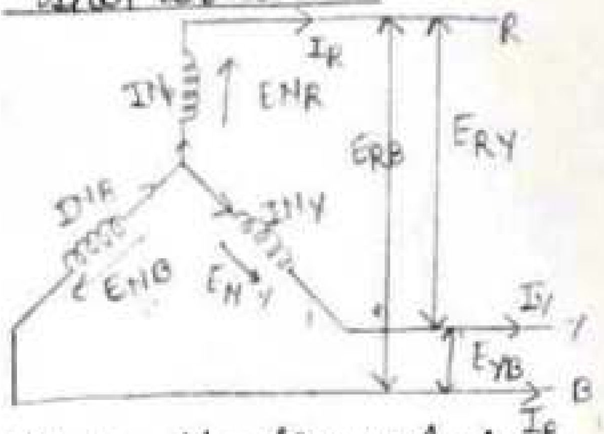
$I_R = \sqrt{I_{ph}^2 + I_{ph}^2 + I_{ph}^2}$

$I_R = \sqrt{3I_{ph}^2}$

$I_R = \sqrt{3}I_{ph}$

Line current = $\sqrt{3}$ × phase current.

Star Connection



- Relation b/w line and phase current.

$I_{NR} = I_R$, $I_{NB} = I_B$

$I_{NY} = I_Y$

Line current = phase current.

- Relation b/w line and phase voltage.

$E_{NR} = E_{NY} = E_{NB} = E_{PR}$ (in mag) (Phase voltage.)

Apply KVL:-

$-E_{NR} - E_{RY} + E_{NY} = 0$

$E_{NY} - E_{NR} = E_{RY}$.

$E_{RY} = E_{NY} - E_{NR}$

$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$E_{RY} = \sqrt{E_{NY}^2 + E_{NR}^2 + 2E_{NY}E_{NR}\cos 60°}$

$= \sqrt{E_{NY}^2 + E_{NR}^2 + E_{NY}E_{NR}}$

$E_{RY} = \sqrt{E_{PR}^2 + E_{PR}^2 + E_{PR}^2}$

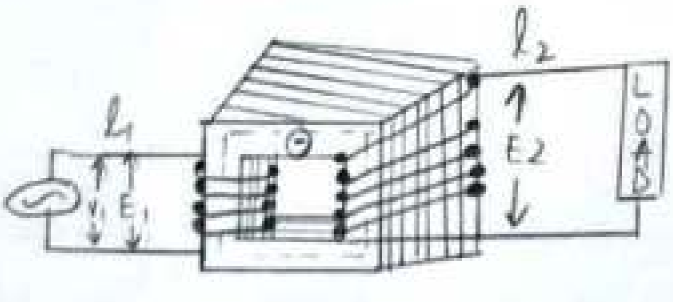
$E_{RY} = \sqrt{3E_{PR}^2}$

$E_{RY} = \sqrt{3}E_{PR}$

8) Write the basic working principle of a transformer

⇒ The main principle of operation of transformer is electromagnetic induction

It consists of two separate winding placed over the laminated silicon steel core. The winding to which ac supply is connected is called primary winding + winding to which load is connected is called secondary winding. When ac supply of voltage V_1 is connected to primary winding, an alternating flux is set up in the the core. This alternating flux when links with the secondary winding, an emf is induced in it called mutual induced emf. The same flux links with primary winding + produces self induced emf.



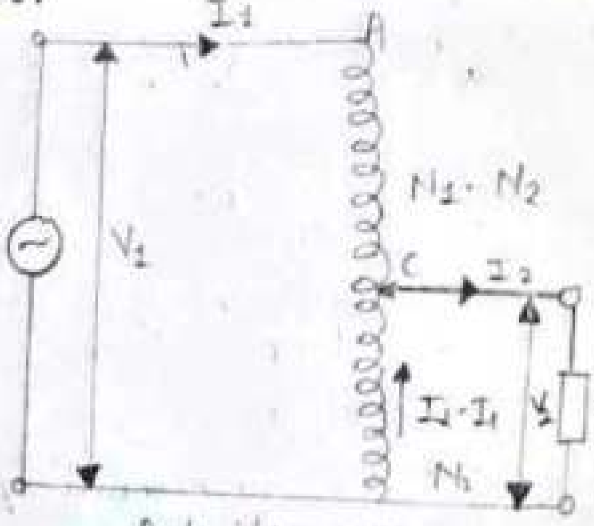
Transformer Core and Windings

Although there is no electrical connection between primary and secondary winding but electrical power is transferred from primary to the secondary circuit through mutual flux.

(Q). What do you understand by an auto-transformer?

→ An autotransformer is a transformer with only one winding wound on a laminated core. A part of this winding is common to both primary and secondary sides.

On load, a part of the load current is obtained directly from the supply and remaining part is obtained by transformer action.



Auto Transformer

V_1 = Primary applied voltage

I_1 = Primary current , I_2 = load current.

V_2 = secondary voltage across the load.

N_1 = number of turns between A and B.

N_2 = number of turns between C and B.

Neglecting no-load current, leakage reactance and losses,

$$V_1 = E_1 \text{ and } V_2 = E_2$$

Transformation ratio :,

$$K = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}$$

i) Why commutator & brushes are used in DC machines
• The brushes in a DC motor have two purposes. They carry current to the armature (the rotating part). The brushes work with the commutator to switch the current to the proper winding of the armature as it rotates. This creates the correct magnet fields to make the motor run. The function of commutator is to ensure that current flowing through the rotor winding is always in the same direction.

j). Define duty ratio of a converter.

Duty ratio is low in buck converters where the output voltage is significantly reduced with regard to input voltage. Design, voltage mode control and non-ideal analysis of a low voltage high current synchronous Buck Converter.

Boost ratio: The boost ratio of the converter can be also called as the duty ratio.

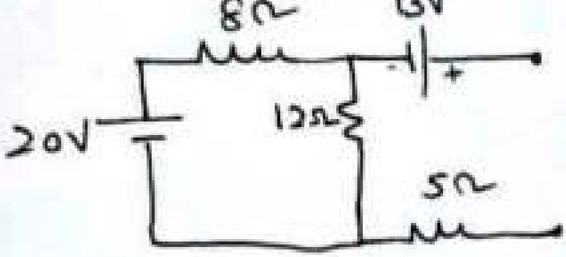
In a pulse radar or similar system, the ratio of average to peak pulse power. Also known as duty cycle.

$$\text{Duty Cycle (D)} = \frac{PW}{T}$$

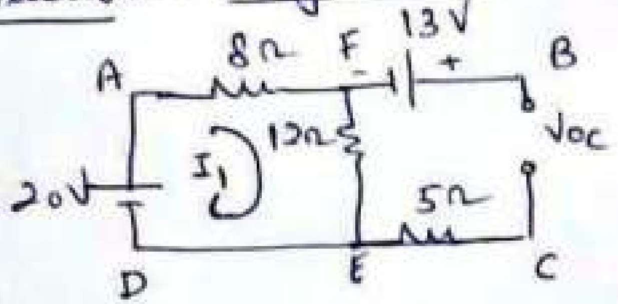
— — —

Section – B

Ques:-2 Calculate the thevenin equivalent for the shown circuit



Solution ① To find V_{oc}



In AFED, Apply KVL

$$8I_1 + 12I_1 - 20 = 0$$

$$20I_1 = 20$$

$$I_1 = \frac{20}{20} \Rightarrow I_1 = 1A$$

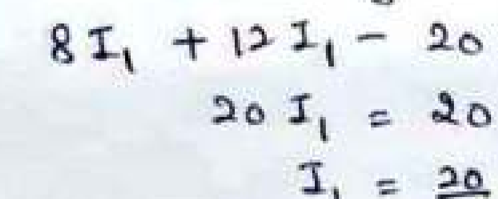
Apply KVL AFBCED

$$8 - 13 + V_{oc} - 20 = 0$$

$$-5 + V_{oc} - 20 = 0$$

② $V_{oc} = 25V$

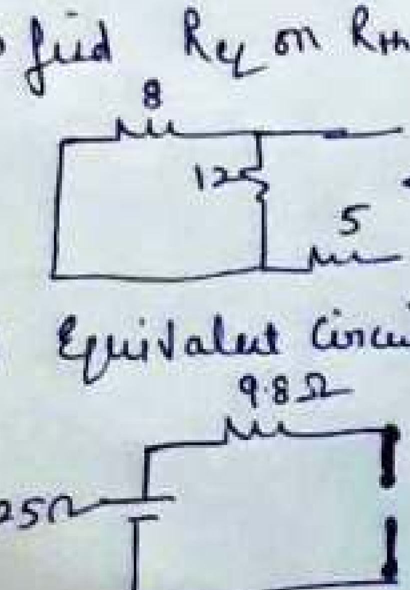
To find R_{eq} or R_{th}



$$R_{th} = 8 \| 12 + 5$$

$$= \frac{96}{20} + 5 = \frac{196}{20} = 9.8\,\Omega$$

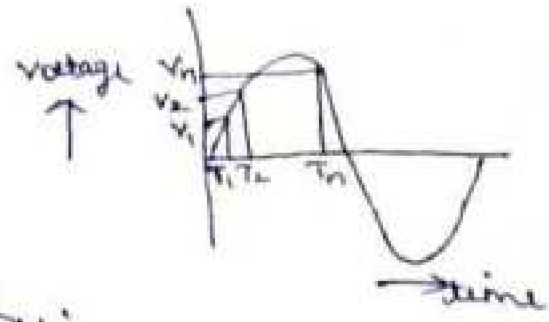
③ Equivalent Circuit



Q3 Define the average value of alternating current having sine wave and derive its expression.

→ Average value:- It is an arithmetic average of all the instantaneous values considered of an alternating quantity over one complete cycle.

Average value: $\frac{V_1 + V_2 + V_3 + \dots + V_n}{n}$



average value = $\frac{\text{Area of alteration}}{\text{Base}}$

The alternating current is given by:-

$I = I_m \sin\theta$ — ①

Area of elementary strip = $I\,d\theta$

$= I_m \sin\theta\, d\theta$

Area of alteration:- $\int_0^{\pi} I_m \sin\theta\, d\theta$

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

$= I_m \left[-\cos\theta\right]_0^{\pi}$

$= -I_m(-1-1)$

$= 2I_m$

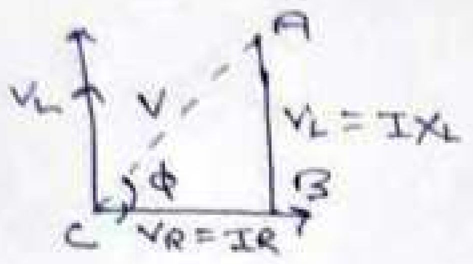
Average Value = $\frac{2I_m}{\pi}$

$V_{avg.} = \frac{2V_m}{\pi}$

Q4 Explain the operation of series RL circuit with single phase AC supply.

→

Phasor's diagram:-



In ΔABC:- $(AB)^2 + (BC)^2 = (AC)^2$

$$V_R^2 + V_L^2 = V^2$$

$$I^2R^2 + I^2X_L^2 = V^2$$

$$I\sqrt{(R^2 + X_L^2)} = V$$

where, $\sqrt{R^2 + X_L^2} = Z$:- Impedance

$\therefore$ $\boxed{V = IZ}$

Phase angle: $\tan\phi = \frac{AB}{AC}$

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

Power:- $P = VI$

$$P = V_m \sin\omega t \times I_m \sin(\omega t - \phi)$$

$$P = \frac{1}{2} V_m I_m \times 2 \sin\omega t \sin(\omega t - \phi)$$

$$P = \frac{1}{2} V_m I_m (\cos\phi - \cos(2\omega t - \phi))$$

$$P = \frac{1}{2} V_m I_m \cos\phi \quad (\because \cos(2\omega t - \phi) = 0)$$

$$P_{avg.} = \frac{V_m I_m \cos\phi}{2}$$

$$P_{avg.} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \cdot \cos\phi$$

$$P_{avg.} = V_{rms} \cdot I_{rms} \cdot \cos\phi$$

Power Factor:- $\cos\phi = \frac{BC}{AC}$

$$\cos\phi = \frac{V_R}{V}$$

$$\cos\phi = \frac{R}{Z}$$

Q5 Derive the emf. eq. of a single phase transformer.

→ The flux generated by the current :-

$$\phi = \phi_m \sin\omega t$$

Acc. to faraday's law, the induced emf can be written as :-

$$e = -\frac{d}{dt}(\phi T)$$

$$e = -T \frac{d\phi}{dt}$$

$$e = -T \frac{d}{dt}(\phi_m \sin\omega t)$$

$$e = -T\omega \phi_m \cos\omega t$$

also, $\cos\omega t = \sin\left(\frac{\pi}{2} - \omega t\right)$

$$\therefore \quad e = T\omega \phi_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

It can also be written as,

$$e = E_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

where, $E_m = -T\omega \phi_m$. It is the max. value of induced emf.

For a sine wave, the rms value of emf. is given by,

$$E_{rms} = E = \frac{E_m}{\sqrt{2}}$$

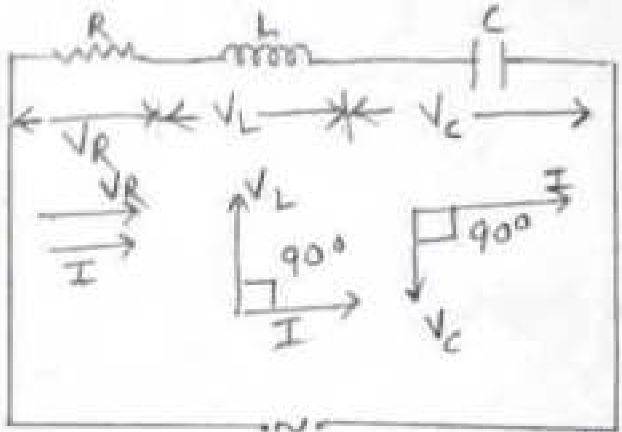
$$E = \frac{T\omega\phi_m}{\sqrt{2}} = \frac{T}{\sqrt{2}}(2\pi f)\phi_m$$

or $E = 4.44\,\phi_m f T$

Section-C

Q.6 → Define Resonance and derive the relation for series resonance in a RLC circuit.

Solve → **Series Resonance →** In R-L-C series circuit, when circuit current is in phase with the applied voltage, the circuit is said to be in series resonance. The condition is obtained in RLC circuit shown in fig.



when $X_C = X_L$ (or $X_L - X_C = 0$)

At resonance.

$$X_L - X_C = 0$$
$$X_L = X_C$$

Impedence, $Z_r = \sqrt{R^2 + (X_L - X_C)}$
$$= R.$$

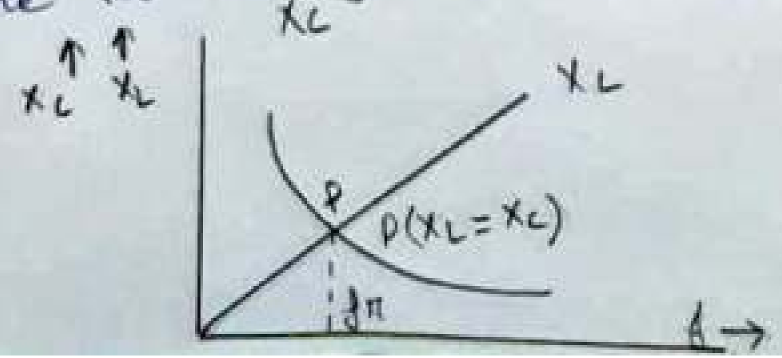
$$I_r = \frac{V}{Z_r} = \frac{V}{R}$$

- Since at resonance, the opposition is due to only resistance, to the flow of current to the circuit, the circuit draws max^m current under this condition.

Resonant frequency → Given condition →

$$X_L = X_C$$
$$\Rightarrow \omega L = \frac{1}{\omega C}$$
$$\Rightarrow \omega^2 = \frac{1}{LC}$$
$$\Rightarrow \omega = \frac{1}{\sqrt{LC}}$$
$$\Rightarrow 2\pi f_r = \frac{1}{\sqrt{LC}}$$
$$\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$$

f_r is the resonant frequency in Hz and L and C are in Henry and Farad respectively.



• Effects of Series Resonance

(i) At resonance $X_L = X_C$. the impedence is minimum and is reduced to resistance only.

$$Z_r = R.$$

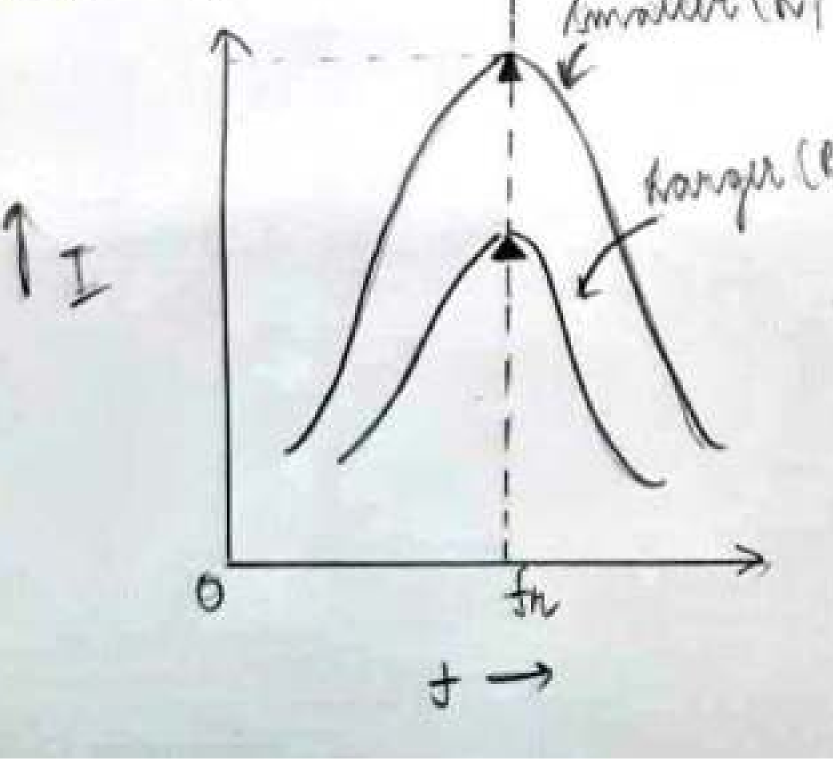
(ii) Since, impedence is minimum. the circuit element's current is maximum. at resonance, that is

$$I_r = \frac{V}{Z_r} = \frac{V}{R}$$

(iii) Power taken by the circuit is maximum, as I_r is maximum. (Acceptor circuit)

$$P_r = I_r^2 R$$

Resonance curve → The curve obtained by plotting a graph between the current and the frequency is known as resonance curve.



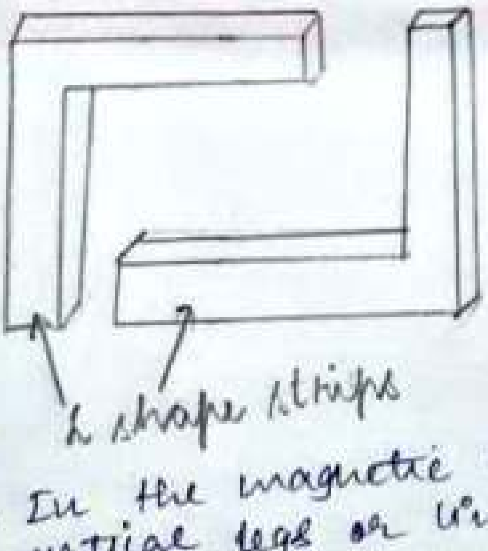
Q.7 → Explain the construction of single-phase transformer with the help of neat sketch while mentioning the purpose of each component.

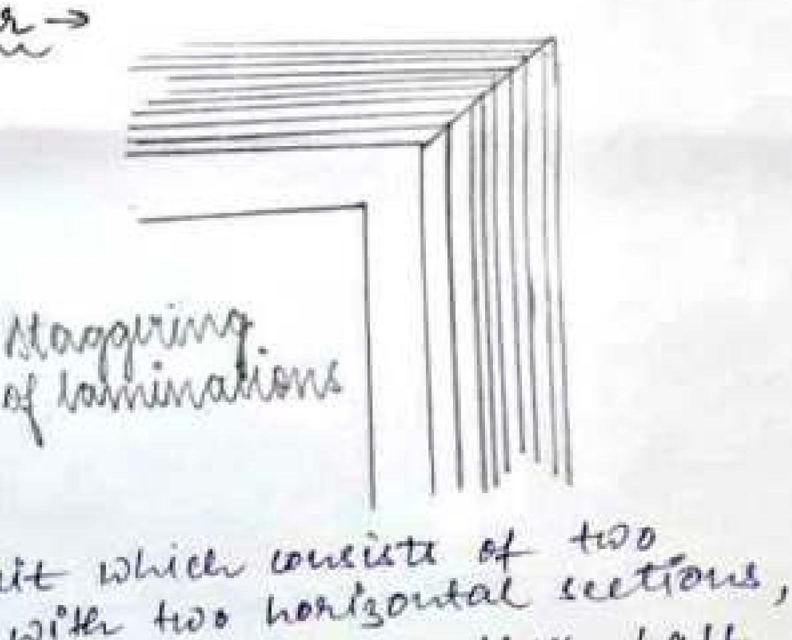
Ans → A single phase transformer consists of primary and secondary windings. The core of the transform -er is made of thin sheets (called laminations) of high grade of silicon. These laminations are provided in the transformer to reduce eddy currents loss, and the silicon steel reduces the hysterisis loss. The laminations present in the transformer are insulated from one another by heat resistant enamel coating L-type and E-type laminations are used for constructions.

There are two basic types of transformer constructions :-

1) core type construction.
2) Shell type construction.

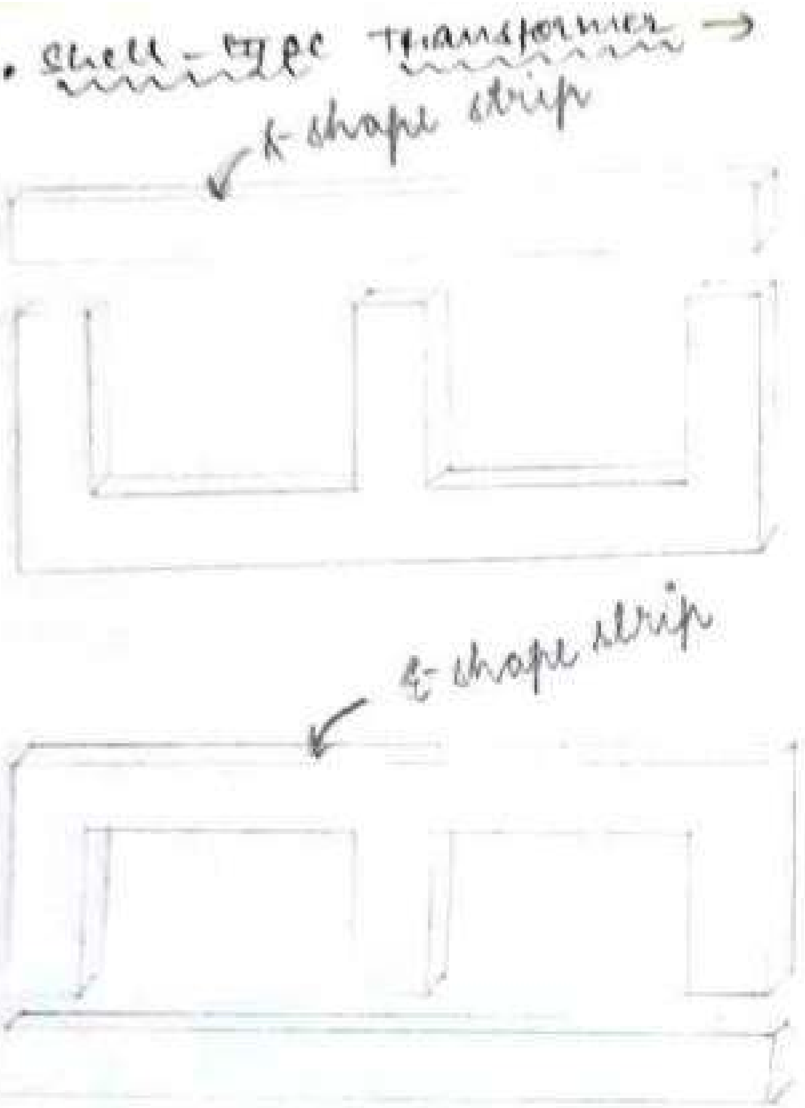
- Core - type Transformer →





- In the magnetic circuit which consists of two vertical legs or limbs with two horizontal sections, called yokes. To minimize the leakage flux, half of each winding is placed on each leg of the core. The low voltage winding is placed next to the core. and the high voltage winding is placed around the low voltage winding to reduce the insulating material required. Thus, the two winding are arranged as concentric coils. Such type of windi -ng is called concentric winding or cylindri -cal winding.

• Shell-type transformer →



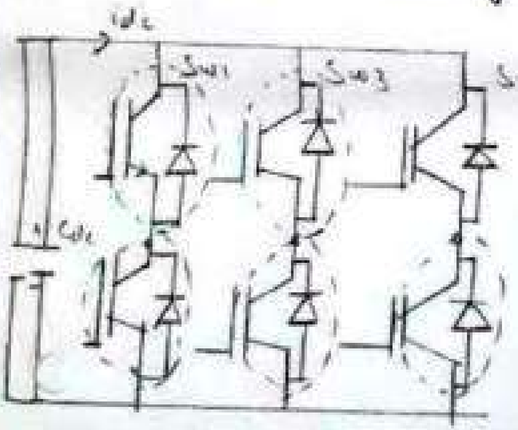
• In the shell type transformer, both the primary and the secondary winding are wounded on the central limb, and the low reluctance path is completed by the outer limbs. Each winding is subdivided into sections. Low voltage (LV) and high voltage (HV) subsections are alternatively placed in the form of sandwich. That is why this winding is called sandwich or disc winding.

• The core is made up of two types of laminations. The core is made up for the core type U, and I shaped. Firstly the U-shaped laminations are stacked together for the required length. Half of the prewound low voltage coil is placed around the limbs. The LV coil is further provided with insulation. Then half of the prewound HV coil is placed around the LV coil. The core is then closed by the I-shaped laminations at the top.

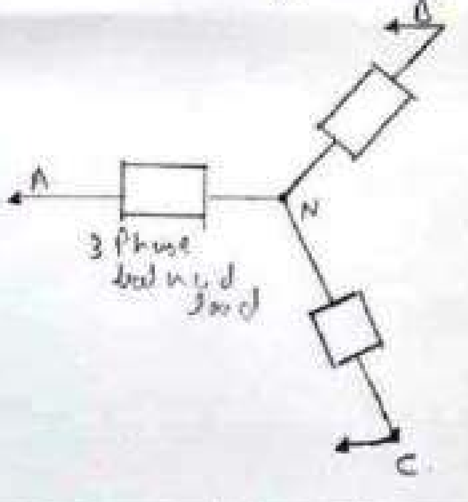
Q.1 Explain the operation of a three phase-voltage source inverter with the help of its circuit diagram & associated waveform.

Ans A three-phase inverter converts a DC input into a three phase AC output. Its three arms are normally delayed by an angle of 120° so as to generate a three phase AC supply. The inverter switches each has a ratio of 50% and switching occurs after every T/6 of the time T 60° angle interval. The switches S1 and S2, the switches S2 and S1 and switches S3 and S6 complement each other.

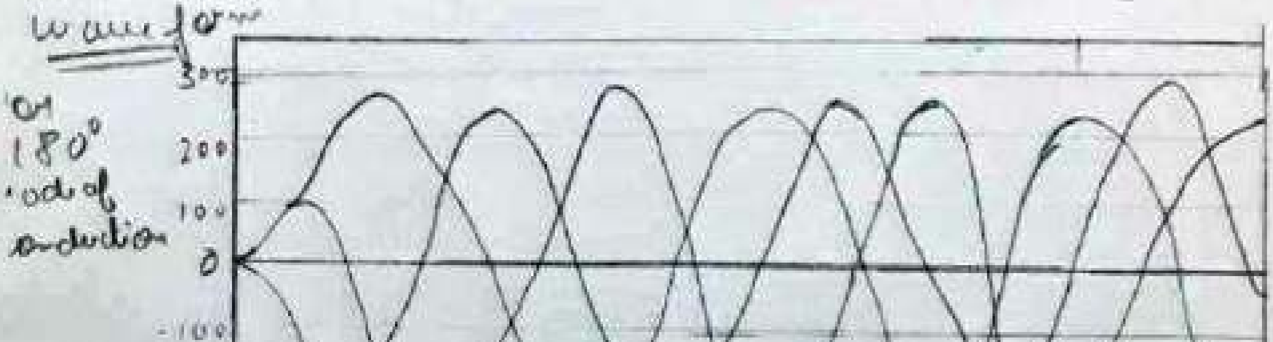
The figure below shows a circuit for a three phase inverter. It is nothing but three single phase inverter put across the same DC source. The pole voltages in a three phase inverter are equal to the pole voltage in single phase half bridge inverter.



circuit diagram



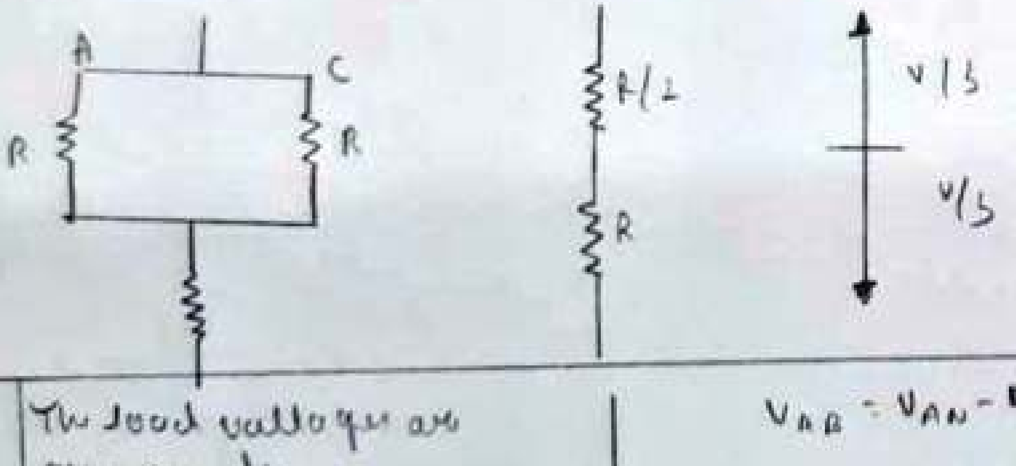
waveform



180° Mode of conduction.

In this mode of conduction, every device is in conduction state for 180° where they are switched ON at 60° intervals. The terminals A, B & C are inputs terminals of the bridge that are connected to the three phase delta or star connection of the load.

The operation of a balanced star connected load is explained in the diagram below. For the period 0° - 60° the points S1, S5 and S6 are in conduction mode. The terminals A and C of the load are connected to the source at its positive points. The terminal B is connected to the source at its negative points. In addition, resistance R/2 is b/w the neutral and positive end. while resistance R is b/w the neutral and the negative terminal.

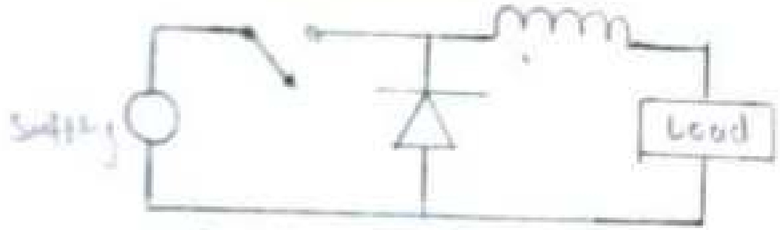


The load voltages are given as for $V_{AN} = V/3$, $V_{BN} = -2V/3$, $V_{CN} = V/3$	$V_{AB} = V_{AN} - V_{BN} = V$ $V_{BC} = V_{BN} - V_{CN} = -V$ $C_{CA} = V_{CN} - V_{AN} = 0$

Q.9 Write a short note on any two of the following.

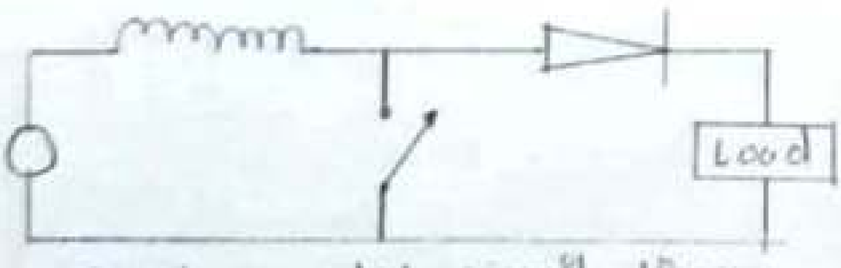
a) DC buck & boost converters.

Ans a) A buck converter is a DC-to-DC power converter which steps down voltage from its input to its output. It is a class of switched-mode power supply typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination.



Buck converter circuit diagram

A Boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage from its input to its output. It is a class of switched-mode power supply containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor or the two in combination. To reduce voltage ripple, filter made of capacitors are added normally to such a converter output & input.

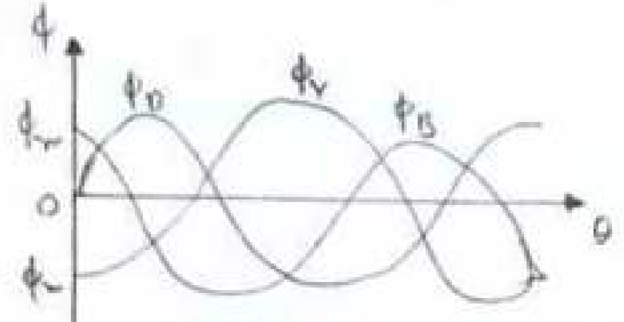


Boost converter circuit diagram

b) Generation of rotating magnetic field in 3 Phase induction motor.

Ans The induction motor rotates due to the rotating magnetic field in 3 Phase induction motor, which is produced by stator winding in the air gap b/w in the stator and the rotor. The stator has a three phase stationary winding which can be either star connected or delta connected. Whenever the AC supply is connected to the stator windings, line current I_R, I_Y and I_B start flowing.

three line currents have phase difference of 120° with respect to each other. Due to each line current, a sinusoidal flux is produced in the air gap. These fluxes have the same frequency as that of the line currents, and they also have the same phase difference of 120° with respect to each other. Let the flux produced by the line current I_R, I_B, I_Y be ϕ_R, ϕ_B, ϕ_Y resp.



<u>Mathematically</u>

$\phi_R = \phi_m \sin \omega t = \phi_m \sin \theta$

$\phi_B = \phi_m \sin(\omega t - 120°) = \phi_m \sin(\theta - 120°)$

$\phi_Y = \phi_m \sin(\omega t - 240°) = \phi_m \sin(\theta - 240°)$

$\phi_T = \phi_R + \phi_Y + \phi_B$

c). Construction & working of a single Phase Induction motor.

<u>Ans</u> <u>Construction</u> of Single Phase Induction Motor:-

Similar to d.c motor, single-phase induction motor also has two main parts, one rotating and other stationary. The stationary part in single phase induction motor is stator & and the rotating part is Rotor.

The stator has laminated construction, made up of stampings. The stampings are slotted on its periphery to carry the winding called stator winding or main winding or main winding. This is excited by a single-phase a.c supply.

The stator winding is wound for a certain definite number of poles means when excited by single-phase a.c supply, stator produce the magnetic field which creates the effects of the certain definite number of poles. The no of poles for which stator winding is wound decides the synchronous speed of the motor. The synchronous speed is denoted as N_s and it has a fixed relation with supply frequency f and number of poles P. The relation is given by.

<u>Working</u> :- For the motoring action, there must exist two fluxes which interact with each other to produce the torque. In d.c motors, field winding produces the main flux while d.c supply given to armature is responsible to

produce armature flux. The main flux and armature flux interacts to produce the torque.

In the single-phase induction motor, single-phase a.c supply is given by the stator winding. The stator winding carries an alternating current which produce the flux which is also called alternating in nature. This flux is called main flux. This flux links with the rotor conductors due to transformer action e.m.f gets induced in the rotor. The induced emf drives current through the rotor as the rotor circuit is the closed circuit.

This rotor current produce another flux called rotor flux required for the motoring action. Thus second flux is produced according to the induction principle due to induced e.m.f hence the ch motor is called induction. As against this d.c motor a separate supply is required to the armature to produce armature flux. This is an important difference b/w d.c & induction motor.