Model Sets-1

Electrical Circuit

Group-A

1. ***Choose the most suitable answer from the following options :***

(i) Two wires A and B have the same cross section and are made of the same material, if $R_A = 600\,\Omega$ and $R_B = 100\,\Omega$. The length of A is......times longer than B.

(a) 6 (b) 2 (c) 4 (d) 5

Ans.(a)

(ii) A constant voltage source is:

(a) Active and unilateral (b) Active and bilateral
(c) Passive and unilateral (d) Passive and bilateral

Ans.(a)

(iii) A closed path made by several branchhes of network is known as :

(a) Circuit (b) Loop (c) Junction (d) Branch

Ans.(b)

(iv) Which bulb will have the minimum resistance ?

(a) 110V, 60W (b) 110V, 100W
(c) 220V, 60W (d) 220V, 110W

Ans. (b)

(v) A circuit of zero lagging power factor behaves as :

(a) An inductive circuit (b) A capacitive circuit
(c) R-L circuit (d) R-C circuit

Ans.(a)

(vi) Maximum power is transfered when the load resistance is

(a) Equal to source resistance
(b) Equal to half of the source resistance
(c) Equal to zero (d) None of the above

Ans.(a)

(vii) Kirchoff's law is applicable to :

(a) Passive networks only (b) A.C. circuits only
(c) D.C. circuits only
(d) Both A.C. as well as D.C. circuits

Ans.(d)

(viii) Thevenin's Theorem is applied to

(a) An active and non-linear network
(b) An active and linear network
(c) A passive and non-linear network
(d) A passive and linear network

Ans.(b)

(ix) In a delta network each element has resistance R. The value of each element in equivalent star network will be :

(a) R/6 (b) R/3 (c) 3R (d) 6R

Ans.(b)

(x) The value of form factor for a pure sine wave is :

(a) 1.414 (b) 0.707 (c) 0.637 (d) 1.11

Ans.(d)

(xi) Norton's theorem reduces a two terminal network to :

(a) A constant voltage source and an impedance in parallel
(b) A constant voltage source and an impedance in series
(c) A constant current source and an impedance in parallel
(d) A constant current source and an impedance in series

Ans.(c)

(xii) A 3 phase, 4 wire system supplies power to a balanced star connected load. The current in each phase is 15A. The current in the neutral wire will be

(a) 15A (b) 30A (c) 45A (d) 0

Ans.(d)

(xiii) The phase sequence RBY denotes that

(a) The e.m.f of phase R lags that of phase B by 120^0
(b) The e.m.f of phase R lags that of phase Y by 120^0
(c) The e.m.f of phase R leads that of phase Y by 120^0
(d) The e.m.f of phase B leads that of phase R by 120^0

Ans.(b)

(xiv) The phase angle of a series R-L-C circuit is leading if

(a) $X_L = 0$ (b) $R = 0$ (c) $X_C > X_L$ (d) $X_C < X_L$

Ans.(c)

(xv) If in a circuit the voltage is reduced to half and resistance is doubled the value of current will be :

(a) Half (b) One quarter (c) Four times (d) Double

Ans.(b)

(xvi) Three resistors, each of R ohms are connected to form a triangle. The resistance between any two terminals will be :

(a) 3R ohms (b) 3/2R ohms (c) 2/3R ohms (d) R ohms

Ans.(c)

(xvii) An alternating current of frequency 50 Hz and maximum value 200 Amp is given by equation.

(a) i = 200sin628t (b) i = 200 sin 314t

(c) $i = \frac{100}{\sqrt{2}} \sin 314t$ (d) $i = \frac{100}{\sqrt{2}} \sin 157t$

Ans.(c)

(xviii) Which of the following quantities are the same in all parts of a series circuit?

(a) Voltage (b) Power (c) Current (d) Resistance

Ans.(c)

(xix) In a series RC circuit, the current...........the total voltage by an angle

(a) Lags. of 45^0 (b) Lags. of 0^0
(c) Leads between 0^0 and 90^0 (d) Lags. of 90^0

Ans.(c)

(xx) The net reactance in an RLC circuit is

(a) X_L (b) X_C (c) $X_C–X_L$ (d) $X_L – X_C$

Ans.(d)

Group-B

Answer all Five Questions.

Q2. State and explain Kirchoff's law.

Ans.*Same as model sets -2 Q.no 4*

OR

Q2. Two coils connected in series have a resistance of 18 Ω and when connected in parallel have a resistance of 4 Ω. Find the resistance of each coil.

Ans. Let R_1 and R_2 be the resistance of 1st coil and 2nd coil respectively.

When coil is connected in series then,

$$R_1 + R_2 = 18 ------(i)$$

When coil is connected in parallel then,

$$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4}$$

$$\Rightarrow \frac{R_1 + R_2}{R_1 R_2} = \frac{1}{4} ---------(ii)$$

Putting the value of R_1 from equation (i) in equation (ii), we get

$$\Rightarrow \frac{18}{(18 - R_2)R_2} = \frac{1}{4}$$

$$\Rightarrow 18R_2 - R_2^2 = 72$$

$$\Rightarrow R_2^2 - 18R_2 + 72 = 0$$

$$\therefore R_2 = 12\Omega \text{ or } 6\Omega$$

$$\text{and } R_1 = 6\Omega \text{ or } 12\Omega$$

Q3. Define r.m.s value, average value, peak factor and form factor of an A.C. waveform.

Ans.*Same as model sets -2 Q.no 3(OR)*

OR

Q3. What do you mean by given A.C. quantities?

(i) In phase (ii) Lagging and (iii) Leading

Ans. The value of θ (theta) is the important factor for leading and lagging current. Leading or lagging current represents a time shift between the current and voltage sine curves, which is represented by the angle by which the curve is ahead or behind of where it would be initially. For example, if θ is zero, the curve will have amplitude zero at time zero.

(ii)Lagging current can be formally defined as "an alternating current that reaches its maximum value up to 90 degrees later than the voltage that produces it".

(iii)Leading current can be formally defined as "an alternating current that reaches its maximum value up to 90 degrees ahead of the voltage that it produces".

Q4. State and explain maximum power transfer theorem.

Ans.*Refers to chapter*

OR

Q4. State and explain Thevenin's Theorem.

Ans.*Refers to chapter*

Q5. Explain the star and delta method of connection of a three phase system.

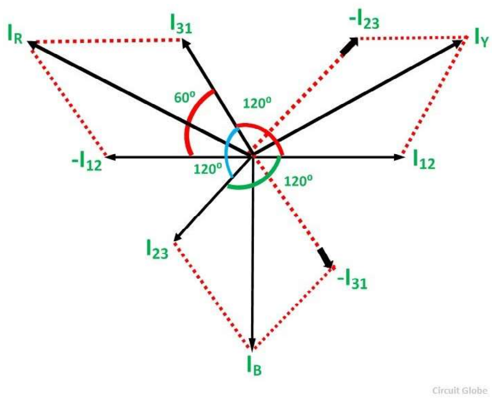
Ans.*Refers to chapter*

OR

Q5. Derive the relation between phase current and line current in star/delta connection.

Ans. As in the balanced system the three phase current I_{12}, I_{23} and I_{31} are equal in magnitude but are displaced from one another by 120 degrees electrical.

The phasor diagram is shown below.



Hence,

$I_{12}=I_{23}=I_{31}=I_{pH}$

If we look at figure A, it is seen that the current is divided at every junction 1, 2 and 3.

Applying Kirchhoff's Law at junction 1

The Incoming currents are equal to outgoing currents.

$$I_{31}=I_R+I_{12}$$

And their vector difference will be given as

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

The vector I_{12} is reversed and is added in the vector I_{31} to get the vector sum of I_{31} and $–I_{12}$ as shown above in the phasor diagram. Therefore

$$I_R = \sqrt{I_{31}^2 + I_{12}^2 + 2I_{31}I_{12}\cos 60^0} \text{ or}$$

$$I_L = \sqrt{I_{ph}^2 + I_{ph}^2 + 2I_{ph}I_{ph} \times 0.5}$$

As we know, $I_R = I_L$, therefore,

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

Similarly,

$$I_Y = I_{12} - I_{23} \text{ or } I_L = \sqrt{3}I_{ph} \text{ and}$$

$$I_B = I_{23} - I_{31} \text{ or } I_L = \sqrt{3}I_{ph}$$

Hence, in Delta connection line current is root three times of phase current.

$$Line\,Current = \sqrt{3} \times Phase\,Current$$

Q6. Derive the expression of the A.C. circuit containing resistance inductance and capacitance in series.

Ans. Figure 1(a) represents a circuit with resistance R ohms,nductance L henrys and capacitance C farads in series,connected across an a.c supply.

Let V and I be the r.m.s values of the applied voltage and the circuit current.Then, we have

Voltage drop across R,V_R=I.R (in phase with I)
Voltage drop across L,V_L=I.X_L(leading I by 90^0)
Voltage drop across C,V_C=I.X_C(Lagging I b 90^0)

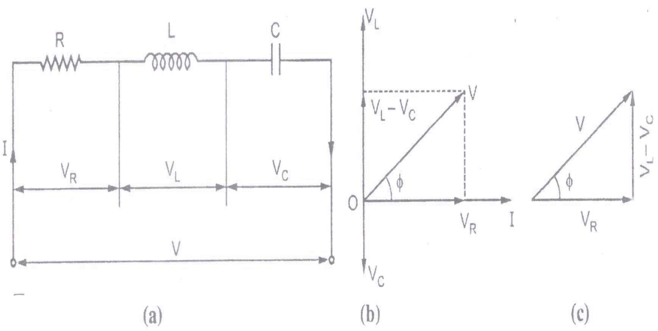


Figure 1(a):(a)R-L-C series circuit,(b)Phasor diagram whenX_L>X_C,(c)Voltage triangle.

Where $X_L(=2\pi fL)$ and $X_C=\left(\frac{1}{2\pi fC}\right)$ are the inductive and capacitive reactances of the inductance and capacitance respectively.

The relative values of X_L and X_C play a very important role in determining the behaviour of R-L-C series circuits.In general, according to the values of X_L and X_C,there are three possible cases.We shall study these cases one by one.

Case (i) X_L>X_C: When X_L is greater than X_C voltage drop across X_L is obviously greater than that across X_C(i.e V_L>V_C) Figure 1(b) shows the phasor diagram for this condition with the current I as a refrence phasor.The applied voltage V is the phasor sum of its component voltages V_R,V_L and V_C i.e

$\overline{V} = \overline{V_R} + \overline{V_L} + \overline{V_C}$ ....(phasor Sum)

Now,Since V_L is in direct phase opposition with V_C,their resultant(V_L-V_C) is given by their simple arithematic subtraction.Moreover,V_L being greater than V_C,this resultant is along the direction of V_L.Therefore,from the voltage triangle of figure 1(c),

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

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

$$I = \frac{V}{\sqrt{(R)^2 + (X_L - X_C)^2}} = \frac{V}{Z}$$

Where $Z = \sqrt{(R)^2 + (X_L - X_C)^2}$

Case (ii) X_L<X_C: In this case, V_C is greater than V_L.Therefore,their resultant (V_C-V_L) is along the direction of V_C.Fig 2(a) shows the phasor diagram and Fig 2(b) the corresponding voltage triangle.

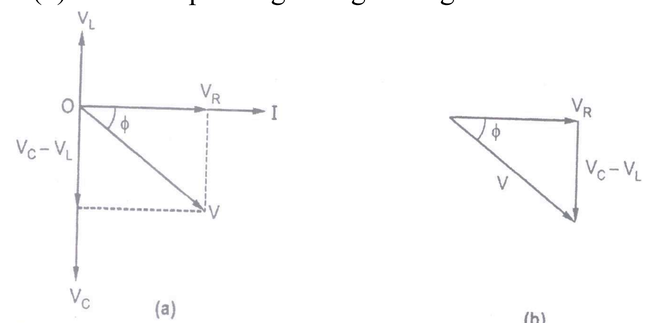


Figure 2(a):Phasor diagram for R-L-C series circuit with X_L<X_C,(c)Voltage triangle.

From the voltage triangle,we get

$$V = \sqrt{(V_R)^2 + (V_C - V_L)^2} == \sqrt{(IR)^2 + (IX_C - IX_L)^2}$$

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

$$I = \frac{V}{\sqrt{(R)^2 + (X_C - X_L)^2}} = \frac{V}{\sqrt{(R)^2 + (X_L - X_C)^2}} = \frac{V}{Z}$$

Where as mentioned in the previous case,

$$Z = \sqrt{(R)^2 + (X_L - X_C)^2}$$

Case (iii) X_L=X_C: Figure 3 shows the phasor diagram for this condition.

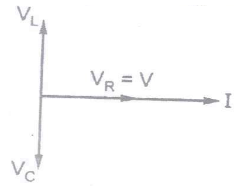


Figure 3:Phasor diagram for R-L-C series circuit with X_L=X_C

In this case, V_L and V_C being equal and in direct phase opposition with each other, their resultant is zero.Therefore,the applied voltage V is equal to the voltage drop across resistance R i.e

$$V = V_R = I.R$$

$$I = \frac{V}{R}$$

OR

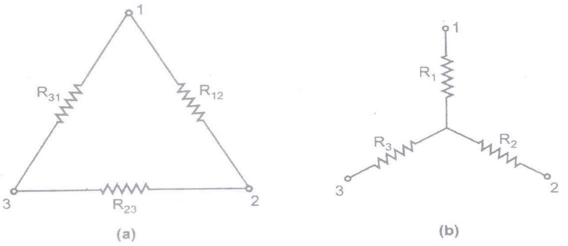
Q6. Show the average power consumed in purely inductive circuit is zero.

Ans.*Same as model sets -2 Q.no 5(OR)*

Group-C

Answer all Five Questions.

Q7. Convert the Delta connected load of the given fig. 1 into equivalent star form as shown.



Ans. Fgure 1(a) shows three resistors R_{12},R_{23} and R_{31} connected in delta fashion between the terminals 1,2 and 3.So far as the terminals 1, 2 and 3 are concerned ,it is always possible to replace these delta connected resistors by three equivalent star connected resistors R_1, R_2 and R_3 as shown in fig 1(b).For these two arrangements to be equivalent,the resistors between any pair of terminals must be same in both the cases.Now, in the delta network of Fig.1(a),the resistance between the terminals 1 and 2 consists of R_{12} in parallel with (R_{23} + R_{31}).Hence in this case,the resistance between the terminals 1 and 2

$$=\frac{R_{12}\left(R_{23}+R_{31}\right)}{R_{12}+R_{23}+R_{31}} \text{-----------------(i)}$$

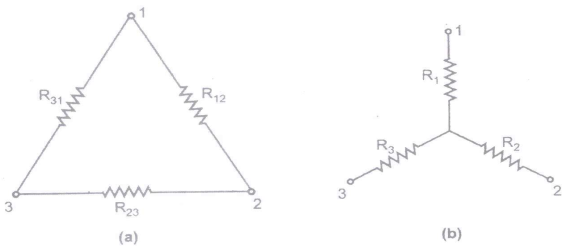


Fig. 1 :Equivalent delta and star networks

In the case of star network of Fig 1(b), the resistance between the terminals 1 and 2 is the series combination of R_1 and R_2 and hence

$$=R_1 + R_2 \text{----------------------- (ii)}$$

So, for equivalence between the two networks,equating the expressions (i) and (ii), we get

$$R_1+R_2=\frac{R_{12}\left(R_{23}+R_{31}\right)}{R_{12}+R_{23}+R_{31}} \text{--------(iii)}$$

Similarly,the equations for the other two terminal pairs can be written as follows:

$$R_2+R_3=\frac{R_{23}\left(R_{31}+R_{12}\right)}{R_{12}+R_{23}+R_{31}} \text{-------(iv)}$$

$$R_3+R_1=\frac{R_{31}\left(R_{12}+R_{23}\right)}{R_{21}+R_{23}+R_{31}} \text{--------(v)}$$

Now, subtracting equation (iii) and (iv), we get

$$R_1-R_3=\frac{R_{12}R_{23}+R_{12}R_{31}-R_{23}R_{31}-R_{23}R_{12}}{R_{12}+R_{23}+R_{31}}$$

$$R_1-R_3=\frac{R_{12}R_{31}-R_{23}R_{31}}{R_{12}+R_{23}+R_{31}} \text{---------------(vi)}$$

Adding the equations (v) and (vi), we get

$$2R_1=\frac{R_{31}R_{12}+R_{12}R_{31}-R_{23}R_{31}-R_{23}R_{31}}{R_{12}+R_{23}+R_{31}}$$

Or, $$R_1=\frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}} \text{---------(vii)}$$

Similarly,

$$R_2=\frac{R_{12}R_{23}}{R_{12}+R_{23}+R_{31}} \text{-------(viii)}$$

and $$R_3=\frac{R_{23}R_{31}}{R_{12}+R_{23}+R_{31}} \text{--------(ix)}$$

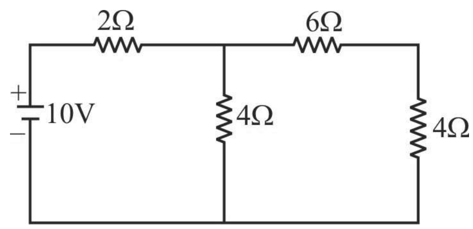
Thus, from the equation (vii),(viii) and (ix),it can be concluded that the equivalent star resistance to be connected to a given terminal is equal to the product of the two delta resistances connected to the same terminal divided by the sum of the delta resistances.

OR

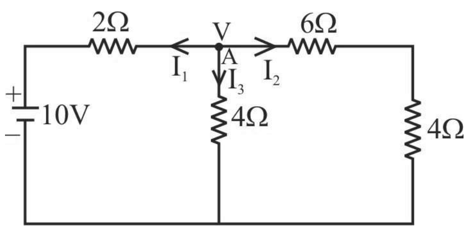
Q7. State Ohm's law and give its limitations.

Ans.*Same as model sets -2 Q.no 9(OR)*

Q8. Find the current in each branch.



Ans.



KCL at point A

$I_1 + I_2 + I_3 = 0$

$$\frac{V-10}{2}+\frac{V}{10}+\frac{V}{4}=0$$

$$\Rightarrow \frac{10V-100+2V+5V}{20}=0 \Rightarrow 10V-100+2V+5V=0$$

$$\Rightarrow 17V - 100 = 0 \Rightarrow 17V = 100$$

$$\therefore \quad V=\frac{100}{17}=5.88V$$

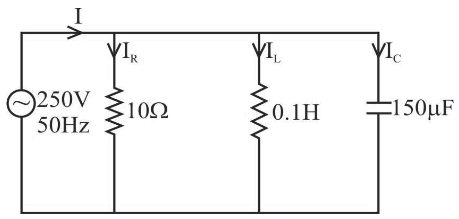
$$\Rightarrow I_1=\frac{V-10}{2}=\frac{5.88-10}{2}=-2.06A$$

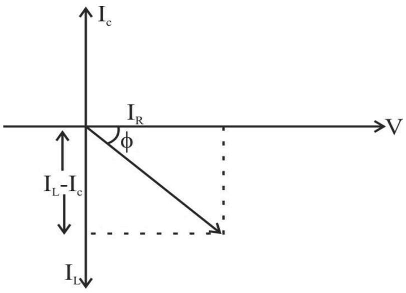
$$\Rightarrow I_2=\frac{V}{10}=\frac{5.88}{10}=0.588A$$

$$\Rightarrow I_3=\frac{V}{4}=\frac{5.88}{4}=1.47A$$

Q9. A resistance of 100 Ω, an inductance of 0.1 H and a capacitance of 150 μF are connnected in parallel across 200v, 50 Hz AC supply. Determine the branch current, total current and the total power taken from the supply.

Ans.





$$X_L = 2\pi FL = 2\pi\times 50\times 0.1 = 31.41\Omega$$

$$X_C=\frac{1}{2\pi FC}=\frac{1}{2\pi\times 50\times 150\times 10^{-6}}=21.220\Omega$$

$$I_R=\frac{V}{R}=\frac{250}{100}=2.5A$$

$$I_L=\frac{V}{X_L}=\frac{250}{31.4}=7.961A$$

$$I_C=\frac{V}{X_C}=\frac{250}{21.22}=11.781$$

Supply current,

$$I=\sqrt{I_R^2+(I_L-I_C)^2}$$

$$=\sqrt{(2.5)^2+(7.96-11.781)}=4.566A$$

$P = I^2R = (4.566)^2 \times 100 = 2084.8356w$

OR

Q9. A coil of resistance 10 Ω and inductance 0.1H connected in series with a condenser of capacitance 150 μF across a 200V 50 Hz supply. Determine the following :

(a) Impedance, (b) Current (c) Power factor

Ans.Given: Resistance(R)=10Ω

Inductance(L)=0.1H

Capacitance(C)=$150\mu F$

Voltage(V)=200V

Frequency(f)=50Hz

Inductive reactance, $X_L = wL = 2\pi fL$

$$= 2\pi\times 50\times 0.1 = 31.4\,\Omega$$

Capacitive reactance, $X_C=\dfrac{1}{\omega C}=\dfrac{1}{2\pi fC}$

$$=\frac{1}{2\pi\times 50\times 150\times 10^{-6}}=21.23\,\Omega$$

(i)Impedance of the circuit, $Z=\sqrt{R^2+(X_L-X_C)^2}$

$$=\sqrt{10^2+(31.4-21.23)^2}$$

$$=14.26\,\Omega$$

(ii)Current(I) $=\dfrac{V}{Z}=\dfrac{200}{14.26}=14.02A$

(iii) Power factor $\cos\phi=\dfrac{R}{Z}=\dfrac{10}{14.26}=0.70$

$$\phi=\cos^{-1}0.70=45.57^0$$

Q10. Explain the advantage of three phase system over single phase system.

Ans.*Same as model sets -2 Q.no 10(OR)*

OR

Q10. Compare between star and delta system of a three phase connection.

Ans.*Same as model sets -2 Q.no 10*

Q11. Write short notes on any two

(a) Superposition Theorem (b) Ohm's Law

(c) Series Resonance (d)Energy Sources

Ans.(a) Superposition Theorem:*Refers to chapter*

Ans.(b) Ohm's Law:*Same as model sets -2 Q.no 9(OR)*

Ans.(c) Series Resonance:*Refers to chapter*

Ans.(d) Energy Sources:*Same as model sets -2 Q.no 11*

Model Sets-2

Electric Circuit

Group-A

Q1. Choose the most suitable answer from the following options.

(i) The resistance of a wire varies inversely as :
(a) area of cross-section (b) length
(c) resistivity (d) temperature
Ans.(a)

(ii) Maximum power is transferred when the load resistance is :
(a) equal to source resistance
(b) equal to half of the source resistance
(c) equal to zero (d) none of the above
Ans.(a)

(iii) Six light bulbs are connected in parallel across 110V. Each bulb is rated at 75 W. How much current flows through each bulb.
(a) 0.682 A (b) 0.7 A (c) 75A (d) 110A
Ans.(a)

(iv) A circuit of unity power factor behave as
(a) as inductive circuit (b) a capacitive circuit
(c) a resistive circuit (d) R-C circuit
Ans.(c)

(v) The peak value of a sine wave is 200V. Its average value is :
(a) 127.4V (b) 141.4V (c) 282.8V (d) 200V
Ans.(b)

(vi) Which of the following expression is true for apparent power in AC circuit?
(a) VIcos0 (b) Vav x lav
(c) Vr.ms. x lr.m.s (d) Vpeak x Ipeak
Ans.(c)

(vii) In a pure inductive circuit if the supply frequency is reduced to 1/2, the current will be :
(a) reduced by half (b) doubled
(c) four times as high (d) reduced to 1/4th
Ans.(b)

(viii) An alternating current is represented as I = 70.7 $\sin(377.142t + \pi/6)$ the frequency of current is :
(a) 50 Hz (b) 60 Hz (c) 25 Hz (d) 100 Hz
Ans.(b)

(ix) The resistance of a conductor having length 'l' area of cross-section 'a' and resistivity 'd' is given by :
(a) $R = \delta r/a$ (b) $R = \delta ra$
(c) $R = \delta a/l$ (d) $R = l/\delta a$
Ans.(a)

(x) Ohm's law is adpplicable to :
(a) Vaccum tubes (b) Carbon resistances
(c) Semiconductors (d) None of these
Ans.(b)

(xi) Kirchoff's current law is applicable to :
(a) electric circuits (b) electronic circuits
(c) closed loops in a network
(d) at junction in a network
Ans.(b)

(xii) In a three phase system, phase voltage differ by :
(a) 180^0 (b) 120^0 (c) 90^0 (d) 360^0
Ans.(b)

(xiii) Is a three phase delta connection line voltage is 400V, then the phase voltage will be :
(a) $400/\sqrt{3}V$ (b) $400/\sqrt{2}V$
(c) $400/\sqrt{3}V$ (d) $200/\sqrt{2}V$
Ans.400V//Vphase=Vline

(xiv) In a star connected system of three phase connection.
(a) Line current is equal to phase current
(b) Line voltage is equal to phase voltage
(c) Line voltage is equal to phase current
(d) Line current is equal to $\sqrt{3}$ phase current
Ans.(a)

(xv) The superposition theorem requires as any circuits to be solved as there are
(a) Meshes (b) Nodes
(c) Sources (d) All of the above
Ans.(c)

(xvi) In case of delta connected circuit when one resistor is open, the power will be
(a) Unaltered (b) Reduced by 1/3
(c) Reduced to 1/9 (d) Reduced to 1/6
Ans.(b)

(xvii) Which of the following theorem is applicable for both linear and non-linear circuits?
(a) Superposition (b) Thevenin
(c) Norton (d) None of these
Ans.(d)

(xviii) The current in an R-L circuit at the instant of connecting it to a dc source of V volts will be :
(a) V/R (b) V/L (c) Zero (d) V/LR
Ans.(a)

(xix) In an R-C series circuit excited by a dc voltage of 'V' volts, the initial current is :
(a) 0 (b) V/R (c) V/C (d) VC/R
Ans.(b)

(xx) Zero sequence current always flows through :
(a) Earth wire (b) Phase wire
(c) Neutral wire (d) Any of these
Ans.(c)

Group-B

Q2. State and explain superposition theorem.

Ans. Same as Chapter

OR

Q2. Two bulbs of 250W, 230V each are connected in parallel across a 200V supply. Calculate the total power drawn from the supply.

Ans. We know that $R = V^2/P$

Hence the resistance of the bulb is

$R = (230)^2/250 = 1058/5$ ohm

The resistance of each bulb is 211.6 ohm

The total resistance of the circuit when the bulb are connected in parallel is 211.6/2 = 105.8 ohm

Therefore, the total power consumed in the circuit is

$P = (230)^2/105.8 = 500$ W

Hence, the total power drawn from the supply is 500 watt.

Q3. An instantaneous current is expressed as i = 250sin (314t + ϕ). Calculate rms value, average value, frequency and time period of the current.

Ans. Given, $i = 250\sin(314t + \phi)$;

$I_{max} = 250$ A

$I_{avg.} = I_{\max} / \pi = 250/\pi = 79.58A$

$I_{rms} = I_{\max} / \sqrt{2} = 250/1.414 = 176.80A$

Frequency (f) $= \omega / 2\pi = 314/2\pi = 49.98 = 50\,Hz$

Time Period (T) = 1/f = 1/50 = 20 ms

Hence, rms value = 79.58 A, average value = 176.80 A

Frequency = 50 Hz, time period = 20 ms

OR

Q3. Explain the following ac quantities :

(i) Form factor

Ans. The ratio of the root mean square value to the average value of an alternating quantity (current or voltage) is called Form Factor.

$$\text{Form Factor } \frac{I_{r.m.s}}{I_{av}} \text{ or } \frac{E_{r.m.s}}{E_{av}}$$

(ii) Peak factor

Ans. Peak Factor is defined as the ratio of maximum value to the R.M.S value of an alternating quantity.

$$\text{Peak Factor } = \frac{I_m}{I_{r.m.s}} \text{ or } \frac{E_m}{E_{r.m.s}}$$

(iii) Instantaneous value

Ans. The intantaneous value of an alternating voltage or current is the value of the current or voltage at a particular instant of time during the cycle of the waveform.

$$\upsilon = V_{\max} \sin \omega t$$

(iv) Rms value

Ans. The Root Mean Square (RMS) value is "the square root of the sum of squares of means of an alternating quantity".

$$I_{rms} = \sqrt{\frac{(i1^2 + i2^2 + ...in^2}{n}}$$

Q4. State and explain Kirchoff's law.

Ans. Kirchoff's law basically consists of two laws :

(i) KCL (Kirchoff's Current law)

(ii) KVL (Kirchoff's Voltage law)

The KCL states that the summation of current at a junction remains zero and according to KVL the sum of the electromotive force and the voltage drops in a closed circuit remains zero.

Now the laws are described as :

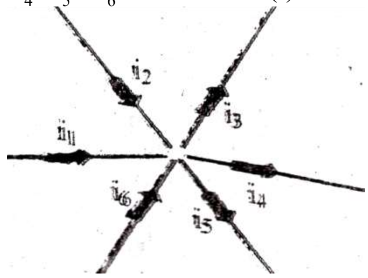
Kirchhoff's Current Law

Kirchhoff's Current Law states that" the algebraic sum of all the currents at any node point or a junction of a circuit is zero".

$$\sum I = 0$$

Considering the figure as per the Kirchhoff's Current Law

$i_1 + i_2 - i_3 - i_4 - i_5 + i_6 = 0$ .....(i)



The direction of incoming currents to a mode is taken as positive while the outgoing currents is taken as negative. The reverse of this can also be taken, i.e. incoming current as negative or outgoing as positive.

The equation (i) can also be written as

$i_1 + i_2 + i_6 = i_3 + i_4 + i_5 = 0$

Sum of incoming currents = Sum of outgoing currents.

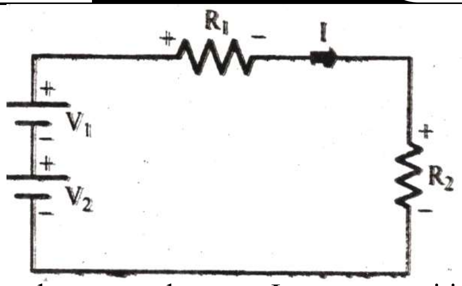
According to the Kirchhoff's current law. The algebraic sum of the currents entering a mode must be equal to the algebraic sum of the currents leaving the node in an electric network.

Kirchhoff's Voltage Law : Kirchhoff's Voltage Law states that the algebraic sum of the voltages (or voltage drops) in any closed path of network that is transverse in a single direction is zero or in other words, in a closed circuit, the algebraic sum of all the EMFs+the algebraic sum of all the voltage drops (product of current (I) and resistance (R) is zero.

$$\sum E + \sum V = 0$$

As per the Kirchhoff's Voltage Law

$- V_1 + (-V_2) + iR_1 + iR_2 = 0$



Hence, the assumed current I causes a positive voltage drop of voltage when flowing from the positive to negative potential while negative potential drop while the current flowing from negative to the positive potential.

$i(R_1+R_2) = V_1 + V_2$ or

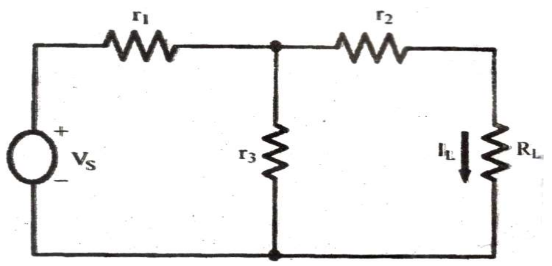
$$i = \frac{V_1+V_2}{(R_1+R_2)}$$

OR

Q4. State and explain Norton's theorem.

Ans.Norton's Theorem states that : A linear active network consisting of independent or dependent voltage source and current sources and the various circuit elements can be substituted by an equivalent circuit consisting of a current source in parallel with a resistance. The current source being the short-circuited current across the load terminal and the resistance being the internal resistance of the source network.

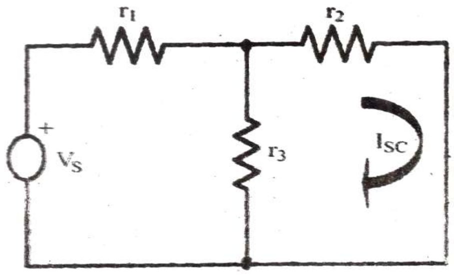
Let's consider a circuit diagram for Norton's Theorem.



To find the current (I_L) through the load resistance R_L as shown in the circuit above the load resistance has to be short-circuited as shown in the circuit below.

Now, the value of current I flowing in the circuit is found out by the equation.

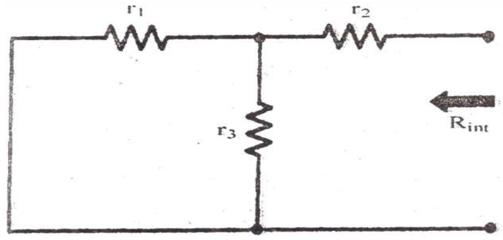
$$i = \frac{V_s}{r_1 + \frac{r_2 r_3}{r_2 + r_3}}$$



And the short-circuit current I_{SC} is given by the equation shown below.

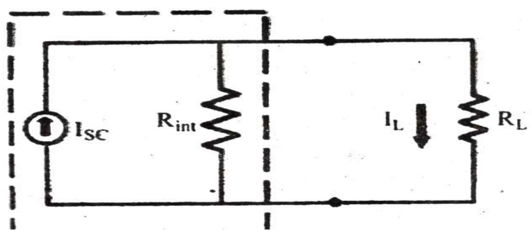
$$I_{SC} = I\frac{r_3}{r_3+r_2}$$

Now the short circuit is removed, and the independent source is deactivated as shown in the circuit below and the value of the internal resistance is calculated by



$$R_{\text{int}} = r_2 + \frac{r_1 r_3}{r_2 + r_3}$$

As per the Norton's Theorem, the equivalent source circuit would contain a current source in parallel to the internal resistance, the current source being the short-circuited current across the shorted terminals of the load resistor. The Norton's Equivalet circuit is represented as



the load current I_L calculated by the equation shown below.

$$I_L = I_{SC}\frac{R_{\text{int}}}{R_{\text{int}} + R_L}$$

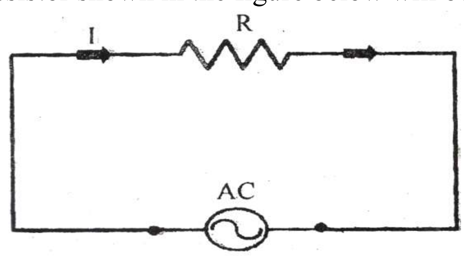
Q5. Derive a relationship between the voltage and current in purely resistive circuit.

Ans. In the pure resistive circuit, the power is dissipated by the resistors and the phase of the voltage and current remains same i.e., both the voltage and current reach their maximum value at the same time.

Let the alternating voltage applied across the circuit be given by the equation.

$$v = V_m \sin \omega t \qquad ......(i)$$

Then the instantaneous value of current flowing through the resistor shown in the figure below will be



$$V = V_m \sin \omega t$$

$$i = \frac{v}{R} = \frac{V_m}{R} \sin \omega t \qquad ....(ii)$$

The value of current will be maximum when $\omega t = 90$ degrees or $\sin \omega t = 1$.

Putting the value of $\sin \omega t$ in equation (ii) we will get

$$i = I_m \sin \omega t \qquad .....(iii)$$

OR

Q5. Show that average power consumed in a purely inductive circuit is zero.

Ans. The power in an AC circuit is the product of instantaneous voltage and current and can be given as

P = v × i

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

Taking integration over a cycle we get,

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

$$P = 1/2\pi(\int_{2n}^{0} V_m \sin \omega t \times I_m \sin(\omega t - 90) d\omega t)$$

$$= (V_m I_m / 2\pi)(\int_{2n}^{0} \sin \omega t \times (-\cos \omega t) dwt)$$

$$= (V_m I_m / 2\pi)(\int_{2n}^{0} (-\sin 2\omega t)/2\, dwt)$$

$$= (V_m I_m / 8\pi)(\cos 4\pi - \cos 0)$$

$$= (V_m I_m / 8\pi)(1 - 1)$$

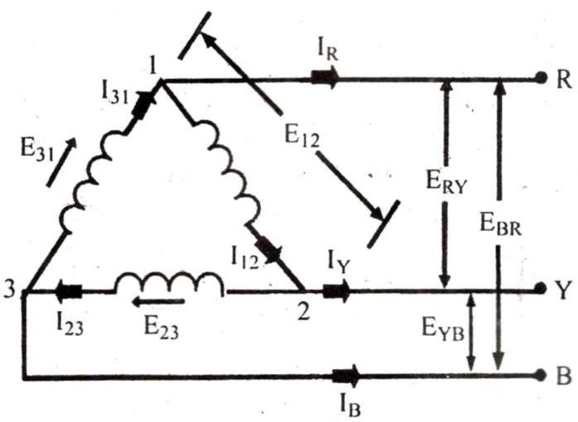
$$= 0$$

The average power in a pure inductor always zero because the amount of energy received from the source in a half-cycle is returned to the source in the next half cycle.

Q6. Derive a relation between the line and phase voltage in star/delta connection of a three phase connection.

Ans.Delta Connection : The relationship between the phase voltage and line voltage in the Delta connection can be described as follows :

Let's consider the figure A as shown.



from the figure that the voltage across terminals 1 and 2 is the same as across the terminals R and Y.Therefore,

$E_{12} = E_{RY}$

similarly, $E_{23} = E_{YB}$ and $E_{31} = E_{BR}$

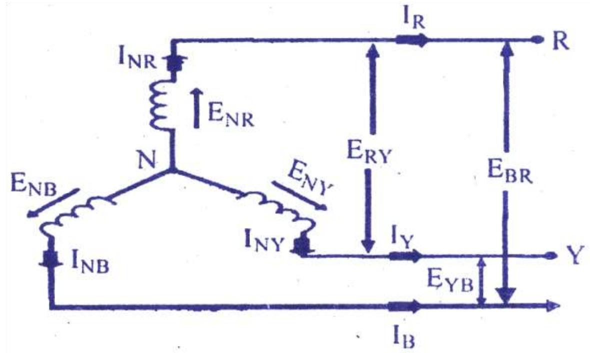
Where, the phase voltages are

$E_{12} = E_{23} = E_{31} = E_{ph}$

The line voltages are $E_{RY} = E_{YB} = E_{BR} = E_L$

Hence, in Delta Connection Line Voltage is equal to Phase Voltage.

Star Connection : The relationship between the phase voltage and line voltage in the star connection can be described as follows :



As the system is balanced, i.e., in R,Y and B, the equal amount of current flows through them. Therefore, the three voltages E_{NR},E_{NY} and E_{NB} are equal in magnitude but displaced from one another by 120 degrees electrical.

Now $E_{NR} = E_{NY} = E_{NB} = E_{ph}$ (in magnitude)

There are two phase voltages between any two lines.

So, by tracing the loop NRYN

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

or $$\overline{E_{NR}} = \overline{E_{NY}} - \overline{E_{NY}} = 0$$

To find the vector sum of E_{NY} and -E_{NR}, we have to reverse the vector E_{NR} and add it with E_{NY}.

Therefore,

$$E_{RY} = \sqrt{E_{NY}^2 + E_{NR}^2 + 2E_{NY}E_{NR}\cos 60^0}$$

or $$E_L = \sqrt{E_{ph}^2 + E_{ph}^2 + 2E_{ph}E_{ph} \times 0.5}$$

or $$E_L = \sqrt{3E_{ph}^2} = \sqrt{3}E_{ph} \text{ (in magnitude)}$$

Similarly,

E_{YB}=E_{NB}-E_{NY} or $E_L = \sqrt{3}E_{ph}$

E_{BR}= E_{NR}- E_{NB} or $E_L = \sqrt{3}E_{ph}$

Hence, in Star Connections Line voltage is root 3 times of phase voltage.

Line voltage = $\sqrt{3}$ × Phase voltage

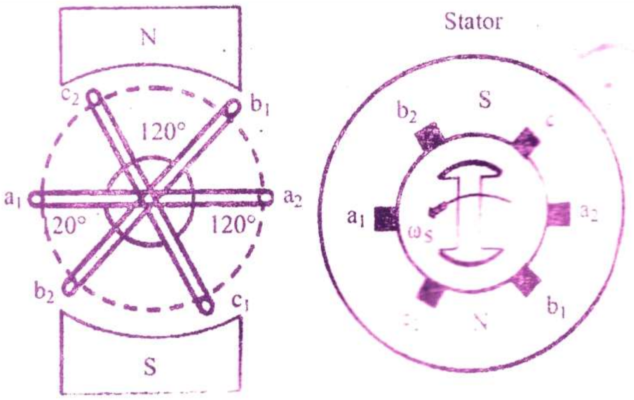
OR

Q5. Explain briefly the principle of generation of the three phase voltages.

Ans. In a 3 phase system, there are three equal voltages of

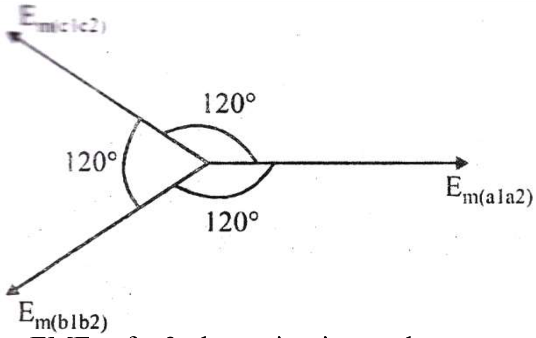
EMF's of the same frequency having a phase difference of 120 degrees. These voltages can be produced by a three-phase AC generator having three identical windings displaced apart from each other by 120 degrees electrical.

When these windings are kept stationary, and the magnetic field is rotated as shown in the figure A or when the windings are kept stationary, and the magnetic field is rotated as shown in figure B, an emf is induced in each winding. The magnitude and frequency of these EMFs are same but are displaced apart from one another by an angle of 120 degrees.



Let's consider three identical coils a_1a_2, b_1b_2 and c_1c_2 as shown in the figure. In the figure a_1, b_1 and c_1 are the starting terminals, whereas a_2, b_2 and c_2 are the finish terminals of the three coils. The phase difference of 120 degrees has to be maintained between the starts terminals a_1, b_1 and c_1.

The EMFs induced in the three coils in a 3 phase circuits are the same magnitude and frequency and are displaced by an angle of 120 degrees from each other as shown in the phasor diagram.



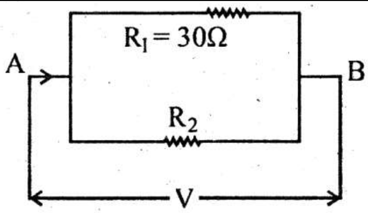
These EMFs of a 3 phase circuits can be expressed in the form of the equations given below.

$$e_{a1a2} = E_m \sin \omega t$$

$$e_{b1b2} = E_m \sin(\omega t - 2\pi/3) = E_m \sin(\omega t - 120^0)$$

Group-C

Q7. Two resistances, one of 30Ω and another of unknown value are connected in parallel. Applied voltage is 90V and the total power dissipated is 450W. Find R_2.



Ans. We know that P = VI

So, I = P/V

I = 450/90 = 5A;

and, $P = V^2/R$

$R = V^2/P = (90)^2/450 = 18$ ohm

$R = R_1 \times R_2/(R_1+R_2) = 18$ ohm

$18 = 30\ R_2/(30+R_2)$;

$18\times30+18\times R_2 = 30\times R_2$

$12\times R_2 = 540$

$R_2 = 540/12 = 45$ ohm

Hence, the value of R_2 is 45 ohm

OR

Q7. Write a short note on star delta transformation.

Ans. The convension of star connected load network to delta connected network. Suppose we have a Star connected load as shown in the figure A and it has to be converted into a Delta connection as shown in figure B. The following Delta values are as follows.

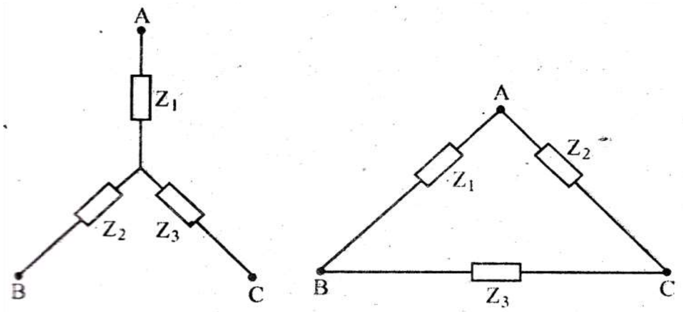


Figure A Figure B

$$Z_1 = \frac{Z_AZ_B + Z_BZ_C + Z_CZ_A}{Z_C} = \frac{\sum Z_AZ_B}{Z_C}$$

$$Z_2 = \frac{Z_AZ_B + Z_BZ_C + Z_CZ_A}{Z_B} = \frac{\sum Z_AZ_B}{Z_B}$$

$$Z_3 = \frac{Z_AZ_B + Z_BZ_C + Z_CZ_A}{Z_A} = \frac{\sum Z_AZ_B}{Z_A}$$

Hence, if the values of Z_A, Z_B and Z_C are known, therefore by knowing these values and by putting them in the above equations, we can convert a star connection into a delta connection.

Q8. A capacitor and resistors are connected in series to an AC supply of 50V and 50 Hz. The current is 2A and the power dissipated is 80W. Calculate the resistance of the resistor and the capacitance of the capacitor.

Ans. Frequency (f) = 50 Hz; Current (I) = 2A

Power dissipated (P) = 80 W

Since, P = $I^2 \times R$

So, R = $P/I^2 = 80/(2)^2 = 80/4 = 20$ ohm

Now, impedance (Z) = V/I = 50/2 = 25 ohm

From, impedance triangle, $Z^2 = R^2 + XC^2$;

So, $X_C^2 = Z^2 - R^2 = 25^2 - 20^2 = 625 - 400 = 225$

$X_C = 15$ ohm

Now, $X_C = \dfrac{1}{2\pi fC}$

So, $C = 1/2\pi(50)(15) = 212.2\pi F$

Hence, Resistance is 20Ω and Capacitance $= 212.2\mu F$

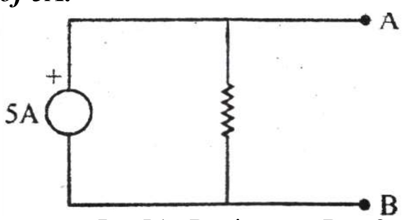
OR

Q8. Compare a series and parallel resonant circuit.

Ans. The comparision between Series and Parallel Resonance circuit are as follows.

Specifications	Series Resonance Circuit	Parallel Resonance Circuit
Impedance at resonance	Minimum	Maximum
Admittance at resonance	Maximum	Minimum
Currentatresonance	Maximum	Minimum
Circuit for f > f_0	Inductive	Capacitive
Circuit for f > f_0	Capacitive	Inductive
Amplification of	Voltage	Current
Q – factor	$Q = \dfrac{\omega_r L}{R}$ $= \dfrac{R_L}{R} = \dfrac{1}{\omega_r CR}$	Quality Factor, $Q = \dfrac{R}{2\pi/L}$ $= 2\pi/CR = R\sqrt{\dfrac{C}{L}}$
Known as	Acceptor Circuit	Rejector Circuit
Power factor	Unity	Unity

Q9. Find the equivalent voltage source for the current source of 5A.



Ans. Given, current I = 5A; Resistance R = 2 ohm

Hence voltage = I*R = 5*2 = 10V

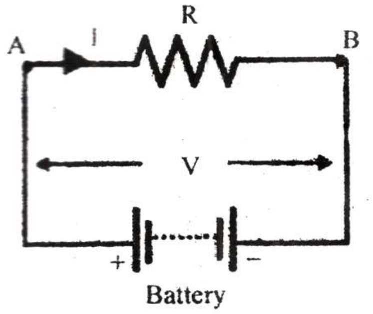
So, the equivalent circuit will be having voltage source 10V and resistance 2 ohm.

OR

Q9. State and explain Ohm's law. Give its limitations.

Ans. Ohm's laws state that the current through any two points of the conductor is directly proportional to the potential difference applied across the conductor, provided physical conditions i.e. temperature, etc. do not change.

It is measured is **Ω (ohm).**



Mathematically it is expressed as

$I \alpha V$

$\dfrac{V}{I} = constant$

$\dfrac{V_1}{I_1} = \dfrac{V_2}{I_2} = ... = \dfrac{V_n}{I_n} = constant$

The constant is also called the resistance (R) of the conductor

$\dfrac{V}{I} = R$

Limitations of Ohm's Law

Ohm's law is not applicable in unilateral networks. Unilateral network allow the current to flow in one direction. Such types of network consist elements like a diode, transistor, etc.

It is not applicable for the non-linear network. In the nonlinear network, the parameter of the network is varied with the voltage and current. Their parameter likes resistance, inductance, capacitance and frequency, etc., not remain constant with the times. So ohms law is not appliable to the nonlinear network.

Q10.Compare between star and delta system of three phase connection.

Ans. The difference between the Star and Delta Connection are given as follows :

Basis	Star Connection	Delta Connection
Basic Definition	The terminals of the three branches are connected to a common point. The network formed is known as Star Connection	The three branches of the network are connected in such a way that it forms a closed loop known as Delta Connection
Connection of terminals	The starting and the finishing point that is the similar ends of the three coils are connected together are connected together.	The end of each coil is connected to the starting point of the other coil that means the opposite terminals of the coils
Neutral point exists in the star	Neutral or the star point connection	Neutral point does not exist in the delta connection
Relation between line and phase voltage	Line voltage is equal to root three times of the phase voltage	Line voltage is equal to the phase voltage.
Speed	The speed of the star connected motors is slow as they receive $1/\sqrt{3}$ of the voltage	The speed of the delta connected motors is high because each phase gets the total of the line voltage.
Phase voltage	Phase voltage is low as $1/\sqrt{3}$ times of the line voltage	Phase voltage is equal to the line voltage.
Number of turns	Requires less number of turns.	Requires large number of turns.
Insulation level	Insulation required is low.	High insulation is required
Network Type	Mainly used in the Power Transmission networks.	Used in the power Distribution networks.
Received voltage Type of system	In Star connection each winding receive 230 volts. Both three phase four wire and three phase three wire system can be derived in	In delta connection each winding receives 414 volts. Three phase four wire system can be derived from the delta connection

OR

Q10. What are the advantages of three phase voltage system over single phase voltage system?

Ans. The following are the main advantages of 3 phase system over Single Phase System :

High Rating

The rating i.e. the output of a three-phase machine is nearly 1.5 times the rating (output) of a single phase machine of the same size.

Constant Power

In single phase circuits, the power delivered is pulsating. Even when the voltage and current are in phase, the power is zero twice in each cycle. Whereas, in the polyphase system, the power delivered is almost constant when the loads are in balanced conditions.

Power Transmission Economics

The three phase system requires only 75% of the weight of conducting material of that required by single phase system to transmit the same amount of power over a fixed distance at a given voltage.

Superiority of 3 Phase Induction Motors

The three phase induction motors have a widespread field of applications in the industries.

Size and Weight of alternator

The 3 phase Alternator is small in size and light in weight as compared to a single phase alternator.

Requirement of Copper and Aluminium

3 Phase system requires less copper and aluminium for the transmission system in comparison to a single phase transmission system.

Frequency of Vibration

In 3 Phase motor, the frequency of vibrations is less as compared to single phase motor because in single phase the power transferred is a function of current and varies constantly.

Dependency

A single phase load can be efficiently fed by a 3 phase load or system, but 3 phase system cannot depend or feed by a single phase system.

Torque

A uniform or constant torque is produced in a 3 phase system, whereas in a single phase system pulsating torque is produced.

Q11. Write short notes on any two :

(i) Energy sources

Ans. Energy sources are classified as Voltage sources and Current sources.

Both as a voltage sources or a current source can be classified as being either *independent* (ideal) or *dependent,* (controlled) that is whose value depends upon a voltage or current elsewhere within the circuit, which itself can be either constant or time-varying.

Voltage Sources :

A voltage source, such as a battery or generator, provides a potential difference (voltage) between two points within an electrical circuit allowing current to flowing around it. Voltage can exist without current. A battery is the most common voltage source for a circuit with the voltage that appears across the positive and negative terminals of the source being called the terminals voltage.

Current Sources :

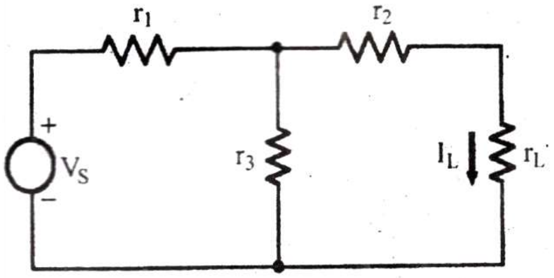
A current source is a circuit element that maintains a constant current flow regardless of the voltage developed across its terminals as this voltage is determined by other circuit elements. That is, an ideal constant current source continually provides a specified amount of current regardless of the impedance that it is driving and as such, an ideal current source could, in theory, supply an infinite amount of energy.

(ii) Thevenin's theorem

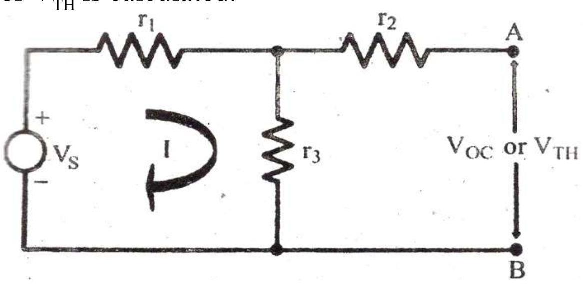
Ans. Thevenin's Theorem states that-any complicated network across its load terminals can be substituted by a voltage source with one resistance in series.

In other words, any linear active network consisting of independent or dependent voltage and current source and the network elements can be replaced by an equivalent circuit having a voltage source in series with a resistance, that voltage source being the open circuited voltage across the open circuited load terminals and the resistance being the internal resistance of the source.

Let us consider a simple DC circuit as shown in the figure, where we have to find the load current I_L by the Thevenin's Theorem.

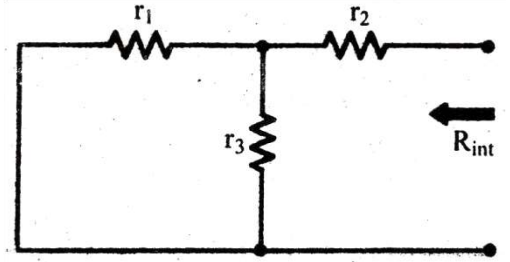


In order to find the equivalent voltage source, r_L is removed from the circuit as shown in the figure and V_{OC} or V_{TH} is calculated.

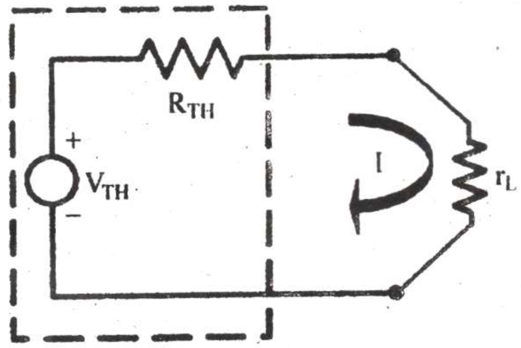


$$V_{OC} = Ir_3 = \frac{V_s}{r_1 + r_3} r_3$$

Now, to find the internal resistance of the network (Thevenin's resistance or equivalent resistance) in series with the Thevenin's voltage V_{TH}, the voltage source is removed as shown in figure.



$$R_{TH} = r_2 + \frac{r_1 r_3}{r_1 + r_3}$$



The load current is determined by the equivalent Thevenin's circuit.

The load current I_L is given as

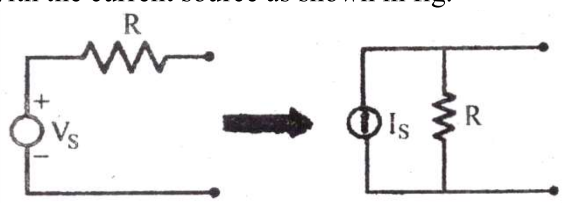
$$I_L = \frac{V_{TH}}{R_{TH} + r_L}$$

(iii) Source conversion

Ans. Source Conversion simply means replacing one source by an equivalent source. A practical voltage source can be transformed into an equivalent practical current source and similarly a practical current source into voltage source.

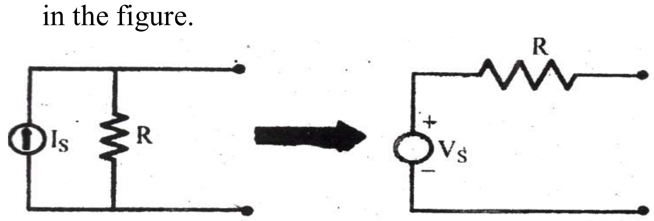
Conversion of Voltage source into Current source :

When the voltage source is connected with the resistance in series and it has to be converted into the current source than the resistance is connected in parallel with the current source as shown in fig.



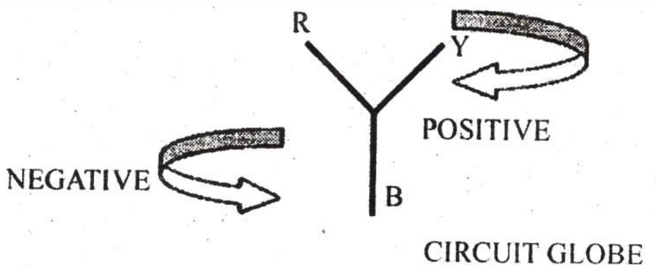
Conversion of Current source into Voltage source :

When the Current source connected in parallel with the resistance is converted into a voltage source by placing the resistance in series with the voltage source as shown in the figure.



(iv) Phase sequence

Ans. In three phase system the order in which the voltages attain their maximum positive value is called Phase Sequence. There are three voltages or EMFs in three phase system with the same magnitude, but the frequency is displaced by an angle of 120 deg electrically. If the phases of any coil are named as R, Y, B then the Positive phase sequence will be RYB, YBR, BRY also called as clockwise sequence and similarly the Negative phase sequence will be RBY, BYR, YRB respectively and known as an anti-clockwise sequence.



It is essential because of the following reasons :-

1. The parallel operation of three phase transformer or alternator is only possible when its phase sequence is known.
2. The rotational direction of three phase induction motor depends upon its sequence of phase on three phase supply and thus to reverse its direction the phase sequence of the supply given to the motor has to be changed.

Model Sets-3

Electric Circuit & Network

Group A

1. *Choose the most suitable answer from the following options:*

(i) An Ideal constant current source has.....internal resistance.

(a) zero (b) Infinity (c) Low (d) None of these

Ans.(b)

(ii) When two different resistance are connected in series, they have........

(a) Same volrtage drop across them
(b) Same current passing through them
(c) Different current passing through them
(d) None of these

Ans.(b)

(iii) Kirchhoff's voltage law is concerned with:

(a) IR drops (b) Battery EMFs
(c) Junction voltage (d) Both (a) and (b)

Ans.(d)

(iv) Which of the following is the ultimate source of energy for us?

(a) LPG (b) Nuclear energy
(c) Solar energy (d) CNG

Ans.(c)

(v) In pure resistive circuit, the phase angle between A.C. voltage and current is....

(a) 0^0 (b) 90^0 (c) 180^0 (d) None of these

Ans.(a)

(vi) In pure inductive circuit, the frequency is.....to the inductance.

(a) Directly proportional (b) Inversely proportional
(c) Un-related (d) None of these

Ans.(a)

(vii) In pure capacitive circuit, the power factor is....

(a) Minimum (b) Maximum
(c) In finity (d) Zero

Ans.(d)

(viii) The R.M.S. value for a pure sine wave form is.....times of maximum value.

(a) 0.637 (b) 0.707
(c) 1.11 (d) 1.414

Ans.(b)

(ix) The power factor of series R-L-C circuit is...

(a) $\dfrac{R}{\sqrt{R^2+(X_L-X_C)^2}}$ (b) $\dfrac{R}{\sqrt{R^2+(X_L+X_C)^2}}$

(c) $\dfrac{R}{\sqrt{R^2-(X_L-X_C)^2}}$ (d) $\dfrac{R}{\sqrt{R^2+(X_L^2-X_C^2)}}$

Ans.(a)

(x) A series circuit is said to be is electrical resonance when its net.......is zero.

(a) Resistance (b) Impedance
(c) Reactance (d) None of these

Ans.(c)

(xi) Quality factor of R-L-C elecric circuit can be increased by increasing, the value of....

(a) Resistance (b) Inductance
(c) Capacitance (d) All of the above

Ans.(d)

(xii) The voltage applied in a series R-L-C circuit when i = 5 mA, V_L = 35 V, V_C = 25 V and R = 1000Ω is....

(a) 65 V (b) 55 V (c) 75 V (d) 45V

Ans.(a)

(xiii) The correct expression for phase angle in R-L-C series circuit is

(a) $\phi = \tan^{-1}\left(\dfrac{X_L-X_C}{R}\right)$ (b) $\phi = \tan^{-1}\left(\dfrac{X_L+X_C}{R}\right)$

(c) $\phi = \tan^{-1}\left(\dfrac{R}{X_L-X_C}\right)$ (d) $\phi = \tan^{-1}\left(\dfrac{R}{X_L+X_C}\right)$

Ans.(a)

(xiv) In a three phase delta connected system.

(a) Line currrent = phase current
(b) Line voltage = phase voltage
(c) Phase current = $\sqrt{3}$x line current
(d) Phase voltage = $\sqrt{3}$x line voltage

Ans.(b)

(xv) There identical resistance each of 15Ω are connected in delta network across 400v, 3-phase supply. The value resistance in each leg of the equivalent star connected load will be.....

(a) 45Ω (b) 30Ω (c) 7.5Ω (d) 5Ω

Ans.(d)

(xvi) By using two wattmeter, power can be measured in:

(a) 3-phase, 2-wire system (b) 3-phase, 2-wire system
(c) 3-phase, 4-wire system (d) All of the above

Ans.(c)

(xvii) Under the condition of maximum power transfer, the efficiency is

(a) 25% (b) 50% (c) 75% (d) 100%

Ans.(b)

(xviii) Thevenin's theorem is applied to....

(a) A passive and linear network
(b) A passive and non-linear network
(c) An active and linear network
(d) An active and non-linear network

Ans.(c)

(xix) Which method is the best for voltage sources?

(a) Mesh analysis (b) Nodal analysis
(c) Super position principle (d) None of these

Ans.(b)

(xx) Norton current is equal to the current passing through the short circuited ....terminals

(a) Input (b) Output
(c) Both (a) and (b) (d) None of these

Ans.(b)

Group B

Answer all Five Questions.

Q2. Define electric current, state and explain Kirchhoff's current law with suitable network.

Ans. Electric current is defined as the rate of flow of negative charges of the conductor. In other words, the continuous flow of electrons in an electric circuit is called an electric current.

Kirchoff's law basically consists of two laws :

(i) KCL (Kirchoff's Current law)
(ii) KVL (Kirchoff's Voltage law)

The KCL states that the summation of current at a junction remains zero and according to KVL the sum of the electromotive force and the voltage drops in a closed circuit remains zero.

Now the laws are described as :

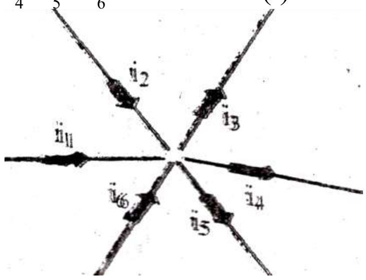
Kirchhoff's Current Law

Kirchhoff's Current Law states that" the algebraic sum of all the currents at any node point or a junction of a circuit is zero".

$$\sum I = 0$$

Considering the figure as per the Kirchhoff's Current Law

$i_1 + i_2 - i_3 - i_4 - i_5 + i_6 = 0$ .....(i)



The direction of incoming currents to a mode is taken as positive while the outgoing currents is taken as negative. The reverse of this can also be taken, i.e. incoming current as negative or outgoing as positive.

The equation (i) can also be written as

$$i_1 + i_2 + i_6 = i_3 + i_4 + i_5 = 0$$

Sum of incoming currents = Sum of outgoing currents.

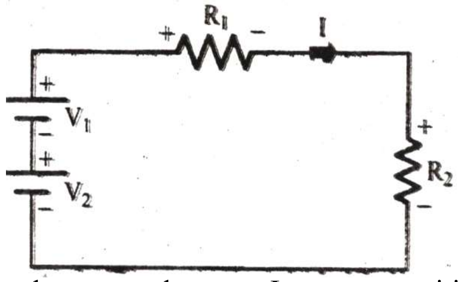
According to the Kirchhoff's current law. The algebraic sum of the currents entering a mode must be equal to the algebraic sum of the currents leaving the node in an electric network.

Kirchhoff's Voltage Law : Kirchhoff's Voltage Law states that the algebraic sum of the voltages (or voltage drops) in any closed path of network that is transverse in a single direction is zero or in other words, in a closed circuit, the algebraic sum of all the EMFs+the algebraic sum of all the voltage drops (product of current (I) and resistance (R) is zero.

$$\sum E + \sum V = 0$$

As per the Kirchhoff's Voltage Law

$$-V_1 + (-V_2) + iR_1 + iR_2 = 0$$



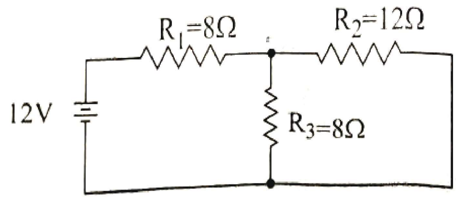
Hence, the assumed current I causes a positive voltage drop of voltage when flowing from the positive to negative potential while negative potential drop while the current flowing from negative to the positive potential.

$$i(R_1+R_2) = V_1 + V_2 \text{ or}$$

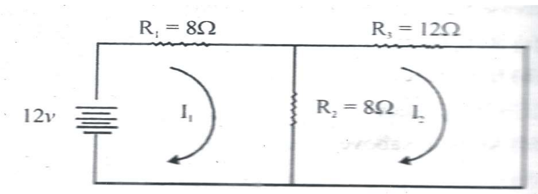
$$i = \frac{V_1 + V_2}{(R_1 + R_2)}$$

OR

Q2. Find the potential difference across R_1 and current flowing through R_2 using Kirchhoff's laws in the given network.



Ans.



Apply KVL to mesh-1 we get,

$$8I_1 + 8(I_1 - I_2) = 12$$

$$16I_1 - 8I_2 = 12$$

$$4I_1 - 2I_2 = 3 \text{ ....(i)}$$

Apply KVL to mesh -2 we get,

$$12I_2 + 8(I_2 - I_1) = 0$$

$$20I_2 = 8I_1$$

$$5I_2 = 2I_1$$

$$I_2 = \frac{2}{5}I_1 \text{ ....(ii)}$$

From equation (i) and (ii)

$$4I_1 - 2\times\frac{2}{5}I_1 = 3$$

$$20I_1 - 4I_1 = 15$$

$$16I_1 = 15$$

$$I_1 = \frac{15}{16}Amp.$$

From equation (ii)

$$I_2 = \frac{2}{5}I_1$$

$$= \frac{2}{5}\times\frac{15}{16} = \frac{3}{8}Amp.$$

The potential difference across R_1 is $= I_1R_1$

$$= \frac{15}{16}\times 8 = \frac{15}{2} = 7.5\,volt$$

The current flowing through R_2 is :

$$= I_2 - I_1$$

$$= \frac{15}{16} - \frac{3}{8} = \frac{15-6}{16} = \frac{9}{16} = 0.5625\,Amp$$

Q3. Define average value of an alternating current and find an expression for it by analytical method.

Ans. For a sinusoidal current or voltage, average value is that value which is obtained by averaging all the instantaneous values of its wave over a period of half cycle.

For sinusoidal current, its instantaneous value is represented by

$$i = I_m \sin\theta$$

Figure below shows one cycle of such sinusoidal current wave.

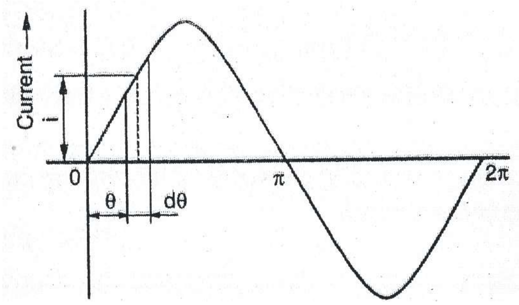


Figure: Average value of sinusoidal current

Total area under the current wave over half a cycle

$$= \int_0^{\pi} i.d\theta$$

∴ Average value of current over half a cycle,

$$I_{av} = \frac{Area\ under\ the\ curve\ over\ half\ a\ cycle}{Length\ of\ base\ over\ half\ a\ cycle} = \frac{1}{\pi}\int_0^{\pi} i.d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi} I_m \sin\theta.d\theta$$

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

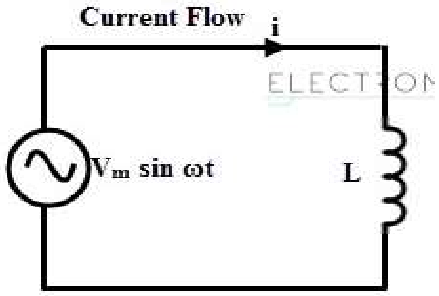
i.e $\quad I_{av} = 0.637I_m$

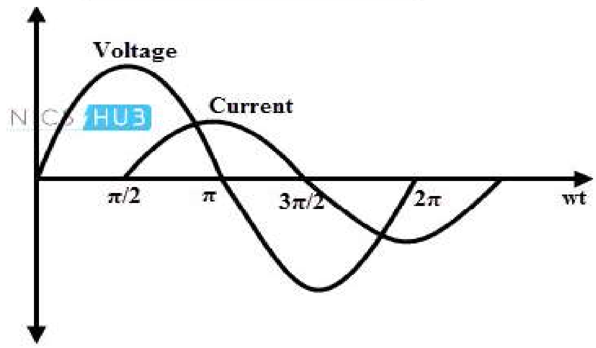
Thus, for sinusoidal current, average value is 0.637 times its maximum value.

OR

Q3. Explain the behavior of A.C. through pure inductance only.

Ans. A pure inductor has no resistance in the coil winding but has only inductance. This property of inductance is exhibited by all motors, transformers and generators (with some resistance in the coil). The figure below shows pure inductive circuit with AC voltage source and their appropriate waveforms.





Let the applied voltage, $V = V_m \sin\omega t$. As stated above that the emf induced is equal and opposite to the applied voltage, i.e., v = – e

Where e is the back emf and is equal to –L di/dt

Substituting the emf expression, we get

$$v = L\,di/dt$$

$$V_m \sin\omega t = L\,di/dt$$

$$di = (V_m/L)\sin\omega t\,dt$$

By applying integration on both sides, we get

$$i = (V_m / L)\int \sin\omega t.dt$$

$$= \left(V_m / \omega L\right)\left(-\cos\omega t\right)$$

$$i = \left(V_m / \omega L\right)\left(\sin\omega t - \pi/2\right)$$

When $\left(\sin\omega t - \pi/2\right)$ is unity, the current flowing through the circuit will be maximum. So

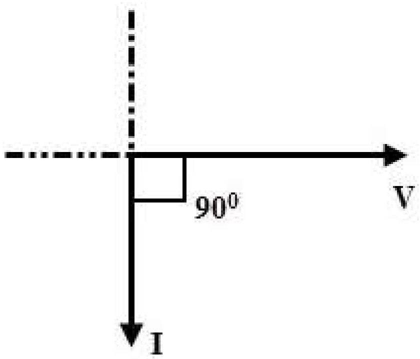
$$i_m = \left(V_m / \omega L\right)$$

Then the current equation becomes,

$$i = i_m\left(\sin\omega t - \pi/2\right)$$

Where $i_m = \left(V_m / \omega L\right)$

From the above current and voltage expressions, it is clear that the current lags the voltage by 90^0. Therefore, in pure inductive circuit current is in quadrature with the voltage as shown in waveforms of the above figure. This means that when the change in the current is maximum (at current passing through zero), the voltage induced across the inductor is maximum. Similarly, at maximum values of current where current is not changing, the induced voltage across the inductor will be zero. Thus, the voltage across an inductor leads the current through that inductor by ¼ (quarter) cycle. The phasor diagram of a pure inductive AC circuit is given below.



Q4.State and explain superposition theorem with suitable circuit.

Ans.*Refers to Chapter*

OR

Q4.State and explain Thevenin's theorem with suitable network.

Ans.*Refers to Chapter*

Q5.What are the reasons for the use of three phase system over single phase system. Describe it.

Ans.*Refers to Chapter*

OR

Q5.Explain star connection in three phase system with neat diagram and give relation between
(i) Line voltage and phase voltage
(ii) Line current and phase current

Ans.*Refers to Chapter*

Q6.Explain resonance in R-L-C parallel circuit and find expression for resonance frequency.

Ans.A parallel circuit like the one that is illustrated in figure 1 (a) is said to be under resonance when the resultant current drawn by it and the line voltage across its terminals are in phase.The frequency at which this happens is known as resonant frequency.To make this more clear consider the commonly used circuit (generally called as a tank circuit) shown in figure 1(a) .It consists of an inductive coil of L henrys and having a resistance of R ohms connected in parallel with a capacitance C farads across a variable frequency supply of V volts.Then at any frequency f, we have

Inductive resistance of the coil, $X_L = \omega L = 2\pi fL \ \ ohms$

Capacitive reactance of the capacitor,

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

Impedance of the coil, $Z_L = \sqrt{R^2 + X_L^2}\ \ ohms$

Current in the inductive branch, $I_L = \dfrac{V}{Z_L} amperes$

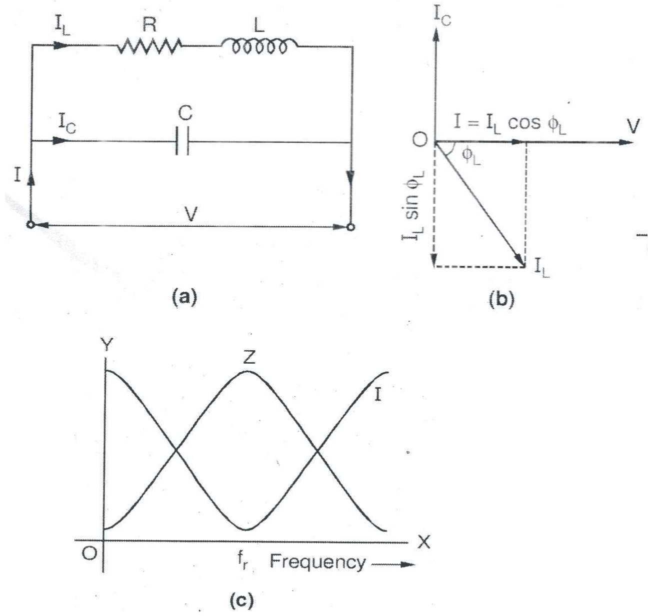


Figure : Parallel resonance

Phase angle between I_L and V $= \phi_L = \tan^{-1}\left(\dfrac{X_L}{R}\right)$

Current in the capacitive branch,

$$I_C = \frac{V}{X_C} amperes, leading\ V\ by\ 90^0$$

The resultant is obtained from the phasor addition of I_L and I_C.If f is of such a value that $I_C = I_L \sin\phi_L$, then, the resultant current I is minimum (=$I_L \cos\phi_L$)and is in phase with the supply voltage as shown in figure 1 (b) .As said earlier, the circuit under this condition is said to be in resonance and the frequency at which this happens is known as resontant frequency.

Resonant Frequency: The expression for the resontant frequency for the circuit under consideration can be derived from the conditions prevailing at the time of resonance .We know that at resonance,

$$I_L \sin\phi_L = I_C$$

$$\therefore \quad \frac{V}{Z_L} \times \frac{X_L}{Z_L} = \frac{V}{X_C}$$

$$\therefore \quad X_L.X_C = Z_L^2$$

$$\therefore \quad \omega L.\frac{1}{\omega C} = R^2 + X_L^2 = R^2 + \omega^2 L^2$$

$$\therefore \quad \frac{L}{C} = R^2 + \omega^2 L^2$$

$$\therefore \quad \omega^2 L^2 = \frac{L}{C} - R^2$$

Or, $$\omega^2 = \frac{1}{LC} - \frac{R^2}{L^2}$$

If fr is the resontant frequency, then,

$$(2\pi f_r)^2 = \frac{1}{LC} - \frac{R^2}{L^2}$$

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

If R is small, then $f_r = \dfrac{1}{2\pi\sqrt{LC}}$

OR

Q6.Explain true power and reactive power for A.C.

Ans.Active Power or True Power : If is the power which is actually dissipated in the circuit resistance. It is also called real or active power. It can be obtained by multiplying the apparent power (VI) by the power factor (cos ϕ) of the circuit and is given in watts or Killo-watts. i.e.

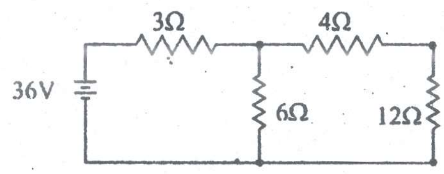
True Power VI cos ϕ watts.

(iii) Reactive Power : It is the power developed in the inductive reactance of the circuit. It is obtained by multiplying the apparent power (VI) by the sine of the angle between voltage and current (sin ϕ). It is also called **watt-less power** and is expressed in reactive volt-amperes (VAR) or Killo-volt-ampere reactive (KVAR), i.e. Reactive power VI sin ϕ VAR.

Group C

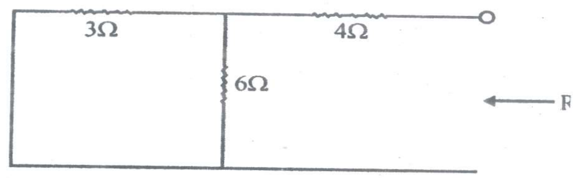
Answer all Five Questions.

Q7.State and explain Norton's theorem. Using Norton's theorem, find the current flowing through circuit given.



Ans.Norton's theorem:*Refers to Chapter 5 Q.no* ***2***

To find R_N or R_{IN}



$$R_N = (3\|6) + 4 = \frac{3\times 6}{3+6} + 4$$

$$= \frac{18}{9} + 4 = 6\Omega$$

To find I_{SC} :

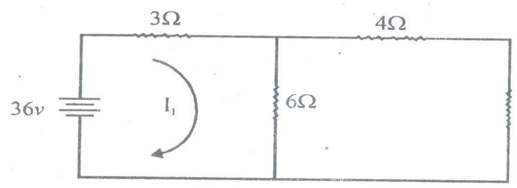


Fig.

Apply KVL in mesh -1 we get,

$$9I_1 - 6I_{SC} = 36$$

$$3I_1 - 2I_{SC} = 12 \text{ ....(i)}$$

Apply KVL in mesh -2 we get,

$$10\, I_{SC} - 6I_1 = 0$$

$$I_1 = \frac{10}{6} I_{SC} \text{ ....(ii)}$$

From equation (i) and (ii)

$$3 \times \frac{10}{6} I_{SC} - 2I_{SC} = 12$$

$$3I_{SC} = 12$$

$$I_{SC} = \frac{12}{3} = 4amp.$$

Norton's equivalent circuit:

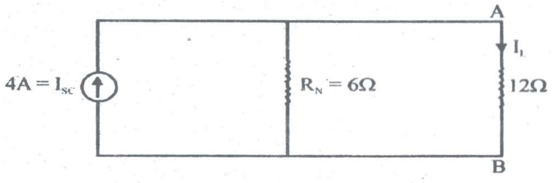


Fig.

The current flowing through the local resistance is given as :

$$I_L = \left(\frac{R_N}{R_N + R_L}\right) I_{SC} = \left(\frac{6}{6+12}\right) \times 4$$

$$= \frac{24}{18} = \frac{4}{3} = 1.33\,Amp.$$

OR

Q7. Three resistances are connected in delta form. Find the equivalent resistances when they are connected star from.

Ans. *Same as Model sets -1 Q.no 7*

Q8. Explain the behavior of A.C. through R-L series circuit with phasor diagram and waveform. Find the expression for power consumed in this circuit.

Ans. Consider the circuit containing resistance of R ohms in series with an inductance of L henries connected across an a.c supply as shown in figure 1(a) .If the circuit draws a current of I amperes, then we have,

Voltage drop across R, V_R = I.R (in phase with I)

Voltage drop across L, $V_L = I.X_L$(leading I by 90^0)

Where XL ($= \omega L$) is the inductive reactance of the inductance L.

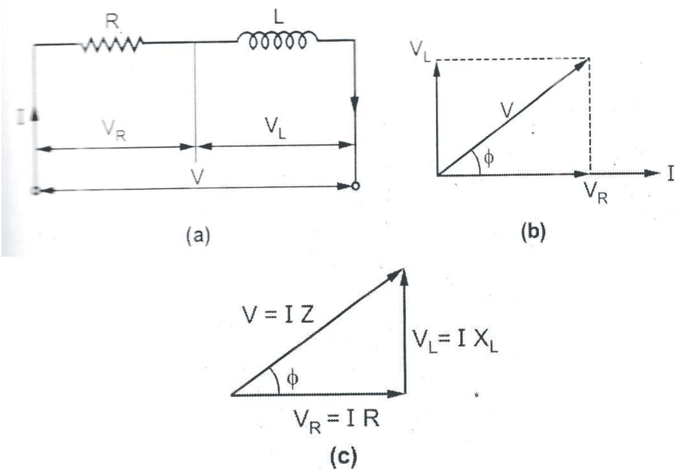


Figure 1:A.C circuit containing resistance and inductance in series.

These voltage drops across the resistance and inductance are represented with the help of phasors taking current as a reference phasor in the phasor diagram of figure 1(b) .The current is chosen as a reference phasor because it is common to all circuit elements .Now,we know that in the d.c series circuits, the total applied voltage is the sum of the voltage drops in the individual parts of the circuit.In the a.c series circuits also, the same general rule is applicable with the exception that the addition must be the phasor addition.Therefore, in the circuit under consideration, the applied voltage can be obtained by the phasor addition of V_R and V_L i.e

$$\overline{V} = \overline{V_R} + \overline{V_L} \qquad \text{(phasor addition)}$$

Then, from the voltage triangle shown in figure 1(c)

$$V = \sqrt{V_R^2 + V_L^2} = \sqrt{(IR)^2 + (IX_L)^2}$$

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

$$\therefore \qquad I = \frac{V}{\sqrt{R^2 + X_L^2}} = \frac{V}{R}$$

Where

$$Z = \sqrt{R^2 + X_L^2}$$

Phase Relationship between Voltage and Current:From the phasor diagram shown in figure 1(b) , it is clear that in such a circuit, the current lags behind the applied voltage by an angle ϕ such that

$$\tan\phi = \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R}$$

Or,

$$\cos\phi = \frac{V_R}{V} = \frac{IR}{IZ} = \frac{R}{Z}$$

It means that if the applied voltage is represented by

$$V = V_m \sin\omega t$$

Then, $$i = I_m \sin(\omega t - \phi)$$

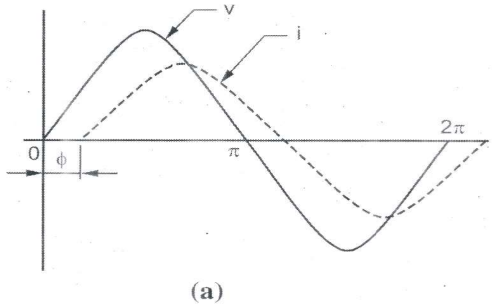


Figure 2: R-L series circuit (a) Waveforms

Power: It is obvious that, average power supplied to the circuit,

P = (Average power taken by the resistance)
+ (Average power taken by the inductance)

But we have a seen that the average power taken by a pure inductance over a complete cycle is always zero.Hence, the inductance L in the circuit consumes no power .

P = Average power taken by the resistance

= I^2R =(IR)I =V_RI

$= V\cos\phi \times I$

i.e P = VI cos ϕ

OR

Q8. A coil of resistance 2.5 Ω and inductance 0.06H is connected in series with a 6.8 μF capacitor across a 230 V, 50 Hz. A.C. supply. Calculate the following:
(i) Impedance
(ii) Current
(iii) Power consumed

Ans. $X_L = 2\pi fL = 2\times3.14\times50\times0.06 = 18.84\Omega$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\times3.14\times50\times6.8\times10^{-6}} = 468\Omega$$

(i) Impedance

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{(2.5)^2 + (18.84-468)^2} = 449.2\Omega$$

(ii) Current

$$I = \frac{V}{Z} = \frac{230}{449.2} == 0.512A$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{18.84-468}{30}\right) = -89.7^0$$

pf = cos ϕ =cos89.7=0.0056 lead

(iii) Power

P = VI cos ϕ

$$= 230\times0.512\times0.0056 = 0.66W$$

Q9. 400 V, 50 Hz, 3-phase A.C. supply is applied to three star connected identical impedance each consisting of 4 Ω resistance in series with 3 Ω inductive reactance. Find
(i) Line current
(ii) Power factor
(iii) Total power supplied

Ans.

Phase voltage,

$$V_P = \frac{Line\ voltage(V_L)}{\sqrt{3}}$$

$$V_P = \frac{400}{\sqrt{3}} = 230.94V$$

Impedance per phase,

$$Z_P = \sqrt{R^2 + X_L^2}$$

$$= \sqrt{(4)^2 + (3)^2} = 5\Omega$$

Phase current,

$$I_P = \frac{V_P}{Z_P}$$

$$= \frac{230.94}{5} = 46.188\,Amp.$$

(i) Line current,

$I_L = I_P$ = 46.188 Amp.

(ii) Power factor

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

$$= \frac{4}{5} = 0.8(lagging)$$

(iii) Total Power,

$$P = \sqrt{3}V_L I_L \cos\phi$$

$$= \sqrt{3}\times400\times46.188\times0.8 = 25.599kW$$

OR

Q9. Explain the following power factor improvement equipment:
(i) Static capacitors
(ii) Synchronous Condensers
(iii) Phase advancers

Ans.(i)Static capacitors: The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static capacitor) draws a leading current and party or completely neutralises the lagging reactive component of load current. This raises the power factor of the load. For three-phase loads, the capacitors can be connected in delta or star as shown in Fig.1 (a). Static capacitors are invariably used for power factor improvement in factories.

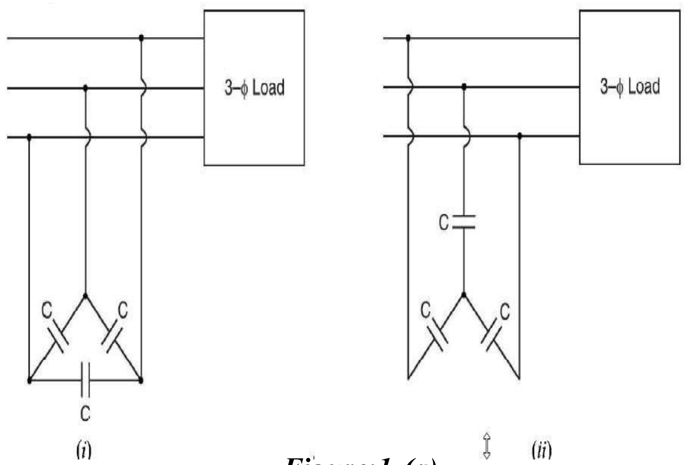


Figure:1 (a)

Advantages:

(i) They have low losses.
(ii) They require little maintenance as there are no rotating parts.
(iii) They can be easily installed as they are light and require no foundation.
(iv) They can work under ordinary atmospheric conditions.

Synchronous condenser: A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as synchronous condenser. When such a machine is connected in parallel with the supply,it takes a leading current which partly neutralises the lagging reactive component of the load. Thus the power factor is improved.

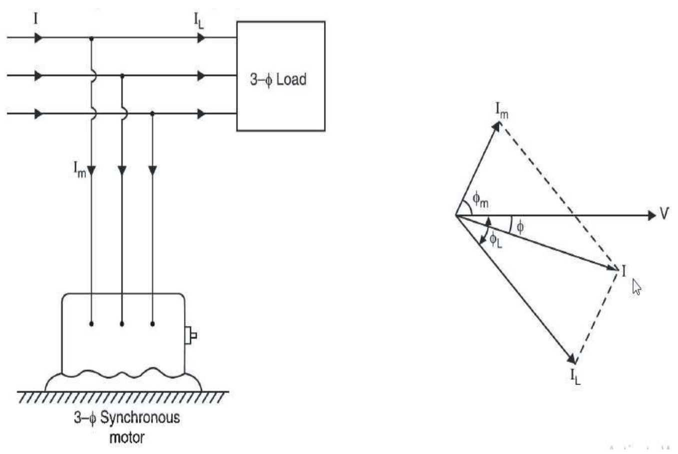


Figure2.(a)

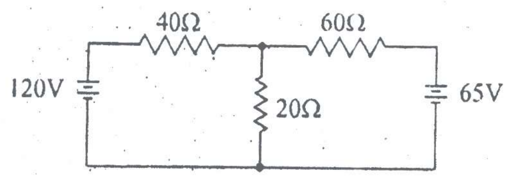
Fig.2 (a) shows the power factor improvement by synchronous condenser method. The 3 ϕ load takes current I_L at low lagging power factor cos ϕ_L. The synchronous condenser takes a current Im, which leads the voltage by an angle ϕ_m. The resultant current jis the phasor sum of Im, and IL and lags behind the voltage by an angle ϕ. It is clear that ϕ is less than ϕ_L so that cos ϕ is greater than cos ϕ_L. Thus the power factor is increased from cos ϕ_L to cos ϕ. Synchronous condensers are generally used at major bulk supply substations for power factor improvement.

Advantages:

(i) By varying the field excitation, the magnitude of current drawn by the motor can be changed by any amount. This helps in achieving stepless control of power factor.
(ii) The motor windings have high thermal stability to short circuit currents.
(iii) The faults can be removed easily.

(iii)Phase advancers: Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags behind the supply voltage by 90°. If the exciting ampere turns can be provided from some other a.c. source, then the stator winding will be relieved of exciting current and the power factor of the motor can be improved. This job is accomplished by the phase advancer which is simply an a.c. exciter. The phase advancer is mounted on the same shaft as the main motor and is connected in the rotor circuit of the motor. It provides exciting ampere turns to the rotor circuit at slip frequency. By providing more ampere turns than required, the induction motor can be made to operate on leading power factor like an over-excited synchronous motor. Phase advancers have two principal advantages. Firstly, as the exciting ampere turns are supplied at slip frequency, therefore, lagging kVAR drawn by the motor are considerably reduced. Secondly, phase advancers can be conveniently used where the use of synchronous motors is unadmissible. However, the major disadvantage of phase advancers is that they are not economical for motors below 200 h.p.

Q10. Use mesh analysis to find the current is each resistor in the given circuit.



Ans.

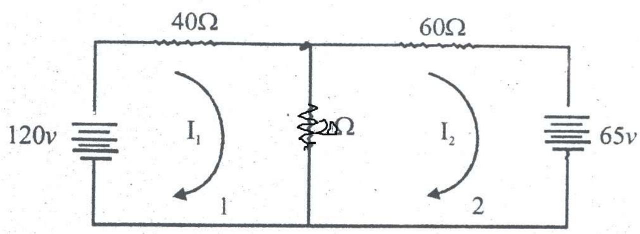


Fig.

Using Mesh Analysis in mesh -1

$$120-40I_1-20(I_1-I_2)=0$$

$$60I_1+20I_2=120$$

$$30I_1+I_2=60$$

$$\Rightarrow I_2=60-30I_1 \quad \text{..............................(i)}$$

Using Mesh Analysis in mesh -2

$$65-20(I_2-I_1)-60I_2=0$$

$$20I_1+80I_2=65$$

$$4I_1 + 16I_2 = 13 \text{ ....(ii)}$$

Putting value of I_2 from equation (i) in equation (ii)

$$4I_1 + 16(60 - 30I_1) = 13$$

$$4I_1 + 960 - 480I_1 = 13$$

$$960 - 13 = 476I_1$$

$$I_1 = \frac{947}{476} = 1.98A$$

Putting $I_1 = 1.98A$ *in equation* (i)

$$I_2 = 60 - 30 \times 1.98 = 0.315\,A$$

Now,

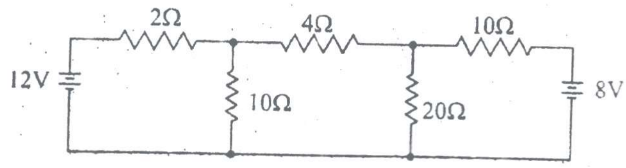
Current through 40 Ohm = I_1 =1.98 A

Current through 20 Ohm = I_1 - I_2 = 1.98 -0.315
= 1.66 A

Current through 60 Ohm = I_2 = 0.315 A

OR

Q10. Find the current in each resistor in the given circuit using Nodal analysis method.



Ans. Let the nodal voltage be VA and VB at node Aand B respectively.

At node A

$$\frac{12 - V_A}{2} = \frac{V_A - V_B}{4} + \frac{V_A}{10}$$

$$6 - \frac{V_A}{2} = \frac{5V_A - 5V_B + 2V_A}{20}$$

$$\Rightarrow \frac{7V_A - 5V_B}{20} + \frac{V_A}{2} = 6$$

$$\Rightarrow \frac{7V_A - 5V_B + 10V_A}{20} = 6$$

$$\Rightarrow 17V_A - 5V_B = 120$$

At node B

$$\frac{V_B}{20} = \frac{V_A - V_B}{4} + \frac{8 - V_B}{10}$$

$$-\frac{V_A}{4} + V_B\left[\frac{1}{20} + \frac{1}{4} + \frac{1}{10}\right] = \frac{8}{10}$$

$$-\frac{V_A}{4} + V_B\left[\frac{1+5+2}{20}\right] = \frac{8}{10}$$

$$-\frac{V_A}{4} + \frac{8}{20}V_B = \frac{8}{10}$$

$$\frac{-5V_A + 8V_B}{20} = \frac{8}{10}$$

$$-5V_A + 8V_B = 16 \text{ ....(i)}$$

From equation (i) and (ii)

V_A = 9.369 volt

V_B = 7.856 volt

∴ Current in 2 Ω resistor

$$\frac{12 - 9.369}{2} = 1.3155\,Amp$$

Current in 10 Ω resistor

$$\frac{9.369}{10} = 0.9369\,Amp$$

Current in 4 Ω resistor

$$\frac{9.369 - 7.856}{4} = 0.37825\,Amp$$

Current in 20 Ω resistor

$$\frac{7.856}{20} = 0.3928\,Amp$$

Current in 10 Ω resistor
= 0.0144 Amp

Q11. Write short notes on any two of the following:

(a) Maximum power transfer theorem

(b) Quality factor

(c) Energy sources

Ans.(a)*Refers to Chapter*

Ans.(b)*Refers to Chapter*

Ans.(c)*Same as Model sets 2 Q.no 11(i)*

OR

Q11.Write short notes on any two of the following

(a) Generation of three phase emf

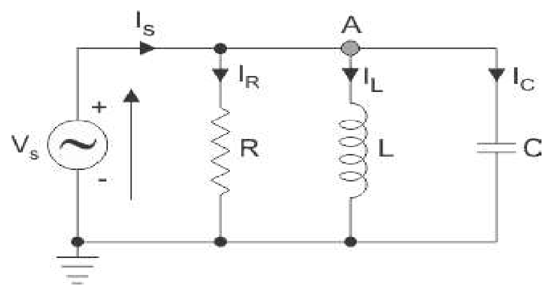
(b) Ideal sources

(c) Parallel R-L-C circuit

Ans.(a) *Refers to Chapter*

Ans.(b) *Refers to Chapter*

Ans.(c) Parallel RLC Circuit: Consider a RLC circuit in which resistor, inductor and capacitor are connected in parallel to each other. This parallel combination is supplied by voltage supply, VS. This parallel RLC circuit is exactly opposite to series RLC circuit.



In series RLC circuit, the current flowing through all the three components i.e the resistor, inductor and capacitor remains the same, but in parallel circuit, the voltage across each element remains the same and the current gets divided in each component depending upon the impedance of each component. That is why parallel RLC circuit is said to have dual relationship with series RLC circuit.

The total current, I_S drawn from the supply is equal to the vector sum of the resistive, inductive and capacitive current, not the mathematic sum of the three individual branch currents, as the current flowing in resistor, inductor and capacitor are not in same phase with each other; so they cannot be added arithmetically.

Apply Kirchhoff's current law, which states that the sum of currents entering a junction or node, is equal to the sum of current leaving that node we get,

$$I_S^2 = I_R^2 + \left(I_L - I_C\right)^2$$