Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

1 Attempt any TEN of the following: 20

1 a) Define: i) Amplitude, ii) Frequency of a.c. quantity

Ans:

i) Amplitude :- A maximum value or peak value attained by an alternating quantity during positive or negative half cycle is called as its amplitude. — 1 Mark each definition

ii) Frequency of a.c. quantity:- It is defined as number of cycles completed by alternating quantity in one second.

1 b) State the average power taken by a pure inductor and a pure capacitor when connected to a.c. supply.

Ans:

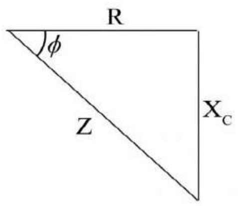
Average power taken by a pure inductor is **Zero**. — 1 Mark each

Average power taken by a pure capacitor is **Zero**.

1 c) Draw impedance triangle for R-C series circuit.

Ans:

Impedance triangle for R-C series circuit:



2 Marks

1 d) Define power factor and state its value for pure resistive circuits.

Ans:

Power Factor: — 1 Mark for any one definition

- It is the cosine of the angle between the applied voltage and the resulting current.
  Power factor = $\cos\phi$
  where, ϕ is the phase angle between applied voltage and current.
- It is the ratio of true or effective or real power to the apparent power.
  Power factor $= \frac{\text{True or Effective or Real Power}}{\text{Apparent Power}} = \frac{\text{VIcos}\emptyset}{\text{VI}} = \cos\emptyset$
- It is the ratio of circuit resistance to the circuit impedance.
  Power factor = $\frac{Circuit\ Resistance}{Circuit\ Impedance} = \frac{R}{Z} = \cos\emptyset$

Value of power factor for purely resistive circuit = **UNITY** i.e one — 1 Mark

1 e) Define terms conductance and susceptance and state their unit.

Ans:-

Conductance (G):

It is defined as the real part of the admittance (Y).

It is also defined as the ability of the purely resistive circuit to pass the alternating current. — 1 Mark for each definition and unit

OR

It is also defined as the ratio of resistance to the square of the impedance.

In general, Conductance, G= $\frac{R}{Z^2}$ siemen. Its unit is **siemen (S).**

Susceptance (B):
It is imaginary part of the admittance (Y).
It is defined as the ability of the purely reactive circuit (purely capacitive or purely inductive) to admit alternating current.

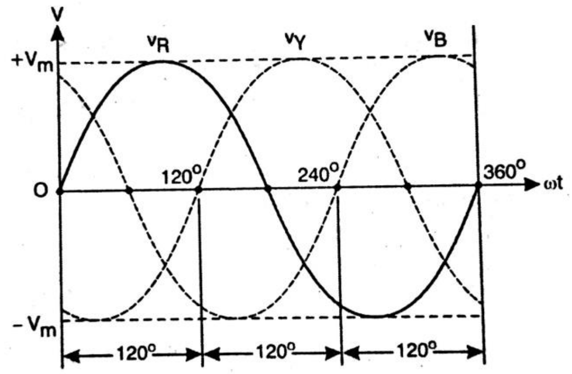
OR

It is also defined as the ratio of reactance to the square of the impedance.
In general, Susceptance (B) = $\frac{X}{Z^2}$ siemen. Its unit is **siemen (S).**

1 f) Define Balanced 3Ø load.
Ans:
Balanced 3-phase Load:
Balanced three-phase load is defined as star or delta connection of three equal impedances having equal real parts and equal imaginary parts. It takes same current of equal magnitude and equal phase angle with respect to respective phase voltage. 2 Marks

1 g) State the relationship for star connected load between:
i) Line current and phase current.
ii) Line voltage and phase voltage.
Ans :
Star Connection: 1 Mark for each relation
i)Line current = Phase current
i. e. $I_L = I_{ph}$
ii)Line voltage = √3 (Phase Voltage)
i.e.$V_L = \sqrt{3}V_{ph}$

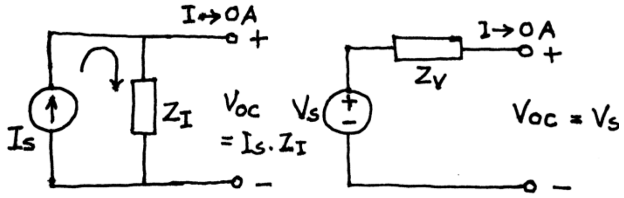
1 h) Draw the sinusoidal waveform of 3-phase emf and also indicate the phase sequence.
Ans:



1 Mark

Phase sequence is R-Y-B 1 Mark

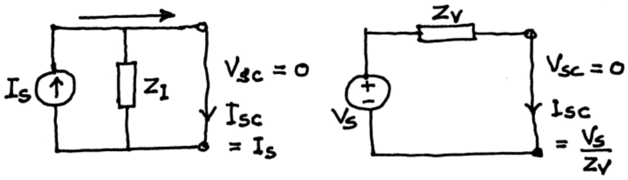
1 i) Write the procedure of converting a given current source into voltage source.
Ans:
Conversion of current source into equivalent voltage source:
Let I_S be the practical current source magnitude and
Z_I be the internal parallel impedance.
V_S be the equivalent practical voltage source magnitude and
Z_V be the internal series impedance of the voltage source.



The open circuit terminal voltage of current source is $V_{OC} = I_S \times Z_I$
The open circuit terminal voltage of voltage source is $V_{OC} = V_S$
Therefore, we get $V_S = I_S \times Z_I$ …………………………(1)

1 Mark for diagram
1 Mark for description

OR



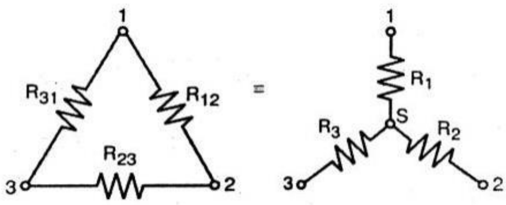
The short circuit output current of current source is $I_{SC} = I_S$
The short circuit output current of voltage source is $I_{SC} = V_S / Z_V$
Therefore, we get $I_S = V_S / Z_V$ …………………………(2)
On comparing eq. (1) and (2), it is clear that $Z_I = Z_V = Z$ ……….. …..(3)
Thus the internal impedance of both the sources is same, and the magnitudes of the source voltage and current are related by Ohm's law, $V_S = I_S \times Z_I$

1 j) Give equations of Delta to Star transformations.
Ans:
Equations of Delta to star transformation:

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

$$R_2 = \frac{R_{12}+R_{23}}{R_{12}+R_{23}+R_{31}}$$

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



(a) Delta Circuit (b) Star Circuit

2 Marks for all three equations

1 k) Write the nodal equation for Node A (Figure No. 1)

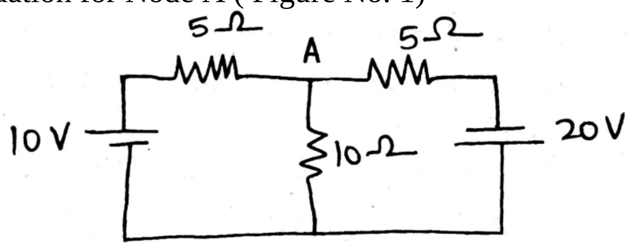
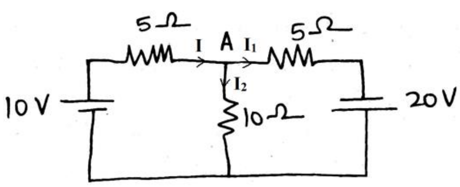


Fig. No. 1

Ans:



Let the voltage at Node A be V_A

$I = I_1 + I_2$

$\frac{10-V_A}{5} = \frac{V_A+20}{5} + \frac{V_A}{10}$ 2 Marks for node equation

$2 - \frac{V_A}{5} = \frac{V_A}{5} + 4 + \frac{V_A}{10}$

$-2 = \frac{2V_A}{5} + \frac{V_A}{10}$

$\therefore \frac{5V_A}{10} = -2$

$\therefore V_A = -4$volt

1 l) State the behaviour of following elements at the final condition $t = \infty$

i) Pure L
ii) Pure C 1 Mark each

Ans:

At $t = \infty$ the inductor acts as **short circuit**.

At $t = \infty$ the capacitor acts as **open circuit**.

2 Attempt any FOUR of the following: 16

2 a) Define: 1) RMS value, 2) Average value of an alternating quantity.

Ans:

1) The **RMS value** is the Root Mean Square value. It is defined as the square root of the mean value of the squares of all the values of the alternating quantity over one cycle. 2 Marks each for appropriate definition

OR

For an alternating current, the RMS value is defined as that value of steady current (DC) which produces the same power or heat as is produced by the alternating current during the same time under the same conditions.

2) The **Average value** is defined as the arithmetical average or mean of all the values of an alternating quantity over one cycle.

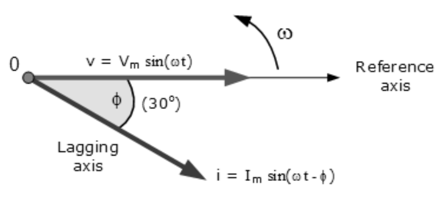
OR

For an alternating current , the average value is defined as that value of steady current (DC) which transfers the same charge as is transferred by the alternating current during the same time under the same conditions.

2 b) The voltage and current in a circuit with 50Hz supply given as $v = 200\sin\omega t$,
$i = 14.14\sin(\omega t - \pi/6)$. Draw phasor and waveform diagram of current and voltage.
Find: i) R.M.S. value of current, ii) Average value of voltage.

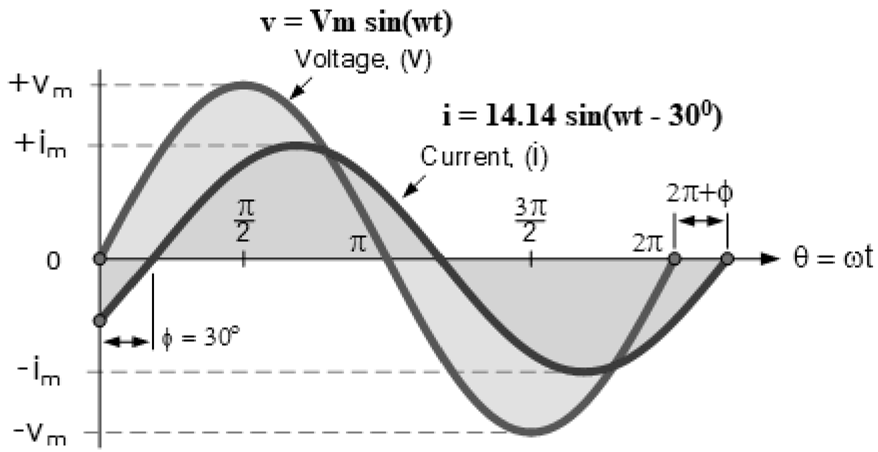
Ans:-

Phasor diagram:



1 Mark for phasor diagram

Waveforms:



Vm = 200V
Im = 14.14A

1 Mark for waveform

Comparing equations with standard forms, we get V_m= 200V, I_m= 14.14A

R.M.S. value of current = I = $\frac{I_m}{\sqrt{2}} = \frac{14.14}{\sqrt{2}} = \mathbf{9.99 \cong 10A.}$

Average value of voltage = V_{av}= 0 (over full cycle)

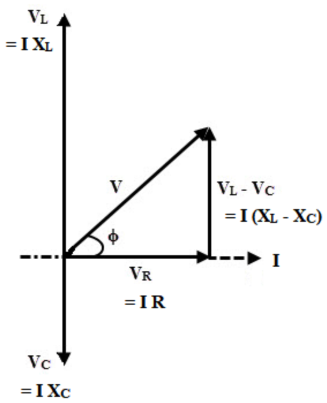
= 0.637× V_m= **127.4 V** (over half-cycle)

1 Mark for each answer

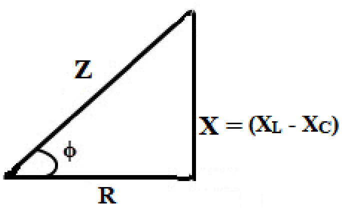
2 c) Draw vector diagram, impedance triangle and power triangle for series R-L-C circuit when connected to single phase a.c. supply for the condition $X_L > X_C$.

Ans:-

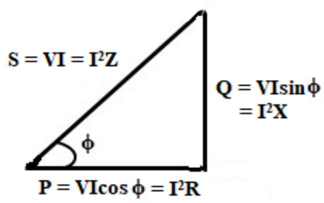
For condition $X_L > X_C$



Vector Diagram



Impedance Triangle



Power Triangle

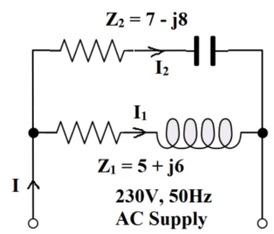
2 Marks for vector diagram

1 Mark for impedance triangle

1 Mark for power triangle

2 d) Two impedances (5+j6) Ω and (7-j8) are connected in parallel across 230V, 1ϕ, 50Hz a.c. supply. Determine current drawn by each path and total current in the circuit.

Ans:-



$\bar{Z}_1 = 5 + j6$= 7.81∠50.19° 1 Mark for Z_1 and Z_2
$\bar{Z}_2 = 7 - j8$= 10.63∠-48.81°

$$\bar{V} = 230\angle 0°$$

$\bar{I}_1 = \frac{\bar{V}}{\bar{Z}_1} = \frac{230\angle 0°}{7.81\angle 50.19°}$ = **29.45∠-50.19°A= (18.86 - j22.62)A** 1 Mark

$\bar{I}_2 = \frac{\bar{V}}{\bar{Z}_2} = \frac{230\angle 0°}{10.63\angle -48.81°}$ = **21.64∠48.81°A = (14.25 + j16.28)A** 1 Mark

$\bar{I} = \bar{I}_1 + \bar{I}_2$

$$= 18.86 - j22.62 + 14.25 + j16.28$$
$$= (\mathbf{33.11 - j6.34})\boldsymbol{A} = \mathbf{33.71\angle -10.84°}\ \boldsymbol{A}$$

1 Mark for total I

2 e) Derive an expression for resonance frequency for the circuit shown in Figure No. 2.

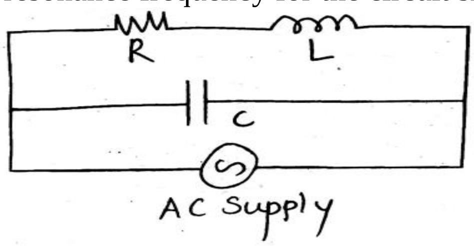
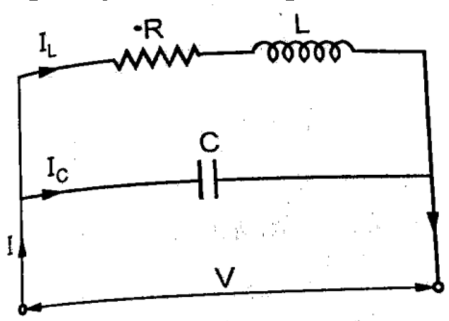
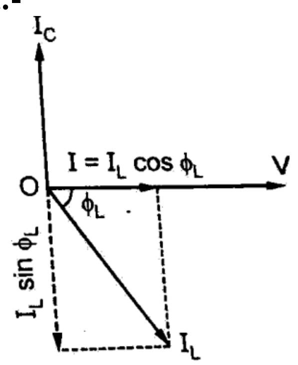


Fig. No. 2

Ans:

Resonance frequency for a RL-C parallel circuit:-





1 Mark for circuit diagram

1 Mark for phasor diagram

The circuit is said to be in electrical resonance when the reactive component of line current becomes zero. The frequency at which this happens is known as resonance frequency. 2 Marks for derivation

Net reactive component = $I_c - I_L sin\emptyset_L$

As at resonance, its value is zero, hence

$I_c - I_L sin\emptyset_L = 0$ **OR** $I_c = I_L sin\emptyset_L$

Now, $I_L = \frac{V}{Z}$ and $I_c = \frac{V}{X_c}$

Hence condition for resonance becomes

$\frac{V}{X_c} = \frac{V}{Z} \times \frac{X_L}{Z}$ OR $X_c X_L = Z^2$ where Z = (R + j X_L)

Now, $X_L = \omega$L, $X_c = \frac{1}{\omega C}$

$\frac{\omega L}{\omega C} = Z^2$ OR $\frac{L}{C} = Z^2$

$\frac{L}{C} = R^2 + {X_L}^2 = R^2 + (2\pi f_0 L)^2$

$(2\pi f_0 L)^2 = \frac{L}{C} - R^2$

$2\pi f_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

2 f) Three impedance each of 5+j6 are connected in star across 400V, 50Hz, 3 phase AC supply. Calculate: i) Phase current ii) Line current iii) Phase voltage iv) Power drawn.

Ans:-

Given $Z_{ph} = 5 + j6$ = 7.81∠50.19°Ω Connected in Star

$\therefore V_L = \sqrt{3}V_{ph}$ and $I_L = I_{ph}$

V_L= 400V.

Hence, $V_{ph} = \frac{400}{\sqrt{3}}$ = **230.94V**

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94\angle 0°}{7.81\angle 50.19°}$

I_{ph} = **29.56∠- 50.19°A**

$I_L = I_{ph}$= 29.56∠-50.19°A = **(18.92- j22.70) A.**

$\emptyset$ *is angle between Voltage and Current.*

1 Mark for each bit

∅= -50.19°

cos∅ = cos(-50.19) = 0.640

Power drawn = $\sqrt{3}V_L I_L$ cos∅

$= \sqrt{3} \times 400 \times 29.56 \times 0.64$

= **13107.05 watt = 13.10705 kW**

OR

Power drawn = $3V_{ph}I_{ph}$ cos∅

$= 3 \times 230.94 \times 29.56 \times 0.64$

= **13107.05 watts = 13.10705 kW.**

3 Attempt any FOUR of the following **16**

3 a) A 50H inductor is connected across a 230V, 50Hz supply, determine:

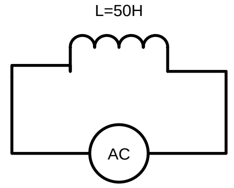
(i) Inductive reactance
(ii) RMS value of current
(iii) Equation for voltage
(iv) Equation for current

Ans:

Given: L=50H, V=230V, f = 50Hz

Find (i) X_L (ii) I_{rms} (iii) Equation for Voltage (iv) Equation for current

1 Mark for Each bit



(i) Inductive Reactance

$$X_L = 2\pi f L = 2\pi \times 50 \times 50 = 15707.96\,\Omega$$

(ii) R. M.S. value of current

$I_{RMS} = \frac{V}{X_L} = \frac{230}{15707.96} = 0.0146\,Amp$

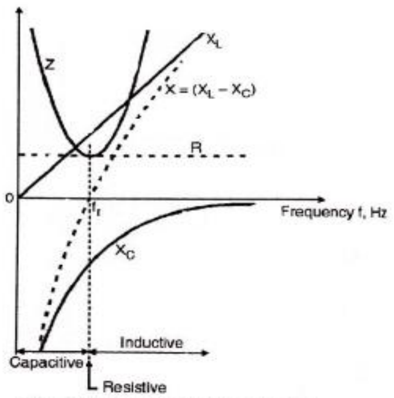
(iii) Equation for Voltage
Angular frequency ω = 2πf = 2×3.142×50 = 314.2 rad/sec

$$v = V_m Sin\omega t = \sqrt{2} \times 230\ Sin(314.2t) = 325.26 \sin(314.2t)$$

(iv) Equation for current

$$i = I_m Sin(\omega t - 90°) = \sqrt{2} \times 0.0146 Sin(314.2t - 90°)$$
$$= 0.0206 \sin(314.2t\text{-}90°)$$

3 b) Draw graphical representation of resistance, inductive reactance, capacitive reactance and impedance related to frequency for series resonance circuit.
Ans:



Variation of reactances and impedance with frequency

1 Mark each for R, X_L, X_C and Z representation

3 c) Calculate current I Shown in Figure No. 3.

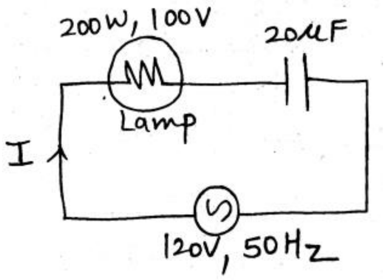


Fig. No. 3

Ans:
Given:
Supply voltage V_s =120V, f = 50 Hz
Lamp (Resistance) R = V_L^2/W = $(100)^2$ /200 **= 50 Ω ,** 1 Mark for R
C=20 x 10^{-6} F, 1 Mark for X_C
Capacitive Reactance: $X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times 20 \times 10^{-6}} = \mathbf{159.15\Omega}$
Impedance 1 Mark for Z

$$Z = \sqrt{R^2 + X^2} = \sqrt{50^2 + (-159.15)^2} = \mathbf{166.82}\Omega$$

Current

$$I = \frac{V}{Z} = \frac{120}{166.81} = \mathbf{0.719\ Amp}$$ 1 Mark for I

3 d) Compare series resonance and parallel resonance circuit on any four parameters.
Ans:
Comparison between Series & Parallel Resonance Circuit:

Sr. no.	Parameter	Series circuit	Parallel circuit
1	Impedance	Minimum Z=R	Maximum $Z_D = L/RC$
2	Nature of circuit	Resistive	Resistive
3	Power factor	Unity	Unity
4	Current	Maximum $I_o = V/R$	Minimum $I_o = V/Z_D$
5	Type of circuit	Accepter circuit	Rejecter circuit
6	Magnification	Voltage magnification	Current magnification
7	Resonant frequency	$fo = \frac{1}{2\pi\sqrt{LC}}$	$fo = \frac{1}{2\pi\sqrt{LC}}$
8	Q-factor	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

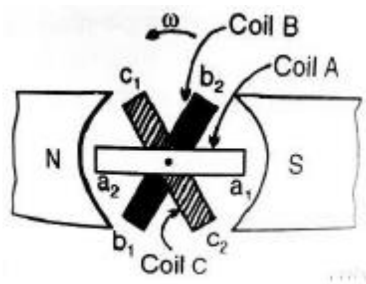
1 Mark for each of any four parameters

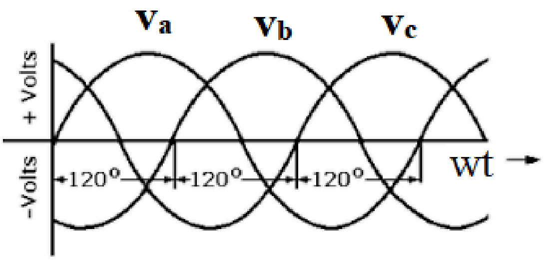
3 e) Explain in detail generation of three phase emf.

Ans:

Generation of Three-phase EMF:

Three identical coils A, B and C displaced by 120° (electrical) from each other and rotating in anticlockwise direction with angular velocity ω rad/sec in the gap between two magnetic poles, cut the magnetic field. According to Faraday's law of electromagnetic induction, the emf will be induced in each coil. The magnitude of emf depends upon the rate of flux cut by the coil. Since the rate of flux cut changes with position of coil in the magnetic field, an alternating emf is induced in each coil. The nature of emf is same but since the coils are displaced from each other by 120°, the emfs induced in them will also get displaced in time phase from each other by 120°.





1 Mark for description

1 Mark for diagram (Rotating armature or Stationary Armature)

1 Mark for equations

1 Mark for waveform

The equations of three emfs can be represented by

$v_a = E_m \sin\omega t$ ……….. ***(i)***

$v_b = E_m \sin(\omega t - 120^o)$ ... ***(ii)***

$v_c = E_m \sin(\omega t - 240^o)$ ...***(iii)***

3 f) Using Thevenin's theorem find current through 5 Ω resistance. Figure No. 4

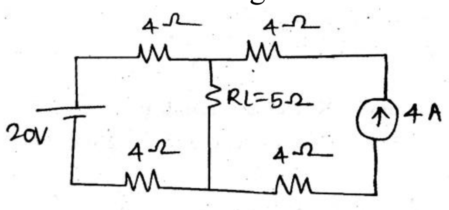
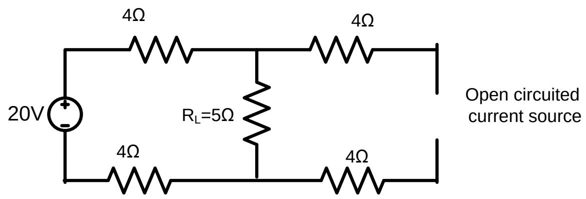


Fig. No. 4

Ans:

V_{TH} can be calculated by using superposition theorem

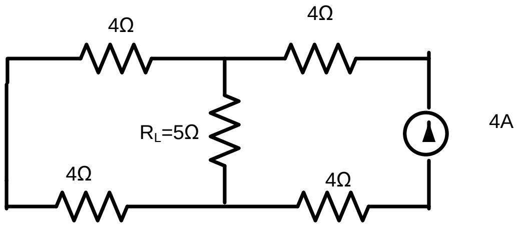
A) Consider 20 V source only:



Req= 4+4+5=13 Ω

Current through 5 Ω load, I_{L1} = 20/13= 1.538 A

B) Consider 4 A source only:



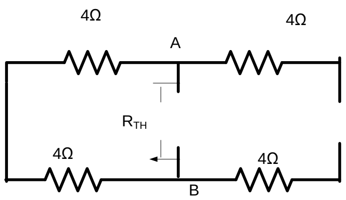
Current through 5 Ω load, I_{L2}= 4 x 8/(8+5)=32/13= 2.461 A

Total Current through 5 Ω load, I_L=1.538 +2.461 = 3.999 A

V_{TH} = 3.999 x 5 = 19.995 V

2 Marks V_{TH}

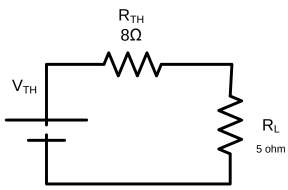
C) Determination of R_{TH}:



R_{TH}= 4+4=8 Ω

1 Mark for R_{TH}

D) Determination of I_L:



1 Mark for I_L

I_L=V_{TH}/(R_{TH}+R_L)= 19.995/(8+5)= 1.538 Amps

4 **Attempt any FOUR of the following.** **16 Marks**

4 a) Define terms: (i) Leading quantity (ii) Lagging quantity

Ans:

When two alternating quantities attain their respective zero or peak values simultaneously, the quantities are said to be in-phase quantities.

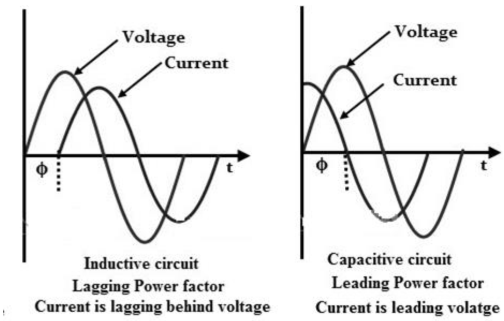
When the quantities do not attain their respective zero or peak values simultaneously, then the quantities are said to be out-of-phase quantities.

(i) Leading Quantity: The quantity which attains the respective zero or peak value first, is called 'Leading Quantity'. 2 Marks for waveform

(ii) Lagging Quantity: The quantity which attains the respective zero or peak value later, is called 'Lagging Quantity' — 1 Mark for leading quantity

In above diagram, it is seen that for inductive circuit, the voltage is leading the current or the current is said to be lagging the voltage.

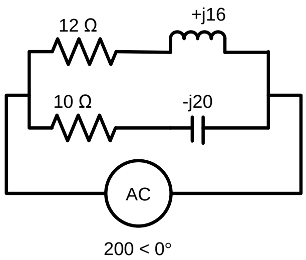
Similarly, for capacitive circuit, the current is leading the voltage or the voltage is said to be lagging behind the current. — 1 Mark for lagging quantity



4 b) A voltage of $200\angle0°$ is applied across two impedances in parallel. The values of impedances are $(12 + j16)$ and $(10 – j20)$. Determine the kVA, kVAR and kW in each branch and power factor of the whole circuit.

Ans:

Given: $V=200\angle0°$, $Z_1= (12+j16)$, $Z_2 = (10-j20)$, Determine kVAR, kVA, kW of each branch, p.f. of whole circuit.



$Z_1= (12+j16)=20\angle53.13°\Omega$,

$Z_2=(10 - j20)= 22.36 \angle-63.43° \Omega$

Branch of Z_1

$$I_1 = \frac{V}{Z_1} = \frac{200\angle0°}{20\angle53.13°} = 10\angle-53.13° = 6 - j7.99\ Amp$$

$kVA_1=V\times I_1 = 200\times10 = 2000$ VA = 2 kVA — ½ Mark

$\cos\phi_1=\frac{R_1}{Z_1} = \frac{12}{20} = 0.6\ lag$

$kW_1= VI_1\cos\phi_1=200\times10\times0.6 = 1200$ W = 1.2 kW — ½ Mark

$\sin\phi_1=Sin\ (cos^{-1}0.6)=0.8$

$kVAR_1= VI_1\sin\phi_1=200\times10\times0.8=1.6$ kVAR — ½ Mark

Branch of Z_2

$$I_2 = \frac{V}{Z_2} = \frac{200\angle0°}{22.36\angle-63.43°} = 8.94\angle63.43° = 3.99 + j7.99\ Amp$$

$kVA_2 = V\times I_2 = 200 \times 8.94 = 1788$VA = 1.788 kVA — ½ Mark

$\cos\phi_2 = \frac{R_2}{Z_2} = \frac{10}{22.36} = 0.447\ lead$

$kW_2= VI_2\cos\phi_2=200\times8.94\times0.447=799.236$W= 0.799 kW — ½ Mark

$\sin\phi_2 =Sin\ (cos^{-1}0.447) = 0.895$

$kVAR_2= VI_2\sin\phi_2=200\times8.94\times0.895 =1599.43$VAR = 1.59943 kVAR — ½ Mark

Power factor of whole circuit

$$Z_{eq} = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{20\angle 53.13° \times 22.36\angle -63.43°}{(12+j16)+(10-j20)}$$ 1 Mark

$$= \frac{20\angle 53.13° \times 22.36\angle -63.43°}{22.36\angle -10.3}$$

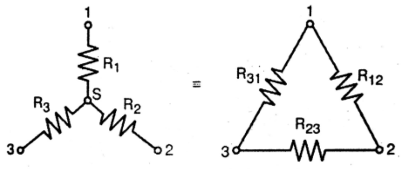
$$= 20\angle 0° = 20 + j0\ \Omega$$

$$\cos\emptyset_T = \frac{R_{eq}}{Z_{eq}} = \frac{20}{20} = \mathbf{1}$$

4 c) Derive the formulae for star to delta transformation.

Ans:

Star-delta Transformation:



(a) Star Circuit (b) Delta Circuit

If the star circuit and delta circuit are equivalent, then the resistance between any two terminals of the circuit must be same.

For star circuit, resistance between terminals 1 & 2, say $R_{1\text{-}2} = R_1 + R_2$

For delta circuit, resistance between terminals 1 & 2, $R_{1\text{-}2} = R_{12}||(R_{31} + R_{23})$

$$\therefore R_1 + R_2 = R_{12}||(R_{31}+R_{23}) = \frac{R_{12}(R_{31}+R_{23})}{R_{12} + (R_{31}+R_{23})} = \frac{R_{12}(R_{31}+R_{23})}{R_{12}+R_{23}+R_{31}}$$

$$\therefore R_1 + R_2 = \frac{R_{12}R_{31}+R_{12}R_{23}}{R_{12}+R_{23}+R_{31}} \dots\dots\dots\dots (1)$$

Similarly, the resistance between terminals 2 & 3 can be equated as,

$$\therefore R_2 + R_3 = \frac{R_{12}R_{23}+R_{23}R_{31}}{R_{12}+R_{23}+R_{31}} \dots\dots\dots\dots (2)$$

And the resistance between terminals 3 & 1 can be equated as,

$$\therefore R_3 + R_1 = \frac{R_{23}R_{31}+R_{12}R_{31}}{R_{12}+R_{23}+R_{31}} \dots\dots\dots\dots (3)$$

Subtracting eq. (2) from eq.(1),

$$\therefore R_1 - R_3 = \frac{R_{12}R_{31}-R_{23}R_{31}}{R_{12}+R_{23}+R_{31}} \dots\dots\dots\dots (4)$$

Adding eq.(3) and eq.(4) and dividing both sides by 2,

$$\therefore R_1 = \left[\frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}\right] \dots\dots\dots\dots (5)$$ 1 mark for (eq.5, 6 & 7)

Similarly, we can obtain,

$$\therefore R_2 = \left[\frac{R_{12}R_{23}}{R_{12}+R_{23}+R_{31}}\right] \dots\dots\dots\dots (6)$$

$$\therefore R_3 = \left[\frac{R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}\right] \dots\dots\dots\dots (7)$$

Multiplying each two of eq.(5), (6) and (7),

$$\therefore R_1R_2 = \left[\frac{(R_{12})^2 R_{31}\, R_{23}}{(R_{12}+R_{23}+R_{31})^2}\right] \dots\dots\dots\dots (8)$$ 1 mark for (eq.8, 9 & 10)

$$\therefore R_2R_3 = \left[\frac{(R_{23})^2 R_{31}\, R_{12}}{(R_{12}+R_{23}+R_{31})^2}\right] \dots\dots\dots\dots (9)$$

$$\therefore\ R_3R_1 = \left[\frac{(R_{31})^2R_{12}\,R_{23}}{(R_{12}+R_{23}+R_{31})^2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(10)$$

Adding the three equations (8), (9) and (10),

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{(R_{12})^2R_{31}\,R_{23}+(R_{23})^2R_{31}\,R_{12} + (R_{31})^2R_{12}\,R_{23}}{(R_{12}+R_{23}+R_{31})^2}$$

$$= \frac{R_{12}R_{31}\,R_{23}(R_{12}+R_{23}+R_{31})}{(R_{12}+R_{23}+R_{31})^2}$$

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}R_{31}\,R_{23}}{R_{12}+R_{23}+R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(11)$$

1 mark for eq. 11

Dividing eq.(11) by eq.(6), (dividing by respective sides)

$$\therefore R_1 + R_3 + \frac{R_3R_1}{R_2} = R_{31}$$

$$\therefore R_{31} = R_3 + R_1 + \frac{R_3R_1}{R_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

Similarly, we can obtain,

$$\therefore R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

$$\therefore R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

1 mark for (eq. 12, 13 & 14)

Thus using known star connected resistors R_1, R_2 and R_3, the unknown resistors R_{12}, R_{23} and R_{31} of equivalent delta connection can be determined.

4 d) Using mesh analysis find value of R_1 and R_2 shown in Figure No. 5

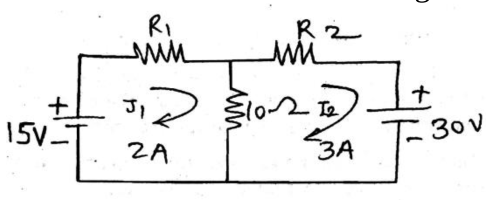


Fig. No. 5

Ans:

By applying KVL to loop 1

$15-2R_1-10(2-3)=0$ 01 Mark

$15+10=2R_1$

$\mathbf{R_1= \frac{25}{2} = 12.5\ \Omega}$ 01 Mark

By applying KVL to loop 2

$-3R_2-30-10(3-2)=0$ 01 Mark

$-3R_2-30-10=0$

$-3R_2=40$

$\mathbf{R_2= -13.33\ \Omega}$ 01 Mark

4 e) Calculate current flowing through 5Ω, resistor connected between A and B in Figure No. 6 by using superposition theorem.

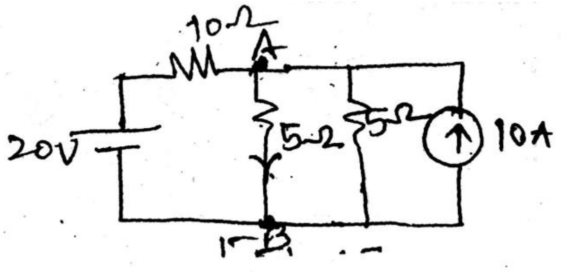
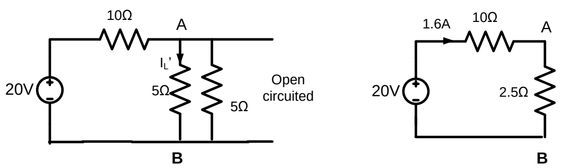


Fig. No. 6

Ans:

A) Consider 20V voltage source only:



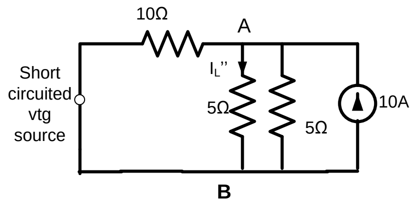
1 Mark

1 Mark

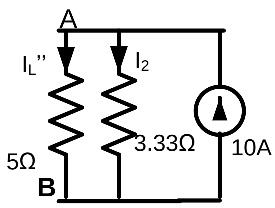
$$I = \frac{20}{10+2.5} = 1.6 \text{ Amp} \quad from\ A\ to\ B$$

$$I_L' = 1.6 \times \frac{5}{10} = 0.8A$$

B) Consider 10A current source only:



10 Ω in parallel to 5 Ω gives resultant = (10 x 5) /15 = 3.33 Ω



1 Mark

1Mark

$$I_L'' = 10 \times \frac{3.33}{8.33} = 4A$$

$$I_L = I_L' + I_L'' = 0.8 + 4 = 4.8\ Amp$$

4 f) Explain the concept of initial and final conditions in switching circuits for R, L and C.

Ans:

For the three basic circuit elements the initial and final conditions are used in following way:

i) Resistor:

At any time it acts like resistor only, with no change in condition.

ii) Inductor:

The current through an inductor cannot change instantly. If the inductor current is zero just before switching, then whatever may be the applied voltage, just after switching the inductor current will remain zero. i.e the inductor must be acting as open-circuit at instant t = 0. If the inductor current is I_0 before switching, then just after switching the inductor current will remain same as I_0, and having stored energy hence it is represented by a current source of value I_0 in parallel with open circuit. As time passes the inductor current slowly rises and finally it becomes constant. Therefore the voltage across the inductor falls to zero $\left[v_L = L\frac{di_L}{dt} = 0\right]$. The presence of current with zero voltage exhibits short circuit condition. Therefore, under steady-state constant current condition, the inductor is represented by a short circuit. If the initial inductor current is non-zero I_0, making it as energy source, then finally inductor is represented by current source I_0 in parallel with a short circuit.

2 Marks for explanation

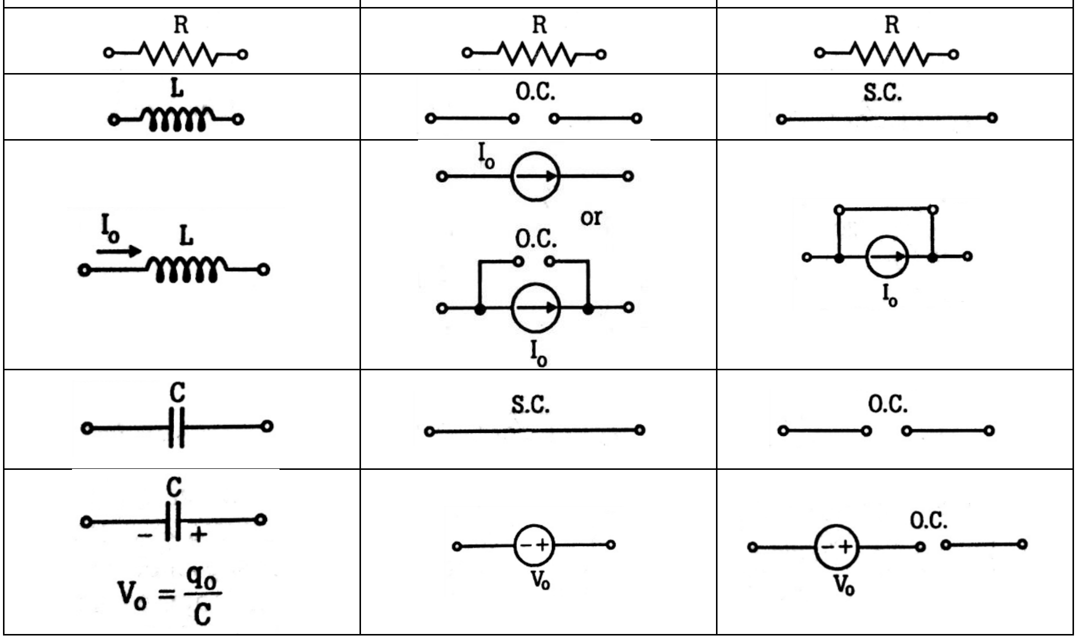
iii) Capacitor:

The voltage across capacitor cannot change instantly. If the capacitor voltage is zero initially just before switching, then whatever may be the current flowing, just after switching the capacitor voltage will remain zero. i.e the capacitor must be acting as short-circuit at instant t = 0. If capacitor is previously charged to some voltage V_0, then also after switching at t = 0, the voltage across capacitor remains same V_0. Since the energy is stored in the capacitor, it is represented by a voltage source V_0 in series with short-circuit.

As time passes the capacitor voltage slowly rises and finally it becomes constant. Therefore the current through the capacitor falls to zero $\left[i_C = C\frac{dv_C}{dt} = 0\right]$. The presence of voltage with zero current exhibits open circuit condition. Therefore, under steady-state constant voltage condition, the capacitor is represented by a open circuit. If the initial capacitor voltage is non-zero V_0, making it as energy source, then finally capacitor is represented by voltage source V_0 in series with a open-circuit.

The initial and final conditions are summarized in following table:

Element and condition at $t = 0^-$	Initial Condition at $t = 0^+$	Final Condition at $t = \infty$



2 Marks for diagrams

5 Attempt any TWO of the following: **16**

5 a) i) If A = 10+j8, B = -7+j5, C = 8+j6
Find (1) AB/C (2) (A+B)/(B - C)

Ans:

Converting A, B and C in Polar form we get,

A = (10 + j8) = 12.80∠38.65°,

B = (-7 + j5) = 8.60∠144.46°,

C = (8 + j6) = 10∠36.87°

(1) AB/C = (12.80∠38.65°) x (8.60∠144.46°) /(10∠36.87°) — 1 Mark

AB/C= 110.08∠183.11°/ (10∠36.87°) — 1 Mark

AB/C = 11.00∠146.24° = - 9.15 + j6.11

(2) (A+B)/(B-C) = [(10+j8) +(-7+j5)] /[(-7+j5)-(8+j6)] = (3+j13)/(-15-j1) — 1 Mark

= 13.34∠77.00°)/(15.03∠-176.185°) — 1 Mark

(A+B)/(B-C) = 0.887∠253.185° = - 0.256 - j0.85

5 a) ii) A RLC series circuit with a resistance of 10 Ω, Inductance of 0.2 H and a capacitance of 50 µF is connected to supply of 200V, 50 Hz.
Find (1) Impedance (2) total current (3) power factor (4) power consumed by series circuit.

Ans:

Given: R = 10 Ω, L = 0.2H, C = 50 µF = 50×10^{-6} F, V = 200V, f = 50 Hz

(1) $X_L = 2\pi f L = 2 \times \pi \times 50 \times 0.2 = 62.83\ \Omega$

$X_C = 1/(2\pi f C) = 1/(2\times \pi \times 50 \times 50 \times 10^{-6}) = 63.66\ \Omega$

Impedance $=Z= \sqrt{[R^2+(X_L-X_C)^2]} = \sqrt{\{10^2 + (62.83-63.66)^2\}} = \mathbf{10.03\ \Omega}$ — 1 Mark

(2) Total current =I = V/Z = 200/ 10.03 = **19.94 A** — 1 Mark

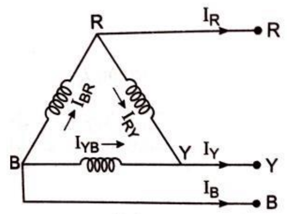
(3) Power factor = cos Ø = R/Z = 10/ 10.03 = **0.997 leading** — 1 Mark

(4) $P = I^2 R = 19.94^2 \times 10$ = 3976.036 watts = **3.97 kW** or — 1 Mark

P = V I cos Ø = 200 x 19.94 x 0.997 = 3976.036 = **3.97 kW**

5 b) State relationship between line voltage and phase voltage, line current and phase current in a balanced delta connection. Draw complete phasor diagram of voltages and current.

Ans:



Delta connection

2 Marks for Balance delta connection

Relationship for balanced delta connection:

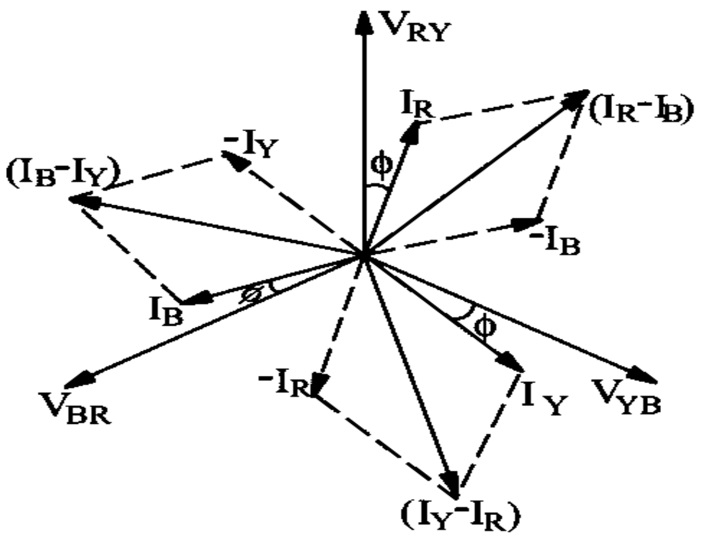
Line voltage = Phase voltage

i.e. $V_L = V_{ph}$ — 1 Mark

Line current = $\sqrt{3}$ Phase current

i.e. $I_L = \sqrt{3}\ I_{ph}$ — 1 Mark

Phasor diagram: (consider any correct equivalent phasor diagram)



Line & Phase Current and Line & Phase Voltage in Delta (Δ) Connection

4 Marks for labeled phasor diagram

5 c) i) State maximum power transfer theorem and write its procedural step to find load resistance.

Ans:

Maximum Power transfer theorem:

"It states that, the maximum amount of power is delivered to the load resistance when the load resistance is equal to the internal resistance of the source or Thevenin's equivalent resistance of the network supplying the power to load." 2 Marks for theorem

According to this theorem, condition for maximum power to be transferred to load is when $R_L = R_{TH}$,

Where, R_{TH} = Thevenin's equivalent resistance of the network across R_L

Steps for Solving Network Using Maximum Power Transfer Theorem:

Following steps are used to solve the problem by Maximum Power Transfer theorem

Step I: Remove the load resistance of the circuit.

Step II: Find the Thevenin's resistance (R_{TH}) of the source network looking through the open circuited load terminals. 2 Marks for Steps

Step III: As per the maximum power transfer theorem, this R_{TH} is the load resistance of the network, i.e. $R_L = R_{TH}$ that allows maximum power transfer.

Step IV: Maximum Power Transfer is calculated by the equation shown below

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

5 c) ii) Find value of R_L and maximum power in Figure No. 7

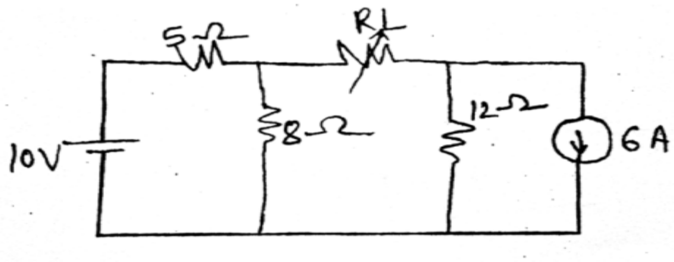
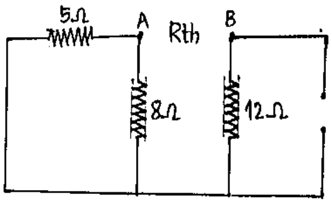


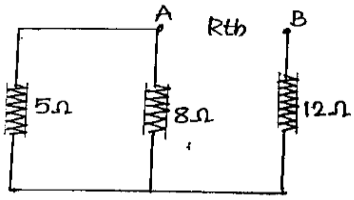
Fig. No. 7

Ans:

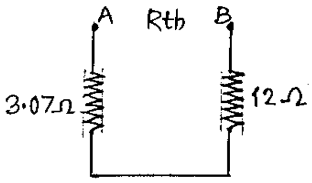
A) Determination of R_{th}:

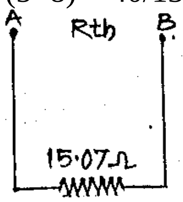
By removing R_L, and short circuiting the voltage source and open circuiting current source.





Resistance of 5 and 8 ohms are in parallel i.e. (5x8)/(5+8) = 40/13 = 3.07 Ω



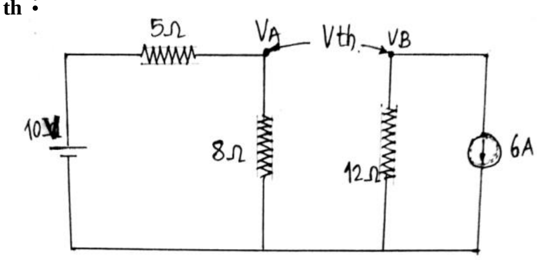


1 Mark for R_{th}

$$\mathbf{R_{th} = R_L = 3.07+12 = 15.07\ \Omega}$$

Hence maximum power will be transferred in the given circuit when $R_L = R_{th} = 15.07\ \Omega$

B) Calculating V_{th} :



Since, full 6 A passes through 12 Ω resistance $V_B = -12 \times 6 = -72$ V

Voltage drop across 8 Ω resistance can be calculated by voltage divider rule, 2 Marks for V_{th}

$$\text{i.e. } V_A = 10 \times \left(\frac{8}{5+8}\right) = 6.15 \text{ V}$$

$$V_{th} = V_A - V_B = 6.15 - (-72) = 78.15 \text{ V}$$

$$P_{max} = \frac{V_{TH}^2}{4R_{TH}}$$ 1 Mark for P_{max}

$$P_{max} = (78.15)^2/(4 \times 15.07) = 101.317 \text{ W}$$

6 Attempt any <u>FOUR</u> of the following: 16

6 a) State any four advantages of polyphase circuit over single phase circuit.

Ans:

Advantages of Polyphase circuit over Single phase circuit: (Any 4)

i) Three-phase transmission is more economical than single-phase transmission. It requires less copper.

ii) Parallel operation of 3-phase alternators is easier than that of single-phase alternators.

iii) Single-phase loads can be connected along with 3-ph loads in a 3-ph system. 1 Mark each of any four = 4 Marks

iv) Instead of pulsating power of single-phase supply, constant power is obtained in 3-phase system.

v) Three-phase induction motors are self-starting. They have high efficiency, better power factor and uniform torque.

vi) The power rating of 3-phase machine is higher than that of 1-phase machine of the same size.

vii) The size of 3-phase machine is smaller than that of 1-phase machine of the same power rating.

viii) Three-phase supply produces a rotating magnetic field in 3-phase rotating machines which gives uniform torque and less noise.

6 b) Find the current in 10 Ω resistor in Figure No.8 by node voltage analysis method.

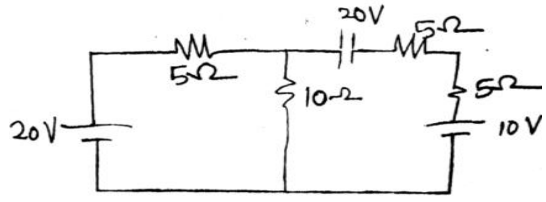
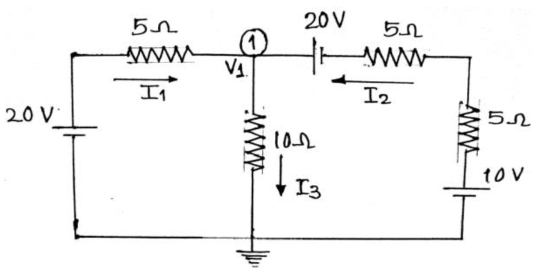


Fig. No. 8

Ans:



1 Mark for current marking

Apply KCL at Node1

We get… $I_1+I_2-I_3=0$ or $I_1+I_2= I_3$

1 Mark for current equation

$$\frac{20-V_1}{5}+\frac{30-V_1}{10}-\frac{V_1}{10}=0$$

1 Mark

From which $4V_1 = 70$ and hence $V_1 = 17.5\ volts$

Current through 10 Ω resistor I_3

$$= V_1/10 = 17.5/10 = \mathbf{1.75}\ \boldsymbol{Amps}$$

1 Mark

6 c) Use Norton's theorem, find the current through 3 Ω resistance for the circuit shown in Figure No. 9

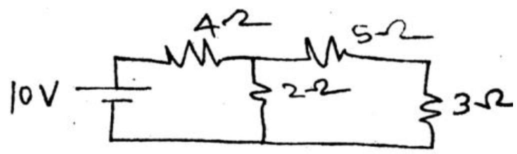
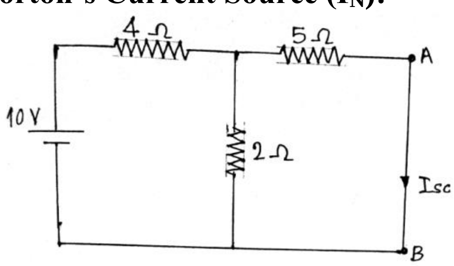


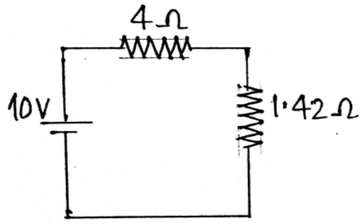
Fig. No. 9

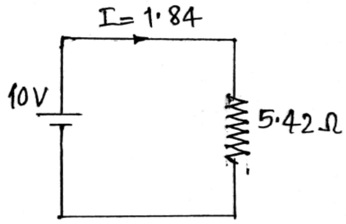
Ans:

A) Determination of Norton's Current Source (I_N):



Short circuit the load resistance R_L i.e. 3 Ω resistance and calculate $I_{SC} = I_N$
Resistance of 2 and 5 ohm are in parallel hence equivalent resistance is
= (2 x 5)/(2+5)= 10/7 = 1.43 Ω

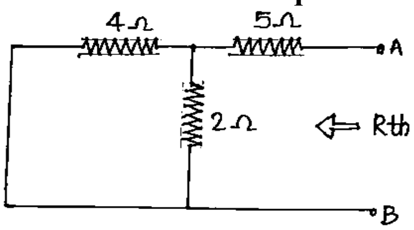


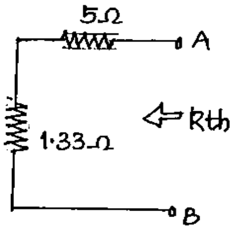


R= 4+1.43=5.43 Ω
I= 10/5.43= 1.841 A
$I_{SC} = I_N$= 1.84 x (2/2+5)= **0.526 A**

2 Marks for I_N

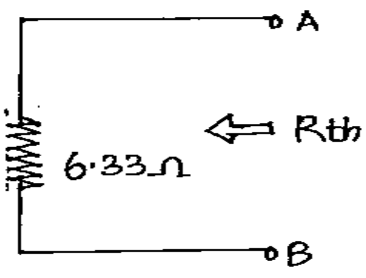
B) Determination of Norton's Equivalent Resistance R_N (or R_{TH}):

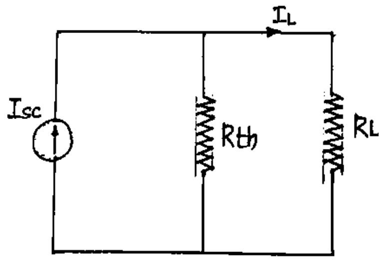




Resistance of 4 and 2 ohms are in parallel =(4 x 2)/(4+2) = 8/6=1.33 Ω
The 5Ω and 1.33Ω resistors appear in series hence
$R_{TH} = R_N$ = 5+1.33= **6.33 Ω**

1 Mark for R_N





Current through 3 Ω resistance= $I_L = I_{SC} \times R_N/(R_N+R_L)$
= 0.526 x 6.33/ (6.33+3)=0.356 A

1 Mark for I_L

I_L = 0.356 A

6 d) State Thevenin's theorem and write its procedural steps to find current in a branch.
Ans:
Thevenin's Theorem:
Any two terminal circuit having number of linear impedances and sources (voltage, current, dependent, independent) can be represented by a simple equivalent circuit consisting of a single voltage source V_{Th} in series with an impedance Z_{Th}, where the source voltage V_{Th} is equal to the open circuit voltage appearing across the two

2 Marks for theorem

terminals due to internal sources of circuit and the series impedance Z_{Th} is equal to the impedance of the circuit while looking back into the circuit across the two terminals, when the internal independent voltage sources are replaced by short-circuits and independent current sources by open circuits.

Procedural steps to find current in a branch using Thevenin's theorem:

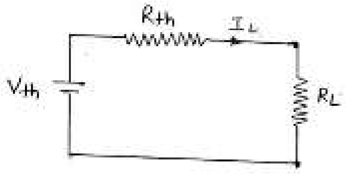
Step I: Identify the load branch (R_L): It is the branch whose current is to be determined.

Step II: Calculation of V_{TH}: Remove R_L and find open circuit voltage across the load terminals A and B, which are now open due to removal of R_L.

Step III: Calculation of R_{TH}: It is the resistance between the open circuited load terminals A & B while looking back into the network with all independent voltage sources replaced by short-circuit & all independent current sources replaced by open-circuit.

2 Marks for Steps

Step IV: Thevenin's equivalent circuit:



Step V: Determination of Load current:

$$I_L = V_{TH}/(R_{TH}+R_L)$$

6 e) Find the current through 4 Ω impedance shown in Figure No. 10 using super position theorem.

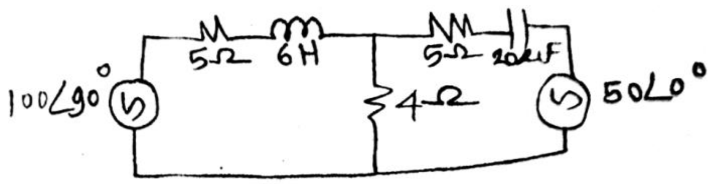


Fig. No. 10

Ans:

NOTE: Frequency is not given in the problem hence assumed as 50 Hz. (Answers may vary according to assumption)

Consider Branch 1 as

$X_{L1} = 2\pi fL = 2 \times \pi \times 50 \times 6 = 1884.96\ \Omega$

$Z_1 = 5 + j\,1884.96\ \Omega = 1884.97 \angle 89.85°\ \Omega$

Consider Branch 2 as

$$X_C = \frac{1}{2\,\pi\,f\,C} = \frac{1}{2 \times \pi \times 50 \times 20 \times 10^{-6}} = 159.15\ \ \Omega$$

$Z_2 = 5 - j\,159.15\ \Omega = 159.23\angle -88.20°\ \Omega$

Consider load Branch as

$Z_L = 4 + j0\ \Omega = 4\angle 0°\ \Omega$

1 Mark for calculation of impedances

(A) Consider voltage source of $100\angle 90^0$ acting alone

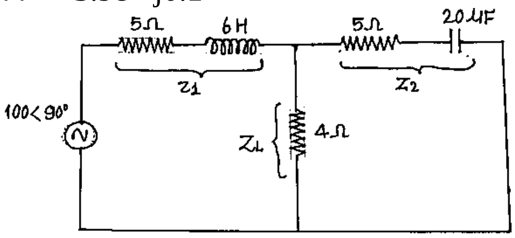
The equivalent impedance of Z_2 parallel with Z_L is given by,

$= Z_2 \times Z_L / (Z_2 + Z_L)$

$= (159.23\angle -88.20°) \times (4\angle 0°)/\{(5 - j159.15) + (4 + j0)\}$

$= 636.92\angle -88.20° /(9 - j159.15) = 636.92\angle -88.20° /(159.40\angle -86.76°)$

$= 3.99 \angle -1.44° = 3.98 - j0.1$



This is in series with Z_1

$Z_{eq} = (3.98-j0.1) + (5+j1884.96) = 8.98+j\,1884.86 = 1884.88\angle 89.73°\ \Omega$

$I = V/Z_{eq} = (100\angle 90°)/(1884.88\angle 89.73°) = 0.053\angle 0.27° = (0.053-j\,0.00025)$ A

By using current divider rule,

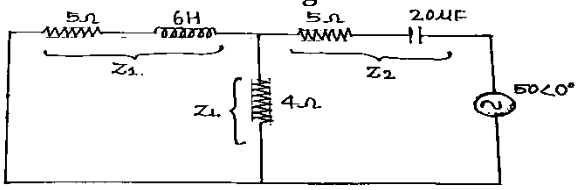
Current through Z_L i.e. $I_{L1} = I \times Z_2/(Z_2+Z_L)$

$= (0.053\angle 0.27°)(4\angle 0°) / (159.40\angle -86.76°)$

$\mathbf{I_{L1}} = 0.212\angle 0.28° / (159.40\angle -86.76°)$

$= \mathbf{0.00133\angle 87.03 = (6.89 \times 10^{-5} + j0.00133)\ A}$ — 1 Mark for I_{L1}

(B) Consider voltage source of $50\angle 0^0$ acting alone



The equivalent of Z_1 parallel with Z_L

$= Z_1 \times Z_L/(Z_1+Z_L)$

$= (1884.97\angle 89.85°)\times(4\angle 0°)/\{(5+j1884.96)+(4+j0)\}$

$= 7539.88\angle 89.85° /(9+j1884.96)$

$= 7539.88\angle 89.84° /(1884.98\angle 89.73°)$

$= 3.99\angle 0.11° = 3.99 + j0.0077$

This is in series with Z_2

$Z_{eq} = (3.99+j0.0077) + (5-j159.15) = 8.99-j159.1423 = 159.4\angle -86.77°\ \Omega$

$I = V/Z_{eq} = (50\angle 0°)/(159.4\angle -86.77°) = 0.3137\angle 86.77° = 0.0177+j\,0.313$ A

By using current divider rule,

Current through Z_L i.e. I_{L2}

$I_{L2} = I \times Z_1/(Z_1+Z_L) = (0.3137\angle 86.77°)(1884.97\angle 89.85°) / (1884.98\angle 89.73°)$

$I_{L2} = 591.31\angle 176.62° / (1884.98\angle 89.73°) = \mathbf{0.314\angle 86.89° = 0.017 + j0.314}$ — 1 Mark for I_{L2}

$I_L = I_{L1}+I_{L2} = (6.89 \times 10^{-5} + j0.00133) + (0.017 + j0.314) = 0.017+j0.31533$

$\mathbf{I_L = 0.316\angle 86.91^o\ A}$ — 1 Mark

6 f) State the behaviour of following elements at the time of switching i.e. transient period:
(i) Pure R (ii) Pure L (iii) Pure C

Ans:

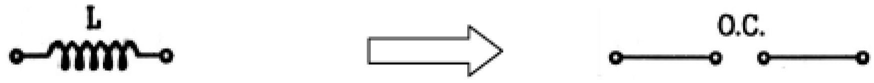
At the time of switching:

(i) **Pure Resistor:** — 1 Mark for Resistor

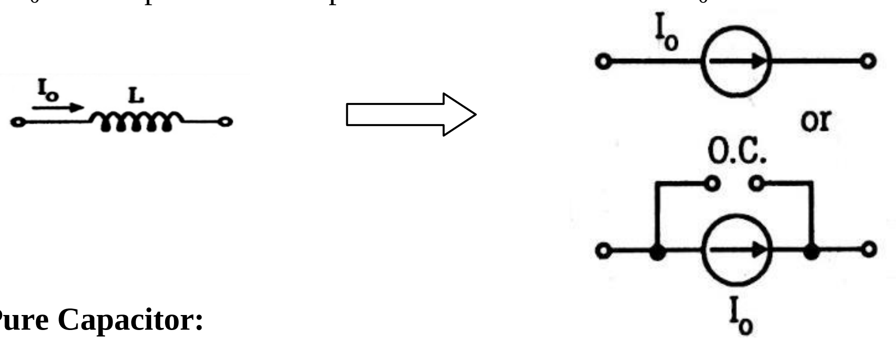
At any time it acts like resistor only, with no change in condition.

(ii) **Pure Inductor:**

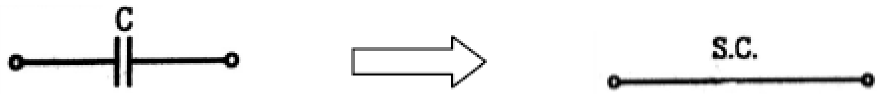
The pure inductor, carrying zero current prior to switching, acts as OPEN CIRCUIT.



The pure inductor, carrying some current, say I_0, prior to switching, acts as a current source I_0 or an Open Circuit in parallel with current source I_0. 1.5 Marks for L



(iii) **Pure Capacitor:**
The pure capacitor, having zero voltage prior to switching, acts as SHORT CIRCUIT.



The pure capacitor, having some voltage, say V_0, prior to switching, acts as a voltage source V_0 or Short Circuit in series with voltage source V_0. 1.5 Marks for C