Model Answers

Summer – 2019 Examinations

Subject & Code: Electrical Circuits & Networks (17323)

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.

Model Answers
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1 Attempt any TEN of the following: 20

1 a) Define waveform and instantaneous value of an alternating quantity.

Ans:

i) Waveform: It is a graph of magnitude of an AC quantity against time. 1 mark

ii) Instantaneous value: It is defined as the value of an AC quantity at a particular instant of time. 1 mark

1 b) An alternating voltage is having maximum value 230 volt. What is its average value and rms value?

Ans:

Assuming that the alternating quantity is a sinusoidal quantity,

i) Average value = 0.637 × maximum value = 0.637 × 230

Average value = 146.51 volt 1 mark

ii) RMS value = 0.707 × maximum value = 0.707×230

RMS value = 162.61 volt. 1 mark

1 c) Define Inductive reactance and Capacitive reactance.

Ans:

i) Inductive reactance:

The opposition offered by the inductance of a circuit to the flow of an alternating current is called an inductive reactance. 1 mark

It is denoted by "X_L" and given by $X_L = 2\pi fL\ \Omega$

ii) Capacitive reactance:

The opposition offered by the capacitance of a circuit to the flow of an alternating current is called an capacitive reactance. 1 mark

It is denoted by "X_C" and given by $X_C = \frac{1}{2\pi fC}\Omega$

1 d) Define power factor and reactive power.

Ans -

i) Power factor:

It is the cosine of the angle between the applied voltage and the resulting current. 1 mark

Power factor = cosΦ

where, Φ is the phase angle between applied voltage and current.

OR

It is the ratio of true or effective or real power to the apparent power.

Power factor = True Or Effective Or Real Power /Apparent Power

= VI cosΦ / VI

= cosΦ

OR

It is the ratio of circuit resistance to the circuit impedance.

Power factor =Circuit Resistance / Circuit Impedance

= R / Z

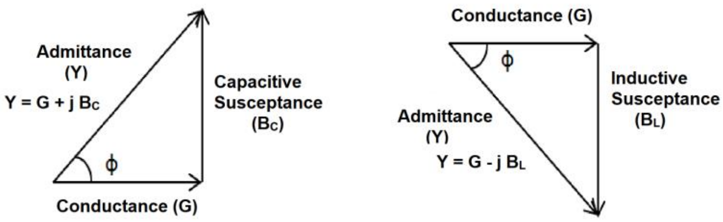
= cosΦ

ii) Reactive Power:

Reactive power (Q) is the product of voltage, current and the sine of the phase angle between voltage and current. 1 mark
Q =VIsinΦ volt-amp-reactive
OR
It is the quantity of "unused" power that is developed by reactive components in an AC circuit.

1 e) Draw a admittance triangle by considering capacitive susceptance and inductive susceptance.

Ans:



1 mark each = 2 marks

1 f) Give any two applications of parallel resonant circuits.

Ans:

Applications of parallel resonant circuits:

i) An oscillator circuit
ii) As current amplifier
iii) As current rejector
iv) Load impedance in output circuits of RF amplifiers.
v) It can be used in induction heating.
vi) In filter circuits.
vii) Tank circuit.
viii) Power-factor improvement circuit

1 mark for each of any two applications = 2 marks

1 g) State the relations between line and phase values of voltage and current for balanced star connected load.

Ans:

For balanced star connected load,

Line voltage =√3 x Phase Voltage 1 mark

i.e $V_L = \sqrt{3} \times V_{ph}$

Line current = Phase current

i.e $I_L = I_{ph}$ 1 mark

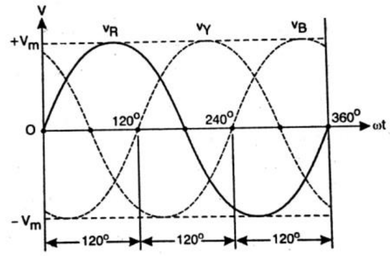
1 h) Define phase sequence of three phase ac quantity.

Ans:

Phase Sequence:

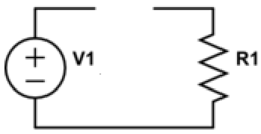
Phase sequence is defined as the order in which the voltages (or any other alternating quantity) of the three phases attain their positive maximum values. 1 mark for correct definition

In the waveforms, it is seen that the R-phase voltage attains the positive maximum value first, and after angular distance of 120°, Y-phase voltage attains its positive maximum and further after 120°, B-phase voltage attains its positive maximum value. So the phase sequence is R-Y-B. 1 mark for diagram



1 i) With a neat diagram explain the concept of open circuit.

Ans -



1 mark for circuit

Concept of open circuit:

Open circuit means a circuit condition where the conducting wire is cut off so there will be **no current flow**, but there is voltage. Open circuit is characterized by infinite resistance, zero current and finite voltage. 1 mark

1 j) Define active network and passive network.

Ans:

i) Active network :
An active network is a network that contains at least one energy source, either a voltage source or current source. 1 mark

ii) Passive network :
A passive network is a network that does not contain any energy source. 1 mark

1 k) State Thevenin's theorem applied to DC circuits.

Ans:

Thevenin's Theorem:

Any two terminal circuit having number of linear resistances 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 resistance R_{Th}, where the source voltage V_{Th} is equal to the open circuit voltage appearing across the two terminals due to internal sources of circuit and the series resistance R_{Th} is equal to the resistance 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. 2 marks for statement

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1 l) Give the meaning of "Steady state condition" and state the behavior of pure C at steady state condition.

Ans:

Meaning of Steady state condition:

Steady state **condition** is that condition which exists after all initial transients or fluctuations have damped out and all currents, voltages or fields are settles down to essentially constant values. 1 mark

Usually the steady state is said to be reached at time instant $t \rightarrow \infty$.

Steady state behavior of Pure C:

At steady state condition the capacitor acts as **open circuit.** 1 mark

2 Attempt any FOUR of the following: 16

2 a) Instantaneous expression for voltage and current are given by

V = 141.4sin314t, i = 28.28sin (314t + π/3)

Determine:

i) Voltmeter and ammeter reading.
ii) Frequency of current
iii) Power factor
iv) Power consumed.

Ans:

Data Given:

V = 141.4sin314t, i = 28.28sin (314t + π/3)

i) Voltmeter and Ammeter reading:

Voltmeter reads RMS value:

∴ Vrms = 0.707 x Vm = 0.707 x 141.4 = 99.97 V ≈ 100 V

Voltmeter reading = 99.97 V i.e. 100V ½ mark

Ammeter reads RMS value:

Irms = 0.707 x Im = 0.707 x 28.28 = 19.99 A i.e. 20A

Ammeter reading = 19.99A ≈ 20A. ½ mark

ii) Frequency of current

Comparing the current equation with standard equation

I = Im sin(ωt+Φ) amp

we get, ω = 314

we know that, f = ω /2π = 314/2π

∴ **Frequency of current f = 49.97 Hz ≈ 50 Hz** 1 mark

iii) Power factor:

Power Factor = Cos(Φ) = Cos (π/3)

∴ **Power factor = 0.5 leading** 1 mark

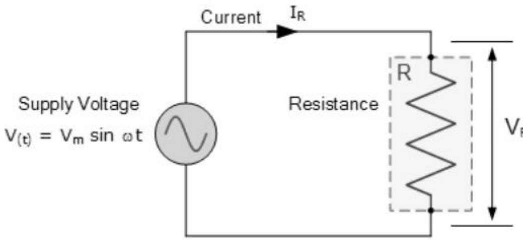
iv) Power consumed:

P = V x I x CosΦ = 99.97 x 19.99 x 0.5

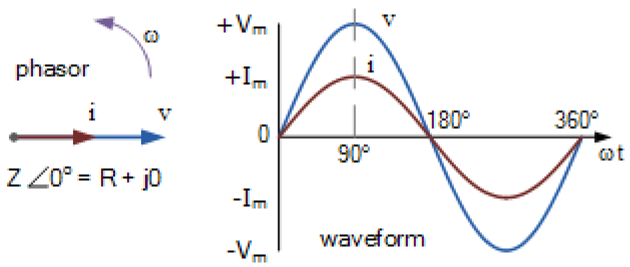
Power consumed = 999.2 Watt ≈ 1000 Watt 1 mark

2 b) Derive the expression for current and voltage in pure resistive circuit when connected to sinusoidal AC voltage. Draw the phasor diagram.

Ans:-



1 mark for circuit diagram



1 mark for phasor diagram

Referring to fig. the instantaneous voltage across the resistor (v_R) is same as source voltage.

Therefore, $\mathbf{v_R = v = V_m \sin(\omega t)}$ **……………………………(1)**

Applying ohms law, the expression for the instantaneous current flowing through the resistor is given by, $i = v_R / R$

$$i = V_m \sin(\omega t) / R = (V_m/R) \sin(\omega t)$$

where, $I_m = V_m/R$, $i = I_m \angle 0^o$

Therefore, $\mathbf{I = I_m \sin(\omega t)}$ **…………………………………(2)**

2 marks for derivation

On comparing Eq. (1) and (2), we conclude that,

- The current flowing through a purely resistive ac circuit is sinusoidal.
- The current through the resistive circuit and the applied voltage are in phase with each other.

2 c) For the given impedance triangle as shown in Fig. No. 1.

i) Identify the type of circuit.
ii) Mark parameters of all sides of the triangle
iii) State the nature of power factor
iv) Draw a sinusoidal waveform of voltage and current.

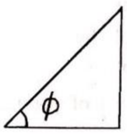


Fig. No. 1

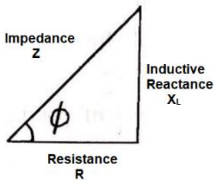
Ans:

i) The types of circuit:

Type of circuit is **R-L series circuit.**

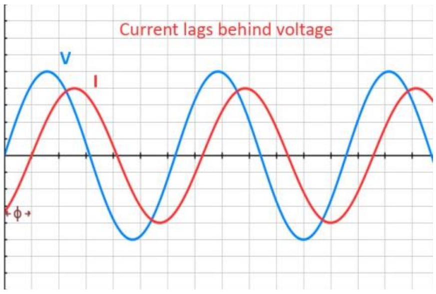
ii) Parameters of all sides of the triangle:

1 mark for each bit = 4 marks



iii) Nature of power factor:
The nature of power factor is **lagging.**

iv) Sinusoidal waveform of voltage and current:



2 d) Define the impedance and draw the impedance triangle.

Ans:

i) Definition of Impedance: The impedance (Z) of the circuit is defined as the total opposition of the circuit to the alternating current flowing through it.

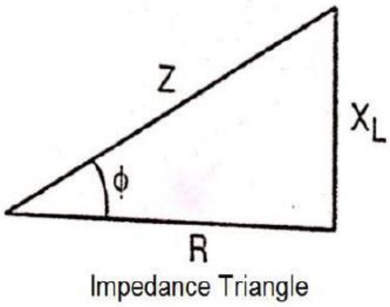
OR

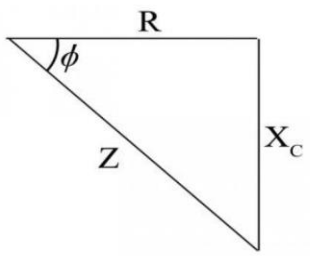
It is combined effect produced by the resistance, inductive reactance and capacitive reactance in the AC circuit. — 2 marks for definition

It is denoted by "Z" and measured in ohm.

ii) Impedance Triangle:

For R-L series circuit — **For R-C series circuit**





1 mark for each triangle = 2 marks

2 e) A resistance of 100Ω and 50µf capacitor are connected in series across a 230V, 50Hz supply. Find:

i) The impedance.
ii) The current flowing through the circuit.
iii) Voltage across resistance and capacitance.
iv) Power factor and Power.

Ans:

$V = 230\angle 0°$ volts, $f = 50Hz$ $R = 100\Omega$ $C = 50\mu F = 50\times 10^{-6}$ F

Capacitive Reactance (X_C):

$X_C = 1 / (2\pi fC)$

$= 1 / (2\pi \times 50 \times 50 \times 10^{-6})$

$X_C = 63.66\ \Omega$

i) **Impedance (Z) = $\sqrt{(R^2 + X_C^2)}$**

$= \sqrt{(100^2 + 63.66^2)}$

Z = 118.54 Ω

ii) **The current flowing through the circuit (I) :**

$I = V / Z$

$= 230 / 118.54$

I = 1.94 amp

iii) **Voltage across resistance(VR) and capacitance(VC)**

Voltage across resistance(V_R) = I x R = 1.94 x 100

= 194 Volt

Voltage across capacitance(V_C) = I x X_c = 1.94 x 63.66

= 123.5 Volt

iv) **Power factor and Power.**

Power Factor (CosΦ) = R / Z = 100 / 118.54

= 0.84 (leading)

Power (P) = V x I x COSΦ = 230 x 1.94 x 0.84

= 374.80 Watt

1 mark for each bit = 4 marks

2 f) A circuit consists of a resistance of 20Ω in series with an inductance of 95.6 mH and a capacitor of 318μf. It is connected to a 500V, 25Hz supply. Find the current in the circuit and power factor.

Ans:

Data Given: R = 20Ω, L = 95.6 mH = 95.6×10^{-3} H C = 318 μf = 318×10^{-6} F
V = 500V f = 25Hz.

Inductive Reactance :

$X_L = 2\pi fL = 2\pi \times 25 \times 95.6 \times 10^{-3}$ ½ mark

$X_L = 15.01\ \Omega$

Capacitive Reactance :

$X_C = 1/2\pi fc = 1/(2\pi \times 25 \times 318 \times 10^{-6})$ ½ mark

$X_C = 20.01\ \Omega$

Impedance :

$Z = \sqrt{\{R^2 + (XL - XC)^2\}} = \sqrt{\{20^2 + (15.01 - 20.01)^2\}}$

Z = 20.61 Ω 1 mark for Z

i) Current in the circuit(I):

I = V / Z = 500 / 20.61

I = 24.26 amp 1 mark for I

ii) Power factor (cosΦ):

cosΦ = R / Z = 20 / 20.61

cosΦ = 0.97 (leading) 1 mark for pf

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

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3 a) Compare series resonance circuit with parallel resonance circuit.

Ans:

Comparison between series and parallel resonance circuit:

Sr. No.	Series resonant Circuit	Parallel resonant Circuit
1	For series R-L-C circuit, the resonance frequency is, $f_r = \frac{1}{2\pi\sqrt{LC}}$	For parallel R-L-C circuit, the resonance frequency is, $f_r = \frac{1}{2\pi\sqrt{LC}}$
2	At resonance, the series RLC circuit offers minimum total impedance Z = R	At resonance, the parallel RLC circuit offers maximum total impedance Z =L/CR
3	At resonance, series RLC circuit draws maximum current from source, I = (V/R)	At resonance, parallel RLC circuit draws minimum current from source, $I = \frac{V}{[^L/_{CR}]}$
4	At resonance, in series RLC circuit, voltage magnification takes place.	At resonance, in parallel RLC circuit, current magnification takes place.
5	The Q-factor for series resonant circuit is $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	The Q-factor for parallel resonant circuit is, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$
6	Series RLC resonant circuit is Accepter circuit.	Parallel RLC resonant circuit is Rejecter circuit.

1 mark for each of any four points = 4 marks

3 b) Derive the expression for resonant frequency for the circuit as shown in Figure No.2

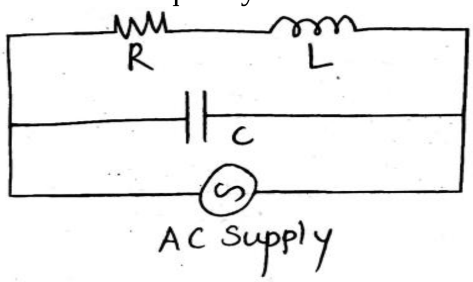
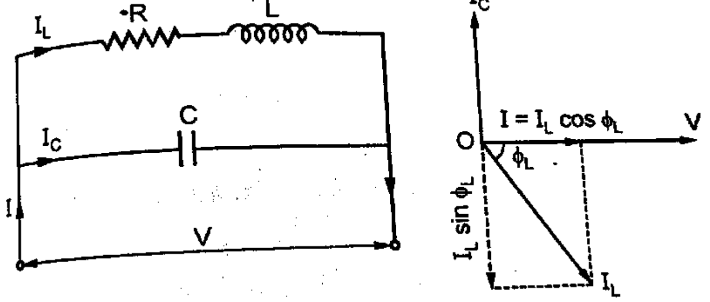


Fig. No. 2

Ans:

Resonance Frequency for a RL-C Parallel Circuit: -



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.

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

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

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

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

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

4 marks for step-wise derivation

3 c) If Z_1=3+j7 and Z_2=12-j16 are connected in parallel. Find the equivalent impedance of combination.

Ans:

Converting Z_1 and Z_2 in Polar form we get,

$Z_1 = (3 + j7) = 7.61\angle 66.80°\Omega$

$Z_2 = (12 – j16) = 20\angle -53.13°\Omega$.

Z_1 and Z_2 are connected in parallel,

1 mark for R to P conversion

$$Z_{eq} = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{7.61\angle 66.80° \times 20\angle -53.13°}{(3+j7)+(12-j16)}$$ 1 mark

$$= \frac{7.61\angle 66.80° \times 20\angle -53.13°}{17.49\angle -30.96^0}$$ 1 mark

$$= \mathbf{8.70\angle 44.53° = (6.20 + j6.10)}\ \Omega$$ 1 mark

OR any equivalent method

3 d) If A = 4+j7, B = 8+j9, C = 5-j6 then calculate,

i) $\frac{A+B}{C}$

ii) $\frac{A \times B}{C}$

iii) $\frac{A+B}{B+C}$

iv) $\frac{B-C}{A}$

Ans:

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

$A = (4 + j7) = 8.06\angle 60.25°$,

$B = (8 + j9) = 12.04\angle 48.37°$,

1 mark for each bit = 4 marks

$C = (5 - j6) = 7.81\angle -50.19°$

i) $\frac{A+B}{C} = \frac{4+j7+8+j9}{7.81\angle -50.19°} = \frac{20\angle 53.13°}{7.81\angle -50.19°}$
$= 2.56\angle 103.32° = 0.589+j2.491$

ii) $\frac{A\times B}{C} = \frac{8.06\angle 60.25°\times 12.04\angle 48.37°}{7.81\angle -50.19°} = \frac{97.04\angle 108.62°}{7.81\angle -50.19°}$
$= 12.42\angle 158.81° = -11.58+j4.489$

iii) $\frac{A+B}{B+C} = \frac{4+j7+8+j9}{8+j9+5-j6°} = \frac{20\angle 53.13°}{13.34\angle -12.99°}$
$= 1.49\angle 66.12°. = 0.603+j1.362$

iv) $\frac{B-C}{A} = \frac{8+j9-5+j6}{8.06\angle 60.25°} = \frac{15.29\angle 78.69°}{8.06\angle 60.25°}$
$= 1.897\angle 18.44°. = 1.799+j0.600$

3 e) What is meant by independent voltage source? What are its type?

Ans.

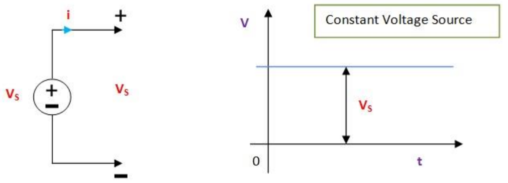
Independent Voltage Source:

The voltage source which can deliver steady voltage (fixed or variable with time) to the circuit and it does not depend on any other elements or quantity in the circuit. 1 mark

Types of Independent Voltage Source:

i) Direct Voltage Source or Time Invariant Voltage Source

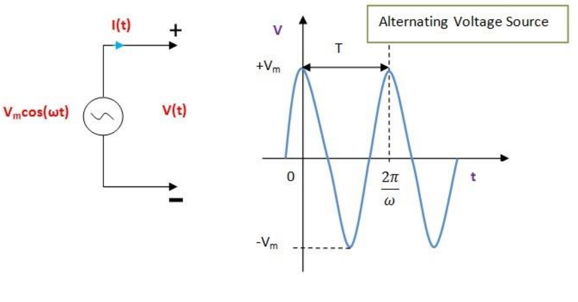
The **voltage source** which can produce or deliver constant voltage as output is termed as Direct Voltage Source. The flow of electrons will be in one direction that is polarity will be always same. The movement of electrons or current will be in one direction always. The value of voltage will not alter with time. Example: DC generator, battery, Cells etc. 1 mark



½ mark

ii) Alternating Voltage Source:

The voltage source which can produce or deliver alternating voltage as output is termed as Alternating Voltage Source. Here, the polarity gets reversed at regular intervals. This voltage causes the current to flow in a direction for a time and after that in a different direction for another time. That means it is time varying. Example: DC to AC converter, Alternator etc. 1 mark



½ mark

3 f) A resistance of 100Ω and capacitor of 50μF are connected in series across a 230V, 50Hz supply. Find:

i) The impedance
ii) The current flowing through circuit
iii) Voltage across resistance and capacitance
iv) Power factor and power

Ans:

Data Given: R =100Ω, C = 50μF, V = 230V, f = 50Hz.

The Capacitive reactance is given by, $X_c = \frac{1}{2\pi fC}$

$= \frac{1}{2\pi(50)(50\times10^{-6})}$

$= \mathbf{63.69}\Omega.$

1 mark for each bit = 4 marks

i) The impedance of Circuit:

$$Z = \sqrt{(R^2 + (-Xc)^2} = \sqrt{(100)^2 + (-63.66)^2} = \mathbf{118.55}\ \Omega.$$

ii) Current flowing through the circuit (I):

$$I = \frac{V_S}{Z} = \frac{230}{118.55} = \mathbf{1.94A}$$

iii) Voltage across Capacitance and Resistance

Voltage across capacitance=V_c=I × Xc
=1.94 x 63.69
=**123.55V**

Voltage across Resistance=V_R=I × R
=1.94 x 100
=**194V**

iv) Power factor and Power:

Phase angle between voltage and current (ϕ)

$$\Phi = \tan^{-1}\frac{(-Xc)}{R} = \tan^{-1}\frac{(-63.69)}{100} = -32.49° = \mathbf{32.49\ leading.}$$

Power factor = cos Φ = cos 32.49 = **0.8434 leading**

Power = VIcos Φ=230 x 1.94 x0.8434=**376.32 W**

4 Attempt any FOUR of the following: 16

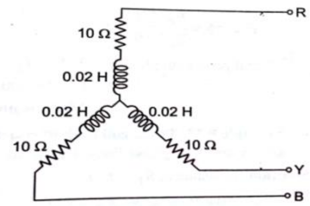
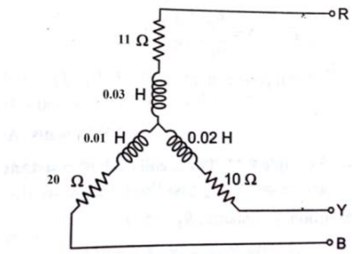
4 a) Distinguish between balanced and unbalanced load.

Ans:

Comparison between balanced and unbalanced load:

Sr. No.	Balanced load	Unbalanced load
1	Balanced three phase load is defined as star or delta connection of three equal impedances having equal real parts and equal imaginary parts.	When the magnitudes and phase angles of three impedances are differ from each other, then it is called as unbalanced load.
2	All the phase and line voltage will have equal magnitudes. Line currents also have equal	All the voltages are fixed and line currents will not be equal nor will have a 120° phase

1 mark for each of any four points = 4 marks

<table>
<tr><td></td><td>magnitude.</td><td>difference.</td></tr>
<tr><td>3</td><td>For balanced load, there is fixed relationship between the phase voltage & the line voltage.</td><td>For unbalanced load, there is not a fixed relationship between the phase voltage & the line voltage</td></tr>
<tr><td>4</td><td>Phase angles of impedances are equal.</td><td>Phase angles of impedances are not equal.</td></tr>
<tr><td>5</td><td>Example circuit:

</td><td>Example circuit:

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4 b) State any four advantages of Polyphase circuits over single phase circuit.

Ans:

Advantages and of Polyphase circuits over Single phase circuit:

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

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.

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.

1 mark for each of any four points = 4 marks

4 c) A 3∅ star connected load having R = 15Ω, L= 0.04H, C = 50μF in each phase. It is supplied by 440V, 3∅,50Hz AC. Find:

i) Impedance per phase (Zph)
ii) Line current
iii) Power factor
iv) Power Consumed

Ans:

Given: R=15Ω, L=0.04H, C=50μF, V=440V, F=50Hz.

In star connected load $V_L = \sqrt{3}\, V_{Ph}$ and $I_L = I_{Ph}$

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{440}{\sqrt{3}} = 254.034 \text{ V}$$

The Capacitive reactance is given by, $X_C = \frac{1}{2\pi fC}$

$= \frac{1}{2\pi(50)(50\times10^{-6})}$

$= 63.69\Omega.$

The inductive reactance is given by, $X_L=2\pi fL$

$= 2\times 3.14 \times 50 \times 0.04$

$= 12.56\Omega.$

i) Impedance per phase: — 1 mark for each bit = 4 marks

$Z_{ph} = R + j(X_L - X_C).$

$Z_{ph} = 15+j(12.56 - 63.69)$

$=$ **$15-j51.13 = 53.28\angle-73.64° \Omega$**

ii) Line Current:

$I_L = I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{254.034\angle0°}{53.28\angle-73.64°} = \mathbf{4.76 \angle 73.64 °A}$

iii) Power factor:

$\cos\phi = \frac{Rph}{Zph} = \frac{15}{53.28} =$ **0.28 (lead).**

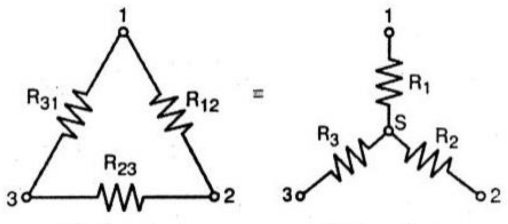
iv) Power Consumed:

$P = \sqrt{3}\ V_L\ I_L \cos\phi = \sqrt{3}\ (440)(4.76)(0.28)$

=**1015.73 watt or 1.015 kW**.

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

Ans:



(a) Delta Circuit (b) Star Circuit

It is possible to replace delta by its equivalent star circuit.

Considering terminals 1 and 2, Resistance R_{12} parallel with ($R_{23}+R_{31}$) ,

Hence resistance between terminals 1 and 2

$\frac{R_{12}(R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}}$…………………..(1) — ½ mark

In Case of Star Network Resistance between terminals 1 and 2 is

$= R_1 + R_2$…………………..(2) — ½ mark

For equivalence between two networks, equating Equation (1) & (2) — ½ mark

$R_1 + R_2 = \frac{R_{12}(R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}}$……………………(3)

Similarly,

$R_2 + R_3 = \frac{R_{23}(R_{31}+R_{12})}{R_{12}+R_{23}+R_{31}}$……………………(4)

$R_3 + R_1 = \frac{R_{31}(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}}$……………………(5)

By subtracting equation (4) from (3)

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

$$R_1 - R_3 = \frac{R_{12}R_{31} - R_{23}R_{31}}{R_{12} + R_{23} + R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots(6)$$ ½ mark

By adding equation (5) & (6)

$$2R_1 = \frac{R_{31}R_{12} + R_{31}R_{23} + R_{12}R_{31} - R_{23}R_{31}}{R_{12} + R_{23} + R_{31}}$$ 1 mark

Equivalent star resistances for delta connection

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

1 mark

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

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

4 e) Using Mesh analysis calculate current through 10Ω resistor as shown in Figure No. 3.

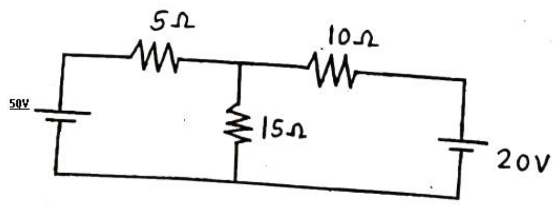
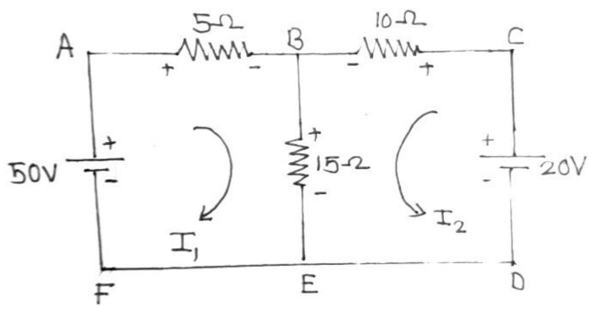


Fig. No. 3

Ans:



By applying KVL to loop ABEFA

$$50 - 5I_1 - 15(I_1 + I_2) = 0$$

$$20I_1 + 15I_2 = 50$$

$$4I_1 + 3I_2 = 10 \ldots\ldots\ldots\ldots (1)$$ 1 mark

By applying KVL to Loop DCBED

$$20 - 10I_2 - 15(I_1 + I_2) = 0$$

$$15I_1 + 25I_2 = 20$$

$$3I_1 + 5I_2 = 4 \ldots\ldots\ldots\ldots\ldots(2)$$ 1 mark

Expressing eq.(1) and (2) in matrix form,

$$\begin{bmatrix} 4 & 3 \\ 3 & 5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 4 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 4 & 3 \\ 3 & 5 \end{vmatrix} = 20 - (9) = 11$$

By Cramer's rule,

$$I_1 = \frac{\begin{vmatrix} 10 & 3 \\ 4 & 5 \end{vmatrix}}{\Delta} = \frac{(10 \times 5) - (4 \times 3)}{11} = \frac{50 - 12}{11} = \mathbf{3.454\ A}$$

1 mark

$$I_2 = \frac{\begin{vmatrix} 4 & 10 \\ 3 & 4 \end{vmatrix}}{\Delta} = \frac{(4 \times 4) - (10 \times 3)}{11} = \frac{16 - 30}{11} = \mathbf{-1.272\ A}$$

Current flowing through resistance of 10Ω = I_2 = - 1.272A from C to B
= +1.272 A from B to C 1 mark

4 f) Using Nodal analysis calculate current through 15Ω resistor as shown in Figure No.4.

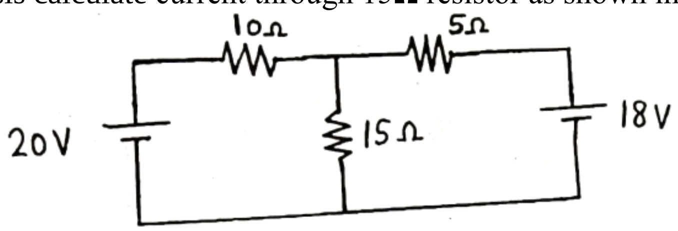
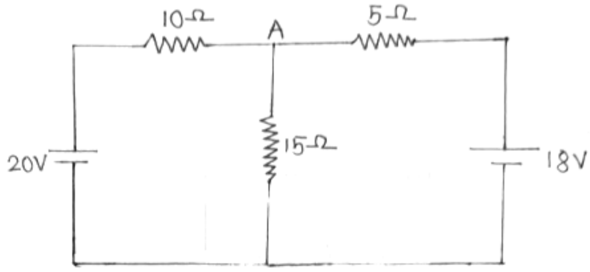


Fig. No. 4

Ans:



1 mark

By applying KCL to Node A

$$\frac{V_A - 20}{10} + \frac{V_A}{15} + \frac{V_A - 18}{5} = 0$$ 1 mark

$$\frac{3V_A - 60 + 2V_A + 6V_A - 108}{30} = 0$$

$$\frac{11V_A - 168}{30} = 0$$

$$V_A = \frac{168}{11} = 15.27 \text{ volts}$$ 1 mark

Current flowing through resistance 15 Ω = $\frac{V_A}{3} = \mathbf{1.018Amp}$ 1 mark

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

5 a) Explain the generation of three phase emf for two pole machines. Represent them mathematical as well as graphical form.

Ans:

Generation of three-phase emf: 2 marks for any one constructional sketch

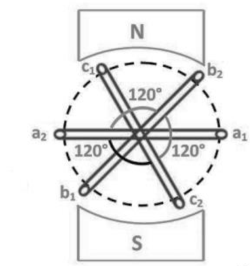


Figure A
Stationary Field - Rotating Armature System

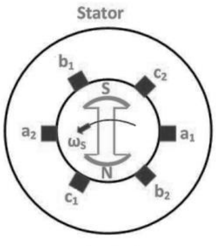
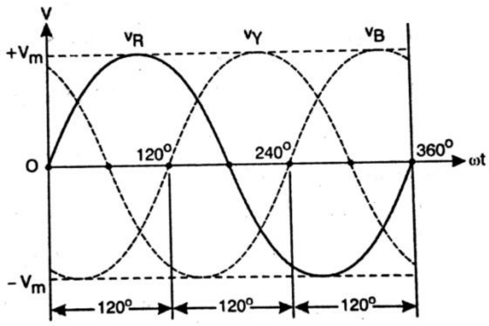


Figure B
Rotating Field - Stationary Armature System



2 marks for waveform

Three-phase emf generation can be possible using following two simple ways:

i) Stationary Field – Rotating Armature System:

Here magnetic field poles are stationary and three coils, say R (a_1-a_2), Y (b_1-b_2) and B (c_1-c_2) coils, are placed on cylindrical rotor (Armature) in the gap between the poles, as shown in Fig. A. When the rotor is rotated, the coils also rotate in the magnetic field and cut the magnetic flux. So according to the Faraday's laws of electromagnetic induction, emf is induced in each coil. Since the coils are identical, the emfs are also identical, but as the coils are displaced in space by 120°, the emfs are displaced in time phase by 120°, as shown in the graph. 3 marks for explanation

ii) Rotating Field – Stationary Armature System:

Here the magnetic field poles are mounted on the rotor and the three-phase winding (three coils) are placed in the stator slots. When rotor is rotated, the magnetic field rotates with respect to the coils. Therefore, each coil cuts the magnetic field and emf is induced in it. Since the coils are identical, the emfs are also identical, but as the coils are displaced in space by 120°, the emfs are displaced in time phase by 120°, as shown in the graph.

Mathematically the three-phase emfs are represented by,

$$e_r = E_m sin\omega t$$
$$e_y = E_m \sin(\omega t - 120^0)$$
$$e_b = E_m \sin(\omega t - 240^0) = E_m \sin(\omega t + 120^0)$$

1 mark for equations

5 b) i) State Norton's theorem and write its procedural steps ~~of~~ to find current in a branch.

Ans:

Norton's theorem:

It states that, any linear, active, resistive network containing one or more voltage and/or current source, can be replaced by an equivalent circuit containing a single current source and equivalent conductance (resistance across the current source). 2 marks for statement

The equivalent current source (Norton's source) I_N is the current through the short circuited terminals of the load. The equivalent conductance G_N (or R_N) is the conductance (or resistance) seen between the load terminals while looking back into the network with the load removed and internal sources replaced by their internal resistances.

If R_L is load resistance then current through it is $I_L = I_N R_N/(R_N + R_L)$.

Procedural steps to apply Norton's theorem to find current in a branch:

1) Identify the branch, whose current is to be determined, as load R_L.
2) Replace load by short circuit.
3) Using circuit analysis techniques, determine the current flowing through the short-circuit, it is the Norton's Equivalent current source I_N.
4) Now remove the short-circuit and keep load terminals open. — 2 marks for stepwise procedure
5) Replace all internal voltage/current sources by their internal resistances. If the sources are ideal, replace voltage sources by short-circuits and current sources by open-circuits.
6) Now determine the equivalent resistance seen between the open load terminals while looking back into the network. It is the Norton's equivalent resistance R_N.
7) Compute the load current using current division formula:

$$I_L = I_N \frac{R_N}{R_N + R_L}$$

5 b) ii) Find the current passing load resistance R_L as shown in Figure No. 5

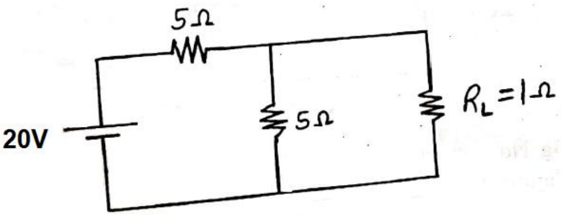


Fig. No. 5

Ans:

Referring to Fig. No. 5, it is seen that 5Ω and R_L=1Ω are in parallel.
Therefore, the total resistance across the voltage source is given by, — 1 mark for R_T
R_T = 5 + 5||1 = 5 + (5/6) = 35/6 = 5.83Ω
Current supplied by voltage source is given by, — 1 mark for I
I = V/R = 20/5.83 = 3.43A
This current is divided and partly flows through 5Ω & R_L. — 1 mark for current division formula
The load current is given by current division formula as,
I_L = I (5/6) = 3.43(5/6)
I_L = 2.86A — 1 mark

5 c) i) State superposition theorem and write its procedural steps to find current in a branch.

Ans:

Superposition Theorm:

Superposition theorem states that the current in any branch is given by the algebraic sum of the currents caused by the independent sources acting alone while the other voltage sources replaced by short circuit and current sources replaced by open circuit. — 1 mark

Procedural Steps to find the branch current:

i) Identify the branch whose current is to be determined as the load branch.
ii) If there are 'n' no. of sources, then consider only one source out them as acting alone in the circuit & other voltage sources being replaced by short-circuit and and current sources being replaced by open-circuit.
iii) Thus with only one source acting alone in the circuit, use circuit analysis techniques to determine the load branch current. Let the load current due to this first source acting alone be I_{L1}.
iv) Repeat the process to find the load current caused by second source acting alone. Let this load current be I_{L2}.
v) Repeat the process to find the load currents I_{L3}, I_{L4}, ……I_{Ln} due to remaining sources acting alone in the circuit.
vi) According to the Superposition theorem, the load current due to all sources acting simultaneously is given by the algebraic sum of the load currents caused by each source acting alone.
i.e $I_L = I_{L1} + I_{L2} + I_{L3} + \ldots\ldots\ldots + I_{Ln}$

3 marks for steps

5 c) ii) Find the I_L for the circuit shown in Figure No. 6 using superposition theorem.

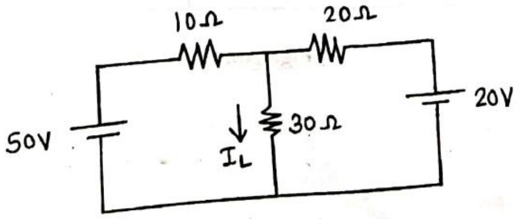
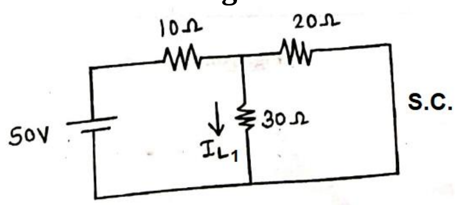


Fig. No. 6

Ans:

(A) Consider voltage source of 50V acting alone:



The total resistance appearing across 50V source is given by,

$R_T = 10+(30||20) = 10+(600/50) = 22\Omega$

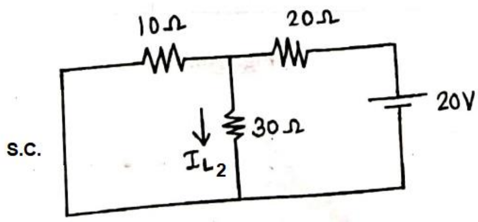
The current I = 50/22 = 2.273A

The current through 30Ω due to 50V source alone is given by,

$I_{L1} = I\ (20/50) = 2.273(20/50) =$ **0.91 A**

1½ Marks for Steps

(B) Consider voltage source of 20V acting alone:



The total resistance appearing across 20V source is given by,

$R_T = 20+30||10 = 20+(300/40) = 27.5\Omega$

The current I = 20/27.5 = 0.73A

1½ Marks

The current through 30Ω due to 20V source alone is given by, — for Steps

I_{L2} = I (10/40) = 0.73(1/4) = **0.182 A**

By Superposition theorem, the current through 30Ω due to both sources is given by,

$I_L = I_{L1} + I_{L2}$ = (0.91+ 0.182) = **1.092A** — 1 mark

6 Attempt any FOUR of the following: 16

6 a) Find current through branch AB using Thevenin's theorem as shown in Figure No. 7

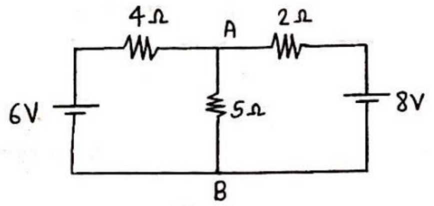
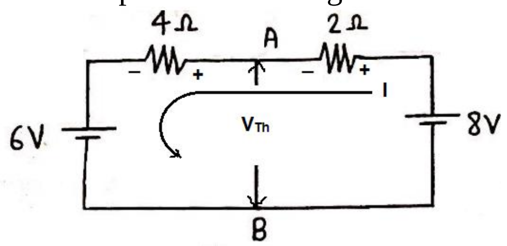


Fig. No. 7

Ans:

i) Calculation of V_{Th}:

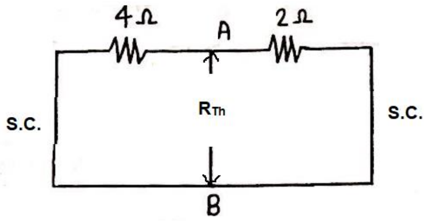
Remove R_L and find open circuit voltage across it. — 1 mark



Current through circuit will be I = (8-6)/(4+2) = 0.33 Amp

$V_{OC} = V_{Th} = V_{AB}$ = 6 + (0.33 × 4) = **7.33 V**

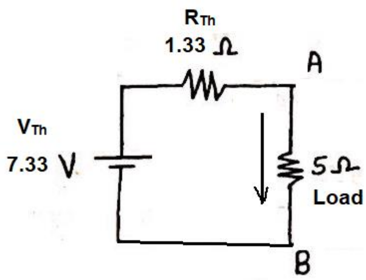
ii) Calculation of R_{Th}: — 1 mark



Resistances 4 & 2 are in parallel = (4 x 2)/(4+2) = **1.33 Ω**

R_{Th} = 1.33 Ω

iii) Thevenin equivalent circuit: — 1 mark



Load Current $I_L = V_{Th}/(R_{Th}+R_L)$=7.33/(1.33+5) = **1.1579 amp** — 1 mark

6 b) Find the value of load resistance R_L to get maximum power transformer to it in Figure No. 8.

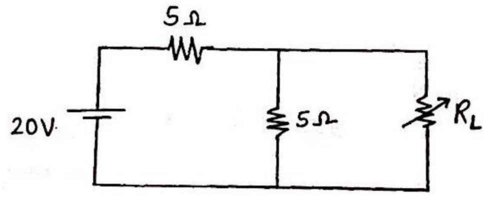
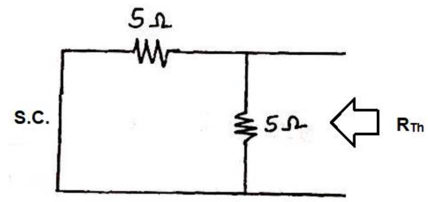


Fig. No. 8

Ans:

Maximum power will be transferred to load R_L, when load resistance R_L is equal to internal resistance i.e. R_L=R_{Th}, Thevenin's equivalent resistance of the network. 1 mark



1 mark

Thevenin's equivalent resistance of the network is given by,

R_{Th} = 5 ‖ 5 = (5×5)/(5+5) = 25/10 = 2.5Ω 1 mark

Thus when $\mathbf{R_L = 2.5\Omega}$, maximum power will be transferred to it. 1 mark

6 c) Using Nodal voltage analysis find current through each branch in Figure No. 9

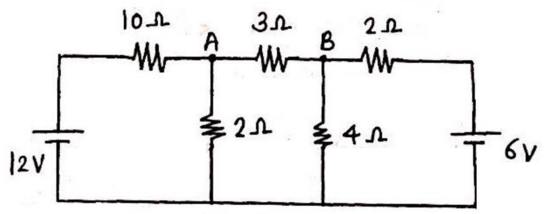
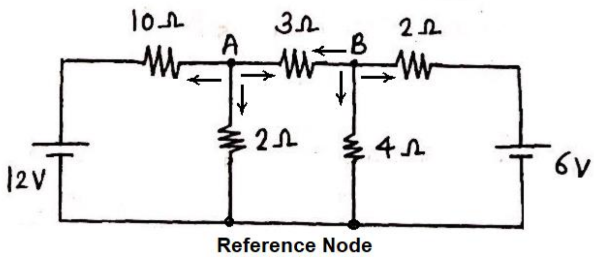


Fig. No. 9

Ans:



Apply KCL at node A

$$\frac{V_A-12}{10}+\frac{V_A}{2}+\frac{V_A-V_B}{3}=0$$

$$V_A\left[\frac{1}{10}+\frac{1}{2}+\frac{1}{3}\right]-V_B\left[\frac{1}{3}\right]-\frac{12}{10}=0$$

$$V_A[0.933]-V_B[0.33]=1.2 \text{ ....(1)}$$

½ mark

Apply KCL at node B

$$\frac{V_B-V_A}{3}+\frac{V_B}{4}+\frac{V_B-6}{2}=0$$

$$V_B\left[\frac{1}{3}+\frac{1}{4}+\frac{1}{2}\right]-V_A\left[\frac{1}{3}\right]-\frac{6}{2}=0$$

$$V_A[-0.33]+V_B[1.0833]=3\text{.......................}(2)$$ ½ mark

Expressing eq.(1) and (2) in matrix form,

$$\begin{bmatrix}0.933 & -0.33\\-0.33 & 1.0833\end{bmatrix}\begin{bmatrix}V_A\\V_B\end{bmatrix}=\begin{bmatrix}1.2\\3\end{bmatrix}$$

$$\therefore \Delta=\begin{vmatrix}0.933 & -0.33\\-0.33 & 1.0833\end{vmatrix}=1.011-0.1089=0.9021$$

By Cramer's rule,

$$V_A=\frac{\begin{vmatrix}1.2 & -0.33\\3 & 1.0833\end{vmatrix}}{\Delta}=\frac{(1.2\times1.0833)-(3\times-0.33)}{0.9021}=\frac{1.29996+0.99}{0.9021}=\mathbf{2.54\ volt}$$ ½ mark

$$V_B=\frac{\begin{vmatrix}0.933 & 1.2\\-0.33 & 3\end{vmatrix}}{\Delta}=\frac{(0.933\times3)-(-0.33\times1.2)}{0.9021}=\frac{2.799+0.396}{0.9021}=\mathbf{3.54\ volt}$$ ½ mark

Current through branch AB (3Ω) = (V_A – V_B)/3 = (2.54-3.54)/3 **= -0.33 amp**
= 0.33A from B to A

Current through branches (12V source & 10Ω) = (12 – V_A)/10 = (12-2.54)/10
= 0.946 amp from 12V source to node A ½ mark

Current through branches (6V source & 2Ω) = (6 – V_B)/2 = (6 - 3.54)/2
= 1.23 amp from 6V source to node B ½ mark

Current through branch (2Ω) = V_A/2 = 2.54/2
= 1.27 amp from noade A to Reference node ½ mark

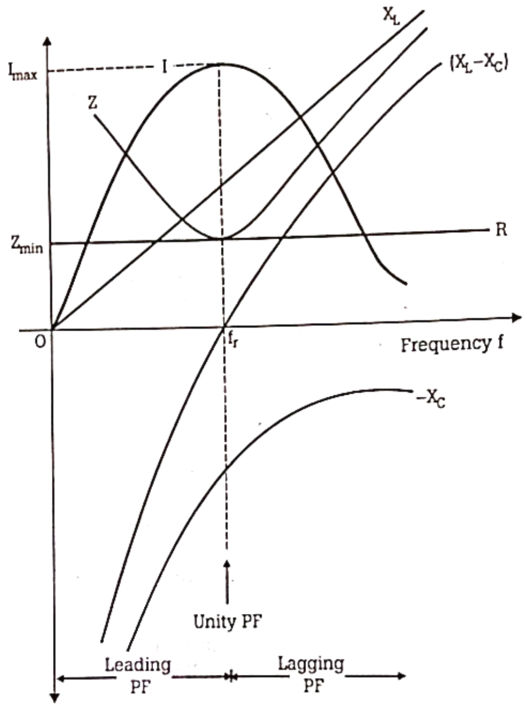
Current through branch (4Ω) = V_B/4 = (3.54)/4
= 0.885 amp from node B to Reference node ½ mark

6 d) Draw the curves for following parameters during series resonance condition with respect to frequency.

i) X_L
ii) X_C
iii) I
iv) Z

Ans:

Model Answers
Summer – 2019 Examinations
Subject & Code: Electrical Circuits & Networks (17323)



1 mark for each curve of X_L, X_C, I & Z

6 e) Explain the concept of initial condition and state switching circuits for the elements R, L, C.

Ans:

Concept of Initial Condition:

When a circuit is disturbed by switching at instant t = 0, then the circuit condition at t = 0 instant is called "Initial Condition". 1 mark

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

i) Resistor:

At any time it acts like resistor only, with no change in condition. 1 mark

ii) Inductor:

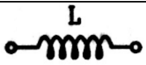
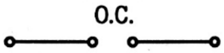
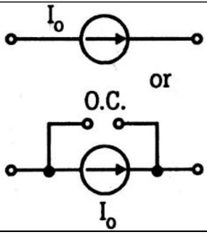
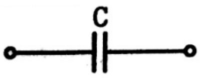
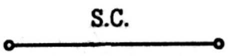
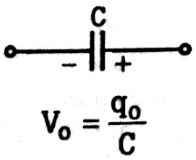
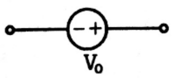
The current through an inductor cannot change instantly. If the inductor current is zero just before switching, then whatever may be the applied voltage, just after switching the inductor current will remain zero. i.e the inductor must be acting as open-circuit at instant t = 0. If the inductor current 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. 1 mark

As time passes the inductor current slowly rises and finally it becomes constant. Therefore the voltage across the inductor falls to zero$\left[v_L = L\frac{di_L}{dt} = 0\right]$.

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 1 mark

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 initial conditions are summarized in following table:

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

6 f) Compare single phase system with three phase system by using following points.
i) Voltage.
ii) Transmission efficiency.
iii) Size of machine to produce same output.
iv) Cross sectional area of conductor.

Ans:

Particulars	**Single-phase System**	**Three-phase System**
Voltage	Only one voltage level is possible i.e phase voltage	Two voltage levels are possible i.e Phase voltage and Line voltage
Transmission Efficiency	Comparatively less	Comparatively higher
Size of machine to produce same output	Comparatively Bigger	Comparatively Smaller
Cross-sectional area of conductor	Comparatively Bigger	Comparatively Smaller

1 mark for each point = 4 marks