11819

3 Hours / 70 Marks

22324

Seat No. | | | | | | | | |

Instructions :

(1) All Questions are compulsory.

(2) Answer each next main Question on a new page.

(3) Illustrate your answers with neat sketches wherever necessary.

(4) Figures to the right indicate full marks.

(5) Assume suitable data, if necessary.

Marks

1. Attempt any FIVE of the following : **10**

(a) Define active power and reactive power for RLC series circuit.

(b) Draw impedance triangle and voltage triangle for RL series circuit.

(c) Define susceptance and admittance for parallel circuit.

(d) Define quality factor for parallel resonance and write its mathematical expression.

(e) Draw sinusoidal waveform of 3 phase emf and indicate the phase sequence.

(f) Write the procedure of converting a current source into voltage source.

(g) State superposition theorem applied to d.c. circuits.

2. Attempt any THREE of the following : **12**

(a) Draw a circuit diagram of R.C. series circuit. Draw impedance triangle and power triangle for same circuit.

(b) Two circuits the impedance of which are given by $Z_1 = 6 + j8$ ohm and $Z_2 = 8 - j6$ ohm are connected in parallel. If the applied voltage to the combination is 100 V. Find (i) Current and power factor at each branch (ii) Overall current and power factor of the combination. (iii) Power consumed by each impedance. Draw phasor diagram.

(c) State any four advantages of polyphase circuits over single phase circuit.

(d) Using mesh analysis, find loop currents I1 and I2 in the circuit, as shown in fig no. 1

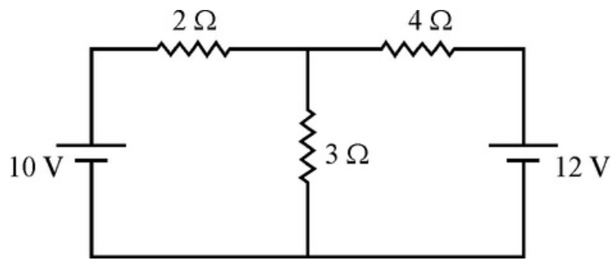


Fig. 1

3. Attempt any THREE of the following : 12

(a) Derive the expression for resonance frequency for a RLC series circuits.

(b) Compare series resonance to parallel resonance on the basis of

(i) Resonant Frequency (ii) Impedance

(iii) Current (iv) Magnification

(c) Compare star & delta connection. (any four points)

(d) By using Nodal analysis calculate the current in 110 □ resister and p.d. across 110 □ resistor as shown in fig. no. 2.

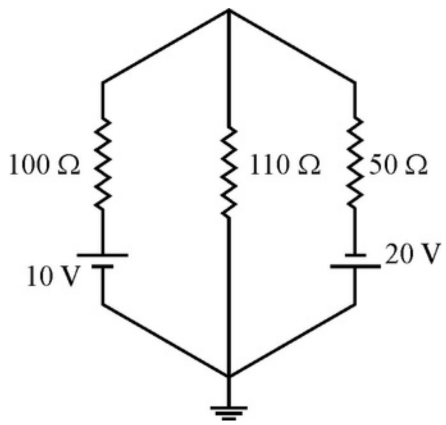


Fig. 2

(e) Convert following circuit as shown in fig. no. 3 into Thevenins circuit across A & B.

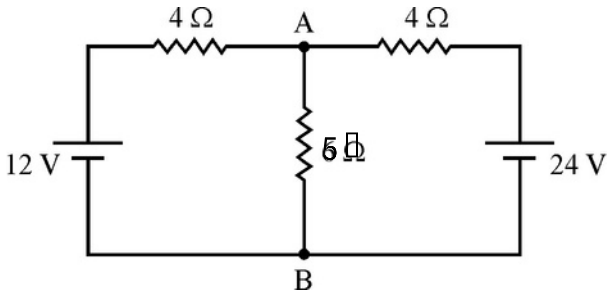


Fig. 3

4. Attempt any THREE of the following : 12

(a) A resistance of 100 Ω, an inductance of 0.2H and capacitance of 150 μF are connected in series across 230 V, 50 Hz ac supply. Calculate the current drawn by the circuit, power factor of the circuit, its nature and power consumed by the circuit. Define :

(b)

(i) Admittance

(ii) Susceptance

(iii) Conductance (iv) State the units for admittance & conductance Delta connected induction motor is supplied by 3 phase, 400 V, 50 Hz. Supply the line

(c) current is 43.03 amp and the total power from the supply is 24 kW. Find resistance and reactance per phase of motor. Derive the formulae for star to delta transformation.

(d)

5. Attempt any TWO of the following : 12

(a) A choke coil has a resistance of 4 Ω and inductance of 0.07 H is connected in parallel with another coil of resistance 10 Ω and inductance of 0.12 H. The combination is connected to 230 V, 50 Hz supply. Determine total current and current through each branch.

(b) Determine the current in 40 □ and 10 □ as shown in fig. no. 4 by node voltage analysis method.

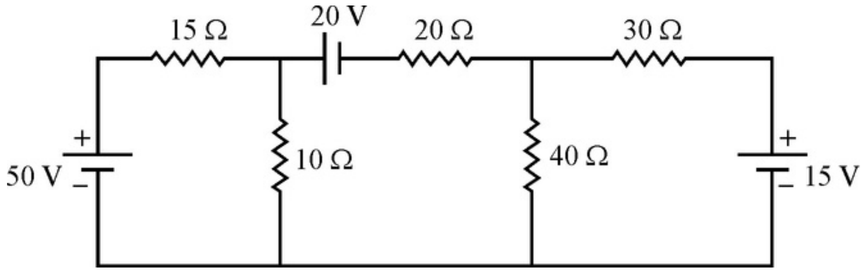


Fig. 4

(c) Use Norton's theorem to find the current through 3 □ resistance, for the circuit shown in fig. no. 5

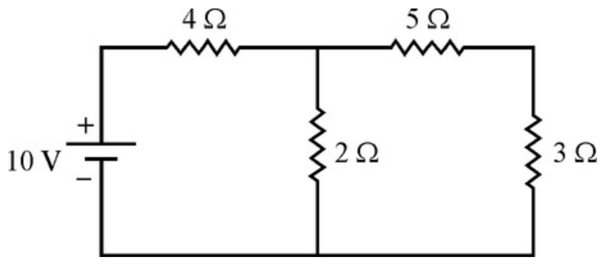


Fig. 5

6. Attempt any TWO of the following : 12

(a) Voltage across a coil is 146.2 V and across a series resistance is 150 V, when they are connected across 220 V, 50 Hz supply. If supply current is 10 amp, find

(i) Resistance of coil

(ii) Inductance of coil

(iii) Power consumed by coil

(iv) Power factor of total circuit

(b) In a 3 phase star connected system, derive the relationship $V_L = \sqrt{3}$ Vph.

(c) State the Thevenin's theorem. Also write stepwise procedure for applying Thevenin's theorem to simple circuits.

____

Model Answers

Winter – 2018 Examinations

Subject & Code: Electrical Circuits (22324)

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
Winter – 2018 Examinations
Subject & Code: Electrical Circuits (22324)

1 Attempt any FIVE of the following: 10

1 a) Define active power and reactive power for RLC series circuit.

Ans:

Active Power (P):

Active power (P) is given by the product of voltage, current and the cosine of the phase angle between voltage and current. 1 mark

Unit: watt (W) or kilo-watt (kW) or Mega-watt (MW).

$P = VI\cos\phi = I^2R$ watt

Reactive Power (Q):

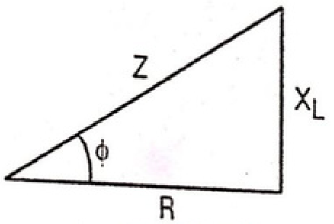
Reactive power (Q) is given by the product of voltage, current and the sine of the phase angle between voltage and current. 1 mark

Unit: volt-ampere-reactive (VAr), or kilo-volt-ampere-reactive (kVAr) or Mega-volt-ampere-reactive (MVAr)

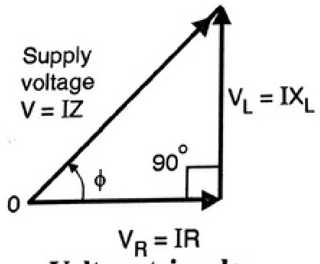
$Q = VI\sin\phi = I^2X$ volt-amp-reactive.

1 b) Draw impedance triangle and voltage triangle for RL series circuit.

Ans:



Impedance Triangle



Voltage triangle

1 mark for each triangle = 2 marks

1 c) Define susceptance and admittance for parallel circuit.

Ans:

Admittance (Y):

Admittance is defined as the ability of the circuit to carry (admit) alternating current through it. It is the reciprocal of impedance Z. i.e Y = 1/Z. 1 mark

For parallel circuit consisting two branches having impedances Z1 and Z2 in parallel, the equivalent impedance of parallel combination is given by, (Equations are optional)

where, Y is the equivalent admittance of the parallel circuit

Y1 and Y2 are the admittances of the two branches respectively.

If the equivalent impedance is expressed as , then the admittance is obtained as,

Susceptance (B):

Susceptance is defined as the imaginary part of the admittance.
It is expressed as, 1 mark

B = ———

In DC circuit, the reactance is absent, hence X = 0 and susceptance equals to zero.

1 d) Define quality factor for parallel resonance and write its mathematical expression.

Ans:

Quality Factor of Parallel AC Circuit at resonance:

The quality factor or Q-factor of parallel circuit is defined as the ratio of the current circulating between two branches of the circuit to the current taken by the parallel circuit from the source. 1 mark

It is the current magnification in parallel circuit.

Formula:

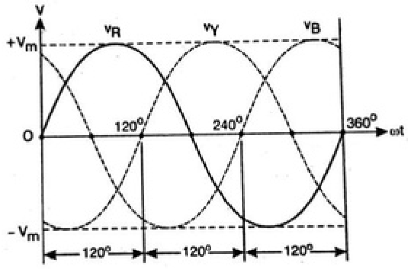
Quality factor (Q-factor) = Current magnification $-\sqrt{-}$ 1 mark

Where, R is the resistance of an inductor in Ω,

L is the inductance of an inductor in henry,
C is capacitance of capacitor in farad,

1 e) Draw sinusoidal waveform of 3 phase emf and indicate the phase sequence.

Ans –



1½ marks for waveform

½ mark for phase sequence

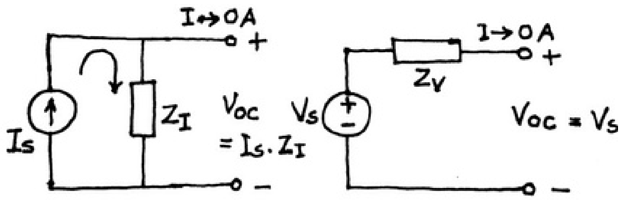
Phase sequence is R-Y-B.

1 f) Write the procedure of converting a given current source into voltage source.

Ans:

Conversion of current source into equivalent voltage source:

Let IS be the practical current source magnitude and
ZI be the internal parallel impedance.
VS be the equivalent practical voltage source magnitude and
ZV be the internal series impedance of the voltage source.

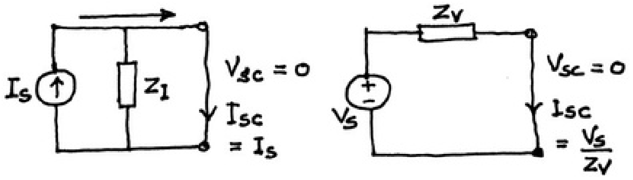


1 mark for diagram
1 mark for description

The open circuit terminal voltage of current source is V_{OC} = IS ZI

The open circuit terminal voltage of voltage source is VOC = VS
Therefore, we get VS = IS × ZI ....(1)

OR



The short circuit output current of current source is ISC = IS
The short circuit output current of voltage source is ISC = VS / ZV
Therefore, we get IS = VS / ZV ....(2)
On comparing eq. (1) and (2), it is clear that ZI = ZV = 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, VS = IS × ZI

1 g) State superposition theorem applied to the d.c. circuits.

Ans:

Superposition Theorem applied to D.C. circuits:

Superposition theorem states that in any linear, bilateral, multisource network, the response (voltage across any element or current through any element) of any branch is equal to the algebraic sum of the responses produced in it with each source acting alone, while the other sources are replaced by their internal resistances. 2 marks

OR

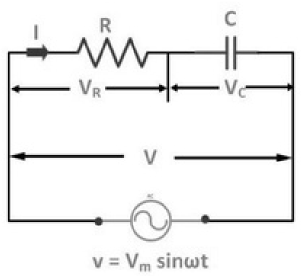
Any other equivalent valid statement

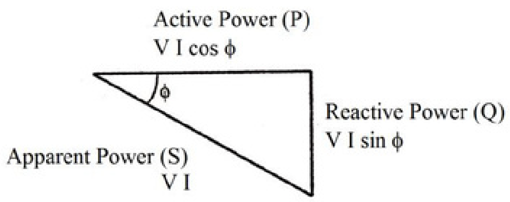
2 Attempt any THREE of the following: 12

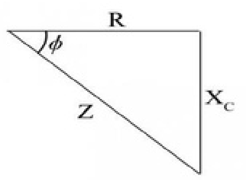
2 a) Draw a circuit diagram of R.C. series circuit. Draw impedance triangle and power triangle for same circuit.

Ans –

1 mark for circuit
½ mark for each of power & voltage triangle

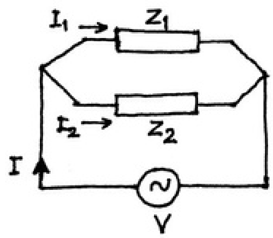






2 b) Two circuits the impedance of which are given by Z1 = 6 + j8 ohm and Z2 = 8 – j6 ohm are connected in parallel. If the applied voltage to the combination is 100V, Find:
(i) Current and power factor at each branch.
(ii) Overall current and power factor of the combination.
(iii) Power consumed by each impedance. Draw phasor diagram.

Ans:



Data given:

□

□

1 mark

(i) Current and power factor at each branch:

Current of branch 1: I1 = V/Z1 =

Power factor of branch 1: cos(53.13°) = **0.6 lagging**

Current of branch 2: I2 = V/Z2 =

Power factor of branch 2: cos(36.87°) = **0.8 leading**

1 mark

(ii) Overall current and power factor of the combination:

Over all current I = I1+I2 =

Overall power factor: cos(8.13°) = **0.98 lagging** 1 mark

(iii) Power consumed by each impedance:

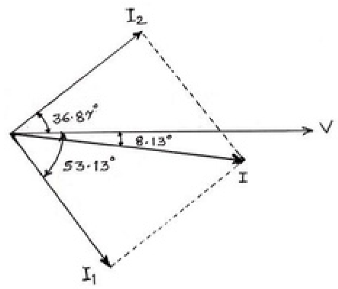
Power consumed by Z1 : V.I1.cos□1 = (100)(10)cos(53.13°) = **600W OR**

$I1^2R1 = (10)^2(6) = 600W$

Power consumed by Z2 : V.I2.cos□2 = (100)(10)cos(36.87°) = **800W OR**

$I2^2R2 = (10)^2(8) = 800W$

(iv) Phasor diagram: 1 mark



2 c) State any four advantages of polyphase circuits over single phase circuit.

Ans:

Advantages of polyphase (3-phase) circuits over Single-phase circuits:

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.

1 mark for 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) For same power rating, three-phase motors are cheaper than the single-phase motors.

2 d) Using mesh analysis, find loop currents I1 and I2 in the circuit, as shown in fig. no. 1

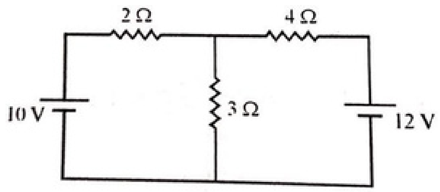
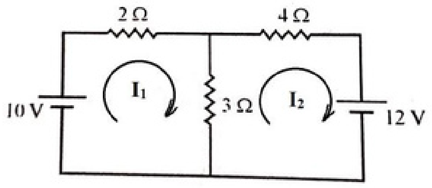


Fig. 1

Ans:
Mesh Analysis:
i) There are two meshes in the network.



ii) Mesh currents I1 and I2 are marked clockwise as shown.
iii) By tracing mesh 1 clockwise, KVL equation is,

1 mark

By tracing mesh 2 clockwise, KVL equation is,

1 mark

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

*   + [   ] *   +

| |

By Cramer's rule,

| |

1 mark

| |

1 mark

3		**Attempt any THREE of the following:**	**12**

3 a) Derive the expression for resonance frequency for a RLC series circuit.

Ans:

Resonant Frequency of Series RLC Circuit:

In RLC series circuit the resonance occurs when the inductive reactance (XL) becomes equal to the capacitive reactance (XC). — 1 mark for equations of reactances

Inductive reactance is given by XL= 2πfL

Capacitive reactance is given by XC = ——

The inductive reactance (XL) becomes equal to capacitive reactance (XC) only at one particular frequency, which is known as resonant frequency and it is denoted by fr. — 1 mark for resonance condition

Hence at resonance,

XL - XC = 0

XL= XC

2 fr L = —— — 1 mark

Rearranging above equation,
We get,

$(fr)^2$ = ——

fr = —— √ Hz OR □r = —— √ rad/sec — 1 mark

3 b) Compare series resonance to parallel resonance on the basis of
(i) Resonant frequency (ii) Impedance (iii) Current (iv) Magnification

Ans:

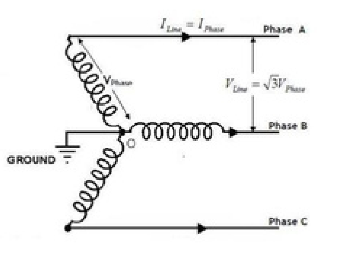
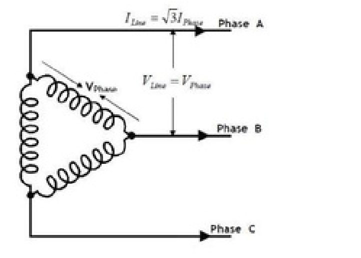
Parameter	Series Resonant Circuit	Parallel Resonant Circuit
Resonant frequency	√ ——	—— √
Impedance	Minimum Z= R ohms	Maximum —
Current	Maximum –	Minimum —
Magnification	Voltage magnification	Current magnification

1 mark for each point = 4 marks

3 c) Compare star and delta connection.(Any four points)

Ans:

Model Answers
Winter – 2018 Examinations
Subject & Code: Electrical Circuits (22324)

Parameter	Star Connection	Delta Connection
Basic definition	One terminal of each of the three branches are connected together to form a common point. Such a connection is known as Star Connection	The three branches of the network are connected in such a way that it forms a closed loop. Such a connection is known as Delta Connection
Connection terminals	The similar ends of the of three coils are connected together to form a common point.	The end of each coil is connected to the starting point of the other coil that opposite terminals of the coils are connected together to form means the a closed loop.
Neutral point	Neutral or the star point exists in the star connection.	Neutral point does not exist in the delta connection.
Relation between line and phase current	Line current is equal to the Phase current.	Line current is equal to √ times the Phase Current.
Relation between line and phase voltage	Line voltage is equal to √ times the Phase Voltage	Line voltage is equal to the Phase voltage.
Diagram		

1 mark for each of any four points = 4 marks

3 d) By using nodal analysis, calculate the current in 110Ω resister and p.d. across 110Ω resistor as shown in fig. no. 2

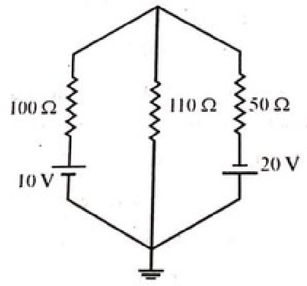
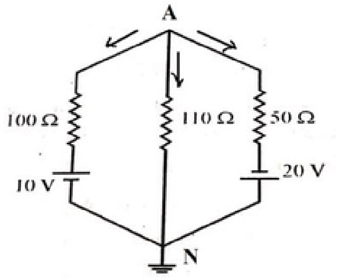


Fig. 2

Ans:



1 mark for diagram with currents

By applying KCL at node A, the node voltage equation can be written as:

1 mark

( )

 P. D. across 110Ω resistor is

(Terminal N is at higher potential than terminal A)

1 mark

Current flowing through 110Ω is given by,

** I = 0.0697A flowing from terminal N to A**

1 mark

3 e) Convert following circuit as shown in fig. no. 3 into Thevenin's circuit across A & B.

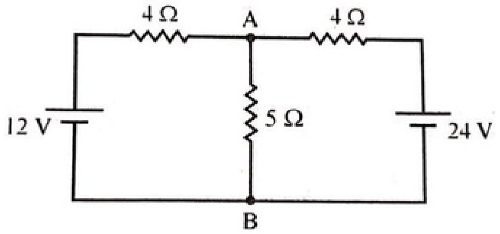


Fig. 3

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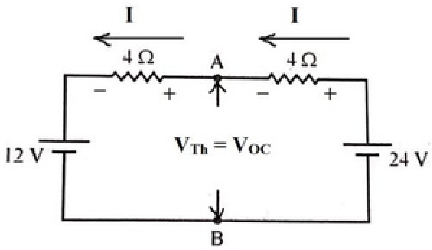
Ans:

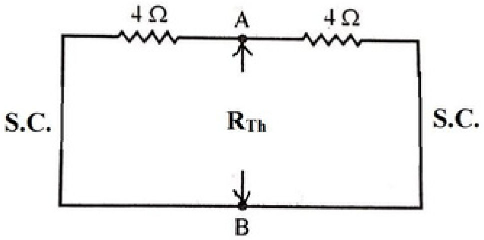
Determination of Thevenin's Equivalent Voltage Source (VTh):



½ mark for figure

Thevenin's equivalent voltage source VTh is the open circuit voltage across the load terminals A-B due to internal sources, as shown in the figure.
By tracing loop in anti-clockwise direction, the voltage equation can be written as:
24 – 4I – 4I – 12 = 0
Circuit current I = (24-12)/8 = 1.5 A
The Thevenin's equivalent voltage is given by,
OR
VTh = VOC = 24 – 4I = 24 – 6 = **18 volt** 1 mark
= 12 + 4I = 12 + 6 = **18 volt**

Determination of Thevenin's Equivalent Resistance (RTh):

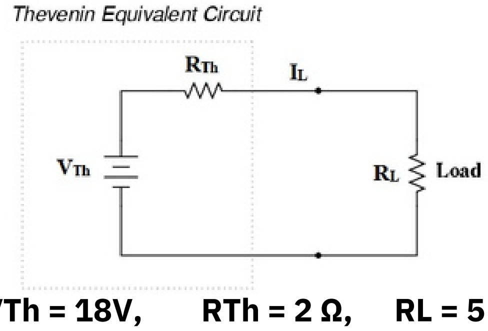


½ mark for figure

Thevenin's equivalent resistance is the resistance seen between the open-circuited load terminals while looking back into the network, with internal independent voltage sources replaced by short-circuit and independent current sources replaced by open-circuit, as shown in the following figure.

_____ ▯ 1 mark

Thevenin's Equivalent Circuit:



1 mark

VTh = 18V, RTh = 2 Ω, RL = 5 Ω

4 **Attempt any THREE of the following.** **12**

4 a) A resistance of 100Ω, an inductance of 0.2 H and capacitance of 150 ▯F are connected in series across 230V, 50 Hz ac supply. Calculate the current drawn by the circuit, power factor of the circuit, its nature and power consumed by the circuit.

Ans:

Given: R = 100 ▯, L = 0.2H, C = 150 μF = 150×10^{-6}F, V = 230V, f = 50 Hz

XL=2 π f L = 2 x π x 50 x 0.2 = 62.83 Ω
XC = 1/(2 π f C) = 1/ (2×π×50×150×10^{-6}) = 21.22 Ω
Impedance =Z= √[R^2+($XL-XC)^2$] = √{100^2 + ($62.83-21.22)^2$)} = **108.31 Ω OR**
= 100+j(62.83 - 21.22) = (100 +j41.61) = **108.31 22.59°Ω** 1 mark

(1) Total current = I = V/Z = 230 0°/ 108.31 22.59° = **2.123 - 22.59° A** 1 mark

(2) Power factor = cos Ø = R/Z = 100/ 108.31 = **0.923 laggingOR**
= cos(22.59°) **= 0.923 lagging** 1 mark
(3) Nature of power factor is **lagging**.
(4) P = I^2R = 2.123^2 x 100 = **450.7 watt** **OR** 1 mark
P = V I cos Ø = 230 x 2.123 x 0.923 = **450.7 watt**

4 b) Define: (i) Admittance (ii) Susceptance
(iii) Conductance (iv) State the units of admittance and conductance

Ans:

(i) Admittance (Y):
Admittance is defined as the ability of the AC circuit to carry (admit) alternating current. It is also defined as reciprocal of impedance (Y). 1 mark

Admittance (Y) = – mho (Ʊ)

(ii) 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. 1 mark

OR

It is ratio of reactance (X) to squared impedance (Z^2).

In general, Susceptance (B) — siemen

(iii) 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

OR

It is the ratio of resistance (R) to squared impedance (Z^2)

Conductance(G) = — siemen

(iv) Units of admittance and conductance: 1 mark
Unit of Admittance (Y) = **mho**
Unit of Conductance (G) = **siemen**

4 c) Delta connected induction motor is supplied by 3 phase 400V, 50 Hz supply the line current is 43.03 amp and the total power from the supply is 24 kW. Find the resistance and reactance per phase of the motor.

Ans:

Data Given:
VL= 400V , 3 ϕ (Delta connected) IL= 43.03 A
P = 24 kW f = 50 Hz

In Delta connection IL = √3 IPh

Iph = $\frac{}{\sqrt{}}$

Iph = $\frac{}{\sqrt{}}$

Iph = 24.84 A ½ mark

In Delta connection VL=Vph
Hence,

Vph = VL = 400 V

Total three-phase power supplied to motor is given by,

P = 3 Vph Iph cosϕ

cosϕ = —— = —— = **0.805 lagging** ½ mark

i) Impedance per phase Zph:

Zph = ——

Zph = ——

Impedance per phase **Zph = 16.10Ω** 1 mark

ii) Resistance per Phase Rph:

cosϕ = —— Rph = Zph cosϕ

Rph= 16.10 x 0.805

Rph = 12.96 Ω 1 mark

iii) Reactance per Phase XLph:

XLph = √ ( )

X_{Lph} = √

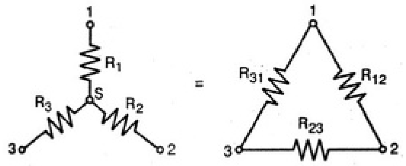
XLph = 9.55 Ω 1 mark

(Correct solution by ant other method may please be considered)

4 d) 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 R1-2

For delta circuit, resistance between terminals 1 & 2, R1-2

Similarly, the resistance between terminals 2 & 3 can be equated as, And the resistance between terminals 3 & 1 can be equated as,

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

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

[ ]

Similarly, we can obtain,

[ ]

[ ]

1 mark for (eq.5, 6 & 7)

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

[ ]

[ ]

[ ]

1 mark for (eq.8, 9 & 10)

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

1 mark for eq. 11

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

Similarly, we can obtain,

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

Thus using known star connected resistors R1, R2 and R3, the unknown resistors R12, R23 and R31 of equivalent delta connection can be determined.

5 Attempt any TWO of the following: 12

5 a) A choke coil has a resistance of 4Ω and inductance of 0.07H is connected in parallel with another coil of resistance 10Ω and inductance 0.12H. The combination is connected to 230V, 50Hz supply. Determine total current and current through each branch.

Ans:

Data Given: $R_1 = 4\ \Omega$ $L_1 = 0.07H$ $R_2 = 10\ \Omega$ $L_2 = 0.12H$ $V = 230V$, $f = 50Hz$ — ½ mark for each of XL1 & XL2

$X_{L1} = 2\ fL_1 = 2\ (50)(0.07) = 21.99\ \ 22\ \Omega$

$X_{L2} = 2\ fL_2 = 2\ (50)(0.12) = 37.7\ \Omega$

$Z_1 = R_1 + j\,X_{L1} = (4+j22) = 22.35\ 79.7\ \Omega$ — 1 mark

$Z_2 = R_2 + j\,X_{L2} = (10+j37.7) = 39\ 75.144\ \Omega$ — 1 mark

Branch 1 current is given by, — 1 mark

= **10.3 -79.7 A = (1.84 – j10.13) A**

Branch 2 current is given by,

= **5.89 -75.144 A = (1.51 - j5.7) A** — 1 mark

Total current is,

$I = I_1 + I_2 = (1.84 – j10.13) + (1.51 - j5.7)$

I = (3.35 - j15.825)A = 16.17 -78.04 A — 1 mark

5 b) Determine the current in 40Ω and 10Ω as shown in fig. no. 4 by node voltage analysis method.

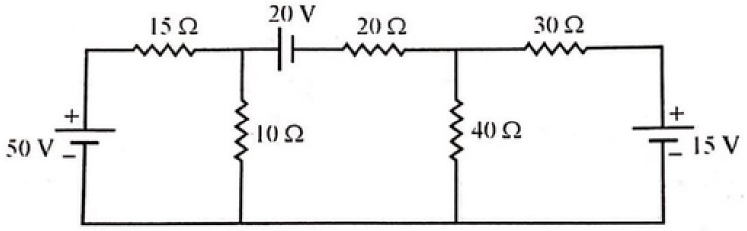
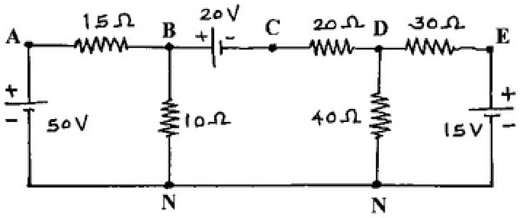


Fig. 4

Ans:

Node Voltage Analysis Method:

Step I: Mark the nodes and reference node. — 1 mark for node identification



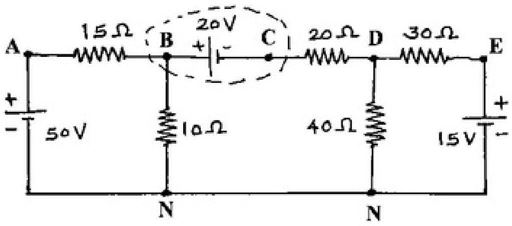
Let the nodes be A, B, C, D, E and reference node is N.

From the above circuit diagram we can write,

Only two unknown voltages are and .

Model Answers
Winter – 2018 Examinations
Subject & Code: Electrical Circuits (22324)

Step II: Apply KCL at nodes with unknown voltages



Since there is a voltage source of 20V between nodes B and C, for writing KCL equations, let us treat nodes B and C with source as "Supernode", encircled by dotted line.
By KCL at this supernode, we can write

——— — ———

——— — ————

[— — —] — — [—] 1 mark for eq. (i)

By KCL at node D, we write

——— — ———

———— — ———

[—] — — [— — —] 1 mark for eq. (ii)

Step III: Solving Simultaneous equations
Expressing eq. (i) and (ii) in matrix form,

* +[ ] * +

| |

By Cramer's rule,

| | 1 mark for stepwise solution for VB and VD

———— ————— ———

| |

———— ————— ———

Step IV: Solving for currents
Current in 40Ω resistor is given by, 1 mark

— ——

Current in 10Ω resistor is given by,

1 mark

5 c) Use Norton's theorem to find the current through 3 Ω resistance, for the circuit shown in fig. no. 5

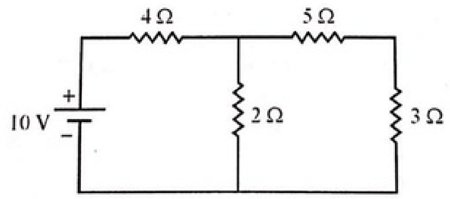
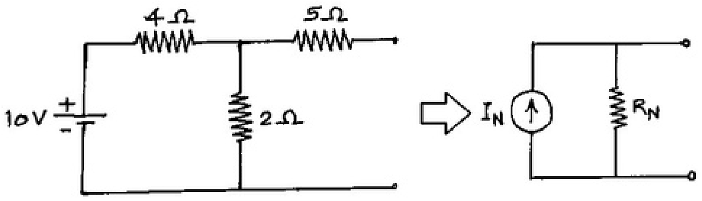


Fig. 5

Ans:

Solution by Norton's Theorem:

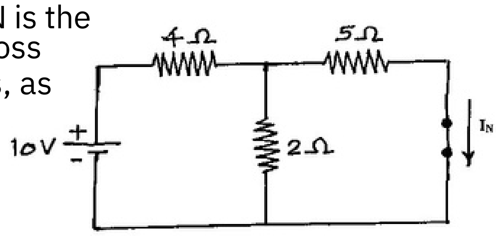
According to Norton's theorem, the circuit between load terminals excluding load resistance can be represented by simple circuit consisting of a current source IN in parallel with a resistance RN, as shown in the following figure.



1 mark

Determination of Norton's Equivalent Current Source (IN): Norton's equivalent current source IN is the current flowing through a short-circuit across the load terminals due to internal sources, as shown in fig.(a).

Total resistance across 10V source is,



(a)

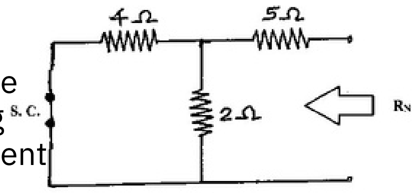
marks for stepwise solution of IN with circuit diagram

Therefore, current supplied by source,

The resistances 2Ω and 5Ω are in parallel. By current division, the current flowing through 5Ω is same as IN.

Determination of Norton's Equivalent Resistance (RN):

Norton's equivalent resistance is the resistance seen between the load terminals while looking back into the network, with internal independent voltage sources replaced by short-circuit and independent current sources replaced by open-circuit. Referring to fig.(b),



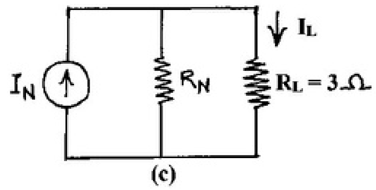
(b)

1 mark for stepwise solution of R^N

1 mark for equivalent

circuit

Determination of Load Current (IL):
Referring to fig.(c), the load current is



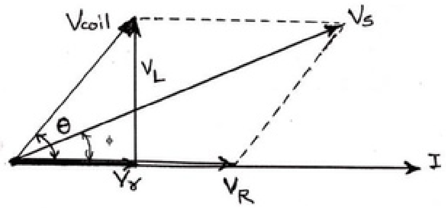
1 mark for IL

6 Attempt any TWO of the following: 12

6 a) Voltage across a coil is 146.2V and across series resistance is 150V, when they are connected across 220V, 50Hz supply. If supply current is 10 amp, find:

i) Resistance of coil
ii) Inductance of coil
iii) Power consumed by coil
iv) Power factor of total circuit

Ans:
Data given:
VS = 220V, f = 50Hz, VCoil = 146.2V, VR = 150V, I = 10A



1 mark for phasor diagram

Referring to the phasor diagram above,

√

½ mark for

 Voltage across resistance of coil, Vr = VCoil cos = (146.2)(0.1032) = 15.087 volt ½ mark
 Voltage across inductance of coil, VL = VCoil sin = (146.2)sin( ) = 145.42volt ½ mark

(i) **Resistance of Coil:**
Resistance of coil, r = Vr / I = 15.087/10 = **1.5087Ω** ½ mark for r

(ii) **Inductance of Coil:**
Inductive Reactance of Coil, XL = VL / I = 145.42/10 = 14.54Ω
Inductance of Coil, L = XL/(2 f) = 14.54/(2 ×50) = **0.0462H** 1 mark for L

(iii) **Power consumed by coil:**
$P = I^2r = (10)^2(1.5087)$ = **150.87 watt** 1 mark for P

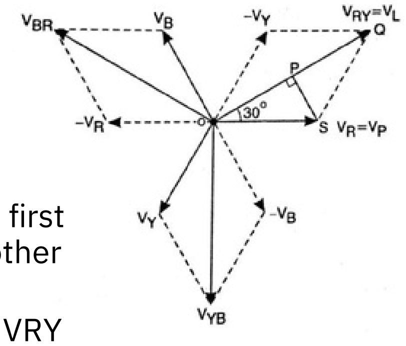
(iv) **Power factor of total circuit:**
Referring to the phasor diagram above,
VS cos = (Vr + VR)
Power factor of total circuit, cos = (Vr + VR)/ VS = (15.087+150)/220
 cos = 0.75 lagging 1 mark for total pf

6 b) In a 3 phase star connected system, derive the relationship V̅L = √ Vph.

Ans:

Relationship Between Line voltage and Phase Voltage in Star Connected System:

Let VR, VY and VB be the phase voltages.
VRY, VYB and VBR be the line voltages.
The line voltages are expressed as:
VRY = VR – VY
VYB = VY – VB
VBR = VB – VR



2 marks for phasor diagram

In phasor diagram, the phase voltages are drawn first with equal amplitude and displaced from each other by 120 . Then line voltages are drawn as per the above equations. It is seen that the line voltage VRY is the phasor sum of phase voltages VR and –VY. We know that in parallelogram, the diagonals bisect each other with an angle of 90 .

3 marks for stepwise explanation

Therefore in OPS, P = 90 and O = 30 .

[OP] = [OS] cos 30

Since [OP] = VL/2 and [OS] = Vph

√

√

Thus **Line voltage = √ (Phase Voltage)**

1 mark for final answer

6 c) State the Thevenin's theorem. Also write stepwise procedure for applying Thevenin's theorem to simple circuits.

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 VTh in series with an impedance ZTh, where the source voltage VTh is equal to the open circuit voltage appearing across the two terminals due to internal sources of circuit and the series impedance ZTh 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.

2 marks for theorem

Stepwise Procedure for applying Thevenin's theorem to simple circuits: Step I: Identify the load branch (RL): It is the branch whose current is to be determined.

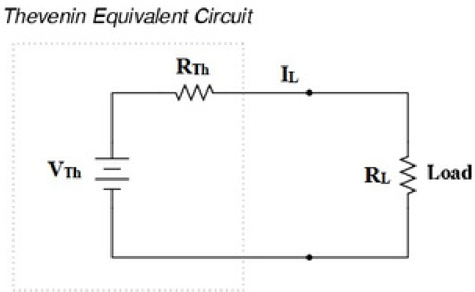
Step II: Calculation of VTh: Remove RL and find open circuit voltage across the load terminals A and B, which are now open due to removal of RL.

Step III: Calculation of RTh: 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

4 marks for Stepwise procedure

replaced by open-circuit.

Step IV: Thevenin's equivalent circuit:



Step V: Determination of Load current:

IL= VTh/(RTh+RL)

22324

21819

3 Hours / 70 Marks

Seat No. | | | | | | | | |

Instructions :

(1) All Questions are compulsory.

(2) Answer each next main Question on a new page.

(3) Illustrate your answers with neat sketches wherever necessary.

(4) Figures to the right indicate full marks.

(5) Assume suitable data, if necessary.

(6) Use of Non-programmable Electronic Pocket Calculator is permissible.

Marks

1. Attempt any FIVE of the following : 10

(a) Draw power triangle for R-C series circuit. State the nature of power factor of this circuit.

(b) Draw a phasor diagram for series R-L circuit showing supply voltage V, supply current I, voltage across resistor VR & voltage across inductor VL.

(c) What is current magnification in parallel R-L-C circuit.

(d) Define : Phase sequence and write equations for instantaneous values of 3-ph voltages.

(e) Distinguish clearly between loop and mesh.

(f) State Thevenin's theorem.

(g) State Reciprocity theorem.

2. Attempt any THREE of the following : 12

(a) An AC series circuit consisting of $R = 15\ \Omega$, $L = 0.1$ H and $C = 80\ \mu F$ is supplied from 230 V, 50 Hz power supply. Determine :

(i) Impedance of circuit

(ii) Current drawn by the circuit

(iii) Circuit power factor

(iv) Reactive power drawn by circuit

(b) An AC circuit consists of two branches in parallel.
Branch I : R = 10 Ω and L = 0.1 H in series.
Branch II : C = 50 μF.
If the circuit is supplied form 200 V, 50 Hz supply, determine :
(i) Branch impedances.
(ii) Branch currents
(iii) Circuit power factor
(iv) Power consumed by the circuit

(c) A star connected 3-ph load is supplied from 3-ph, 415 V, 50 Hz supply. If the line current is 20 A and total power taken from supply is 10 kW, then determine :
(i) Load resistance and reactance per phase.
(ii) Load power factor
(iii) Total 3-phase reactive power

(d) Using Node analysis, find current I in the circuit shown in Fig. No. 1.

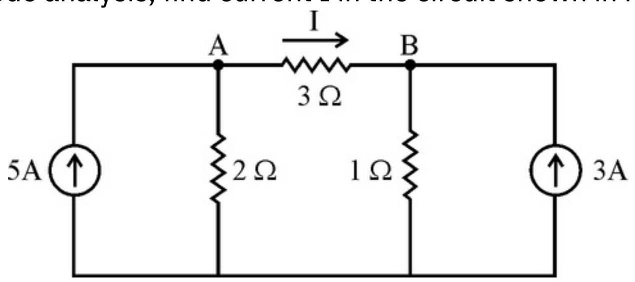


Fig. No. 1

3. Attempt any THREE of the following : 12

(a) A series R-L-C circuit consists of R = 15 Ω, L = 0.5 H and C = 25 μF. If the circuit is supplied from 230 V, 50 Hz Ac supply, determine :
(i) Circuit power factor
(ii) Active power
(iii) Reactive power
(iv) Apparent power

(b) Two parallel impedances Z 1 = (10 + j8) Ω and Z2 = (15 – j10) Ω are connected to 230 V, 50 Hz AC supply. Using admittance method, calculate branch currents, total current and power factor of whole circuit.

(c) Explain 'Neutral Shift' in case of 3-phase star-connected unbalanced load.

(d) With neat circuit diagram, explain how to convert voltage source into current source and vice-versa.

(e) Using Mesh analysis, find current I in the circuit shown in Fig. No. 2.

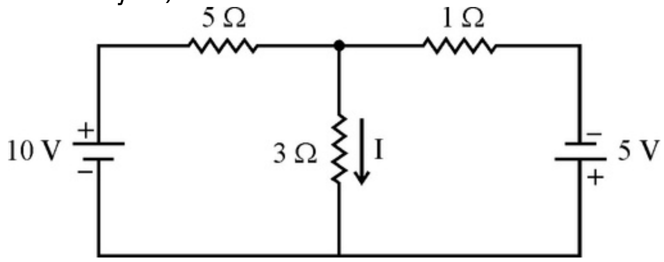


Fig. No. 2

4. Attempt any THREE of the following : 12

(a) An inductive coil having resistance of 5 Ω and inductance of 0.2 H is connected in series with a capacitor of 20 μF. If this combination is connected to 230 V, variable frequency supply, determine :

(i) Resonant Frequency

(ii) Quality factor

(iii) Current at resonance (iv) Voltage across inductive coil at resonance A coil having resistance of 10 Ω and inductance of 0.15 H is connected in parallel with

(b) R-C series combination having R= 5 Ω & C = 20 μF. If supply voltage is 110 V, 50 Hz, then

(i) Draw circuit diagram

(ii) Calculate branch currents using impedance method

(iii) Power absorbed by the coil

(c) Three equal impedances having R = 20 Ω in series with C = 50 μF, are connected in delta across 415 V, 3-ph, 50 Hz AC supply. Determine :

(i) Impedance per phase

(ii) Phase and line currents

(iii) Total 3-ph power consumed by load

(d) With neat circuit diagram, explain the concept of duality in Electric circuit. State any four examples (pairs) of duality in electric circuit.

5. Attempt any TWO of the following : 12

(a) An inductive coil having resistance of 10 Ω and inductance of 0.5 H is connected in parallel with a capacitor of 50 μF. Determine :

(i) Parallel resonant frequency

(ii) Quality factor of parallel circuit

(iii) Power consumed by circuit at resonance, if the supply voltage is 230 V.

(b) Reduce the network shown in Fig. No. 3 by applying Star/Delta or Delta/Star transformation and determine equivalent resistance R_{AB}.

All R = 1 Ω

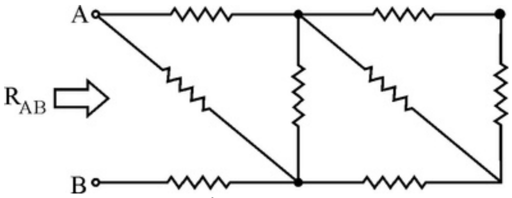


Fig. No. 3

(c) For network shown in Fig. No. 4, determine value of R so that maximum power is delivered to it. Also compute the maximum power delivered.

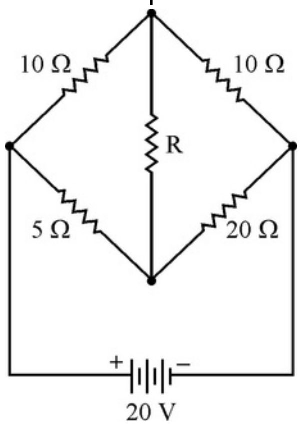


Fig. No. 4

6. Attempt any TWO of the following : 12

(a) A series RLC circuit consists of R = 10 Ω, L = 0.5 H and C = 20 μF, is connected to 230 V, variable frequency supply. Determine :
(i) Resonant frequency
(ii) Voltage magnification
(iii) Current drawn by circuit
(iv) Voltage across each element
(v) Power factor at resonance
(vi) The power consumed at resonance

(b) Draw complete phasor diagram of voltages & currents for balanced delta-connected load, and prove the relationship between :
(i) Line current & phase current
(ii) Line voltage & phase voltage

(c) Apply superposition theorem to compute current I in the network shown in Fig. No. 5.

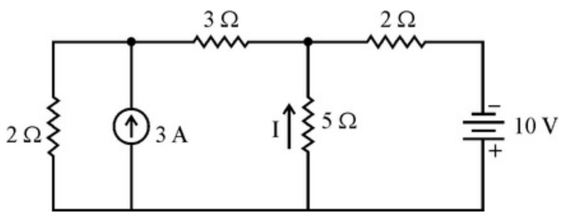


Fig. No. 5

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC-27001-2005 Certified)

Summer – 2019 Examinations
Model Answer
Subject & Code: ELECTRICAL CIRCUITS (22324)

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answ scheme.

2) The model answer and the answer written by candidate may vary but the examiner should assess understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given importance (Not applica for subject English and Communication Skills).

4) While assessing figures, examiner may give credit for principal components indicated in the figure. Th figures drawn by candidate and model answer may vary. The examiner should give credit for any equivalent figure/figures drawn.

5) Credits to be given step wise for numerical problems. In some cases, the assumed constant values vary and there may be some difference in the candidate's answers and model answer (as long as the assumptions are not incorrect).

6) In case of some questions credit may be given by judgment on part of examiner of relevant answer bas on candidate's understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept

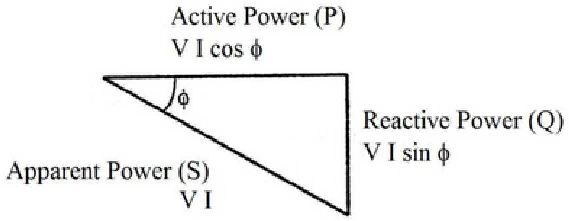
MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC-27001-2005 Certified)

Summer – 2019 Examinations
Model Answer
Subject & Code: ELECTRICAL CIRCUITS (22324)

1 Attempt any FIVE of the following: 10

1 a) Draw power triangle for R-C series circuit. State the nature of power factor of this circuit.

Ans:

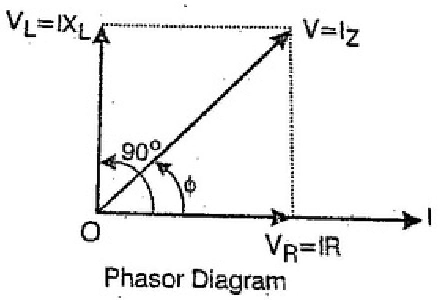


1 Mark for figure

Nature of Power-factor: **Leading** 1 Mark

1 b) Draw a phasor diagram for series R-L circuit showing supply voltage V, supply current I, voltage across resistor VR and voltage across inductor VL.

Ans –



2 Marks for correct phasor diagram

1 c) What is current magnification in parallel R-L-C circuit?

Ans:

Current Magnification in Parallel R-L-C Circuit:

It is the ratio of current circulating between its branches to the line current drawn from the supply.

Current magnification = $\frac{\text{Current through individual L or C branch}}{\text{Total Current}}$ 1 Mark for definition

$= \frac{I_L}{I}$ or $\frac{I_C}{I}$

OR

Current magnification in parallel resonant circuit is also known as Quality factor**.** 1 Mark for equation

$$Q \text{ factor} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

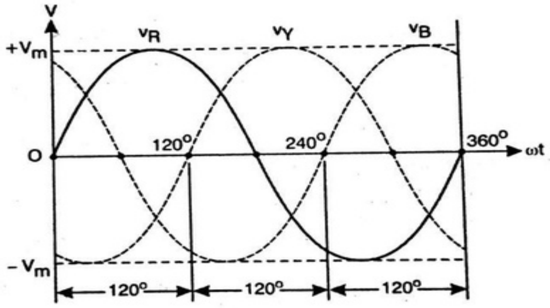
1 d) Define: Phase sequence and write equations for instantaneous value of 3-ph voltages.

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 definition

In the following 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.



Equations for instantaneous value of 3-ph voltages:

$v_R = V_m \sin(\omega t)$ volt

$v_Y = V_m \sin(\omega t - 120^\circ)$ volt

$v_B = V_m \sin(\omega t - 240^\circ)$ volt

$= V_m \sin(\omega t + 120^\circ)$ volt

1 Mark for equations

1 e) Distinguish clearly between loop and mesh.

Ans:

Distinction between Loop & Mesh:

Sr. No.	Loop	Mesh
1	A loop is any closed path in a circuit, in which no node is encountered more than once	A mesh is a loop that has no other loops inside of it
2	Every loop is not a mesh	Every mesh is a loop
3	Loops are used in a more general way for circuit analysis	Meshes are used to analyze planar circuits

1 Mark for each of any two points = 2 Marks

1 f) State Thevenin's theorem.

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 VTh in series with resistance RTh, where the source voltage VTh is equal to the open circuit voltage appearing across the two terminals due to internal sources of circuit and the series resistance RTh 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 correct statement

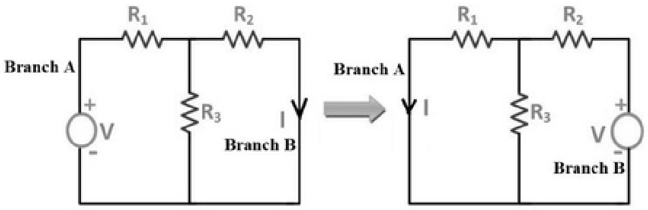
1 g) State Reciprocity theorem.

Ans:

Reciprocity theorem :

Reciprocity Theorem states that in any bilateral network if an **emf E or voltage source V** in one branch, say branch 'A' produces a **current I** in another branch, say branch 'B', then if the **emf E or voltage source**

V is moved from the branch A to the branch B, it will cause the same current I in the first branch 'A', where the emf has been replaced by a short circuit. — 1 Mark for statement, 1 Mark for circuit



2 **Attempt any THREE of the following:** **12**

2 a) An AC series circuit consisting of R = 15 Ω, L = 0.1 H and C = 80 μF is supplied from 230V, 50Hz power supply. Determine:
- (i) Impedance of circuit
- (ii) Current drawn by the circuit
- (iii) Circuit power factor
- (iv) Reactive power drawn by circuit

Ans:

Data Given: R = 15 Ω, L = 0.1 H, C = 80 μF = 80 x 10^{-6} F,
V = 230V, f = 50Hz

1 Mark for each bit = 4 Marks

(i) Impedance of circuit (Z):

$X_L = 2\pi f L$
$= 2 \times \pi \times 50 \times 0.1$
$\mathbf{X_L = 31.42\ \Omega}$

$X_C = 1 / (2\pi f C)$
$= 1 / (2 \times \pi \times 50 \times 80 \times 10^{-6})$
$\mathbf{X_C = 39.79\ \Omega}$

$Z = R + j(X_L - X_C) = 15 + j(31.4 - 39.79)$
$= \mathbf{15 - j8.4 = 17.19\angle -29.24^\circ\ \Omega}$

(ii) Current drawn by circuit:

$$I = \frac{V}{Z} = \frac{230\angle 0^\circ}{17.19\angle -29.24^\circ} = \text{[illegible]}$$

(iii) Circuit Power factor:

$$\cos\phi = \frac{R}{Z} = \frac{15}{17.19} = \mathbf{0.87\ (lead)} \quad \textbf{OR}$$
$$= \cos(29.24) = \mathbf{0.87\ (lead)}$$

(iv) Reactive power drawn by circuit:

$$P = VI\sin\phi = 230 \times 13.37 \times (0.48)$$
$$= \mathbf{1476.04\ watt}$$

2 b) An AC circuit consist of two branches in parallel.
Branch I: R = 10 Ω and L = 0.1 H in series
Branch II: C = 50μF.
If the circuit is supplied from 200V, 50Hz supply, determine:
- (i) Branch impedances.
- (ii) Branch currents
- (iii) Circuit power factor
- (iv) Power consumed by the circuit.

Ans:

Data Given: Branch I: R = 10 Ω and L = 0.1 H
Branch II: C = 50μF = 50 x 10^{-6} F
V = 200V, F = 50Hz

(i) Branch impedances (Z1 and Z2):

Inductive reactance XL = 2πfL
= 2 x π x 50 x 0.1
XL = 31.416 Ω

Capacitive reactance XC = 1 / (2πfC)
XC = 1 / (2π x 50 x 50 x 10^{-6})
XC = 63.66 Ω

Impedance Z1 = (10 + j31.416) Ω = **32.96 ∠72.34°Ω**
Impedance Z2 = 0 – j63.67 Ω = **63.67 ∠-90°Ω**

1 Mark for each bit = 4 Marks

(ii) Branch currents (I_1 and I_2) :

Branch 1 current (I1): I1 = V / Z1 = 200∠0° / 32.96 ∠72.34°
I1 = 6.06 ∠-72.34° A = (1.84 –j5.77) A

Branch 2 current (I2): I2 = V / Z2 = 200∠0° / 63.67 ∠-90°
I2 = 3.14∠90° A = (0 +j3.14) A

Total Current (I): I=I1+I2=(**1.84 –j5.77**)+(**0 +j3.14**)
= 1.84−j 2.63= 3.21∠−55.02° A

Angle between V and I is {0-(-55.02)} = 55.02°

(iii) Circuit power factor (cosφ) :

cosφ = cos(55.02°) = **0.573 lagging**

(iv) Power consumed by the circuit:

P = V × I × cosφ = 200 × 3.21 × 0.573
P = 367.86 watt

2 c) A star connected 3-ph load is supplied from 3-ph, 415V, 50Hz supply. If the line current is 20 A and total power taken from supply is 10 kW, then determine:
(i) Load resistance and reactance per phase.
(ii) Load power factor
(iii) Total 3-phase reactive power

Ans:

Data Given: VL = 415V, f = 50Hz, IL = 20A, P = 10 kW = 10000 W
In Star connection,
VL = √3 x VPh and IL = IPh
Therefore, VPh = VL / √3 = 415 / √3 **= 239.6 Volt.**
And IL = IPh **= 20Amp.**
∴ Impedance per phase, ZPh = VPh / IPh = 239.6 / 20
ZPh= 11.98 Ω

Total three-phase power is given by,
P = 3VPh IPh cosφ **Or** P = √3VL IL cosφ
10 x 10^3 = 3 x 239.6 x 20 x cosφ
Therefore,
cosφ = 10 x 10^3 / (3 x 239.6 x 20)

$\therefore \cos\phi = 0.695$

$\phi = \cos^{-1}(0.695) = \mathbf{45.97°}$

(i) Load Resistance and Reactance per phase: — 1 Mark for RPh

Resistance per phase (Rph) = Zph x $\cos\phi$ = 11.98 x 0.695 — 1 Mark for XPh

Rph = 8.326 Ω

Reactance per phase (Xph) = Zph x $\sin\phi$ = 11.98 x 0.718 — 1 Mark for pf

Xph = 8.601 Ω

(ii) Load Power Factor:

$\cos\phi$ = 0.695 (lagging)

(iii) Total 3-phase reactive power: — 1 Mark for Reactive power

Preactive = √3 x VL x IL x $\sin\phi$ = 3 VPh IPh $\sin\phi$

= √3 x 415 x 20 x sin(45.97°)

= 10336.01 VAR

Preactive = 10.336 kVAR

2 d) Using Node analysis, find current I in the circuit shown in Fig. No. 1

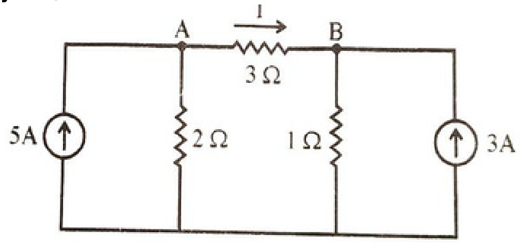


Fig. No. 1

Ans:

Apply KCL at node A

$$-5 + \frac{V_A}{2} + \frac{V_A - V_B}{3} = 0$$

$$V_A\left[\frac{1}{2} + \frac{1}{3}\right] - V_B\left[\frac{1}{3}\right] = 5$$

$V_A[0.833] - V_B[0.33] = 5$........................(1) — 1 Mark for Eq. (1)

Apply KCL at node B

$$\frac{V_B - V_A}{3} + \frac{V_B}{1} - 3 = 0$$

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

$V_A[-0.33] + V_B[1.333] = 3$ ....(2) — 1 Mark for Eq. (2)

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

$$\begin{bmatrix} 0.833 & -0.33 \\ -0.33 & 1.333 \end{bmatrix}\begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 5 \\ 3 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 0.833 & -0.33 \\ -0.33 & 1.333 \end{vmatrix} = 1.1079 - 0.1089 = 0.999$$

By Cramer's rule,

$$V_A = \frac{\begin{vmatrix} 5 & -0.33 \\ 3 & 1.333 \end{vmatrix}}{\Delta} = \frac{(5\times1.333)-(3\times-0.33)}{0.999} = \frac{6.665+0.99}{0.999} = \mathbf{7.662\ volt}$$

$$V_B = \frac{\begin{vmatrix} 0.833 & 5 \\ -0.333 & 3 \end{vmatrix}}{\Delta} = \frac{(0.833\times3)-(-0.33\times5)}{0.999} = \frac{2.499+1.65}{0.999} = \mathbf{4.153\ volt}$$

1 Mark for V_A & V_B

Current through branch AB (3Ω) = (VA – VB)/3 = (7.662 – 4.153)/3

= 1.169 A from A to B

1 Mark for I

3 Attempt any FOUR of the following: 16

3 a) A series R-L-C circuit consists of R = 15 Ω, L = 0.5 H and C = 25μF. If the circuit is supplied from 230V, 50 Hz AC supply, determine:

(i) Circuit power factor
(ii) Active power
(iii) Reactive power
(iv) Apparent power

Ans:

Data Given: R = 15 Ω, L = 0.5 H, C = 25μF = 25×10^{-6}F
V = 230V, f = 50 Hz

(i) Circuit power factor:

$X_L = 2\pi fL = 2\times\pi\times50\times0.5 = 157.08\ \Omega$

$X_C = \frac{1}{2\pi fC} = \frac{1}{2\times\pi\times50\times25\times10^{-6}} = 127.32\ \Omega$

$Z = \sqrt{R^2+(X_L-X_C)^2} = \sqrt{15^2+(157.08-127.32)^2}$

$= 33.326\ \Omega$

Circuit power factor $\cos\phi = \frac{R}{Z} = \frac{15}{33.326}$ = **0.45 (lagging)**

Power factor angle $\phi = \cos^{-1}(0.45) = 63.25°$

1 Mark for each bit = 4 Marks

(ii) Active Power (P):

Circuit current $I = \frac{V}{Z} = \frac{230}{33.326} = 6.901$ A

P = VI cos φ = 230 × 6.901 × 0.45

= **714.25 W**

(iii) Reactive Power (Q):

Q = VI sin φ = 230 × 6.901 × sin(63.25°)

= **1417.36 VAR**

(iv) Apparent Power (S):

Apparent Power = S = VI = 230 × 6.901 = **1587.23 VA**

3 b) Two parallel impedances Z1 = (10 + j8) Ω and Z2 = (15 – j10) Ω are connected to 230V, 50 Hz AC supply. Using admittance method, calculate branch currents, total current and power factor of whole circuit.

Ans:

Data Given: Z1 = (10 + j8) Ω = 12.806∠38.66° Ω
Z2 = (15 – j10) Ω = 18.03∠-33.69° Ω
V = 230∠0° V, f = 50 Hz

$Y1 = \frac{1}{Z1} = \frac{1}{12.806\angle 38.66°} = 0.078\angle -38.66°\ \mho = (0.06 - j0.049)\mho$

$Y2 = \frac{1}{Z2} = \frac{1}{18.03\angle -33.69°} = 0.055\angle 33.69°\ \mho = (0.046 + j0.031)\mho$

1 Mark for each bit = 4 Marks

$Y = Y_1 + Y_2 = G + jB = 0.06 - j0.049 + 0.046 + j0.031 = 0.106 - j0.018$
$= 0.1075\angle -9.64°\ \mho$

(i) Current I1 flowing through admittance Y1:

$= V \times Y1 = (230\angle 0°) \times (0.078\angle -38.66°)$

$I1 = 17.94\angle -38.66°\ A = (14 - j\,11.21)\ A$

(ii) Current I2 flowing through admittance Y2:

$= V \times Y2 = (230\angle 0°) \times (0.055\angle 33.69°)$

$I_2 = 12.65\angle 33.69°\ A = (10.53 + j\,7.02)\ A$

(iii) Total Current (I):

$I = V \times Y = (230\angle 0°) \times (0.1075\angle -9.64°) = \mathbf{24.725\angle -9.64°\ A}$

OR

$I = I1 + I2 = (14 - j\,11.21) + (10.53 + j\,7.02)$
$= (24.53 - j\,4.19) = \mathbf{24.89\angle -9.69°\ A}$

(iv) Power factor (cosϕ)

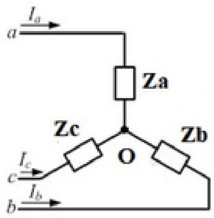
ϕ = voltage ref. angle - current angle = 0 – (-9.64°) = 9.64

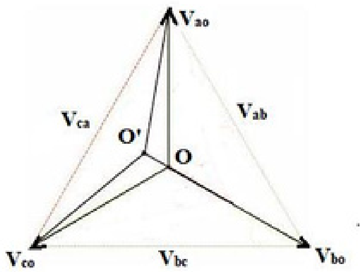
Therefore, Power factor = cos(9.64) = **0.986 (lagging)**

3 c) Explain 'Neutral Shift' in case of 3-phase star-connected unbalanced load.

Ans:

Neutral Shift:





1 Mark for phasor diagram

Electrically "Neutral" means no resultant charge or zero potential condition.

When three impedances are connected in star, there is a common point "O" where one end of each impedance is connected. This common point is called star point. Other remaining ends are connected to the three-phase supply terminals, as shown above.

3 Marks for explanation

When the three-phase supply voltage is balanced and three impedances Za, Zb and Zc are identical i.e Za = Zb = Zc = Z, then all the three impedances carry equal currents but displaced from each other by 120°. Thus currents are balanced, phase voltages are also balanced and the star point "O" is held at zero potential. Even if this point "O" is not connected to neutral, its potential is zero. Therefore, this point is referred as neutral. In other words we can say that under balanced condition (i.e when both supply voltage and load are balanced), the neutral point appears at physical common or star point "O".

When the three-phase supply voltage is balanced but three impedances Za, Zb and Zc are not identical i.e Za ≠ Zb ≠ Zc, then the three impedances carry unequal currents. Thus currents are unbalanced, phase voltages then get unbalanced and the star point "O" can not be maintained at zero potential, rather it has some nonzero potential. Therefore, this point "O" can not be now referred as neutral. However, it is observed that there is some another point O' at which the potential is zero. So this point O' is now referred as neutral. In other words we can say that under unbalanced condition, the neutral point get shifted from star point "O" to some other point O', as shown in the phasor diagram. This is referred as "Neutral Shift".

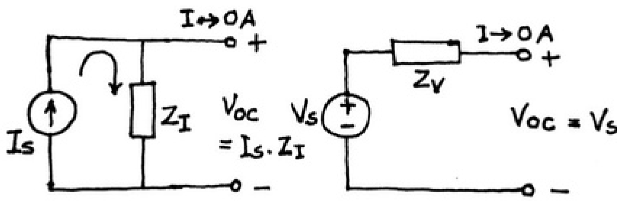
3 d) With neat circuit diagram, explain how to convert voltage source into current source and vice-versa.

Ans:

Conversion of voltage source into equivalent current source & vice-versa:

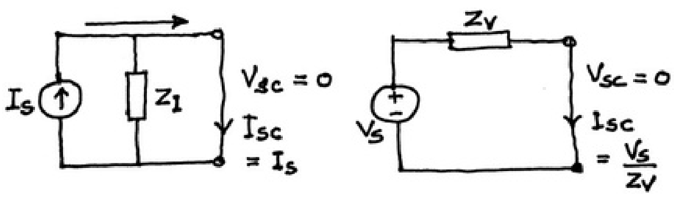
Let VS be the practical voltage source magnitude and

ZV be the internal series impedance of the voltage source.
IS be the equivalent current source magnitude and
ZI be the internal parallel impedance of current source.



1 mark

The open circuit terminal voltage of voltage source is VOC = VS
The open circuit terminal voltage of current source is VOC = IS ZI
Therefore, we get VS = IS ZI ....(1) ½ mark



1 mark

The short circuit output current of voltage source is ISC = VS / ZV
The short circuit output current of current source is ISC = IS
Therefore, we get IS = VS / ZV ....(2)
Therefore, we get VS = IS ZV...............................(3) ½ mark
On comparing eq. (1) and (3), it is clear that ZI = ZV = Z ....(4) ½ mark
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,

VS = IS Z

½ mark

3 e) Using mesh analysis, find current I in the circuit shown in Fig No.2

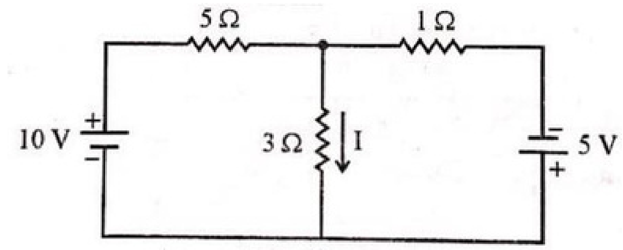
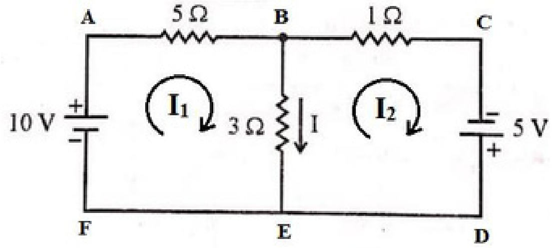


Fig. No. 2

Ans:



By applying KVL to loop ABEFA

$$10 - 5I_1 - 3(I_1 - I_2) = 0$$

$$8I_1 - 3I_2 = 10 \text{ .... (1)}$$

1 Mark for Eq. 1

By applying KVL to Loop DCBED

$$5 - 1I_2 + 3(I_1 - I_2) = 0$$

$$-3I_1 + 4I_2 = 5 \text{ ....(2)}$$

1 Mark for Eq. 2

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

$$\begin{bmatrix} 8 & -3 \\ -3 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 5 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 8 & -3 \\ -3 & 4 \end{vmatrix} = 32 - (9) = 23$$

By Cramer's rule,

$$I_1 = \frac{\begin{vmatrix} 10 & -3 \\ 5 & 4 \end{vmatrix}}{\Delta} = \frac{(10\times4)-(5\times-3)}{23} = \frac{40+15}{23} = \mathbf{2.39\ A}$$

½ Mark

$$I_2 = \frac{\begin{vmatrix} 8 & 10 \\ -3 & 5 \end{vmatrix}}{\Delta} = \frac{(8\times5)-(10\times-3)}{23} = \frac{40+30}{23} = \mathbf{3.043\ A}$$

½ Mark

Current flowing through resistance of 3Ω = (I2 – I1) = (3.043 – 2.39)
= 0.653 A from E to B
= -0.653A from B to E

1 Mark

4	**Attempt any <u>THREE</u> of the following:**	**12**

4 a) An inductive coil having resistance of 5Ω and inductance of 0.2 H is connected in series with a capacitor of 20μF. If this combination is connected to 230 V, variable frequency supply, determine:

(i) Resonant frequency
(ii) Quality factor
(iii) Current at resonance
(iv) Voltage across inductive coil at resonance.

Ans:

Data Given: R = 5Ω , L= 0.2 H, C = 20 μF = $20\times10^{-6}F$, V=230 V

i) Resonant Frequency:

Resonant frequency = $f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times3.142\sqrt{0.2\times20\times10^{-6}}}$ = **79.58 Hz** — 1 Mark

ii) Quality factor:

Q factor = $\frac{1}{R}\sqrt{L/C}$

Q factor = $\frac{1}{5}\sqrt{0.2/(20\times10^{-6})}$ = **20** — 1 Mark

iii) Current:

At resonance R=Z

∴ Current I =V/Z = 230/5 = **46 A** — 1 Mark

iv) Voltage across inductive coil at resonance:

Inductive reactance of coil at resonance XL = 2πfrL

XL = 2π(79.58)(0.2) = 100 Ω

Impedance of inductive coil at resonance, Z = R+jXL

Z = 5+j100 = 100.125∠87.14°

Voltage across inductive coil at resonance,

VL = I Z = 46(100.125) = **4605.75 volt** — 1 Mark

4 b) A coil having resistance of 10 Ω and inductance of 0.15 H is connected in parallel with R-C series combination having R= 5Ω and C = 20 μF. If supply voltage is 110 V, 50Hz, then

(i) Draw circuit diagram

(ii) Calculate branch currents using impedance method

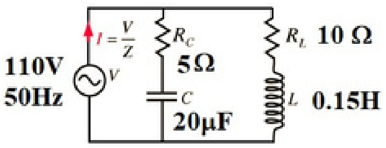
(iii) Power absorbed by the coil

Ans:

Data Given: RL = 10 Ω , L= 0.15 H, RC = 5 Ω , C = 20 μF = $20\times10^{-6}F$

V=110∠0° V, f = 50Hz

Circuit Diagram:



1 Mark for circuit diagram

Branch Currents:

Inductive reactance, XL=2πfL=2π×50×0.15 = 47.124 Ω

Capacitive reactance, $X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi\times50\times20\times10^{-6}}$ =159.155 Ω

Impedance of inductive coil,

ZL = RL+jXL =10+j47.124 = 48.17∠78.02° Ω

Impedance of R-C series combination,

ZC = RC-jXC =5-j159.155 =159.23∠-88.20° Ω

Inductive coil current is given by,

$I_L = \frac{V}{Z_L} = \frac{110\angle0^\circ}{48.17\angle78.02^\circ}$ = **2.28∠-78.02° A = (0.47-j2.23) A** — 1 Mark for IL

Capacitive branch current is given by, — 1 Mark for IC

$I_C = \frac{V}{Z_C} = \frac{110\angle 0°}{159.23\angle -88.20°}$ = **0.69∠88.20° A = (0.0217+j0.69) A** — 1 Mark for Pcoil

Power absorbed by the coil:

Pcoil $= V \times I_L \times \cos\phi_1 = 110 \times 2.28 \times \cos(78.02)$ = **52.06 watt OR**

= $(I_L)^2 R_L$ **=** $(2.28)^2(10)$ **= 51.984 watt**

(NOTE: Examiner is requested to ignore the round-off errors)

4 c) Three equal impedances having R = 20 Ω in series with C = 50 μF are connected in delta across 415 V, 3-ph, 50 Hz AC supply. Determine:

i) Impedance per phase
ii) Phase and line currents
iii) Total 3-ph power consumed by load

Ans:

Data Given: R_{ph} = 20 Ω, C = 50 μF = 50×10^{-6} F, V_L = 415 V , f = 50 Hz

X_C per phase $= \frac{1}{2\pi fC} = \frac{1}{2\pi\times50\times50\times10^{-6}}$ = **63.66 Ω** — ½ Mark

∴ **Impedance per phase,** $Z_{ph} = \sqrt{R_{ph}^2 + X_c^2} = \sqrt{20^2 + 63.66^2}$ = **66.73 Ω** — 1 Mark

For delta connected load

Phase voltage = $V_{ph} = V_L$ = 415 V — ½ Mark for I_{Ph}

Phase current, $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{415}{66.73}$ = **6.22 A**

Line current, $I_L = \sqrt{3}\times I_{ph} = \sqrt{3}\times6.22$ = **10.77 A** — 1 Mark for IL

Load power factor, $\cos\phi = \frac{R_{ph}}{Z_{ph}} = \frac{20}{66.73}$ = 0.2997 (leading)

Total 3-ph Power consumed by load, — 1 Mark

$P_{3\phi} = \sqrt{3}\times V_L\times I_L\times\cos\phi = \sqrt{3}\times415\times10.77\times0.2997$ = **2320.12 W**

OR

$= 3\times V_{ph}\times I_{ph}\times\cos\phi = 3\times415\times6.22\times0.2997$ = **2320.85 W**

(NOTE: Examiner is requested to ignore the round-off errors)

4 d) With neat circuit diagram, explain the concept of duality in electric circuit. State any four examples (pairs) of duality in electric circuit.

Ans:

Concept of duality:

When the two circuit elements are represented by mathematical equations of similar nature, then these elements are called dual elements of each other. — 1 Mark

Examples:

(i) A resistance is represented by mathematical equation based on Ohm's law as, R = V/I and the conductance is represented by G = I/V. — 1 Mark

(ii) A voltage across an inductance is represented by $v = L\frac{di}{dt}$ and the current through a capacitor is represented by $i = C\frac{dv}{dt}$

On comparing the above equations we can form pairs of dual elements or quantities:

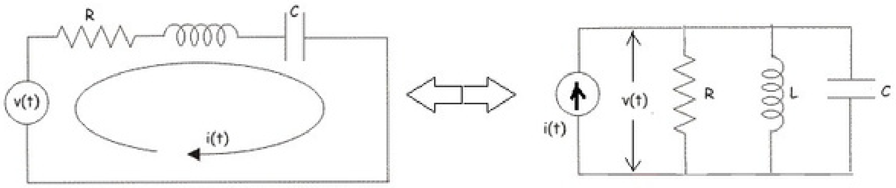
Resistance R ←→ Conductance G
Inductance L ←→ Capacitance C
Voltage v ←→ Current i

Similarly, we can apply this concept to electric circuits and say that when the two circuits are represented by similar mathematical equations, then such circuits are called dual circuits of each other. Consider a series R-L-C circuit, the voltage equation can be written as: 1 Mark

$v(t) = R.i(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)dt$ ....(1)

Consider a parallel R-L-C circuit, the current equation can be written as:

$i(t) = \frac{1}{R}v(t) + C\frac{dv(t)}{dt} + \frac{1}{L}\int v(t)dt$ ....(2)



1 Mark

On comparing equations (1) & (2), it is seen that both the equations are integro-differential equations of similar kind. Therefore, the two circuits are dual circuits. The dual element pairs are:

Voltage source v(t) ←→ Current source i(t)
Resistance (R) ←→ Conductance (G = 1/R)
Inductance (L) ←→ Capacitance (C)
Series Circuit ←→ Parallel circuit

Examples of duality in electric circuit

- voltage – current
- parallel circuit – series circuit
- resistance – conductance
- voltage division – current division
- impedance – admittance
- capacitance – inductance
- reactance – susceptance
- short circuit – open circuit
- Kirchhoff's Voltage law – Kirchhoff's Current law
- Mesh – Node
- Thevenin's theorem – Norton's theorem

1 Mark for any four pairs

5 Attempt any TWO of the following: 12

5 a) An inductive coil having resistance of 10 Ω and inductance of 0.5 H is connected in parallel with a capacitor of 50 μF. Determine:

(i) Parallel resonant frequency.
(ii) Quality factor of parallel circuit
(iii) Power consumed by circuit at resonance, if the supply voltage is 230V.

Ans:
Data Given:

R= 10 Ω, L=0.5 H, C=50 μF, V = 230V

i) Parallel resonant frequency

$fr = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L}}$ — 1 Mark

$= \frac{1}{2\pi}\sqrt{\frac{1}{0.5\times50\times10^{-6}} - \frac{10^2}{0.5^2}}$ — 1 Mark

= 31.67 Hz

ii) Quality factor of parallel circuit

Q factor $= \frac{2\pi L f_r}{R}$ — 1 Mark

$= \frac{2\pi \times 0.5 \times 31.67}{10}$

= 9.949 — 1 Mark

iii) Power consumed by circuit at resonance:

Reactance of coil = XL = 2πfrL = 2π(31.67)(0.5) = 99.49Ω — 1 Mark

Impedance of coil = Z = R + j XL = (10 + j99.49) = 99.99∠84.26°Ω — 1 Mark

OR

Current flowing through rthe coil I = V/Z = 230/99.99 = 2.3A — 1 Mark

Power consumed by circuit at resonance = Power consumed by coil resistance = $I^2R = (2.3)^2(10)$ = **52.9 W** — 1 Mark

5 b) Reduce the network shown in Fig. No. 3 by applying Star/Delta or Delta/Star transformation and determine equivalent resistance RAB.

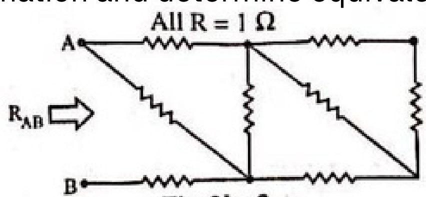
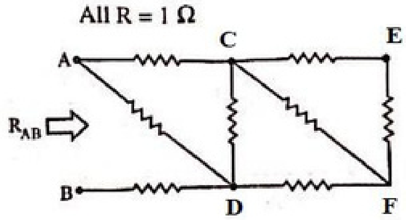


Fig. No. 3

Ans:

(NOTE: This problem can be solved without using Star/Delta or Delta/Star transformations. However, since it is asked to use the transformation, the marks are awarded only if student has solved this problem using at least one Star/Delta or Delta/Star transformation)



The resistance RCE and REF are in series.

∴RCF1 = 1 + 1 = 2Ω

There is another path from C to F directly through 1Ω

∴RCF2 = 1 Ω

Since the two paths from C to F are in parallel,

RCF = RCF1 || RCF2 = 2||1 = (2)(1)/(2+1) = 2/3 ≈0.667

This RCF appears in series with RFD

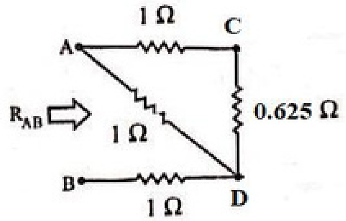
∴RCD1 = RCF + RDF = 0.667+ 1 = 1.667Ω

There is another path from C to D directly through 1 Ω.

∴RCD2 = 1 Ω

Since the two paths from C to D are in parallel,

RCD = RCD1 || RCD2 = 1.667||1 = (1.667)(1)/(1.667+1) = 1.667/2.667 = 0.625Ω



2 Marks

Converting Delta ACD into equivalent Star,

RC = (RAC.RCD)/(RAC+RCD+RDA) = (1)(0.625)/(1+0.625+1) = 0.625/2.625

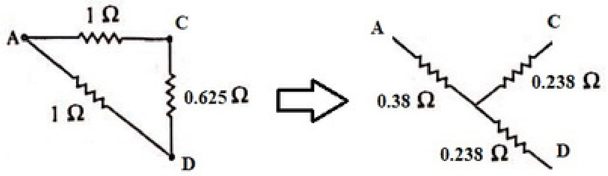
RC = 0.238Ω

RA = (RAC.RDA)/(RAC+RCD+RDA) = (1)(1)/(1+0.625+1) = 1/2.625

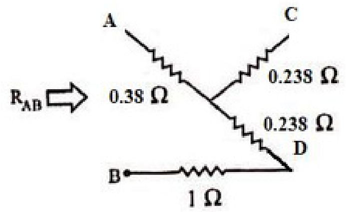
RA = 0.38Ω

RD = (RCD.RDA)/(RAC+RCD+RDA) = (0.625)(1)/(1+0.625+1) = 0.625/2.625

RD = 0.238Ω



3 Marks



RAB = RA + RD + RDB = 0.38 + 0.238 + 1 = 1.618Ω

RAB = 1.618 Ω 1 Mark

5 c) For network shown in Fig. No. 4, determine value of R so that maximum power is delivered to it. Also compute the maximum power delivered.

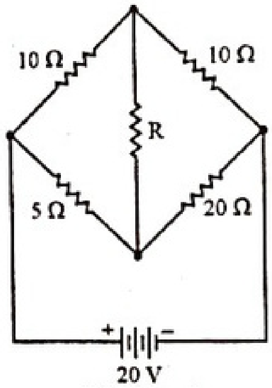
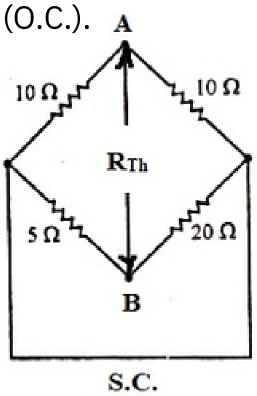
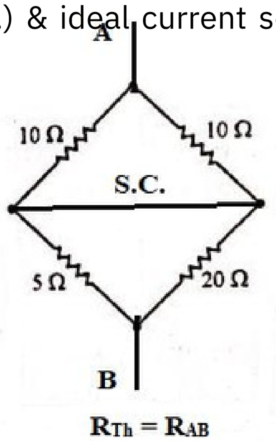


Fig. No. 4

Ans: According to the maximum power transfer theorem, the maximum power will be transferred to the resistance R only when the value of R is equal to the Thevenin equivalent resistance RTh of the remaining circuit seen between the open-circuited terminals of the resistance R with all internal independent sources replaced by their respective internal resistances, i.e ideal voltage source by short-circuit (S.C.) & ideal current source by open-circuit (O.C.).





From the simplified circuit, we can write,

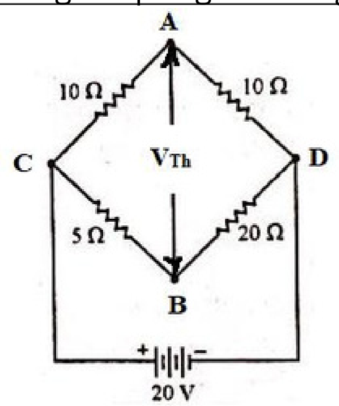
RTh = (10||10) + (5||20) = (100/20) + (100/25) = 5 + 4 = **9Ω** 2 Marks

∴ For maximum power transfer R = RTh = 9 Ω

Computation of Maximum power delivered:

The current that can flow through R can be determined by using Thevenin theorem. The circuit excluding R can be represented by simple Thevenin equivalent circuit comprising a voltage source VTh in series with resistance RTh.

A) Determination of Thevenin equivalent voltage (VTh):



Current flowing through path CAD: I1 = 20/(10+10) = 20/20 = 1A
Current flowing through path CBD: I2 = 20/(5+20) = 20/25 = 0.8A
Voltage between terminals A & D : VAD = I1 (10) = 1(10) = 10V
Voltage between terminals B & D : VBD = I2 (20) = 0.8(20) = 16V
It is seen that potential of A is 10V above that of D and potential of B is 16V above that of D. Therefore, point B is at higher potential

than A by 6V. i.e VTh = VBA = VBD – VAD = 16 – 10 = 6V — 1 Mark for VTh

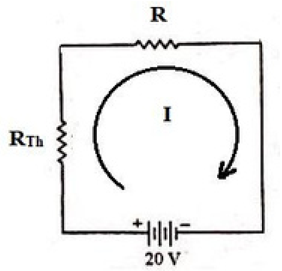
∴VTh = 6V

B) Determination of Thevenin equivalent resistance (RTh):

It is already computed above..

∴R Th = 9 Ω

C) Thevenin equivalent circuit :



2 Marks for Thevenin eq. circuit

Circuit current I = V/(RTh+R) = 20/(9+9) = 20/18 = 1.11A — 1 Mark for max. power

Maximum Power delivered to R = PRmax = I^2 R

= $(1.11)^2$ (9) = 11.09 watt

6	**Attempt any TWO of the following:**	**12**

6 a) A series RLC circuit consists of R = 10 Ω, L = 0.5 H and C = 20 μF is connected to 230V, variable frequency supply. Determine:

(i) Resonant frequency
(ii) Voltage magnification
(iii) Current drawn by the circuit
(iv) Voltage across each element
(v) Power factor at resonance
(vi) The power consumed at resonance.

Ans:

i) Resonant Frequency:

Resonant frequency $f_r = \frac{1}{2\pi\sqrt{LC}}$

$\therefore f_r = \frac{1}{2\pi\sqrt{0.5 \times 20 \times 10^{-6}}} =$ **50.33 Hz**

1 Mark for each bit = 6 Marks

ii) Voltage Magnification:

Q factor $= \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{0.5}{20\times 10^{-6}}}$

= 15.81

iii) Current drawn by the circuit:

At resonance R=Z

$\therefore$ Current I= $\frac{V}{Z} = \frac{230}{10} =$ **23 A**

iv) Voltage across each element:

VR = I.R =23×10 = **230V**

VL = I.XL =I×2πf_r L = 23×2π×50.33×0.5 = **3636.68V**

VC = I.XC = I×1/(2πf_rC)

= 23×1/(2π×50.33×20x 10^{-6}) = **3636.56V**

v) Power factor at resonance

vi) At Resonance p.f = **1**

Power at resonance:

At Resonance p.f = 1

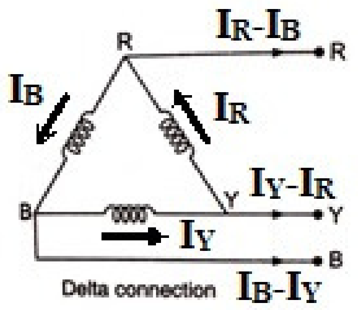
∴ P= V × I = 230 × 23=**5290 W**

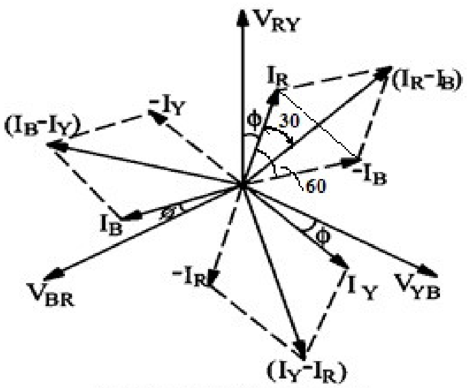
6 b) Draw complete phasor diagram of voltages & currents for balanced delta-connected load and prove the relation between:

(i) Line current and Phase current

(ii) Line voltage and Phase voltage

Ans:





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

1 Mark for circuit diagram

2 Marks for Phasor diagram

(i) Line current and Phase current:

From above diagram current in each lines are vector difference of the two phase currents flowing through that line.

For example:

Current in line R is $IL1=IR-IB$

Current in line Y is $IL2=IY-IR$

Current in line B is $IL3=IB-IY$

Current in line R is found by compounding IR and IB and value given by parallelogram in phasor diagram.

Angle between IR and $-IB$ is 60°,

where $|IR|=|IB|$ = Phase current Iph

$$I_{L1} = IR-I_B = 2Iph\cos(\frac{60}{2})=2I_{ph}\frac{\sqrt{3}}{2}=\sqrt{3}I_{ph}$$

$$I_{L2} = IY-I_R = 2Iph\cos(\frac{60}{2}) = 2I_{ph}\frac{\sqrt{3}}{2}=\sqrt{3}I_{ph}$$

$$I_{L3} = IB-I_Y = 2Iph\cos(\frac{60}{2})=2I_{ph}\frac{\sqrt{3}}{2}=\sqrt{3}I_{ph}$$

As $IL1=IL2=IL3 = I_L$

$$\mathbf{IL=\sqrt{3}Iph}$$

M marks for stepwise derivation of current relationship

(ii) Line Voltage and Phase voltage:

From circuit diagram, it is clear that:

Voltage across Phase R (winding connected between terminals R & Y)

= Voltage between lines R & Y = VL = Line voltage — 1 Mark for voltage relationship
⇒ **Phase Voltage = Line Voltage**
⇒ **VPh = VL**

6 c) Apply superposition theorem to compute current I in the network shown in Fig. No. 5.

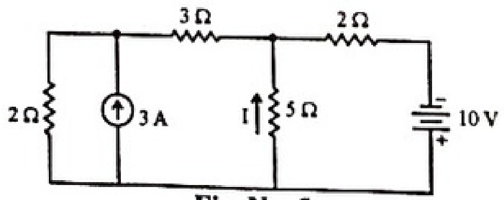
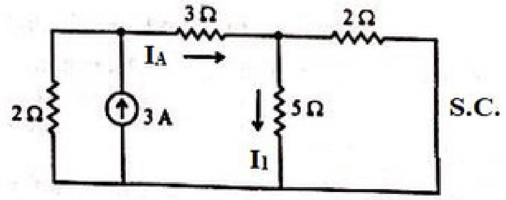


Fig. No. 5

Ans:

(A) Consider current source of 3A acting alone:

The 10V source is replaced by short-circuit (S.C.)



½ Mark for figure

The total resistance appearing across 2Ω (or current source) is given by,

= 3+{5||2}= 3+(10/7) = 31/7 = 4.43Ω

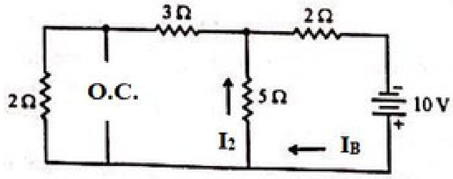
The current IA = 3×{2/(2+4.43)} = 0.933A — 1 Mark for IA

The current through 5Ω due to 3A source alone is given by current division formula as, — 1 Mark for I1

I1 = IA (2)/(2+5) = 0.933(2/7) = **0.2666 A (downward)**

(B) Consider voltage source of 10V acting alone:

The 3A source is replaced by open-circuit (O.C.)



½ Mark for figure

The total resistance appearing across 5Ω is given by,

= 3+2 = 5 Ω

The total resistance appearing across 10V source is, — 1 Mark for IB

R = 2+(5||5) = 2 + (25/10) = 2+2.5 = 4.5 Ω

The current IB = V/R = 10/4.5 = 2.22A — 1 Mark for I2

The current through 5 Ω due to 10V source alone is given by,

I2 = IB (5)/(5+5) = 2.22(0.5) = **1.11 A (upward)**

By Superposition theorem, the upward current through 5Ω due to both sources is given by, — 1 mark for I

I = -I1+I2= (-0.2666+ 1.11) = **0.8434A**

22324

11920

3 Hours / 70 Marks

Seat No. | | | | | | | |

Instructions :

(1) All Questions are compulsory.

(2) Answer each next main Question on a new page.

(3) Illustrate your answers with neat sketches wherever necessary.

(4) Figures to the right indicate full marks.

(5) Assume suitable data, if necessary.

(6) Use of Non-programmable Electronic Pocket Calculator is permissible.

(7) Mobile Phone, Pager and any other Electronic Communication devices are not permissible in Examination Hall.

Marks

1. Attempt any FIVE of the following : 10

(a) Define Conductance and Susceptance related to AC circuit and state their units.

(b) Draw power triangle for R-L series circuit. Write equation of power in rectangular form.

(c) Express an instantaneous value of an alternating current varying sinusoidally in terms of its maximum value, frequency and time.

(d) State relationship between line and phase values of voltage and current in balanced delta connection.

(e) Distinguish clearly between loop and mesh.

(f) State the value of internal resistance of (i) Ideal Voltage Source and (ii) Ideal Current Source.

(g) State Norton's Theorem.

2. Attempt any THREE of the following : 12

(a) With neat diagram, explain the phasor representation of sinusoidal quantity. For

(b) a parallel circuit consisting of an inductive branch (RL) in parallel with a capacitive branch (RC), draw phasor diagram and derive equation for resonant frequency. With the help of neat phasor diagram, derive the relationship

(c) between line and phase values of voltage in balanced star connection. State the equivalent delta connection for star connection of three resistances

(d)

R1, R2 & R2,with proper equations.

3. Attempt any THREE of the following : 12

(a) For series R-L-C circuit, draw neat circuit diagram. State the conditions for RLC series ckt. Draw phasor diagram and voltage triangle impedance triangle for any 1 condition. State any four properties of Parallel Resonance. With neat labelled

(b) diagram, explain unbalanced star connected load.

(c)

(d) With neat circuit diagram, explain how to convert a practical voltage source into an equivalent practical current source.

(e) Explain the concept of “duality” in electric circuit with one example.

4. Attempt any THREE of the following : 12

(a) A series R-L-C circuit has R = 5Ω, L = 10 mH and C = 15 μF. Calculate :

(i) Resonant frequency

(ii) Q-factor of the circuit

(iii) Bandwidth (iv) Voltage magnification. Explain the “Current Magnification” in parallel resonant circuit consisting of inductive branch (RL) in parallel with a

(b) pure capacitor (C). Derive equation for it.

(c) Draw waveform of three-phase voltages. Draw phasor diagram for these voltages. Write equations for instantaneous values of these voltages. Express these voltages in polar form.

(d) State and explain "Reciprocity theorem".

5. Attempt any TWO of the following : 12

(a) A coil having resistance of 5 Ω and an inductance of 0.2 H is connected in parallel with a series combination of 10 Ω resistor and 80 μF capacitor. If supply voltage is 230 V, 50 Hz, determine :

(i) Total circuit impedance.

(ii) Total current taken by the circuit.

(iii) Power factor of the circuit.

(iv) Branch currents.

(v) Power consumed by the circuit.

(b) Using mesh analysis, find current in 5 Ω resistor in the network shown in Fig. 5(b).

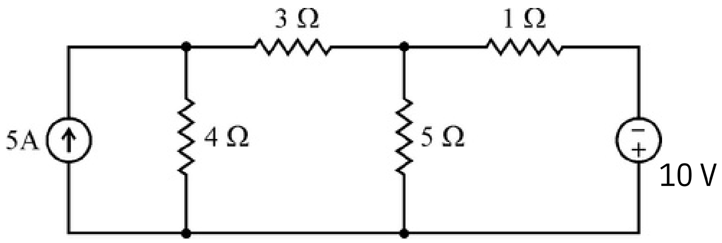


Fig. No. 5 (b)

(c) Find the current in 5 Ω resistor in the network shown in Fig. 5(c) by using Thevenin's theorem.

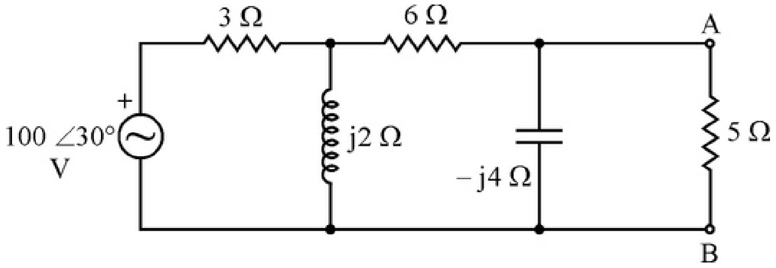


Fig. No. 5 (c)

6. Attempt any TWO of the following : 12

(a) For a series R-L-C circuit consisting of R = 5 Ω, L = 0.01 H and C = 10 μF supplied with 230 V, 50 Hz supply, determine :

(i) Circuit impedance

(ii) Circuit current

(iii) Circuit power factor

(iv) Active power

(v) Reactive power

(vi) Apparent power

(b) A star connected capacitive load is supplied from 3 Φ, 415 V, 50 Hz supply. If the line current is 15 A and total 3 Φ power taken from supply is 30 kW , find :

(i) Power factor

(ii) Resistance in cash phase

(iii) Capacitance in each phase.

(c) Determine the voltage 'V' across 5 Ω resistor in network shown in Fig. 6(c) using superpositon theorem.

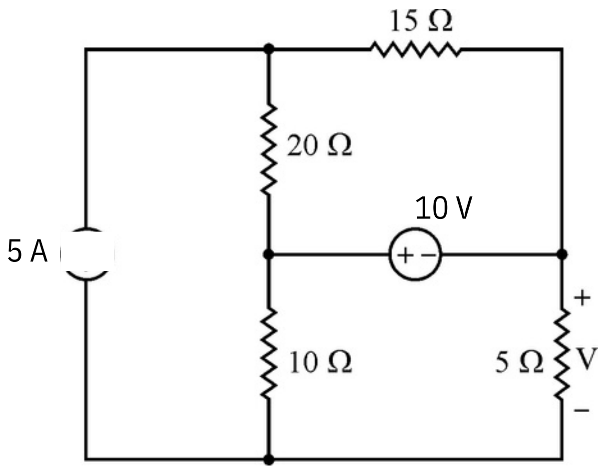


Fig. No. 6 (c)

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Model Answers

Winter – 2019 Examinations

Subject & Code: Electrical Circuits (22324)

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
Winter – 2019 Examinations
Subject & Code: Electrical Circuits (22324)

1 Attempt any TEN of the following: 20

1 a) Define Conductance and Susceptance related to AC circuit and state their units.

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.

OR

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

In general, Conductance, G= siemen. Its unit is **siemen (S).**

½ Mark for definition

½ Mark for unit

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.

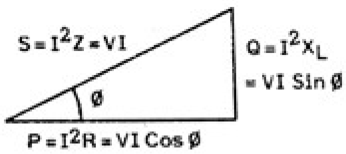
In general, Susceptance (B)= siemen. Its unit is **siemen (S).**

½ Mark for definition

½ Mark for unit

1 b) Draw power triangle for R-L series circuit. Write equation of power in rectangular form.

Ans:



1 Mark for power triangle

$S = P + jQ$

$VI = VI\cos\phi + j\, VI\sin\phi$

$I^2Z = I^2R + j\, I^2X_L$

1 Mark for equation

1 c) Express an instantaneous value of an alternating current varying sinusoidally in terms of its maximum value, frequency and time.

Ans:

$i = I_m \sin(\omega t \pm \Phi)$ amp

where, i = Instantaneous value

I_m = Maximum value
ω = Angular frequency in rad/sec = $2\pi f$
f = frequency in cycles/sec or Hz
t = time in sec
Φ = phase angle

1 Mark for equation

1 Mark for terms

1 d) State relationship between line and phase values of voltage and current in balanced delta connection.

Ans:

Balanced Delta Connection:

1 Mark

i.e

1 Mark

√

i.e √

1 e) Distinguish clearly between loop and mesh.

Ans:

Distinction between Loop & Mesh:

Sr. No.	Loop	Mesh
1	A loop is any closed path in a circuit, in which no node is encountered more than once	A mesh is a loop that has no other loops inside of it
2	Every loop is not a mesh	Every mesh is a loop
3	Loops are used in a more general way for circuit analysis	Meshes are used to analyze planar circuits

1 Mark for each of any two points = 2 Marks

1 f) State the value of internal resistance of (i) Ideal Voltage Source and (ii) Ideal Current Source.

Ans:

Value of Internal Resistance of Ideal Voltage Source Rs = 0
Value of Internal Resistance of Ideal Current Source Rs =

1 Mark each

1 g) State Norton‟s Theorem.

Ans:

Norton'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 current source IN in parallel with an impedance ZN across the two terminals, where the source current IN is equal to the short circuit current caused by internal sources when the two terminals are short circuited and the value of the parallel impedance ZN 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.

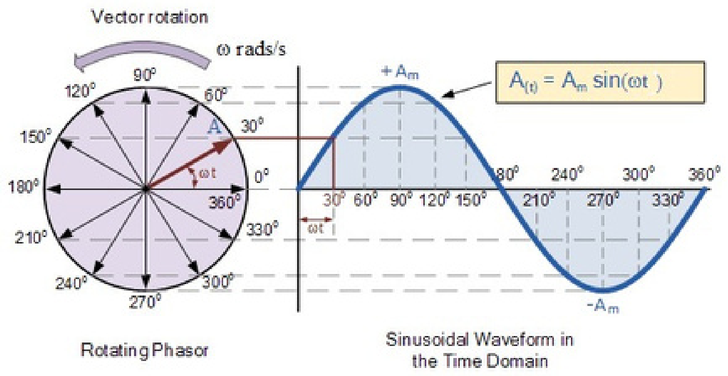
2 Marks for correct statement

2 Attempt any THREE of the following: 12

2 a) With neat diagram, explain the phasor representation of sinusoidal quantity.

Ans:

Phasor Representation of Sinusoidal Quantity:



2 Marks for diagram

OR Equivalent Figure

When number of waveforms are drawn in the same figure, the complexity of diagram increases and it becomes very difficult to extract the information from the waveforms. Therefore, to extract the same information, simplified alternate approach is preferred, called "Phasor representation of Sinusoidal quantity".

2 Marks for explanation

A sinusoidal quantity is represented by a rotating vector or rotating phasor "A" whose length is equal to the amplitude of the quantity "Am", as shown above. The points on the waveform are represented by the positions of the phasor during rotation drawn from the same reference point. The phasor making an angle of "ωt" with respect to positive x-axis reference, represents the instantaneous value of the quantity at an angle of "ωt" from its zero value, as shown above. In fact, the vertical component of the phasor represents the magnitude of the quantity at that particular instant. From the above diagram, it is clear that the vertical component of the phasor is "Am sin(ωt)" which is the instantaneous value of the quantity at instant "ωt".

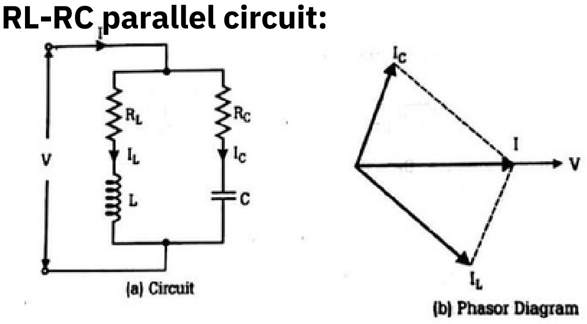
The speed of rotation of the phasor is equal to ω rad/sec where ω = 2πf.

One rotation of the phasor corresponds to one cycle of the alternating waveform as shown in figure.

2 b) For a parallel circuit consisting of an inductive branch (RL) in parallel with a capacitive branch (RC), draw phasor diagram and derive equation for resonant frequency.

Ans:

Parallel Resonance in RL-RC parallel circuit:



1 Mark for phasor diagram

Parallel Resonance for RL-RC Parallel Circuit

The circuit diagram and phasor diagram is as shown in the figure. Under parallel resonance (anti-resonance) condition, the circuit will take an input current (I) in phase with the applied voltage (V). At resonance, the circuit impedance becomes purely resistive in spite of presence of L & C and the circuit power factor becomes unity.

Model Answers

Winter – 2019 Examinations

Subject & Code: Electrical Circuits (22324)

The admittance of inductive branch is:

The admittance of capacitive branch is:

Total admittance of the parallel circuit:

[ ]

[ ] [ ]

3 Marks for stepwise derivation

At resonance, = ar (anti-resonant angular frequency), the reactive term must be zero.

[ ]

[ ]

[ ] [ ]

[ ]

√ [ ] rad/sec

Anti-resonant frequency √ [ ]

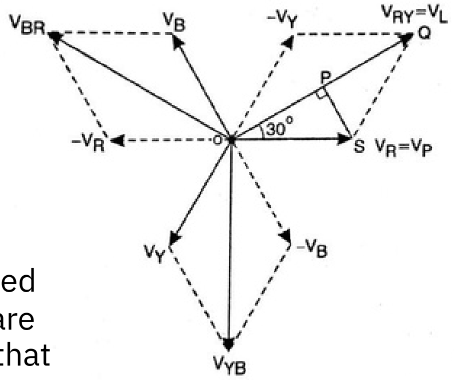
√ √ [ ]

2 c) With the help of neat phasor diagram, derive the relationship between line and phase values of voltage in balanced star connection.

Ans:

Relationship Between Line voltage and Phase Voltage in Balanced Star Connection:

Let VR, VY and VB be the phase voltages.
VRY, VYB and VBR be the line voltages.
The line voltages are expressed as:
VRY = VR – VY
VYB = VY – VB
VBR = VB – VR



1 Mark for phasor diagram

In phasor diagram, the phase voltages are drawn first with equal amplitude and displaced from each other by 120▯. Then line voltages are drawn as per the above equations. It is seen that the line voltage VRY is the phasor sum of phase voltages VR and –VY. We know that in parallelogram, the diagonals bisect each other with an angle of 90▯.

Therefore in ▯OPS, ▯P = 90▯ and ▯O = 30▯.

3 Marks for stepwise derivation

[OP] = [OS] cos 30▯
Since [OP] = VL/2 and [OS] = Vph

—

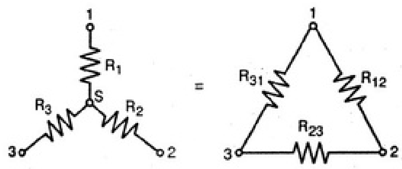
√‾
—

√‾

Thus **Line voltage = √ (Phase Voltage)**

2 d) State the equivalent delta connection for star connection of three resistances R1, R2 & R3 with proper equations.

Ans:



(a) Star Circuit (b) Delta Circuit

1 mark for circuit diagram + 1 mark for each of 3 equations = 4 Marks

R12 ________________

= ________________

R23 R31 = ________________

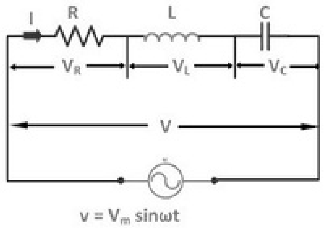
=

3 Attempt any <u>THREE</u> of the following: 12

3 a) For series R-L-C circuit, draw neat circuit diagram. State the conditions for RLC series ckt. Draw phasor diagram and voltage triangle impedance triangle for any 1 condition.

Ans:

Circuit Diagram for R-L-C Series Circuit:



½ Mark for circuit diagram + ½ Mark for each of 3 circuit conditions = 2 Mark

Conditions for R-L-C Series Circuit:

(i) When XL   XC : Phase angle is positive and circuit will be inductive. In other words, in such a case, the circuit current I will lag behind the applied voltage V by angle .

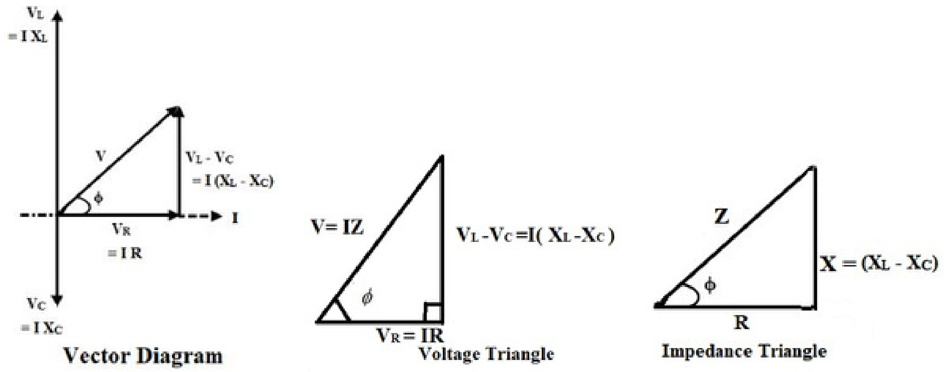
(ii) When XL   XC : Phase angle is negative and circuit will be capactive. In other words, in such a case, the circuit current I leads the applied voltage V by angle .

(iii) When XL   XC : The circuit is purely resistive. In other word circuit current I and applied voltage V will be in phase i.e.   The circuit will have unity power factor.

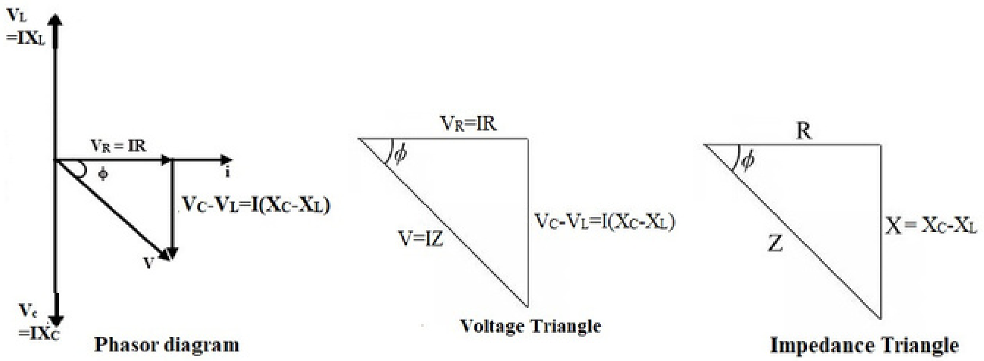
1 Mark for phasor diagram + ½ Mark each for voltage triangle & impedance triangle for any one condition = 2 Mark

Phasor Diagram, Voltage Triangle & Impedance Triangle:

(i) Condition XL>XC



(ii) Condition XL   XC



3 b) State any four properties of Parallel Resonance.

Ans:

Properties of Parallel Resonance:

1. At resonance, the parallel RLC circuit behaves as purely resistive circuit.
2. At resonance, the Parallel RLC circuit power factor is unity.
3. At resonance, the parallel RLC circuit offers maximum total impedance Z=L/CR
4. At resonance, parallel RLC circuit draws minimum current from source,

[⁄]

5. At resonance, in parallel RLC circuit, current magnification takes place.
6. The Q-factor for parallel resonant circuit is,

–√–

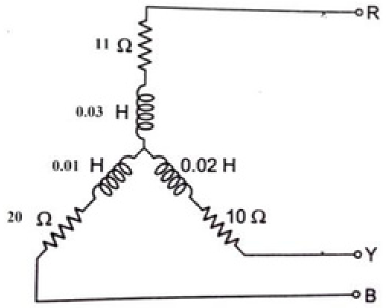
7. Parallel RLC resonant circuit is Rejecter circuit.

1 Mark for each of any four properties = 4 Marks

3 c) With neat labeled diagram, explain unbalanced star connected load.

Ans:

Unbalanced Star connected Load:



1. When the magnitudes and phase angles of three impedances are differ from each other, then it is called as unbalanced load.
2. Phase angles of impedance are not equal.
3. For unbalanced load, the phase voltage is √ of the line voltage.
4. All the voltages are fixed and line currents will not be equal nor will have a phase difference.

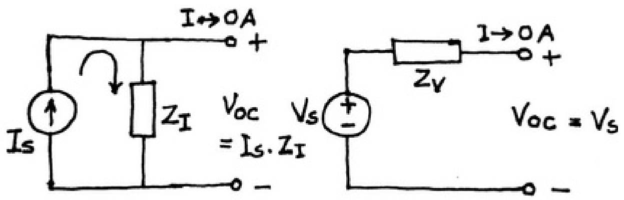
1 Mark for labeled circuit diagram + 3 Marks for explanation (any 3 points) = 4 Marks

3 d) With neat circuit diagram, explain how to convert a practical voltage source into an equivalent practical current source.

Ans:

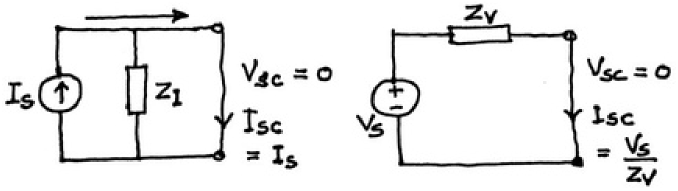
Conversion of practical voltage source into equivalent practical current source:

Let VS be the practical voltage source magnitude and
ZV be the internal series impedance of the voltage source.
IS be the equivalent practical current source magnitude and
ZI be the internal parallel impedance of current source.



1 Mark for each equation = 4 Marks

The open circuit terminal voltage of voltage source is VOC = VS
The open circuit terminal voltage of current source is VOC = IS × ZI
Therefore, we get VS = IS × ZI ....(1)



The short circuit output current of voltage source is ISC = VS / ZV
The short circuit output current of current source is ISC = IS
Therefore, we get IS = VS / ZV ....(2)
Therefore, we get VS = IS × ZV..............................(3)
On comparing eq. (1) and (3), it is clear that ZI = ZV = Z ....(4)

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, VS = IS × Z

3 e) Explain the concept of "duality" in electric circuit with one example.

Ans:

Concept of duality:

When the two circuit elements are represented by mathematical equations of similar nature, then these elements are called dual elements of each other. 1 Mark

Examples:

(i) A resistance is represented by mathematical equation based on Ohm‟s law as, R = V/I and the conductance is represented by G = I/V. 1 Mark

(ii) A voltage across an inductance is represented by v = L and the current through a capacitor is represented by i = C 1 Mark

On comparing the above equations we can form pairs of dual elements or quantities: 1 Mark

Resistance R ←→ Conductance G
Inductance L ←→ Capacitance C
Voltage v ←→ Current i

OR

OR

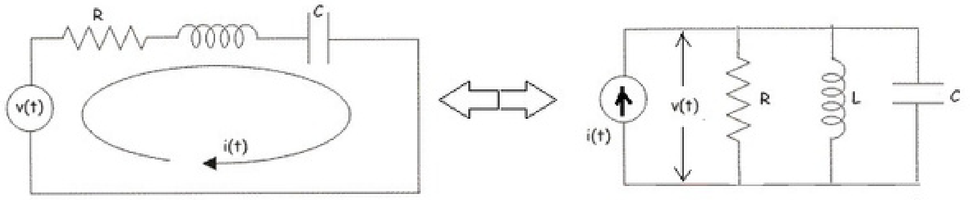
Similarly, we can apply this concept to electric circuits and say that when the two circuits are represented by similar mathematical equations, then such circuits are called dual circuits of each other.

Consider a series R-L-C circuit, the voltage equation can be written as:

v(t) = R.i(t) + L—— +∫ .... (1) 1 Mark

Consider a parallel R-L-C circuit, the current equation can be written as:

i(t) = v(t) + C —— + ∫ v( ) ....(2) 1 Mark



1 Mark

On comparing equations (1) & (2), it is seen that both the equations are integro-differential equations of similar kind. Therefore, the two circuits are dual circuits. The dual element pairs are:

Voltage source v(t) ←→ Current source i(t)
Resistance (R) ←→ Conductance (G = 1/R)
Inductance (L) ←→ Capacitance (C)
Series Circuit ←→ Parallel circuit

1 Mark

Examples of duality in electric circuit

- voltage – current
- parallel circuit – series circuit
- resistance – conductance
- voltage division – current division
- impedance – admittance
- capacitance – inductance
- reactance – susceptance
- short circuit – open circuit
- Kirchhoff"s Voltage law – Kirchhoff"s Current law
- Mesh – Node
- Thevenin"s theorem – Norton"s theorem

4 **Attempt any THREE of the following.** **12**

4 a) A series R-L-C circuit has R = 5Ω, L = 10mH and C = 15μF. Calculate:

(i) Resonant frequency
(ii) Q-factor of the circuit
(iii) Bandwidth
(iv) Voltage Magnification.

Ans:

Data Given:

R= 5 , L=10mH = 10 , C=15 F = 15 ,

i) Resonant frequency:

fr= √

= √

= 410.94 Hz

1 Mark for each bit = 4 Marks

ii) Quality factor of circuit:

Q factor = = √

=

= 5.16

iii) Bandwidth:

Bandwidth =

= = **79.64 Hz**

iv) Voltage Magnification:

Q factor = √ √

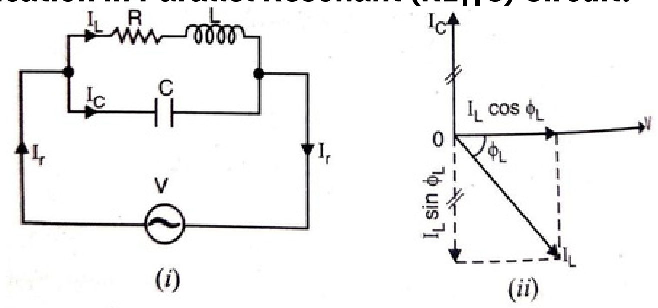
= –

= 5.16

4 b) Explain the “Current Magnification” in parallel resonant circuit consisting of inductive branch (RL) in parallel with a pure capacitor (C). Derive equation for it.

Ans:

Current Magnification in Parallel Resonant (RL||C) Circuit:



1 Mark for diagram

Current Magnification:

The Current Magnification or quality factor or Q-factor of parallel resonant circuit is defined as the ratio of the current circulating between two branches of the circuit to the current taken by the parallel circuit from the source. 1 Mark

Current Magnification = Q-factor =

At parallel resonance, the circulating current is IC and circuit condition is,

IC – IL = 0

I_C IL

.....................(1)

Total circuit input current, I=$_L$I

If the circuit impedance at resonance is Z, then

Substituting Z^2 from eq. (1),

2 Marks for stepwise derivation

— — —

— .... (2)

Now, circulating current IC = V/XC = —

and input line current taken by circuit Ir — — [—] —

Current Magnification = Q-factor —

Current Magnification = Q-factor = — — —

The Q-factor of a parallel resonant circuit can also be expressed in term of L and C.

Neglecting resistance R, the resonance frequency is given by;

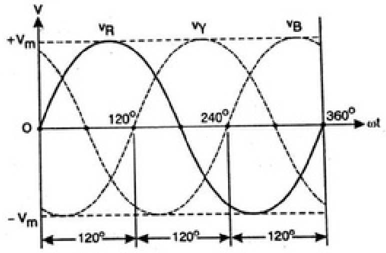
fr= —√—

Now,

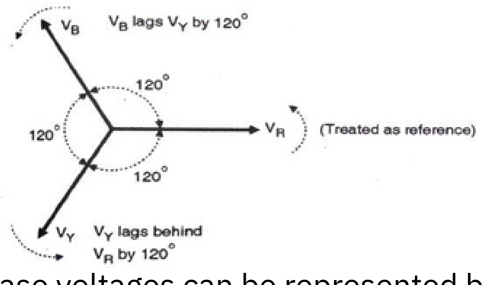
Current Magnification = Q- factor = — — —√— – √ –

4 c) Draw waveform of three-phase voltages. Draw phasor diagram for these voltages. Write equations for instantaneous values of these voltages. Express these voltages in polar form.

Ans:



1 Mark for waveform



1 Mark for phasor diagram

The equations of three-phase voltages can be represented by,

vR =Vm Sin□t

vY = Vm Sin(□t-120)

vB = Vm Sin(□t-240) = Vm Sin(□t+120)

1 Mark for equations

Polar Form:

Let V be the RMS value of the phase voltage, V = —√—

□

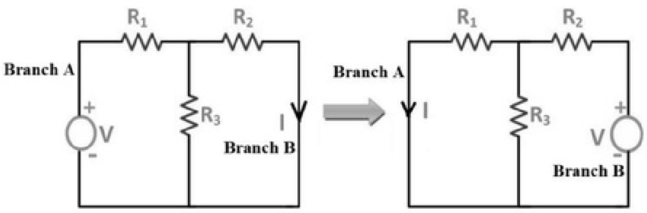
□

□ □

1 Mark for polar form

4 d) State and explain "Reciprocity theorem".

Ans: Reciprocity theorem : Reciprocity Theorem states that in any bilateral network if a voltage source V in one branch, say branch „A", produces a current I in another branch, say branch „B", then if the voltage source V is moved from the branch A to the branch B, it will cause the same current I in the first branch „A", where the voltage source has been replaced by a short circuit. 2 Marks for statement



Steps for Solving a Network Utilizing Reciprocity Theorem:

Step 1: Firstly, select the branches, say A and B, between which reciprocity has to be established.

Step 2: The current I1 in the branch B is obtained using any conventional network analysis method, when the source is in the branch A. 2 Marks for explanation

Step 3: The voltage source is moved to branch B.

Step 4: The current I2 in the branch A, where the voltage source was existing earlier, is calculated.

Step 5: It is seen that the current I1 obtained in the previous connection, i.e., in step 2 and the current I2 which is calculated when the source is moved to branch B in step 4, are equal to each other.

The limitation of this theorem is that it is applicable only to single source networks and not in the multi-source network. The network where reciprocity theorem is applied should be linear and consist of resistors, inductors, capacitors and coupled circuits. The circuit should not have any time-varying elements.

5 **Attempt any TWO of the following:** **12**

5 a) A coil having resistance of 5 Ω and an inductance of 0.2 H is connected in parallel with a series combination of 10 Ω resistor and 80 μF capacitor. If supply voltage is 230 V, 50 Hz, determine:

1) Total circuit impedance
2) Total current taken by the circuit
3) Power factor of the circuit
4) Branch currents
5) Power consumed by the circuit

Ans:

Data Given: Branch I: R1 = 5 Ω and L = 0.2 H

Branch II: R2 = 10 Ω and C = 80μF = 80 x 10^{-6} F

V = 230V, f = 50Hz

(i) Total circuit impedance (Z):

Inductive reactance XL = 2πfL

= 2 x π x 50 x 0.2 — ½ Mark for XL

XL = 62.83 Ω

Capacitive reactance XC = 1 / (2πfC)

XC = 1 / (2π x 50 x 80 x 10⁻⁶) — ½ Mark for XC

XC = 39.79 Ω

Branch 1 Impedance Z1 = (5 + j62.83) Ω = **63.03 ∠85.45°Ω**

Branch 2 Impedance Z2 = (10 – j39.79) Ω = **41.03 ∠-75.89°Ω**

Since impedances are in parallel, total circuit impedance is given by,

1 Mark for Z

∴Total circuit impedance Z

(ii) Total current (I) :

Total Current (I): — 1 Mark for I

Angle between V and I is {0-47.37} = - 47.37

(iii) Power factor of the circuit (cos) : — 1 Mark for pf

cos = cos(-47.37°) = **0.68 leading**

(iv) Branch Currents: — ½ Mark for each branch current = 1 Mark

Branch current I1 = V/Z1 =

Branch current I2 = V/Z2 =

(v) Power consumed by the circuit: — 1 Mark for P

P = V × I × cos = 230 × 2.44 × 0.68

P = 381.62 watt

5 b) Using mesh analysis, find current in 5 Ω resistor in the network shown in Fig. 5(b).

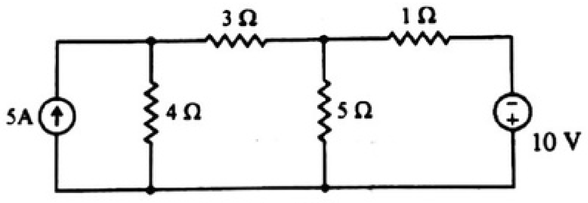


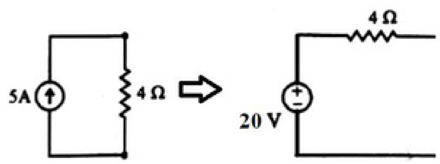
Fig. No. 5 (b)

Ans:

A) Converting current source of 5A, 4Ω into equivalent voltage source:

Emf of voltage source V = I × R = 5×4= 20 volt

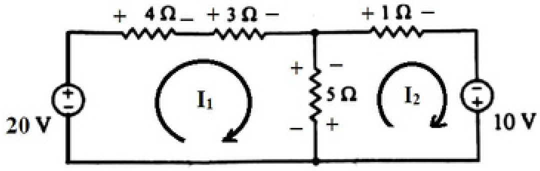
Internal resistance of voltage source = internal resistance of current source = 4 Ω



1 Mark

B) Modified circuit:

Replacing current source with equivalent voltage source, the modified circuit diagram is as shown below. The mesh currents can be marked as shown.



C) Mesh Analysis:

By applying KVL to Mesh 1:

.... (1) — 1 Mark for Eq. (1)

By applying KVL to Mesh 2:

................(2) — 1 Mark for Eq. (2)

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

[ ] [ ] [ ] — 1 Mark for Eq. in matrix form

| |

By Cramer"s rule,

| | — ½ Mark for I1

| | — ½ Mark for I2

Current flowing through resistance of 5 Ω = I2 – I1 = 4.68 – 3.62
= 1.06 A in the direction of I2 — 1 Mark

5 c) Find the current in 5 Ω resistor in the network shown in Fig. 5(c) by using Thevenin"s theorem.

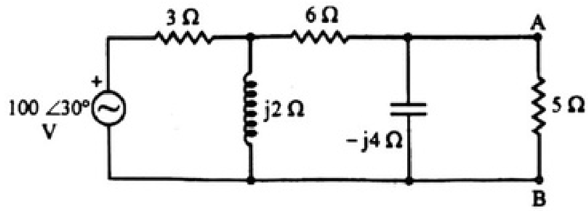
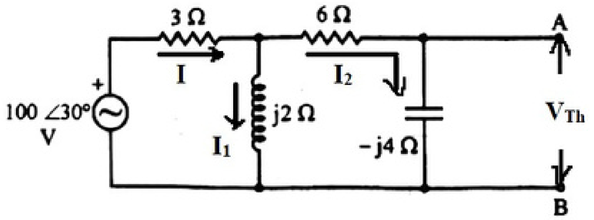


Fig. No. 5 (c)

Ans:

1) Determination of Thevenin's equivalent voltage VTh:



2 Marks for stepwise calculation of VTh

Thevenin‟s voltage VTh is the open circuit voltage between load terminals A & B. It is seen that it is the voltage across capacitor.

The net impedance across 100V source is given by,

Z = 3 + (j2)||(6-j4)

The total current I = V/Z =

The capacitor current I2 =

=

= 7.5∠107° = (- 2.2+j7.17) A

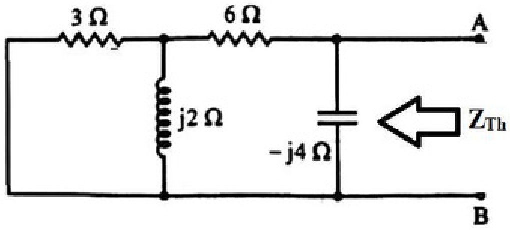
Thevenin‟s voltage VTh = (-j4)I2 = (4∠90°)(7.5∠107°)

VTh = 30∠197° volt = (-28.69 – j8.77) volt

2) Determination of Thevenin's Equivalent Impedance ZTh:

It is the impedance seen between the open circuited terminals A & B with all internal independent voltage sources replaced by short circuit and all internal independent current sources by open circuit.

2 Marks for stepwise calculation of ZTh



ZTh = (-j4) || {6 + (3||j2)}

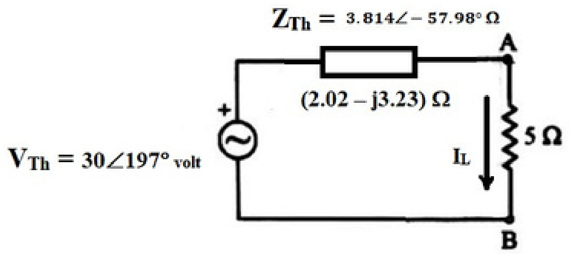
= (-j4) || {6 + ( )}= (-j4) || {6 + ( )}

= (-j4) || {6 + (∠56.3°)}= (-j4) || {6 + 0.92 + j1.38}

= (-j4) || {6.92 + j1.38}= (-j4) || {7.056∠11.28°}

ZTh (2.02 – j3.23) Ω

3) Thevenin's Equivalent Circuit:



1 Mark for Thevenin‟s Eq. circuit

1 Mark for IL

The current in 5 resistor is given by,

I_L=

IL

6 Attempt any TWO of the following: 12

6 a) For a series R-L-C circuit consisting of R = 5, L = 0.01 H and C = 10 F supplied with 230 V, 50 Hz supply, determine:

i) Circuit impedance
ii) Circuit current
iii) Circuit power factor
iv) Active power
v) Reactive power
vi) Apparent power

Ans:

Data Given: R = 5 Ω, L = 0.01 H, C = 10F = 10×10F
V = 230V, f = 50 Hz

1 Mark for each bit = 6 Marks

(i) Circuit Impedance:

= 3.142 Ω

= = 318.31 Ω

Z = R + j (XL – XC) = 5 + j (3.142 – 318.31)

Z = (5 – j 315.168) = 315.21-89.1

(ii) Circuit current:

Circuit current I = = = **0.7389.1 A**

(iii) Circuit power factor:

Circuit Power factor angle = 89.1° leading

Circuit power factor cos = cos(89.1) = **0.016 (leading)**

(iv) Active Power (P):

P = VI cos = 230 × 0.73 × 0.016

= **2.6864 W**

(v) Reactive Power (Q):

Q = VI sin = 230 × 0.73 × sin(89.1°)

= **167.88 VAR**

(vi) Apparent Power (S):

Apparent Power = S = VI = 230 × 0.73 = 167.9 VA

6 b) A star connected capacitive load is supplied from 3, 415V, 50Hz supply. If the line current is 15 A and total 3 power taken from supply is 30 kW, find:

(i) Power factor
(ii) Resistance in each phase.
(iii) Capacitance in each phase

Ans:

Data Given: V_L = 415V, f = 50Hz, I_L = 15A, P = 30 kW = 30000 W

In Star connection,

$V_L = \sqrt{3} \times V_{Ph}$ and $I_L = I_{Ph}$

Therefore, $V_{Ph} = V_L / \sqrt{3} = 415 / \sqrt{3}$ **= 239.6 Volt.**

And $I_L = I_{Ph}$ **= 15Amp.**

∴ Impedance per phase, $Z_{Ph} = V_{Ph} / I_{Ph} = 239.6 / 15$

Z_{Ph} = 15.97 Ω — 1 Mark for Z_{Ph}

i) Power factor:

Total three-phase power is given by,

$P = 3V_{Ph} I_{Ph} \cos\phi$ **Or** $P = \sqrt{3} V_L I_L \cos\phi$

$30 \times 10^3 = 3 \times 239.6 \times 15 \times \cos\phi$

Therefore,

$\cos\phi = 30 \times 10^3 / (3 \times 239.6 \times 15)$

∴ $\cos\phi$ = **2.78 !!!!!!!!!!**

Since maximum value of cosφ = 1, here is data mismatch !!!!!!!!!!!

Assuming total 3φ power as 3 kW instead of 30 kW,

$\cos\phi = 3 \times 10^3 / (3 \times 239.6 \times 15)$ — 1 Mark for cosφ

cosφ = 0.278 leading

$\phi = \cos^{-1}(0.278)$ = **73.84°** — 1 Mark for φ

(NOTE: Examiner is requested to award appropriate marks to the student for any other suitable assumption of data and if attempted to solve)

ii) Resistance in each phase: — 1 Mark for RPh

Resistance per phase (R_{ph}) = $Z_{ph} \times \cos\phi = 15.97 \times 0.278$

R_{ph} = 4.44 Ω — 1 Mark for XPh

iii) Reactance in each phase:

Reactance per phase (X_{ph}) = $Z_{ph} \times \sin\phi = 15.97 \times \sin(73.84°)$

X_{ph} = 15.34 Ω

Since capacitive reactance $X_C = X_{ph}$ = ____ — 1 Mark for C

Capacitance in each phase C = ____ ________ **F**

6 c) Determine the voltage „V" across 5 Ω resistor in the network shown in Fig. 6(c) using superposition theorem.

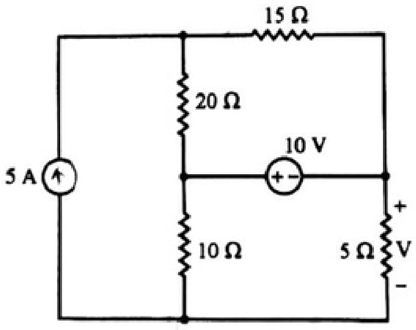
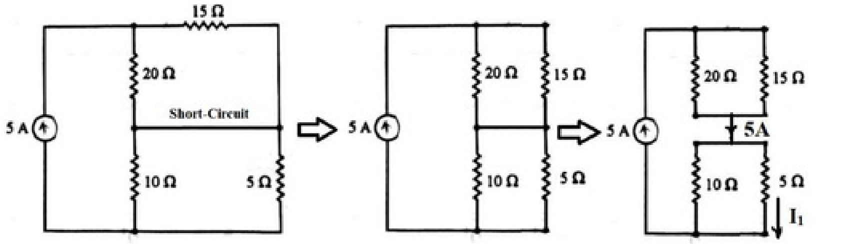


Fig. No. 6 (c)

Ans:

(A) Consider current source of 5A acting alone:

The 10V source is replaced by short-circuit (S.C.)



1 Mark for diagram
1 Mark for I1

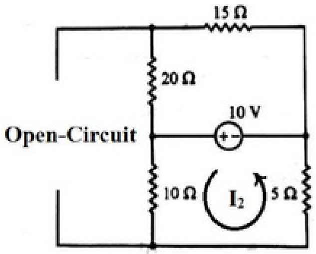
The total source current of 5A is divided and then flows through 5Ω & 10Ω

The current flowing through 5Ω is given by current division formula as,

I1 = 5×{10/(10+5)} = **3.33A (Downward)**

(B) Consider voltage source of 10V acting alone:

The 5A source is replaced by open-circuit (O.C.)



1 Mark for diagram
1 Mark for I2

The current in lower mesh and flowing through 5Ω is given by,

I2 = 10/(10+5) = **0.67 A (Upward)**

(C) Total current in 5Ω resistor:

By Superposition theorem, the current through 5Ω due to both sources, assuming downward current positive and upward current negative, is given by,

I = I1-I2= (3.33- 0.67) = **2.66 A (Downward)** 1 Mark for I

Voltage across 5Ω resistor is given by,

V = 5(I) = 5(2.66) = 13.3 volt 1 Mark for V

V = 13.3 volt