Model Answers
Winter – 2018 Examinations
Subject & Code: Electrical Circuits & Networks (17323)

Important Instructions to examiners:
1) The answers should be examined by key words and not as word-to-word as given in the model
   answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess
   the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not
   applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure.
   The figures drawn by candidate and model answer may vary. The examiner may give credit for any
   equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values
   may vary and there may be some difference in the candidate’s answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer
   based on candidate’s understanding.
7) For programming language papers, credit may be given to any other program based on equivalent
   concept.
1 Attempt any TEN of the following: 20

1 a) Identify the circuit of Figure No. 1

Ans:
Given circuit is purely inductive type. 2 mark

1 b) Define - Frequency. State its relation with time period.

Ans:
(i) Frequency: It is defined as number of cycles completed by an alternating quantity in one second. 1 mark
(ii) Frequency is inversely proportional to time period
\[ f = \frac{1}{T} \] 1 mark

1 c) If maximum value of a sine wave is 25A. Calculate its average value.

Ans:
Data Given: \( I_{\text{max}} = 25 \, \text{A} \),
We have,
\[ I_{\text{avg}} = 0.637 \times I_{\text{max}} \]
\[ = 0.637 \times 25 \]
\[ I_{\text{avg}} = 15.92 \, \text{A} \] 1 mark

1 d) Draw a power triangle and state the relation between its sides.

Ans -

Relation Between the sides of Power triangle –

\[ S = \sqrt{P^2 + Q^2} \] 1 mark

Where,
\( S \) = Apparent Power
\( P \) = Active Power
\( Q \) = Reactive Power
1 e) State the range of phase angle and hence p.f. for a series RC circuit.

Ans:
- The range of phase angle: 0 to 90°
- The range of Power factor (\(\cos\phi\)) for a series RC circuit: \(0 \leq \cos\phi < 1\) (leading)

1 f) In a series RL circuit \(V_R = 100V\) and \(V_L = 150V\). Find the equivalent voltage across the circuit.

Ans:
The equivalent voltage across the circuit is given by,
\[
V = \sqrt{(V_R^2 + V_L^2)}
\]
\[
= \sqrt{100^2 + 150^2} = \sqrt{32500} = 180.27 \text{ volt}
\]

1 g) Write equation of resonant frequency and quality factor in terms of circuit components for a parallel circuit.

Ans:
Equation for resonance frequency in terms of circuit components for parallel circuit.
\[
f_r = \frac{1}{2\pi\sqrt{LC}}
\]
Equation for quality factor in terms of circuit components for parallel circuit.
\[
Q = \frac{1}{R\sqrt{C}}
\]

1 h) Draw phasor diagram for 3 φ generated voltages.

Ans –

1 i) List any two advantages of 3 φ circuits over single-phase circuits.

Ans -
**Advantages of 3 φ circuits over 1 φ circuits.**

i) The power generated by 3-phase machine is higher than that of 1-phase machine of the same size.

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

iii) Three-phase transmission is more economical than single-phase transmission. It requires less copper material.
iv) Three-phase induction motors are self-starting.

v) Three-phase machines have high efficiency, better power factor and uniform torque.

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

1 j) State only the formula for star to delta transformation.

Ans:

\[
R_{12} = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_3}  \\
R_{23} = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_1}  \\
R_{31} = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_2}
\]

2 marks for formula

1 k) State ‘Norton’s’ Theorem.

Ans: Norton’s Theorem:

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

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

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

1 l) Find \(R_{TH}\) from Figure No. 2

Ans:

\[R_{TH} = R_{AB} = 20 \parallel 16 = 320/36 = 8.89 \ \Omega\]

1 mark for circuit diagram

1 mark for stepwise solution
1 m) State Maximum Power Transfer theorem for AC circuits.

Ans:
**Maximum Power transfer theorem for AC circuits:**
“It states that the maximum amount of power is delivered to the load impedance when the load impedance is equal to the complex conjugate of the internal impedance of the source or Thevenin’s equivalent impedance of the network supplying the power to load.”

According to this theorem, condition for maximum power to be transferred to load is when 
\[ Z_L = Z_{TH}^* = Z_S^* \]
where 
- \( Z_L \) = Load impedance
- \( Z_S \) = Internal impedance of the source
- \( Z_{TH} \) = Thevenin’s Equivalent impedance of the network supplying power to the load.

1 n) State meaning of \( t = 0^- \) and \( t = 0^+ \).

Ans –
1) \( t = 0^- \) is the instant just before the switching instant \( t = 0 \)
2) \( t = 0^+ \) is the instant just after the switching instant \( t = 0 \)

2 Attempt any FOUR of the following: 16

2 a) For a single loop AC generator-
   (i) Draw a neat sketch.
   (ii) Identify components used.
   (iii) Write equation of generated emf.
   (iv) Draw waveform of output voltage.

Ans:
(i) Neat sketch of single loop AC generator

![Neat sketch of single loop AC generator](image)

OR any other equivalent sketch

(ii) Components used:
- a) Permanent magnets.
- b) Single turn coil.
- c) Slip rings
- d) Brushes
- e) Shaft.

(iii) Equation of generated emf:
\[
e = B. \ell \cdot v \cdot \sin(\omega t) \text{ volt} = E_m \sin(\omega t) \text{ volt}
\]
where, \( e \) = Instantaneous value of the emf
\( B \) = Flux-density in Wb/m^2
\( \ell \) = Active length of conductor in m
\( v \) = Linear velocity of conductor in m/s.
\( \omega \) = Angular velocity of conductor in rad/sec
\( t \) = time in sec.

(iii) Waveform of output voltage.

![Waveform of output voltage](image)

2 b) An alternating current is given by \( i = 20 \sin (314t) \).
Find –
(i) Current at \( t = 0.0025 \) sec at first instant.
(ii) Time period to reach at 12A for first time.

**Ans:**

i) **Current at \( t = 0.0025 \) sec at first instant:**
Instantaneous value \( i = 20 \sin(314 \times 0.0025) = 20 \sin(0.785) \)
\[ \therefore i = 14.1365 \text{ A} \]
Thus the current at \( t = 0.0025 \) sec at first instant is 14.1365 A.

ii) **Time period to reach at 12A for first time:**
Instantaneous value \( i = 12 = 20 \sin(314t) \)
\[ \therefore \sin(314t) = \frac{12}{20} = 0.6 \]
\[ \therefore 314t = \sin^{-1}(0.6) \]
\[ \therefore t = \frac{0.6435}{314} = 0.00205 \text{ sec} \]
Thus the current takes \( t = 0.00205 \) sec to reach at 12A for first time.

2 c) In RLC series circuit \( R = 8\Omega \), \( L = 0.42 \text{ H} \) with an unknown capacitor. If the circuit is connected across 230V, 50Hz, 1φ AC. Calculate value of capacitor so that circuit resonates at supply frequency. Also calculate current and p.f. at this instant.

**Ans:**
Data given:
Resistance \( R = 8\Omega \)
Inductance \( L = 0.42 \text{ H} \)
Supply voltage \( V = 230 \text{V} \)
Supply frequency \( f = 50 \text{ Hz} \)
Resonant frequency is given by,
\[ f = \frac{1}{2\pi\sqrt{LC}} \]

1 mark
\[ \therefore \frac{1}{50 \sqrt{0.42 \times C}} = 4.911 \times 10^{-3} \]

\[ \therefore C = 24.12 \times 10^{-6} F = 24.12 \mu F \quad \text{(Ans)} \]

At resonance, the current is given by,

\[ I = \frac{V}{\sqrt{R}} = \frac{230}{8} = 28.75 \, \text{A} \quad \text{1 mark} \]

P.F. of the circuit:

The power factor of the circuit at resonance is \text{UNITY},

\[ \cos \theta = 1 \quad \text{1 mark} \]

2. d) A series circuit has a leading pf. Express it with circuit, waveform and phasor diagram.

\text{Ans:-}

i) The series circuit having leading pf is capacitive circuit (i.e RC series circuit).

\[ v = V_m \sin \omega t \quad \text{1 mark for circuit diagram} \]

ii) The waveform and phasor diagram of voltage, current are as follows:

2. e) Find current I in the circuit shown in Figure No. 3 using admittance method.
Ans:

\[ V = 100 \angle 0^\circ \text{ volts}, \quad f = 50\text{Hz} \]

\[ X_L = 2\pi f L = 2\pi (50)(0.01) = 3.142 \Omega \]

\[ Z_1 = R_1 + jX_L = (2 + j3.142)\Omega = 3.724 \angle 57.52^\circ \]

\[ \begin{align*}
Z_C &= \frac{1}{\frac{2\pi f C}{2\pi (50)(1500 \times 10^{-6})}} = 2.12 \Omega \\
Z_2 &= R_2 - jX_C = (0 - j2.12)\Omega = 2.12 \angle 90^\circ \\
Y_1 &= \frac{1}{Z_1} = \frac{1}{3.724 \angle 57.52^\circ} = 0.268 \angle -57.52^\circ = 0.144 - j0.226 \\
Y_2 &= \frac{1}{Z_2} = \frac{1}{2.12 \angle 90^\circ} = 0.472 \angle 90^\circ = 0 + j0.472 \\
Y &= Y_1 + Y_2 = G + jB = 0.144 - j0.226 + 0 + j0.472 = 0.144 + j0.246 = 0.285 \angle 59.66^\circ
\]

Total Current \( I = V \times Y = (100 \angle 0^\circ) \times (0.285 \angle 59.66^\circ) = 28.5 \angle 59.66^\circ \text{ amp} \)

(Truncation errors may please be ignored)

2 f) List any four observations from the phasor diagram of a 3Φ delta connection.

Ans:

For balanced delta connection, the observations from phasor diagram are:

- Line voltage = Phase voltage.
- Line current = \( \sqrt{3} \) Phase current
- Phase currents are \( I_R, I_Y \) and \( I_B \) whereas the line currents are \((I_R - I_B), (I_Y - I_R)\) and \((I_B - I_Y)\).
- The phase currents \( I_R, I_Y \) and \( I_B \) lag behind the corresponding phase voltages \( V_{RY}, V_{YB} \) and \( V_{BR} \) respectively by an angle \( \phi \).
- For balanced supply, the phase voltages (also line voltages) are balanced i.e.

\[ \text{For balanced delta connection, the observations from phasor diagram are:} \]

\[ \cdot \quad \text{Line voltage = Phase voltage.} \]
\[ \cdot \quad \text{Line current = } \sqrt{3} \text{ Phase current} \]
\[ \cdot \quad \text{Phase currents are } I_R, I_Y \text{ and } I_B \text{ whereas the line currents are } (I_R - I_B), (I_Y - I_R) \text{ and } (I_B - I_Y). \]
\[ \cdot \quad \text{The phase currents } I_R, I_Y \text{ and } I_B \text{ lag behind the corresponding phase voltages } V_{RY}, V_{YB} \text{ and } V_{BR} \text{ respectively by an angle } \phi. \]
\[ \cdot \quad \text{For balanced supply, the phase voltages (also line voltages) are balanced i.e.} \]
their RMS magnitudes are equal but displaced from each other by 120°.

- For balanced supply, the phase currents (also line currents) are balanced i.e their RMS magnitudes are equal but displaced from each other by 120°.
- All the three impedances are identical.

3 Attempt any FOUR of the following:

3 a) Define peak factor and form factor. State value of each for a pure sine wave.
Ans:

i) **Peak Factor:**
   - It is defined as the ratio of the peak or crest value to the RMS value of an alternating quantity.
   - Peak factor \( \frac{\text{Peak Value}}{\text{RMS Value}} = 1.141 \) for a pure sine wave

ii) **Form Factor:**
   - It is defined as the ratio of RMS value to average value of an alternating quantity.
   - Form factor \( \frac{\text{RMS Value}}{\text{Average Value}} = 1.11 \) for a pure sine wave

3 b) State nature of pf for any two conditions in RLC series circuit. Draw phasor diagram for each.
Ans:

<table>
<thead>
<tr>
<th>( X_C &gt; X_L )</th>
<th>( X_L &gt; X_C )</th>
<th>( X_L = X_C )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power factor is leading</strong></td>
<td><strong>Power factor is lagging</strong></td>
<td><strong>Power factor is Unity</strong></td>
</tr>
</tbody>
</table>

(Any two conditions)

2 marks for nature of pfs
2 marks for phasor diagrams

3 c) A series RLC circuit consists of \( R = 20 \, \Omega \), \( L = 1 \, H \) and \( C = 2500 \, \mu F \). If it is connected across 230V, 1Φ AC, calculate Q factor and resonant frequency.
Ans:

Given:
Supply voltage \( V_s = 230V \),
\( R = 20 \, \Omega \), \( L = 1 \, H \), \( C = 2500 \, \mu F \)

Q-factor is given by,
Q-factor \( Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{20} \sqrt{\frac{1}{2500 \times 10^{-6}}} = 1 \)

Resonant frequency \( f_r = \frac{1}{2\pi \sqrt{LC}} = \frac{1}{2\pi \sqrt{1(2500 \times 10^{-6})}} = 3.183 \text{ Hz} \)

3 d) Two admittances \( Y_1 = 0.012 \angle 60^\circ \text{ mho} \) and \( Y_2 = 0.015 \angle 45^\circ \text{ mho} \) are connected in parallel across 250V, 50Hz AC. Calculate power consumed by the circuit.

**Ans:**

**Given:**

\( Y_1 = 0.012 \angle 60^\circ = 6 \times 10^{-3} + j0.0104 \)

\( Y_2 = 0.015 \angle 45^\circ = 0.0106 + j0.0106 \)

Total equivalent admittance is given by,

\[
Y = Y_1 + Y_2 = 6 \times 10^{-3} + j0.0104 + 0.0106 + j0.0106 = 0.0166 + j0.021 = 0.0268 \angle 51.67^\circ
\]

Circuit current is given by,

\[
I = VY = (250 \angle 0^\circ)(0.0268 \angle 51.67^\circ) = 6.7 \angle 51.67^\circ \text{ amp.}
\]

Power consumed by the circuit is given by,

\[
P = VI\cos\phi = (250)(6.7)\cos(51.67^\circ) = 1038.82 \text{ watt}
\]

3 e) Draw an experimental set up to find current and power for parallel circuit of \( R = 50 \Omega \) and \( L = 0.2 \text{ H} \), \( V = 230 \text{ V}, 50 \text{ Hz}, 1\phi \text{ AC.} \)

**Ans:**

\[
\text{Power } = V \times I_R = I_R^2 \times R
\]

OR Any other equivalent diagram

3 f) Three resistors each of 23 \( \Omega \) are connected in delta across a 230V, 3\( \phi \), 50 Hz, AC. Calculate the power consumed by the load.

**Ans:**

For delta connection, Phase voltage is equal to line voltage, \( \therefore V_{ph} = V_L = 230 \text{V} \)

Load is purely resistive, hence load pf = \( \cos\phi = 1 \)

Phase current \( I_{ph} = V_{ph}/R = 230/23 = 10 \text{ A} \)

Total 3\( \phi \) power consumed by load \( P_{3\phi} = 3 \times V_{ph} I_{ph} \cos\phi = 3 \times (230)(10)(1) = 6900 \text{ W} \)

4 Attempt any FOUR of the following. 16 Marks

4 a) A choke coil when connected across a 200V, 50Hz, 1\( \phi \) AC will take current at 0.8 pf lagging. The circuit consumes 2kW. Find circuit components.

**Ans:**
Circuit is inductive in nature.

Power factor \( \cos \phi = 0.8 \) lagging \( \therefore \) Phase angle \( \phi = 36.87^\circ \) ½ mark

Active power \( P = 2kW = 2000 \) W. ½ mark

Apparent power \( S = P/\cos \phi = 2000/0.8 = 2500 \) VA ½ mark

\( \therefore \) Current \( I = S/V = 2500/200 = 12.5A \) ½ mark

Impedance \( Z = V/I = 200/12.5 = 16\Omega \) ½ mark

Resistance \( R = Z\cos \phi = 16(0.8) = 12.8\Omega \) 1 mark

Inductive reactance \( X_L = Z\sin \phi = 16(0.6) = 9.6\Omega \) 1 mark

Inductance \( L = X_L/(2\pi f) = 9.6/(2\pi \times 50) = 0.03056H \) 1 mark

4 b) Derive the condition for resonance in an RLC series circuit. Also derive the equation for Q factor.

Ans:

Resonant Frequency of Series RLC Circuit:

For series R-L-C circuit, the complex impedance is given by,

\[ Z = R + jX_L - jX_C = R + jX \]

where, inductive reactance is given by \( X_L = 2\pi fL \)

capacitive reactance is given by \( X_C = \frac{1}{2\pi fC} \)

When the inductive reactance becomes equal to the capacitive reactance, the circuit impedance becomes purely resistive and equal to \( R \). This condition is called the series resonance.

Hence, at resonance, \( X_L = X_C \)

\[ 2\pi f_L L = \frac{1}{2\pi f_C C} \]

\[ f_r^2 = \frac{1}{(2\pi)^2 LC} \]

\( \therefore \) Series Resonant frequency \( f_r = \frac{1}{2\pi \sqrt{LC}} \) Hz

Resonant Angular frequency \( \omega_r = \frac{1}{\sqrt{LC}} \) rad/sec

Thus when supply frequency becomes equal to \( f_r \) the resonance is observed.

Derivation of equation of Q-factor:

A quality factor (Q-factor) basically represents a figure of merit of the component or circuit. It is defined as,

\[ Q = 2\pi \left[ \frac{\text{Maximum energy stored}}{\text{Energy dissipated per cycle}} \right] \]

Under resonance condition, the maximum energy stored in inductor is equal to that stored in capacitor.

\[ E_{\text{max}} = \frac{1}{2} L I_m^2 = \frac{1}{2} C V_m^2 = \frac{1}{2} C(I_mX_C)^2 = \frac{1}{2} I_m^2 \frac{1}{2\omega_r^2 C} \]

The energy dissipated per cycle is given by,

\[ E_d = (\text{Average power dissipated}) \times (\text{Time of one cycle}) \]

\[ = I^2 R T = \left[ \frac{I_m}{\sqrt{2}} \right]^2 R \frac{1}{f_r} = \frac{1}{2} I_m^2 R \left( \frac{2\pi}{\omega_r} \right) \]

Therefore, the Q-factor of series RLC circuit at resonance is given by,
Since series resonant \( \omega_r = \frac{1}{\sqrt{LC}} \)

\[ Q_r = \frac{1}{\sqrt{LC}} R \quad \text{or} \quad Q_r = \frac{1}{\sqrt{LC}} \frac{L}{R} \]

\[ \therefore Q_r = \frac{1}{R} \sqrt{\frac{L}{C}} \]

4 c) Three impedances each of \( Z = (15+j18)\Omega \) are connected in star across a 400V, 3φ, AC. Calculate: i) \( V_{ph} \) ii) \( I_{ph} \) iii) \( I_L \) iv) pf

Ans:

i) **Phase voltage \( V_{ph} \):**
   
   Line voltage \( V_L = 400V \)
   
   For star connection, Phase voltage \( V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94V \)

ii) **Phase current \( I_{ph} \):**

   Impedance per phase \( Z = 15+j18 = 23.43 \angle 50.19^\circ \Omega \)
   
   Phase current \( I_{ph} = \frac{V_{ph}}{Z} = \frac{230.94}{23.43} = 9.86A \)

iii) **Line current \( I_L \):**

   For star connection, Line current = Phase current = 9.86A

iv) **Power factor:**

   Power factor = \( \cos(50.19^\circ) = 0.64 \) lagging
4. d) Find the value of V of Figure No. 4 if the voltage at node A is 12V.

\[
\text{Ans:} \\
\text{Given: } V_A = 12\text{V} \\
\text{By applying KCL at node A, the equation can be written as,} \\
\frac{V_A - V}{6} + \frac{V_A}{12} + \frac{V_A - 16}{8} = 0 \\
V_A \left[ \frac{1}{6} + \frac{1}{12} + \frac{1}{8} \right] - \frac{V}{6} - 2 = 0 \\
(0.375)V_A - (0.167)V = 2 \\
(0.375)(12) - (0.167)V = 2 \\
4.5 - 2 = 0.167V \\
\therefore V = 14.97\text{ volt} \\
\]

4. e) Find the value of maximum power transferred to \( R_L = 6\Omega \) from the source of Figure No. 5

\[
\text{Ans:} \\
\text{This problem can be solved by using Thevenin's theorem.} \\
\text{A) Determination of Thevenin's equivalent Voltage } V_{Th}: \\
\]

Referring to above figure, it is clear that when load is removed and terminals are kept open, the current through 4\(\Omega\) and 2\(\Omega\) becomes zero. Therefore, no voltage drops across them and the open-circuit voltage is given by,

\[ V_{Th} = V_{OC} = 12\text{ volt} \]

\[
\text{B) Determination of Thevenin's equivalent Resistance } R_{Th}: \\
\]

Referring to above figure, since 8Ω is short-circuited, the \( R_{Th} = 4+2 = 6\Omega \)

C) Thevenin’s Equivalent Circuit:

Circuit current \( I = \frac{V_{Th}}{R_{Th}+R_L} \)

\[ I = \frac{12}{6+6} = 1 \text{ amp} \]

Maximum power transferred to load of 6Ω,

\[ P_{Max} = I^2 R_L = (1)^2 (6) = 6 \text{ watt} \]

4) Write a step by step procedure to find current through \( R_L \) of a circuit using Norton’s theorem.

**Ans:**

**Steps for finding load current by Norton’s Theorem:**

i) Identify the load branch whose current is to be found.

ii) Redraw the circuit with load branch separated from the rest of the circuit such that the load branch appears between terminals, say A and B, which are connected to rest of the circuit by two wires.

iii) Remove the load branch from terminals A and B, so that the rest of the circuit appears between these terminals A and B.

iv) Short the terminals A and B and then find the short-circuit current flowing through the shorted terminals A and B due to internal independent sources, using any circuit analysis technique. Let this short-circuit current be \( I_N \).

v) Determine the equivalent impedance of the circuit seen between the open terminals A and B, while looking back into the circuit, with all internal independent voltage sources replaced by short-circuit and all internal independent current sources replaced by open-circuit. Let this equivalent impedance be \( Z_N \).

vi) The circuit appearing between open circuited terminals A and B (due to removal of load branch) is now represented by simple circuit consisting of a current source, having magnitude \( I_N \) in parallel with an impedance \( Z_N \).

vii) If the load impedance is \( Z_L \), then connecting it between terminals A and B gives rise to load current \( I_L = I_N \left( \frac{Z_N}{Z_N+Z_L} \right) \)

5) Attempt any **FOUR** of the following:

5 a) A balanced load connected in delta across a 415V, 3ϕ, 50Hz supply takes a phase
current of 15A at 0.8 pf lag. Find components of the load.

Ans:
For delta connection, Phase voltage = Line voltage = 415V
Phase current = 15A
Power factor pf = 0.8 lagging
\[ \therefore \text{Phase angle } \phi = \cos^{-1}(0.8) = 36.87^\circ \text{ lagging} \]
\[ \therefore \text{Load impedance per phase} = Z_{ph} = \frac{V_{ph}}{I_{ph}} = 415\angle0^\circ/15\angle-36.87^\circ \]
\[ = 27.67\angle36.87^\circ \]
\[ = (22.14+j16.6)\Omega \]
\[ \therefore \text{Load Components are: Resistance } R = 22.14\Omega \]
\[ \text{Inductive reactance } X_L = 16.6\Omega \]
\[ \text{Inductance } L = \frac{X_L}{2\pi f} = 16.6/(2\pi \times 50) = 0.053 H \]

5 b) Derive relation between \( I_L \) and \( I_{ph} \) from the phasor diagram of a 3\( \Phi \) delta connected balanced load.

Ans:
From the diagram, the current in each line is vector difference of the two phase currents.

For example:

Current in line R is \( I_R = I_{BR} - I_{RY} \)
Current in line Y is \( I_Y = I_{RY} - I_{YB} \)
Current in line B is \( I_B = I_{YB} - I_{BR} \)

Current in line R is found by compounding \( I_{BR} \) and \( I_{RY} \) and value given by parallelogram in phasor diagram.

Angle between \( I_{BR} \) and \(-I_{RY}\) is 60°,
where \( |I_{BR}| = |I_{RY}| = \text{Phase current } I_{ph} \)

\[ I_R = I_{BR} - I_{RY} = 2I_{ph} \cos \frac{60^\circ}{2} = 2I_{ph} \frac{\sqrt{3}}{2} = \sqrt{3}I_{ph} \]
\[ I_Y = I_{RY} - I_{YB} = 2I_{ph} \cos \frac{60^\circ}{2} = 2I_{ph} \frac{\sqrt{3}}{2} = \sqrt{3}I_{ph} \]
\[ I_B = I_{YB} - I_{BR} = 2I_{ph} \cos \frac{60^\circ}{2} = 2I_{ph} \frac{\sqrt{3}}{2} = \sqrt{3}I_{ph} \]

As \( I_R = I_Y = I_B = I_L \)
\[ I_L = \sqrt{3}I_{ph} \]

5 c) Find current through 8\( \Omega \) resistor of Figure No. 6 using Nodal Analysis.
Referring to figure, the nodal equation at node A can be written as:

\[ 6 = \frac{V_A}{8} + \frac{V_A - 15}{5} \]

\[ \therefore V_A \left[ \frac{1}{8} + \frac{1}{5} \right] = 9 \]

\[ \therefore V_A = 27.69V \]

Current flowing through 8Ω resistor is then given by,

\[ I = \frac{V_A}{8} = 27.69/8 = 3.46A \]

5 d) Write a step by step procedure to find current through a load resistor using Mesh analysis.

**Ans:**

**Steps to Solve Circuit using Mesh Analysis:**

i) For a given planar circuit, convert each current source, if any, into voltage source.

ii) Assign a mesh current to each mesh. The direction for each mesh current can be marked arbitrarily, however if same direction is considered for all mesh currents, then the resulting equations will have certain symmetry properties.

iii) Write KVL equation for each mesh. The equations will have terms with currents on one side and constant on the other side.

iv) Solve the resulting set of simultaneous algebraic equations and find the mesh currents.

v) Using mesh currents then find the branch currents and branch voltages.

5 e) Find current through 8Ω resistor of Figure No. 7 using super position theorem.
(A) Consider voltage source of 36V acting alone:

The total resistance appearing across 36V source is given by,
\[ R_T = 1+2+(4\parallel 8) = 1+2+(32/12) = 5.67 \, \Omega \]

The current \[ I = \frac{36}{5.67} = 6.35 \, \text{A} \]

The current through 8Ω due to 36V source alone is given by,
\[ I_1 = I \times \frac{4}{12} = 6.35 \times \frac{1}{3} = 2.12 \, \text{A} \]

(B) Consider voltage source of 54V acting alone:

The total resistance appearing across 54V source is given by,
\[ R_T = 4+(2+1)\parallel 8 = 4+ \frac{24}{11} = 6.182 \, \Omega \]

The current \[ I = \frac{54}{6.182} = 8.735 \, \text{A} \]

The current through 8Ω due to 54V source alone is given by,
\[ I_2 = I \times \frac{3}{12} = 8.735 \times \frac{1}{4} = 2.184 \, \text{A} \]

By Superposition theorem, the current through 8Ω due to both sources is given by,
\[ I_L = I_1 + I_2 = (2.12 + 2.184) = 4.304 \, \text{A} \]

5 f) Find current through 8Ω resistor of Figure No. 7 using Thevenin’s theorem.

Ans:
The circuit is redrawn as shown in the figure.

A) Determination of Thevenin’s Equivalent Voltage (V_{TH}):
The Thevenin’s equivalent voltage $V_{TH}$ is given by the open circuit voltage $V_{OC}$ appearing across the load (8 $\Omega$) terminals A-B when it is removed, as shown below.

When the load branch (8 $\Omega$) is removed, only one loop remains in the circuit making the loop or circuit current equal to that delivered by both the sources

$$I = \frac{54 - 36}{(4+2+1)} = \frac{18}{7} = 2.57A$$

The Thevenin’s equivalent voltage is given by,

$$V_{Th} = V_{OC} = V_{AB} = 54 - 4I = 54 - 4(2.57) = 43.72 \text{ V}$$

**B) Determination of $R_{TH}$:**

$$R_{Th} = 4||3 = 1.71 \text{ $\Omega$}$$

**C) Determination of $I_L$:**

$$I_L = V_{Th}/(R_{Th}+R_L) = 43.72/(1.71+8) = 4.5 \text{ A}$$

6 Attempt any FOUR of the following: 16

6 a) Find $I_1, I_2$ and $I$ of the Figure No. 8

Ans:

For parallel circuit shown in the figure,

$$I_1 = V.Y_1 = 200 \angle 0^\circ \times 0.033 \angle -30^\circ = 6.6 \angle -30^\circ \text{ A} = (5.716-j3.3) \text{ A}$$
\[ I_2 = V.Y_2 = 200 \angle 0^\circ \times 0.025 \angle 60^\circ = 5 \angle 60^\circ \ A = (2.5+j4.33) \ A \]

Total current \[ I = I_1 + I_2 = (5.716-j3.3) + (2.5+j4.33) \]
\[ = (8.216 +j 1.03) \ A = 8.28 \angle 7.146^\circ \ A \]

6 b) Current drawn by a 3φ star connected load of 12Amp. 0.8 p.f. lagging when connected across 3φ, 440V AC. Find active, reactive and apparent power.

**Ans:**

**Data given:**

Line Voltage \( V_L = 440V \)

Line current \( I_L = \) Phase current \( I_{ph} = 12 \ A \)

Power factor \( \cos \phi = 0.8 \) lagging \( \therefore \sin \phi = 0.6 \)

i) Active power \( P = \sqrt{3}V_LI_L\cos \phi = \sqrt{3}(440)(12)(0.8) = 7316.18 \ W \)

ii) Reactive power \( Q = \sqrt{3}V_LI_L\sin \phi = \sqrt{3}(440)(12)(0.6) = 5487.14 \ VAr \)

iii) Apparent power \( S = \sqrt{3}V_LI_L = \sqrt{3}(440)(12) = 9145.23 \ VA \)

6 c) Find \( I_L \) of Figure No. 9 using Mesh analysis.

**Ans:**

By applying KVL to loop ABCDA
\[ 10 - 9I_1 - 6(I_1 - I_2) - 5I_1 = 0 \]
\[ 20I_1 - 6I_2 = 10 \quad .............(1) \]

By applying KVL to Loop EFCBE
\[ 20 - 10I_2 - 6(I_2 - I_1) - 4I_2 = 0 \]
\[ 6I_1 - 20I_2 = -20 \quad .............(2) \]

Expressing eq.(1) and (2) in matrix form,
\[
\begin{bmatrix}
20 & -6 \\
6 & -20
\end{bmatrix}
\begin{bmatrix}
I_1 \\
I_2
\end{bmatrix}
= \begin{bmatrix}
10 \\
-20
\end{bmatrix}
\]

\[ \therefore \Delta = \begin{vmatrix} 20 & -6 \\ 6 & -20 \end{vmatrix} = -400 + 36 = -364 \]

By Cramer’s rule,
\[
I_1 = \frac{10(-20) - (-6)(-20)}{-364} = \frac{-200 - 120}{-364} = 0.879 \ A
\]

\[
\frac{1}{2} \text{ mark}
\]
Current flowing through load resistance of 6Ω

\[ I_L = I_2 - I_1 = 1.264 - 0.879 = 0.385 \text{ A (Upward direction)} \]

6 d) Find current through 12Ω resistor using superposition theorem.

\[ I_L = I_1 + I_2 = (0.6374 + 0.5453) = 1.1827 \text{ A} \]
6 e) Find $R_{TH}$ for the circuit shown in Figure No. 11.

![Circuit Diagram](image)

**Ans:**

NOTE: Assume unspecified value of resistance equal to $1\Omega$

Referring to the figure, the Thevenin’s equivalent resistance is given by,

\[
R_{TH} = \frac{1 + 2}{(1 + 1)(1 + 1)} = \frac{3}{2.67} = \frac{3\times2.67}{3+2.67} = 1.41\Omega
\]

6 f) Explain the concept of initial condition in switching circuits for the elements R, L, C.

**Ans:**

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

i) **Resistor:**
At any time it acts like resistor only, with no change in condition.

ii) **Inductor:**
The current through an inductor cannot change instantly. If the inductor current is zero just before switching, then whatever may be the applied voltage, just after switching the inductor current will remain zero. i.e the inductor must be acting as open-circuit at instant $t = 0$. If the inductor current is $I_0$ before switching, then just after switching the inductor current will remain same as $I_0$ and having stored energy hence it is represented by a current source of value $I_0$ in parallel with open circuit.

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

iii) **Capacitor:**
The voltage across capacitor cannot change instantly. If the capacitor voltage is zero initially just before switching, then whatever may be the current flowing, just after switching the capacitor voltage will remain zero. i.e the capacitor must be acting as short-circuit at instant $t = 0$. If capacitor is previously charged to some voltage $V_0$, then also after switching at $t = 0$, the voltage across capacitor remains same $V_0$. Since the energy is stored in the capacitor, it is represented by a voltage source $V_0$ in series with short-circuit.
As time passes the capacitor voltage slowly rises and finally it becomes constant. Therefore the current through the capacitor falls to zero \[ i_C = C \frac{dv_C}{dt} = 0 \].

The initial conditions are summarized in the following table:

<table>
<thead>
<tr>
<th>Element and condition at ( t = 0^- )</th>
<th>Initial Condition at ( t = 0^+ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R )</td>
<td>( R )</td>
</tr>
<tr>
<td>( L )</td>
<td>( \text{O.C.} )</td>
</tr>
<tr>
<td>( I_0 \rightarrow L )</td>
<td>( \text{O.C.} )</td>
</tr>
<tr>
<td>( C )</td>
<td>( \text{S.C.} )</td>
</tr>
<tr>
<td>[ V_0 = \frac{q_0}{C} ]</td>
<td>( -V_0 )</td>
</tr>
</tbody>
</table>