Important Instructions to examiners:

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

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

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

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

5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate’s answers and model answer.

6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate’s understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept.
1 Attempt any TEN of the following: 20

1 a) Define: i) Amplitude, ii) Frequency of a.c. quantity
Ans:
   i) Amplitude : A maximum value or peak value attained by an alternating quantity during positive or negative half cycle is called as its amplitude.
   ii) Frequency of a.c. quantity: It is defined as number of cycles completed by alternating quantity in one second.

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

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


2 Marks

1 d) Define power factor and state its value for pure resistive circuits.
Ans:
   Power Factor:
   - It is the cosine of the angle between the applied voltage and the resulting current.
     Power factor = \(\cos \phi\)
     where, \(\phi\) is the phase angle between applied voltage and current.
   - It is the ratio of true or effective or real power to the apparent power.
     Power factor = \(\frac{\text{True or Effective or Real Power}}{\text{Apparent Power}} = \frac{V \cos \phi}{VI} = \cos \phi\)
   - It is the ratio of circuit resistance to the circuit impedance.
     Power factor = \(\frac{\text{Circuit Resistance}}{\text{Circuit Impedance}} = \frac{R}{Z} = \cos \phi\)

   Value of power factor for purely resistive circuit = UNITY i.e one

1 e) Define terms conductance and susceptance and state their unit.
Ans:-
   Conductance (G):
   It is defined as the real part of the admittance (Y).
   It is also defined as the ability of the purely resistive circuit to pass the alternating current.
   OR
   It is also defined as the ratio of resistance to the square of the impedance.
   In general, Conductance, \(G=\frac{R}{Z^2}\) siemen. Its unit is siemen (S).
Susceptance (B): 
It is imaginary part of the admittance (Y).
It is defined as the ability of the purely reactive circuit (purely capacitive or purely inductive) to admit alternating current.

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

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

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

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

1 i) Write the procedure of converting a given current source into voltage source.
Ans:
**Conversion of current source into equivalent voltage source:**
Let \( I_S \) be the practical current source magnitude and
\( Z_1 \) be the internal parallel impedance.
\( V_S \) be the equivalent practical voltage source magnitude and
\( Z_V \) be the internal series impedance of the voltage source.
The open circuit terminal voltage of current source is \( V_{OC} = I_S \times Z_I \)

The open circuit terminal voltage of voltage source is \( V_{OC} = V_S \)

Therefore, we get \( V_S = I_S \times Z_I \) ...........................................(1)

\( \text{OR} \)

The short circuit output current of current source is \( I_{SC} = I_S \)

The short circuit output current of voltage source is \( I_{SC} = V_S / Z_V \)

Therefore, we get \( I_S = V_S / Z_V \) .................................(2)

On comparing eq. (1) and (2), it is clear that \( Z_I = Z_V = Z \) ............ ....(3)

Thus the internal impedance of both the sources is same, and the magnitudes of the source voltage and current are related by Ohm’s law, \( V_S = I_S \times Z_I \)

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

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

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

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

   2 Marks for all three equations

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

   Ans:

   ![Diagram](image_url)
Let the voltage at Node A be $V_A$

\[ I = I_1 + I_2 \]

\[ \frac{10 - V_A}{5} = \frac{V_A + 20}{5} + \frac{V_A}{10} \]

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

\[ -2 = \frac{2V_A}{5} + \frac{V_A}{10} \]

\[ 5V_A = -2 \]

\[ \therefore V_A = -4 \text{ volt} \]

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

i) Pure L

ii) Pure C

**Ans:**

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

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

2) Attempt any FOUR of the following:

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

**Ans:**

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

   **OR**

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

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

   **OR**

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

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

Find: i) R.M.S. value of current, ii) Average value of voltage.

**Ans:**

**Phasor diagram:**
Waveforms:

\[ v = V_m \sin(\omega t) \]

\[ i = 14.14 \sin(\omega t - 30^\circ) \]

R.M.S. value of current:

\[ I = \frac{I_m}{\sqrt{2}} = 9.99 \approx 10 \text{A.} \]

Average value of voltage:

\[ V_{av} = 0 \text{ (over full cycle)} \]

\[ = 0.637 \times V_m = 127.4 \text{V (over half-cycle)} \]

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

**Ans:**

For condition \( X_L > X_C \)

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

**Ans:**
Derive an expression for resonance frequency for the circuit shown in Figure No. 2.

Ans:

Resonance frequency for a RL-C parallel circuit:

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

Net reactive component = \( I_c - I_L \sin \phi_L \)

As at resonance, its value is zero, hence

\[ I_c = I_L \sin \phi_L \]

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

Hence condition for resonance becomes

\[ \frac{V}{X_c} = \frac{V}{Z} \times \frac{X_L}{Z} \]

OR \( X_cX_L = Z^2 \) where \( Z = (R + jX_L) \)

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

\[ \frac{\omega L}{\omega C} = Z^2 \]

OR \( \frac{L}{C} = Z^2 \)

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

\[ (2\pi f_0 L)^2 = \frac{L}{C} - R^2 \]
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\[ 2\pi f_0 = \frac{1}{\sqrt{LC - \frac{R^2}{L^2}}} \]
\[ f_0 = \frac{1}{2\pi \sqrt{LC - \frac{R^2}{L^2}}} \]

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

Ans:-
Given \( Z_{ph} = 5 + j6 = 7.81 \angle 50.19^\circ \Omega \) Connected in Star
\[ V_L = \sqrt{3} V_{ph} \text{ and } I_L = I_{ph} \]
\( V_L = 400V. \)
Hence, \( V_{ph} = \frac{400}{\sqrt{3}} = 230.94V \)
\[ I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94}{7.81 \angle 50.19^\circ} \]
\[ I_{ph} = 29.56 \angle -50.19^\circ \text{A} \]
\[ I_L = I_{ph} = 29.56 \angle -50.19^\circ \text{A} = (18.92 - j22.70) \text{A}. \]
\[ \phi = -50.19^\circ \]
\[ \cos \phi = \cos(-50.19) = 0.640 \]
Power drawn = \( \sqrt{3} V_L I_L \cos \phi \)
\[ = \sqrt{3} \times 400 \times 29.56 \times 0.64 \]
\[ = 13107.05 \text{ watt} = 13.10705 \text{ kW} \]

OR
Power drawn = \( 3 V_{ph} I_{ph} \cos \phi \)
\[ = 3 \times 230.94 \times 29.56 \times 0.64 \]
\[ = 13107.05 \text{ watts} = 13.10705 \text{ kW}. \]

3 Attempt any FOUR of the following

3 a) A 50H inductor is connected across a 230V, 50Hz supply, determine:
   (i) Inductive reactance
   (ii) RMS value of current
   (iii) Equation for voltage
   (iv) Equation for current

Ans:
Given: \( L=50H, V=230V, f = 50Hz \)
Find (i) \( X_L \) (ii) \( I_{rms} \) (iii) Equation for Voltage (iv) Equation for current

(i) Inductive Reactance
\[ X_L = 2\pi f L = 2\pi \times 50 \times 50 = 15707.96 \Omega \]

(ii) R. M.S. value of current
\[ I_{RMS} = \frac{V}{X_L} = \frac{230}{15707.96} = 0.0146 \text{ Amp} \]
(iii) Equation for Voltage
Angular frequency $\omega = 2\pi f = 2 \times 3.142 \times 50 = 314.2$ rad/sec

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

(iv) Equation for current

\[ i = I_m \sin(\omega t - 90^\circ) = \sqrt{2} \times 0.0146 \sin(314.2t - 90^\circ) \]
\[ = 0.0206 \sin(314.2t-90^\circ) \]

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

Ans:

3 c) Calculate current $I$ shown in Figure No. 3.

Ans:

Given:
Supply voltage $V_s = 120V$, $f = 50$ Hz
Lamp (Resistance) $R = \frac{V_L^2}{W} = \frac{(100)^2}{200} = 50 \, \Omega$,
C = $20 \times 10^{-6}$ F,
Capacitive Reactance: $X_c = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 20 \times 10^{-6}} = 159.15 \, \Omega$
Impedance
\[ Z = \sqrt{R^2 + X_c^2} = \sqrt{50^2 + (-159.15)^2} = 166.82 \, \Omega \]
Current
\[ I = \frac{V}{Z} = \frac{120}{166.81} = 0.719 \, \text{Amp} \]

3 d) Compare series resonance and parallel resonance circuit on any four parameters.

Ans:

Comparison between Series & Parallel Resonance Circuit:
3 e) Explain in detail generation of three phase emf.

Ans:

**Generation of Three-phase EMF:**

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

The equations of three emfs can be represented by

\[ v_a = E_m \sin(\omega t) \quad \text{(i)} \]

\[ v_b = E_m \sin(\omega t - 120^\circ) \quad \text{(ii)} \]

\[ v_c = E_m \sin(\omega t - 240^\circ) \quad \text{(iii)} \]

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

Ans:

\( V_{TH} \) can be calculated by using superposition theorem

A) Consider 20 V source only:
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B) Consider 4 A source only:

\[ I_{L2} = \frac{4 \times 8}{8+5} = \frac{32}{13} = 2.461 \text{ A} \]

Total Current through 5 \( \Omega \) load, \( I_L = 1.538 + 2.461 = 3.999 \text{ A} \)

\[ V_{TH} = 3.999 \times 5 = 19.995 \text{ V} \]

C) Determination of \( R_{TH} \):

\[ R_{TH} = 4+4 = 8 \text{ } \Omega \]

D) Determination of \( I_L \):

\[ I_L = \frac{V_{TH}}{R_{TH} + R_L} = \frac{19.995}{(8+5)} = 1.538 \text{ Amps} \]

4 Attempt any FOUR of the following. 16 Marks

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

_ans:

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

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

(i) **Leading Quantity**: The quantity which attains the respective zero or peak value first, is called ‘Leading Quantity’.

\[ R_{TH} \]

1 Mark for \( R_{TH} \)

\[ I_L \]

1 Mark for \( I_L \)

\[ I_L = \frac{V_{TH}}{R_{TH} + R_L} = \frac{19.995}{(8+5)} = 1.538 \text{ Amps} \]

\[ V_{TH} \]

2 Marks for waveform
(ii) **Lagging Quantity:** The quantity which attains the respective zero or peak value later, is called ‘Lagging Quantity’

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

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

![Diagram showing inductive and capacitive circuit](image)

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

**Ans:**

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

**Branch of $Z_1$**

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

$kVA_1 = VI_1 = 200 \times 10 = 2000$ VA = 2 kVA

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

$kW_1 = VI_1 \cos \phi_1 = 200 \times 10 \times 0.6 = 1200$ W = 1.2 kW

$kVAR_1 = VI_1 \sin \phi_1 = 200 \times 10 \times 0.8 = 1.6$ kVAR

**Branch of $Z_2$**

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

$kVA_2 = VI_2 = 200 \times 8.94 = 1788$ VA = 1.788 kVA

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

$kW_2 = VI_2 \cos \phi_2 = 200 \times 8.94 \times 0.447 = 799.236$ W = 0.799 kW

$kVAR_2 = VI_2 \sin \phi_2 = 200 \times 8.94 \times 0.895 = 1599.43$ VAR = 1.59943 kVAR

½ Mark for leading quantity

½ Mark for lagging quantity
Power factor of whole circuit

\[ \cos \Phi_T = \frac{R_{eq}}{Z_{eq}} = \frac{20}{20} = 1 \]

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

**Ans:**

**Star-delta Transformation:**

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

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

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

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

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

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

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

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

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

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

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

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

Similarly, we can obtain,

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

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

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

\[ R_1R_2 = \frac{(R_{12})^2R_{31}R_{23}}{(R_{12} + R_{23} + R_{31})^2} \]  

\[ R_2R_3 = \frac{(R_{23})^2R_{31}R_{12}}{(R_{12} + R_{23} + R_{31})^2} \]
\[ R_3R_1 = \left[ \frac{(R_{31})^2R_{12}R_{23}}{(R_{12}+R_{23}+R_{31})^2} \right] \] .............................. (10)  

Adding the three equations (8), (9) and (10),  
\[ R_1R_2 + R_2R_3 + R_3R_1 = \frac{(R_{12})^2R_{31}R_{23} + (R_{23})^2R_{31}R_{12} + (R_{31})^2R_{12}R_{23}}{(R_{12}+R_{23}+R_{31})^2} \]  
\[ R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}R_{31}R_{23}}{R_{12}+R_{23}+R_{31}} \] .............................. (11)  

Dividing eq.(11) by eq.(6), (dividing by respective sides)  
\[ R_1 + R_2 + \frac{R_3R_1}{R_2} = R_{31} \] .............................. (12)  

Similarly, we can obtain,  
\[ R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3} \] .............................. (13)  

\[ R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1} \] .............................. (14)  

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

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

\[ \text{Ans:} \]  

By applying KVL to loop 1  
\[ 15-2R_1-10(2-3)=0 \]  
\[ 15+10=2R_1 \]  
\[ R_1= \frac{25}{2} = 12.5 \, \Omega \]  

By applying KVL to loop 2  
\[ -3R_2-30-10(3-2)=0 \]  
\[ -3R_2-30-10=0 \]  
\[ -3R_2=-40 \]  
\[ R_2= -13.33 \, \Omega \]  

4 e) Calculate current flowing through 5Ω, resistor connected between A and B in Figure No. 6 by using superposition theorem.
A) Consider 20V voltage source only:

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

\[ I'_{L} = 1.6 \times 5 = 0.8 \text{A} \]

B) Consider 10A current source only:

10 \Omega in parallel to 5 \Omega gives resultant = \( (10 \times 5) / 15 = 3.33 \ \Omega \)

\[ I''_{L} = 10 \times \frac{3.33}{8.33} = 4 \text{A} \]

\[ I_{L} = I'_{L} + I''_{L} = 0.8 + 4 = 4.8 \text{ Amp} \]

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

Ans:

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

i) **Resistor:**

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

ii) **Inductor:**

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

As time passes the inductor current slowly rises and finally it becomes constant. Therefore the voltage across the inductor falls to zero \[v_L = L \frac{di_L}{dt} = 0\]. The presence of current with zero voltage exhibits short circuit condition. Therefore, under steady-state constant current condition, the inductor is represented by a short circuit. If the initial inductor current is non-zero \(I_0\), making it as energy source, then finally inductor is represented by current source \(I_0\) in parallel with a short circuit.

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 presence of voltage with zero current exhibits open circuit condition. Therefore, under steady-state constant voltage condition, the capacitor is represented by a open circuit. If the initial capacitor voltage is non-zero \(V_0\), making it as energy source, then finally capacitor is represented by voltage source \(V_0\) in series with a open-circuit.

The initial and final conditions are summarized in following table:

<table>
<thead>
<tr>
<th>Element and condition at (t = 0)</th>
<th>Initial Condition at (t = 0^+)</th>
<th>Final Condition at (t = \infty)</th>
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<td><img src="image3" alt="Resistor" /> (R)</td>
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<td><img src="image5" alt="Inductor" /> (L)</td>
<td><img src="image6" alt="Capacitor" /> (C)</td>
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<td><img src="image4" alt="Capacitor" /> (C)</td>
<td><img src="image5" alt="Inductor" /> (L)</td>
<td><img src="image6" alt="Capacitor" /> (C)</td>
</tr>
<tr>
<td>(I_0)</td>
<td>(0)</td>
<td>(0)</td>
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<td>(V_0)</td>
<td>(V_0)</td>
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</table>

5 a) i) If \(A = 10+j8\), \(B = -7+j5\), \(C = 8+j6\),

\[
\text{Find } (1) \frac{AB}{C} (2) \frac{(A+B)}{(B-C)}
\]
Ans:
Converting A, B and C in Polar form we get,
A = (10 + j8) = 12.80∠38.65°,
B = (-7 + j5) = 8.60∠144.46°,
C = (8 + j6) = 10∠36.87°

(1) \( \frac{AB}{C} = (12.80∠38.65°) \times (8.60∠144.46°) / (10∠36.87°) \)
\( \frac{AB}{C} = 110.08∠183.11° / (10∠36.87°) \)
\( \frac{AB}{C} = 11.00∠146.24° = -9.15 + j6.11 \)

(2) \( \frac{A+B}{B-C} = [(10+j8) +(-7+j5)] / [(-7+j5)-(8+j6)] = (3+j13)/(-15-j1) \)
= 13.34∠77.00°)/(15.03∠-176.185°)
\( \frac{A+B}{B-C} = 0.887∠253.185° = -0.256 - j0.85 \)

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

Ans:
Given: \( R = 10 \, \Omega, \, L = 0.2 \, H, \, C = 50 \, \mu F = 50 \times 10^{-6} \, F, \, V = 200V, \, f = 50 \, Hz \)

(1) \( X_L = 2 \pi f L = 2 \times \pi \times 50 \times 0.2 = 62.83 \, \Omega \)
\( X_C = \frac{1}{(2 \pi f C)} = 1/(2 \times \pi \times 50 \times 50 \times 10^{-6}) = 63.66 \, \Omega \)
Impedance \( Z = \sqrt{R^2+(X_L-X_C)^2} = \sqrt{10^2+(62.83-63.66)^2} = 10.03 \, \Omega \)

(2) Total current \( I = \frac{V}{Z} = 200/10.03 = 19.94 \, A \)

(3) Power factor = \( \cos \phi = \frac{R}{Z} = \frac{10}{10.03} = 0.997 \, leading \)

(4) \( P = I^2 R = 19.94^2 \times 10 = 3976.036 \, watts = 3.97 \, kW \)
\( P = V \, I \cos \phi = 200 \times 19.94 \times 0.997 = 3976.036 = 3.97 \, kW \)

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

Ans:

Relationship for balanced delta connection:
Line voltage = Phase voltage
i.e. \( V_L = V_{ph} \)

Line current = \( \sqrt{3} \) Phase current
i.e. \( I_L = \sqrt{3} \, I_{ph} \)

Phasor diagram: (consider any correct equivalent phasor diagram)
5 c) i) State maximum power transfer theorem and write its procedural step to find load resistance.

**Ans:**

**Maximum Power transfer theorem:**

“It states that, the maximum amount of power is delivered to the load resistance when the load resistance is equal to the internal resistance of the source or Thevenin’s equivalent resistance of the network supplying the power to load.”

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

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

**Steps for Solving Network Using Maximum Power Transfer Theorem:**

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

**Step I:** Remove the load resistance of the circuit.

**Step II:** Find the Thevenin’s resistance ($R_{TH}$) of the source network looking through the open circuited load terminals.

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

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

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

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

A) Determination of $R_{th}$:
By removing $R_L$ and short circuiting the voltage source and open circuiting current source.

Resistance of 5 and 8 ohms are in parallel i.e. \( \frac{5 \times 8}{5 + 8} = \frac{40}{13} = 3.07 \Omega \)

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

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

B) Calculating $V_{th}$:

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

Voltage drop across 8 Ω resistance can be calculated by voltage divider rule,

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

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

\[ P_{max} = \frac{V_{th}^2}{4R_{th}} \]

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

6 Attempt any FOUR of the following: 16

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

Ans:

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

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

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

iii) Single-phase loads can be connected along with 3-ph loads in a 3-ph system.

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.

1 Mark each of any four = 4 Marks
vi) The power rating of 3-phase machine is higher than that of 1-phase machine of the same size.

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

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

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

\[ \text{Ans:} \]

Apply KCL at Node1
\[ \text{We get} \quad I_1 + I_2 - I_3 = 0 \quad \text{or} \quad I_1 + I_2 = I_3 \]
\[ \frac{20 - V_1}{5} + \frac{30 - V_1}{10} - \frac{V_1}{10} = 0 \]
From which \[ 4V_1 = 70 \] and hence \[ V_1 = 17.5 \text{ volts} \]
Current through 10 Ω resistor \[ I_3 = \frac{V_1}{10} = \frac{17.5}{10} = 1.75 \text{ Amps} \]

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

\[ \text{Ans:} \]

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

\[ \text{\ldots} \]
Short circuit the load resistance $R_L$ i.e. $3 \, \Omega$ resistance and calculate $I_{SC} = I_N$

Resistance of 2 and 5 ohm are in parallel hence equivalent resistance is

$$= \frac{2 \times 5}{2+5} = \frac{10}{7} = 1.43 \, \Omega$$

$$R = 4 + 1.43 = 5.43 \, \Omega$$

$$I = \frac{10}{5.43} = 1.84 \, A$$

$$I_{SC} = I_N = 1.84 \times \frac{2}{2+5} = 0.526 \, A$$

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

Resistance of 4 and 2 ohms are in parallel $= \frac{4 \times 2}{4+2} = \frac{8}{6} = 1.33 \, \Omega$

The $5\, \Omega$ and 1.33\, $\Omega$ resistors appear in series hence

$$R_{TH} = R_N = 5 + 1.33 = 6.33 \, \Omega$$

Current through 3\, $\Omega$ resistance $= I_L = I_{SC} \times \frac{R_N}{(R_N + R_L)}$

$$= 0.526 \times \frac{6.33}{(6.33+3)} = 0.356 \, A$$

$$I_L = 0.356 \, A$$

6 d) State Thevenin’s theorem and write its procedural steps to find current in a branch.

**Ans:**

**Thevenin’s Theorem:**

Any two terminal circuit having number of linear impedances and sources (voltage, current, dependent, independent) can be represented by a simple equivalent circuit consisting of a single voltage source $V_{Th}$ in series with an impedance $Z_{Th}$, where the source voltage $V_{Th}$ is equal to the open circuit voltage appearing across the two
terminals due to internal sources of circuit and the series impedance $Z_{\text{Th}}$ is equal to the impedance of the circuit while looking back into the circuit across the two terminals, when the internal independent voltage sources are replaced by short-circuits and independent current sources by open circuits.

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

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

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

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

**Step IV:** Thevenin’s equivalent circuit:

**Step V:** Determination of Load current:

$$I_L = \frac{V_{\text{Th}}}{R_{\text{Th}} + R_L}$$

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

![Figure No. 10](image)

**Ans:**

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

Consider Branch 1 as

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

$$Z_L = 5 + j 1884.96 \Omega = 1884.97 \angle 89.85^\circ \Omega$$

Consider Branch 2 as

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

$$Z_2 = 5 - j 159.15 \Omega = 159.23 \angle -88.20^\circ \Omega$$

Consider load Branch as

$$Z_L = 4 + j 0 \ \Omega = 4 \angle 0^\circ \Omega$$

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

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

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

$$= (159.23 \angle -88.20^\circ) \times 4 \angle 0^\circ / (159.23 + 4 + j 0)$$

$$= 636.92 \angle -88.20^\circ / (159.40 \angle -86.76^\circ)$$

1 Mark for calculation of impedances
\[ 3.99 \angle -1.44^\circ = 3.98 - j0.1 \]

This is in series with \( Z_1 \)

\[ Z_{eq} = (3.98-j0.1) + (5+j1884.96) = 8.98+j1884.86 = 1884.88 \angle 89.73^\circ \ \Omega \]

\[ I = \frac{V}{Z_{eq}} = \frac{100 \angle 90^\circ / (1884.88 \angle 89.73^\circ)}{0.053 \angle 0.27^\circ} = 0.053-j0.00025 \ A \]

By using current divider rule,
Current through \( Z_L \) i.e. \( I_{L1} = I \times Z_2 / (Z_2 + Z_L) \)

\[ I_{L1} = 0.212 \angle 0.28^\circ / (159.40 \angle -86.76^\circ) \]

\[ I_{L1} = 0.00133 \angle 87.03 = (6.89 \times 10^{-5} + j0.00133) \ A \]

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

The equivalent of \( Z_1 \) parallel with \( Z_L \)

\[ = Z_1 \times Z_L / (Z_1 + Z_L) \]

\[ = (1884.97 \angle 89.84^\circ) / ((5 + j1884.96) + (4 + j0)) \]

\[ = 7539.88 \angle 89.85^\circ / (9+j1884.96) \]

\[ = 7539.88 \angle 89.84^\circ / (1884.98 \angle 89.73^\circ) \]

\[ = 3.99 \angle 0.11^\circ = 3.99 + j0.0077 \]

This is in series with \( Z_2 \)

\[ Z_{eq} = (3.99+j0.0077) + (5-j159.15) = 8.99+j159.1423 = 159.4 \angle -86.77^\circ \ \Omega \]

\[ I = \frac{V}{Z_{eq}} = \frac{50 \angle 0^\circ / (159.4 \angle -86.77^\circ)}{0.3137 \angle 86.77^\circ} = 0.0177+j0.313 \ A \]

By using current divider rule,
Current through \( Z_L \) i.e. \( I_{L2} \)

\[ I_{L2} = I \times Z_2 / (Z_2 + Z_L) = (0.3137 \angle 86.77^\circ) / (1884.98 \angle 89.73^\circ) \]

\[ I_{L2} = 591.31 \angle 176.62^\circ / (1884.98 \angle 89.73^\circ) = 0.314 \angle 86.89^\circ = 0.017 + j0.314 \]

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

\[ I_L = 0.316 \angle 86.91^\circ \ A \]

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

**Ans:**

**At the time of switching:**

(i) **Pure Resistor:**

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

(ii) **Pure Inductor:**
The pure inductor, carrying zero current prior to switching, acts as OPEN CIRCUIT.

\[ L \rightarrow \text{O.C.} \]

The pure inductor, carrying some current, say \( I_0 \), prior to switching, acts as a current source \( I_0 \) or an Open Circuit in parallel with current source \( I_0 \).

\[ I_0 \rightarrow \text{O.C. or} \]

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

\[ C \rightarrow \text{S.C.} \]

The pure capacitor, having some voltage, say \( V_0 \), prior to switching, acts as a voltage source \( V_0 \) or Short Circuit in series with voltage source \( V_0 \).

\[ V_0 = \frac{q_0}{C} \rightarrow -V_0 \]

1.5 Marks for L

1.5 Marks for C