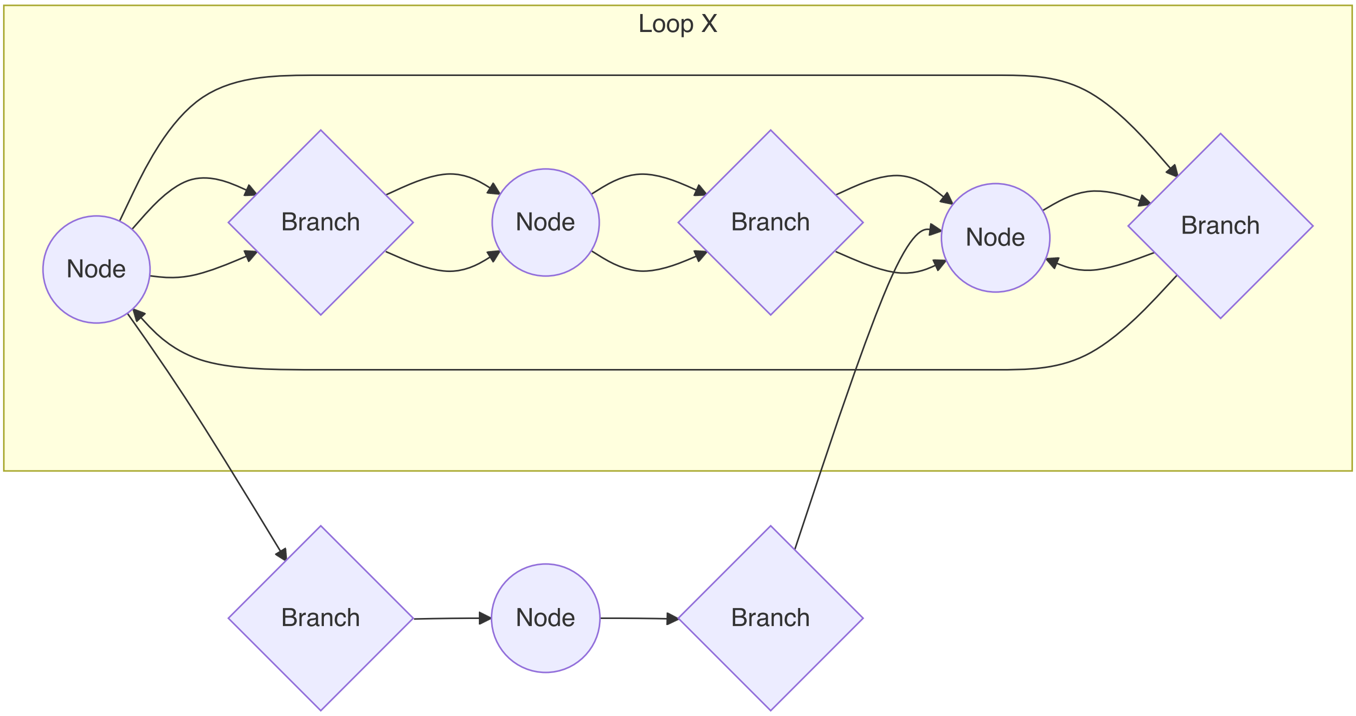
Question 1(a) [3 marks]

Define node, branch and loop with suitable diagram.

Answer:

Diagram:



- **Node**: A point where two or more circuit elements join together
- **Branch**: A single element connecting two nodes
- **Loop**: Any closed path in a circuit where no node is encountered more than once

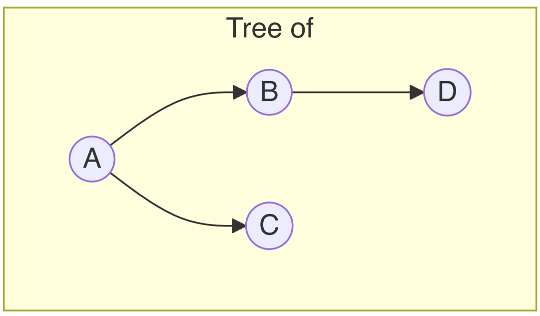
Mnemonic: "NBA circuit" - Nodes are junctions, Branches are roads, Loops are Alternate paths

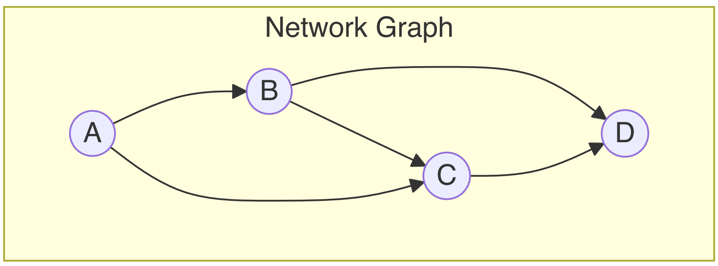
Question 1(b) [4 marks]

Explain "Tree" and "Graph" of a network.

Answer:

Diagram:





Feature	Graph	Tree
Definition	Complete topological representation of network	Connected subgraph containing all nodes but no loops
Elements	Contains all branches and nodes	Contains N-1 branches where N is number of nodes
Loops	Contains loops	No loops
Application	Used for complete circuit analysis	Used for simplifying network calculations

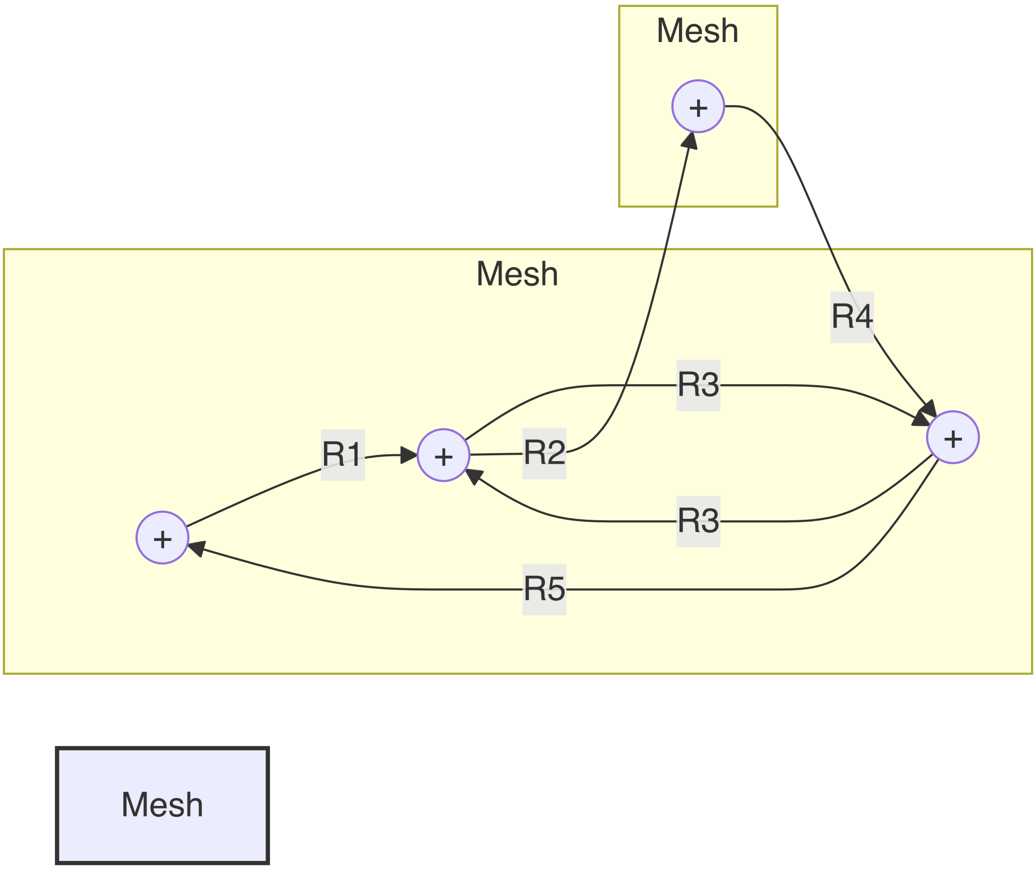
Mnemonic: "GRAND Tree" - Graph has Routes And Nodes with Detours, Tree has only single Routes

Question 1(c) [7 marks]

Explain "Mesh current Method" using suitable diagram.

Answer:

Diagram:



Step	Description
1	Identify independent meshes in the circuit
2	Assign mesh currents (I_1, I_2, etc.) in clockwise direction
3	Apply KVL to each mesh
4	Form equations using: ΣR·I(own) - ΣR·I(adjacent) = ΣV
5	Solve the simultaneous equations

- **Advantage**: Fewer equations than branch current method
- **Application**: Best for planar networks
- **Limitation**: Less efficient for non-planar networks

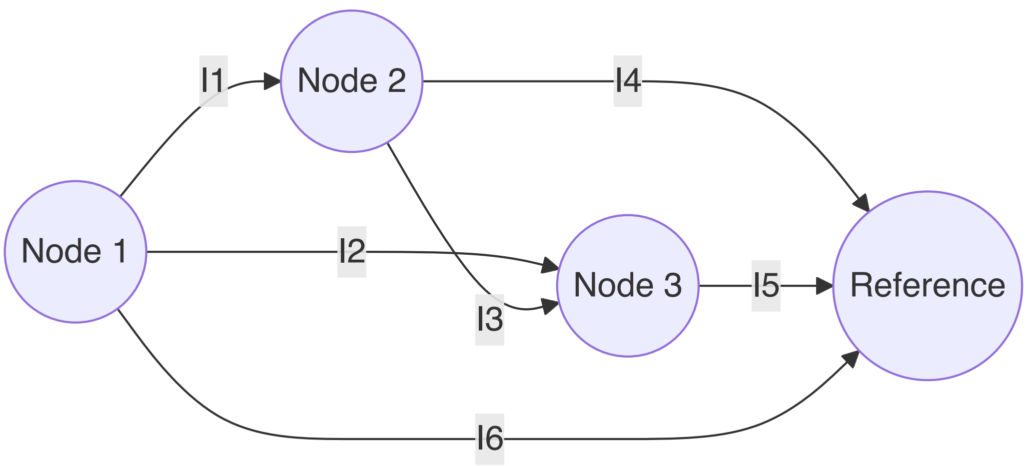
Mnemonic: "MIAMI" - Meshes Identified, Assign currents, Make equations, Intersection currents calculated, Solve

Question 1(c OR) [7 marks]

Explain "Node pair voltage Method" using suitable diagram.

Answer:

Diagram:



Step	Description
1	Select a reference node (ground)
2	Assign node voltages (V_1, V_2, etc.) to remaining nodes
3	Apply KCL at each node (except reference)
4	Express currents in terms of node voltages using Ohm's Law
5	Solve the simultaneous equations

- **Advantage**: Fewer equations than mesh method for circuits with many meshes
- **Application**: Efficient for non-planar circuits
- **Key equation**: ΣG·V(own) - ΣG·V(adjacent) = ΣI

Mnemonic: "GRAND" - Ground node fixed, Remaining nodes numbered, Apply KCL, Note voltage differences, Derive solutions

Question 2(a) [3 marks]

Explain KCL with example.

Answer:

Diagram:

```
    I1 →
  +-----+
  |     |
  |     I3 ↓
I2 ↓    |
  |     |
  +-----+
    I4 ↑
```

Kirchhoff's Current Law (KCL): The algebraic sum of all currents entering and leaving a node is zero.

Mathematical Form	Example Application
ΣI = 0	At node: $I_1 - I_2 - I_3 + I_4 = 0$
ΣIin = ΣIout	Currents entering = Currents leaving

Mnemonic: "ZINC" - Zero Is Net Current at a node

Question 2(b) [4 marks]

Explain Z-parameter, Y-parameter, h-parameter and ABCD-parameter using suitable network.

Answer:

Diagram:

```
         +-----+
   V1    |     |    V2
   →     |  2  |    →
+-------+|  P  |+-----+
   I1    |  O  |    I2
   →     |  R  |    ←
         |  T  |
         +-----+
```

Parameter	Definition	Equations	Usage
Z	Impedance parameters	$V_1 = Z_{11}I_1 + Z_{12}I_2$, $V_2 = Z_{21}I_1 + Z_{22}I_2$	High impedance circuits
Y	Admittance parameters	$I_1 = Y_{11}V_1 + Y_{12}V_2$, $I_2 = Y_{21}V_1 + Y_{22}V_2$	Low impedance circuits
h	Hybrid parameters	$V_1 = h_{11}I_1 + h_{12}V_2$, $I_2 = h_{21}I_1 + h_{22}V_2$	Transistor circuits
ABCD	Transmission parameters	$V_1 = AV_2 - BI_2$, $I_1 = CV_2 - DI_2$	Cascaded networks

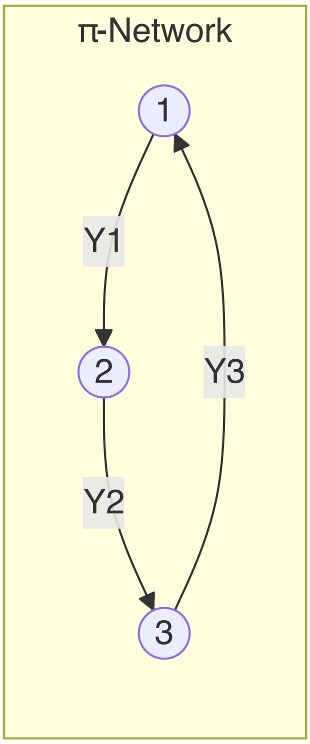
Mnemonic: "ZANY HAB" - Z for high impedance, A for low, hy-brid for transistors, ABCD for Cascades

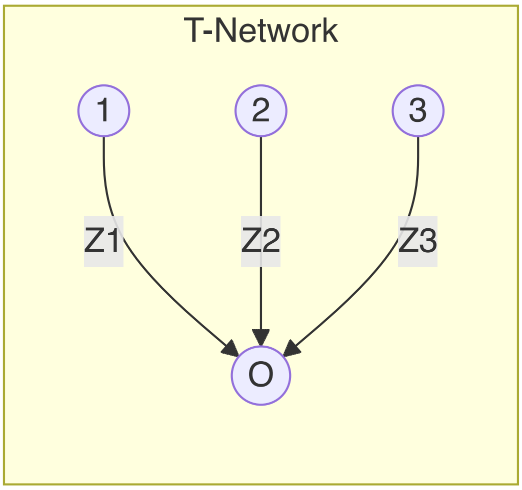
Question 2(c) [7 marks]

Derive the equations to convert π-type network into T-type network and T-type network into π-type network.

Answer:

Diagram:





Conversion	Formulas
π to T	$Z_1 = (Z_{12} \cdot Z_{31})/(Z_{12}+Z_{23}+Z_{31})$ $Z_2 = (Z_{12} \cdot Z_{23})/(Z_{12}+Z_{23}+Z_{31})$ $Z_3 = (Z_{23} \cdot Z_{31})/(Z_{12}+Z_{23}+Z_{31})$
T to π	$Z_{12} = (Z_1 \cdot Z_2+Z_2 \cdot Z_3+Z_3 \cdot Z_1)/Z_3$ $Z_{23} = (Z_1 \cdot Z_2+Z_2 \cdot Z_3+Z_3 \cdot Z_1)/Z_1$ $Z_{31} = (Z_1 \cdot Z_2+Z_2 \cdot Z_3+Z_3 \cdot Z_1)/Z_2$

- **Application**: Network simplification and analysis
- **Condition**: Both networks must be equivalent at terminals
- **Limitation**: Only applies for linear networks

Mnemonic: "TRIP" - T and π networks Relate Impedances through Products and sums

Question 2(a OR) [3 marks]

Explain KVL with example.

Answer:

Diagram:

```
   +--R1--+
   |      |
  V1      R2
   |      |
   +--R3--+
```

Kirchhoff's Voltage Law (KVL): The algebraic sum of all voltages around any closed loop is zero.

Mathematical Form	Example Application
$\Sigma V = 0$	In loop: $V_1 - IR_1 - IR_2 - IR_3 = 0$
$\Sigma V_{rises} = \Sigma V_{drops}$	Voltage rises = Voltage drops

Mnemonic: "ZERO" - Zero is Every voltage Round a loop's Output

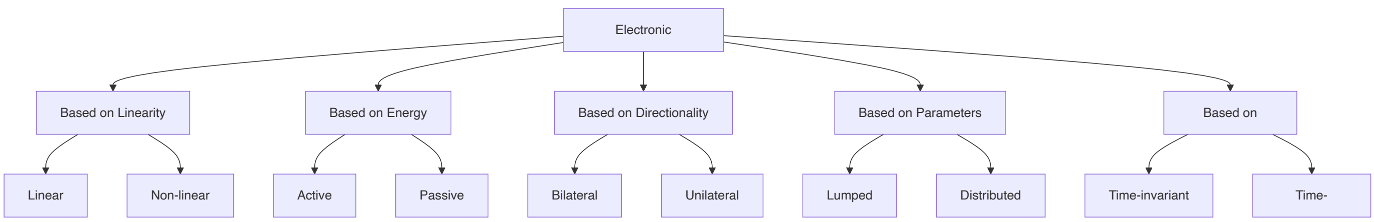
Question 2(b OR) [4 marks]

Classify and explain various Electronics network.

Answer:

Network Type	Description	Example
Linear vs Non-linear	Follows/doesn't follow proportionality principle	Resistors vs Diodes
Passive vs Active	Don't/do supply energy	RC circuit vs Amplifier
Bilateral vs Unilateral	Same/different properties in either direction	Resistors vs Diodes
Lumped vs Distributed	Parameters concentrated/spread	RC circuit vs Transmission line
Time variant vs Invariant	Parameters change/don't change with time	Electronic switch vs Fixed resistor

Diagram:



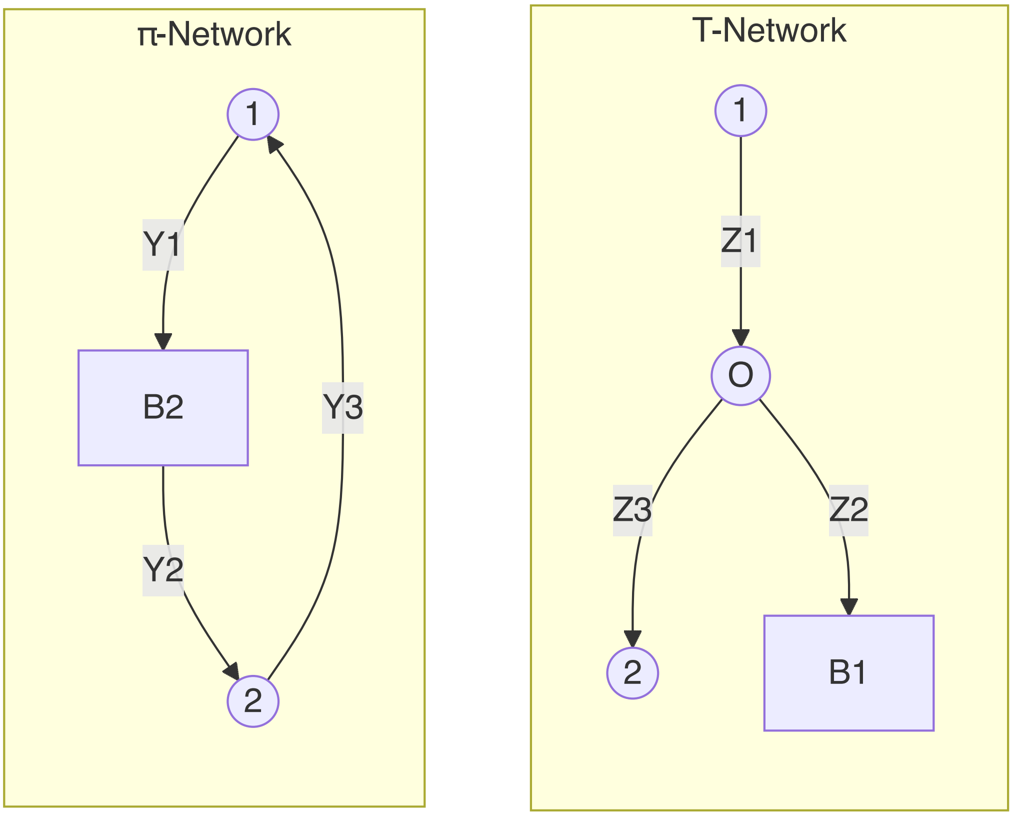
Mnemonic: "PLANT" - Proportionality for Linear, Lively for Active, All directions for bilateral, Near for lumped, Time-fixed for invariant

Question 2(c OR) [7 marks]

Derive the equation of characteristic impedance for T-network and π-network.

Answer:

Diagram:



Network	Characteristic Impedance Equation	Derivation Steps
T-Network	$Z_0T = \sqrt{[(Z_1+Z_2)(Z_2+Z_3)]}$	1. Apply symmetrical load Z_0 2. Find input impedance 3. For impedance matching, Zin = Z_0 4. Solve for Z_0
π-Network	$Z_0\pi = 1/\sqrt{[(Y_1+Y_3)(Y_2+Y_3)]}$	1. Apply symmetrical load Z_0 2. Find input impedance 3. For impedance matching, Zin = Z_0 4. Solve for Z_0

- **Relation**: $Z_0T \times Z_0\pi = Z_1 \cdot Z_3$
- **Application**: Impedance matching and filters
- **Limitation**: Valid only for symmetrical networks

Mnemonic: "TIPSZ" - T-networks and π-networks Impedances are Products and Square roots of Z values

Question 3(a) [3 marks]

Explain the principle of duality with example.

Answer:

Diagram:

```
Original Circuit          Dual Circuit
   +---R1---+               +---G1---+
   |        |               |        |
  V1       R2        =>    I1       G2
   |        |               |        |
   +---R3---+               +---G3---+
```

Principle of Duality: For every electrical network, there exists a dual network where:

Original	**Dual**	**Example**
Voltage (V)	Current (I)	10V source → 10A source
Current (I)	Voltage (V)	5A → 5V
Resistance (R)	Conductance (G)	100Ω → 100S
Series connection	Parallel connection	Series resistors → Parallel conductors
KVL	KCL	ΣV = 0 → ΣI = 0

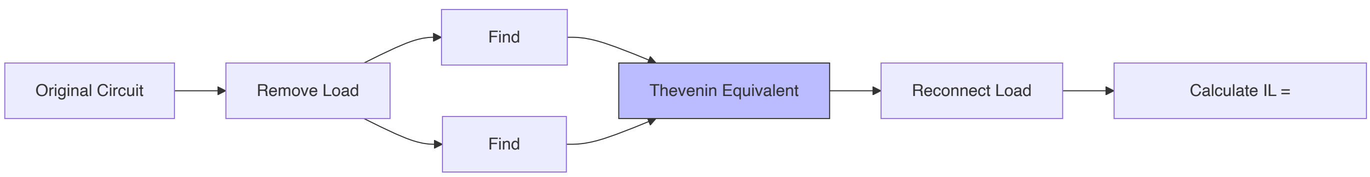
Mnemonic: "VIGOR" **-** Voltage to current, Impedance to admittance, Graph remains, Open to closed, Resistors to conductors

Question 3(b) [4 marks]

Explain the steps to calculate the load current in the circuit using Thevenin's Theorem.

Answer:

Diagram:



Step	Description
1	Remove the load resistor from the circuit
2	Find open-circuit voltage (Vth) across load terminals
3	Calculate Thevenin resistance (Rth) looking back into circuit
4	Draw Thevenin equivalent circuit (Vth in series with Rth)
5	Reconnect load resistor (RL) to Thevenin circuit
6	Calculate load current: IL = Vth/(Rth+RL)

Mnemonic: "REVOLT" - Remove load, Evaluate Voc, Obtain Rth, Look at Thevenin circuit, Use I = V/R formula

Question 3(c) [7 marks]

Find the current through load resistor using superposition theorem.

Answer:

Diagram:

```
    4Ω          10Ω
   ┌──────┬───────┐
   │      │       │
12V┘     6Ω       ┌12A
   │     IL↓      │
   │      │       │
   └──────┴───────┘
```

Table: Step-by-Step Solution:

Step	Description	Calculation
1	Consider 12V source only (replace 12A with open)	I_1 = 12/(4+6+10) = 0.6A I_1 through 6Ω = 0.6A
2	Consider 12A source only (replace 12V with short)	I_2 = -12×10/(4+10+6) = -6A I_2 through 6Ω = -12×4/(4+10+6) = -2.4A
3	Apply superposition	IL = I_1 + I_2 = 0.6 + (-2.4) = -1.8A

Answer: IL = -1.8A (current flowing upward through 6Ω load resistor)

Mnemonic: "SONAR" - Sources Only one at a time, Neutralize others, Add Results

Question 3(a OR) [3 marks]

Write Maximum Power Transfer Theorem statement. What are the conditions for maximum power transfer for AC and DC networks?

Answer:

Maximum Power Transfer Theorem: Maximum power is transferred from source to load when the load impedance is equal to the complex conjugate of the source internal impedance.

Network Type	Condition for Maximum Power Transfer
DC Networks	RL = Rth (Load resistance equals Thevenin resistance)
AC Networks	ZL = Zth* (Load impedance equals complex conjugate of Thevenin impedance) RL = Rth and XL = -Xth

Diagram:

```
    Rth
     ┌─/\/\/\─┐
     │        │
   Vth┘       RL
     │        │
     └────────┘
    DC Network

    Rth      Xth
     ┌─/\/\/\─┬─XX─┐
     │        │    │
   Vth┘       RL   XL
     │        │    │
     └────────┴────┘
      AC Network
```

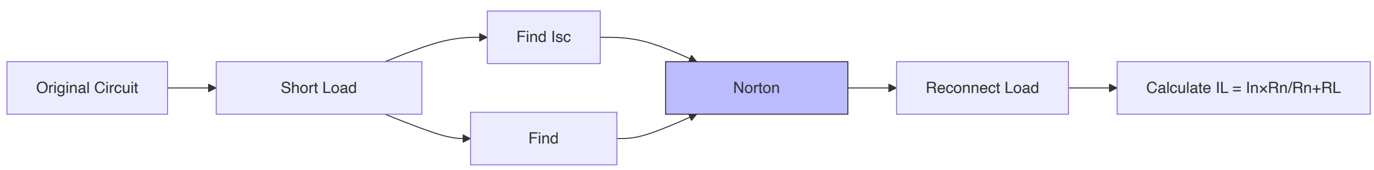
Mnemonic: "MATCH" - Maximum power At Terminals when Conjugate impedances are Honored

Question 3(b OR) [4 marks]

Explain the steps to calculate the load current in the circuit using Norton's Theorem.

Answer:

Diagram:



Step	Description
1	Remove the load resistor from the circuit
2	Find short-circuit current (In) across load terminals
3	Calculate Norton resistance (Rn) looking back into circuit
4	Draw Norton equivalent circuit (In in parallel with Rn)
5	Reconnect load resistor (RL) to Norton circuit
6	Calculate load current: IL = In×Rn/(Rn+RL)

Mnemonic: "SENIOR" - Short terminals, Evaluate Isc, Notice Rn value, Implement Norton circuit, Obtain result

Question 3(c OR) [7 marks]

Demonstrate how the reciprocity theorem is applied to a given network.

Answer:

Diagram:

```
      2Ω              2Ω

      ┌────────┬──────────┐
      │        │          │
  10V┘        4Ω         2Ω
      │        │          │
      └────────┴──────────┘
```

Table: Applying Reciprocity Theorem:

Step	Circuit 1	Circuit 2	Verification
1	10V source at left, Find I_1 at right	10V source at right, Find I_2 at left	$I_1 = I_2$ confirms reciprocity
2	Create mesh equations using KVL	Create new mesh equations for swapped source	Solve both systems
3	$I_1 = 10×2/(2×4 + 2×2 + 4×2) = 0.625A$	$I_2 = 10×2/(2×4 + 2×2 + 4×2) = 0.625A$	$I_1 = I_2 = 0.625A$ ✓

Principle: In a passive network containing only bilateral elements, if voltage source E in branch 1 produces current I in branch 2, then the same voltage source E placed in branch 2 will produce the same current I in branch 1.

Mnemonic: "RESPECT" - Rewire sources, Exchange positions, See if currents Preserve Equality when Circuit Transformed

Question 4(a) [3 marks]

Explain coupled circuit.

Answer:

Diagram:

```
    L1          L2
   ┌─0000─┐    ┌─0000─┐
   │      │    │      │
V1 ┘      │    │      RL
   │   M  │    │      │
   └──────┘    └──────┘
    Primary     Secondary
```

Coupled Circuit: A circuit where energy is transferred between inductors through mutual inductance.

Parameter	Description
Mutual Inductance (M)	Measure of magnetic coupling between coils
Coupling Coefficient (k)	$k = M/\sqrt{(L_1L_2)}$, ranges from 0 (no coupling) to 1 (perfect coupling)
Applications	Transformers, filters, tuned circuits

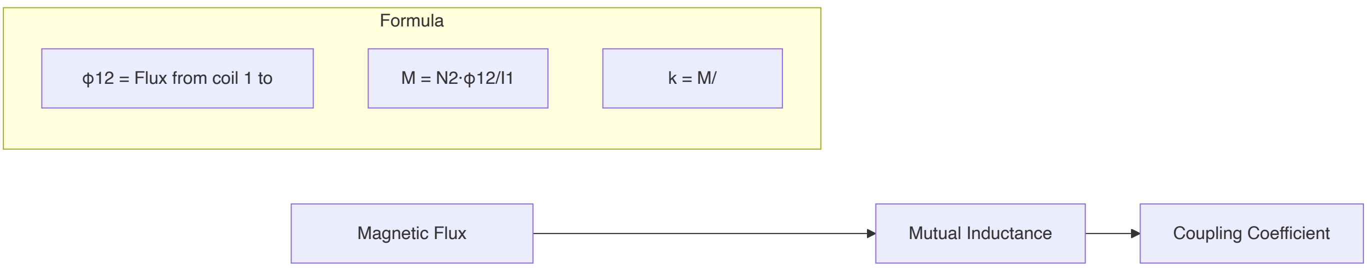
Mnemonic: "MICE" - Mutual Inductance Creates Energy transfer

Question 4(b) [4 marks]

Derive the equation of co-efficient of coupling for coupled circuit.

Answer:

Diagram:



Step	Description	Equation
1	Define mutual inductance	$M = N_2 \cdot \Phi_{12}/I_1$
2	Define self-inductances	$L_1 = N_1 \cdot \Phi_{11}/I_1$, $L_2 = N_2 \cdot \Phi_{22}/I_2$
3	Maximum possible M	$M_{max} = \sqrt{(L_1 \cdot L_2)}$
4	Define coupling coefficient	$k = M/\sqrt{(L_1 \cdot L_2)}$

- **Range**: $0 \leq k \leq 1$
- **Physical meaning**: Fraction of flux from one coil linking with the other coil
- **Perfect coupling**: $k = 1$, when all flux links both coils

Mnemonic: "MASK" - Mutual inductance And Self inductances create K

Question 4(c) [7 marks]

Derive equation of resonance frequency for series resonance. Calculate resonant frequency, Q factor and bandwidth of series RLC circuit with R=20Ω, L=1H, C=1μF.

Answer:

Diagram:

```
     R        L
   ┌─/\/\/\─┬─oooo─┐
   │        │      │
 V ┘        │      │
   │        │      │
   └────────┴──||──┘
               C
```

Derivation:

Step	Description	Equation
1	Impedance of series RLC	$Z = R + j(\omega L - 1/\omega C)$
2	At resonance, Im(Z) = 0	$\omega L - 1/\omega C = 0$
3	Solve for resonant frequency	$\omega_0 = 1/\sqrt{(LC)}$ or $f_0 = 1/(2\pi\sqrt{(LC)})$

Calculations:

Parameter	Formula	Calculation	Result
Resonant frequency	$f_0 = 1/(2\pi\sqrt{(LC)})$	$f_0 = 1/(2\pi\sqrt{(1\times10^{-6})})$	159.15 Hz
Q factor	$Q = \omega_0 L/R$	$Q = 2\pi\times159.15\times1/20$	50
Bandwidth	$BW = f_0/Q$	$BW = 159.15/50$	3.18 Hz

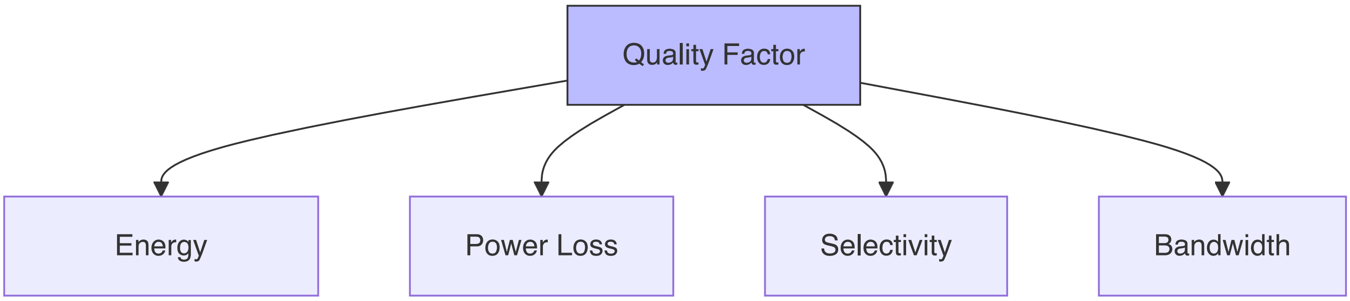
Mnemonic: "FQBR" - Frequency from reactances, Q from resistance ratio, Bandwidth from Resonance divided by Q

Question 4(a OR) [3 marks]

Explain Quality factor.

Answer:

Diagram:



Quality Factor (Q): A dimensionless parameter that indicates how under-damped a resonator is, or alternatively, characterizes a resonator's bandwidth relative to its center frequency.

Definition	Mathematical Expression
Energy perspective	$Q = 2\pi \times$ Energy stored / Energy dissipated per cycle
Circuit perspective	$Q = X/R$ (where X is reactance, R is resistance)
Frequency perspective	$Q = f_0/BW$ (where f_0 is resonant frequency, BW is bandwidth)

Mnemonic: "QSEL" - Quality shows Energy vs. Loss and Selectivity

Question 4(b OR) [4 marks]

Derive the equation of quality factor for a capacitor.

Answer:

Diagram:

```
    Ideal C    ESR
      ||      /\/\/\
      ||        R
     ┌||┐      ┌─┐
     |  |      | |
     |  |      | |
     └──┘      └─┘
    Real capacitor model
```

Derivation:

Step	Description	Equation
1	Define energy stored	Estored = $CV^2/2$
2	Define energy loss per cycle	Eloss = $\pi CV^2/\omega CR = \pi V^2/\omega R$
3	Define Q factor	Q = 2π × Estored / Eloss
4	Substitute and simplify	$Q = 2\pi \times (CV^2/2) \div (\pi V^2/\omega R) = \omega CR$

Final equation: $Q = \omega CR = 1/(\omega RC) = 1/\tan\delta$

Where:

- ω = Angular frequency ($2\pi f$)
- R = Equivalent series resistance (ESR)
- C = Capacitance
- $\tan\delta$ = Dissipation factor

Mnemonic: "CORE" - Capacitors' Quality equals One over Resistance times Capacitance

Question 4(c OR) [7 marks]

Derive equation of resonance frequency for parallel resonance. Calculate resonant frequency, Q factor and bandwidth of parallel RLC circuit with R=30Ω, L=1H, C=1μF.

Answer:

Diagram:

```
               L
    ┌─────┬─OOOO─┬─────┐
    |     |      |     |
  V ┘  R  |      |  C  |
    |     |      |     |
    └─────┴──────┴─────┘
```

Derivation:

Step	Description	Equation
1	Admittance of parallel RLC	$Y = 1/R + 1/j\omega L + j\omega C$
2	At resonance, Im(Y) = 0	$1/j\omega L + j\omega C = 0$
3	Solve for resonant frequency	$\omega_0 = 1/\sqrt{(LC)}$ or $f_0 = 1/(2\pi\sqrt{(LC)})$

Calculations:

Parameter	Formula	Calculation	Result
Resonant frequency	$f_0 = 1/(2\pi\sqrt{(LC)})$	$f_0 = 1/(2\pi\sqrt{(1\times10^{-6})})$	159.15 Hz
Q factor	$Q = R/\omega_0 L$	$Q = 30/(2\pi\times159.15\times1)$	0.03
Bandwidth	$BW = f_0/Q$	$BW = 159.15/0.03$	5305 Hz

Mnemonic: "FPQB" - Frequency from Parallel elements, Q from Resistance divided by reactance, Bandwidth from division

Question 5(a) [3 marks]

Explain the T type attenuator.

Answer:

Diagram:

```
    Z1
    ┌─/\/\/\─┐
    │        │
In ┘     Z3  │       Out
    │   /\/\/│        │
    └─/\/\/\─┘        │
        Z2
```

T-type Attenuator: A passive network in T configuration used to reduce signal amplitude.

Component	Description	Formula
Z1, Z2	Series arms	$Z1 = Z2 = Z_0(N-1)/(N+1)$
Z3	Shunt arm	$Z3 = 2Z_0/(N^2-1)$
N	Attenuation ratio	$N = 10^{(dB/20)}$

- **Characteristic**: Symmetrical for matched source and load
- **Applications**: Signal level control, impedance matching
- **Advantage**: Maintains impedance matching with proper design

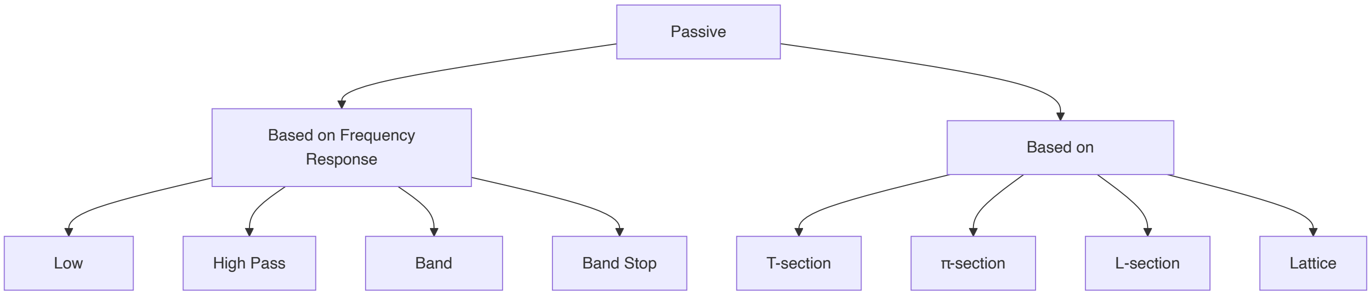
Mnemonic: "TSAR" - T-shape with Series Arms and Resistance in middle

Question 5(b) [4 marks]

Classify the various passive filter circuits.

Answer:

Diagram:



Filter Type	Function	Typical Circuit	Applications
Low Pass	Passes low frequencies	RC, RL circuits	Audio filters, Power supplies
High Pass	Passes high frequencies	CR, LR circuits	Noise filtering, Signal conditioning
Band Pass	Passes a band of frequencies	RLC circuits	Radio tuning, Signal selection
Band Stop	Blocks a band of frequencies	Parallel RLC	Interference rejection

Mnemonic: "LHBB" - Low High Band Band filters for Pass and Block

Question 5(c) [7 marks]

Design constant-k type low pass and High pass filter with T-section having cutoff frequency= 1000Hz & load of 500Ω.

Answer:

Diagram:

```
Low Pass T-Filter          High Pass T-Filter
     L/2       L/2              C/2       C/2
   --OOOO------OOOO--         ---||--------||---
    |                 |         |                 |
    |                 |         |                 |
    |       C         |         |        L        |
    |       ||        |         |       OOOO      |
    |                 |         |                 |
  ----------------------      ----------------------
```

Design Calculations:

For Constant-k T-type low pass filter:

Parameter	Formula	Calculation	Value
Cut-off frequency	fc = 1000 Hz	Given	1000 Hz
Load impedance	R_0 = 500 Ω	Given	500 Ω
Series inductor	L = R_0/πfc	L = 500/(π×1000)	159.15 mH
Half sections	L/2	159.15/2	79.58 mH
Shunt capacitor	C = 1/(πfcR_0)	C = 1/(π×1000×500)	0.636 μF

For Constant-k T-type high pass filter:

Parameter	Formula	Calculation	Value
Series capacitor	C = 1/(4πfcR_0)	C = 1/(4π×1000×500)	0.159 μF
Half sections	C/2	0.159/2	0.0795 μF
Shunt inductor	L = R_0/(4πfc)	L = 500/(4π×1000)	39.79 mH

Mnemonic: "FRED" - Frequency Ratio determines Element Dimensions

Question 5(a OR) [3 marks]

Explain the π type attenuator.

Answer:

Diagram:

```
            Z2
            |
      ┌────┐|┌────┐
      |    |||    |
  In ┘  Z1|||Z3   |   Out
      |    |||    |
      └────┘|└────┘
            |
```

π-type Attenuator: A passive network in π configuration used to reduce signal amplitude.

Component	Description	Formula
Z2	Series arm	$Z2 = 2Z_0/(N^2-1)$
Z1, Z3	Shunt arms	$Z1 = Z3 = Z_0(N+1)/(N-1)$
N	Attenuation ratio	N = 10^(dB/20)

- **Characteristic**: Symmetrical for matched source and load
- **Applications**: Signal level control, impedance matching
- **Advantage**: Good isolation between input and output

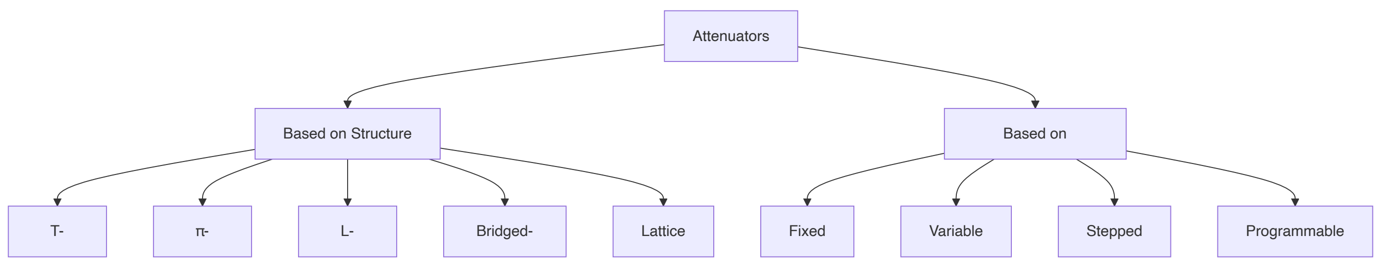
Mnemonic: "PASS" - Pi-Attenuator has Series in middle and Shunt arms outside

Question 5(b OR) [4 marks]

Classify various types of attenuators.

Answer:

Diagram:



Attenuator Type	Characteristics	Applications	Advantages
T-type	Series-Shunt-Series	Audio systems	Simple design
π-type	Shunt-Series-Shunt	RF circuits	Better isolation
L-type	Series-Shunt	Simple matching	Impedance transformation
Bridged-T	Balanced structure	Test equipment	Minimal distortion
Balanced	Symmetric dual paths	Differential signals	Common mode rejection

Mnemonic: "TPLBV" - T, Pi, L, Bridged-T, and Variable attenuators

Question 5(c OR) [7 marks]

Design a symmetrical T type attenuator and π type attenuator to give attenuation of 40dB and to work into the load of 500Ω.

Answer:

Diagram:

```
T-type Attenuator           π-type Attenuator
     R1       R1                      R2
   --/\/\----/\/\--              --/\/\--
   |               |            |        |
   |               |            |        |
   |       R2      |            R1      R1
   |      /\/\     |           /\/\    /\/\
   |               |            |        |
   -----------------            ----------
```

Design Calculations:

Step	Formula	Calculation	Value
Given	Attenuation = 40 dB	-	40 dB
Step 1	N = 10^(dB/20)	10^(40/20)	100
Step 2	K = (N-1)/(N+1)	(100-1)/(100+1)	0.98

For T-type attenuator:

Component	Formula	Calculation	Value
R_1 (series)	$Z_0 \cdot K$	500 × 0.98	490 Ω
R_2 (shunt)	$Z_0/(K \cdot (N-K))$	500/(0.98×(100-0.98))	5.15 Ω

For π-type attenuator:

Component	Formula	Calculation	Value
R_1 (shunt)	Z_0/K	500/0.98	510.2 Ω
R_2 (series)	$Z_0 \cdot K \cdot (N-K)$	500 × 0.98 × (100-0.98)	48,541 Ω

Mnemonic: "DANK" - dB Attenuation is Number K, which determines resistor values