Question 1(a) [3 marks]

Define following terms. (i) Active elements (ii) Bilateral elements (iii) Linear elements

Answer:

Term	Definition
Active elements	Electronic components that can supply energy or power to a circuit (like batteries, generators, op-amps)
Bilateral elements	Components that allow current flow equally in both directions with same characteristics (like resistors, capacitors, inductors)
Linear elements	Components whose current-voltage relationship follows a straight line and obeys the principle of superposition (like resistors following Ohm's law)

Mnemonic: "ABL: Active powers Batteries, Bilateral flows Both ways, Linear stays Lawful"

Question 1(b) [4 marks]

Capacitors of 10μF, 20μF and 30μF are connected in series and supply of 200V DC is given. Find voltage across each capacitor.

Answer:

For series-connected capacitors:

1. Find equivalent capacitance: $1/Ceq = 1/C_1 + 1/C_2 + 1/C_3$
2. Voltage division: $VC = (C_1/C) \times V$

Calculation:
1/Ceq = 1/10 + 1/20 + 1/30 = 0.1 + 0.05 + 0.033 = 0.183
Ceq = 5.46 μF

Capacitor	Formula	Calculation	Voltage
C_1 = 10μF	$V_1 = (Ceq/C_1) \times V$	(5.46/10) × 200 = 109.2V	109.2V
C_2 = 20μF	$V_2 = (Ceq/C_2) \times V$	(5.46/20) × 200 = 54.6V	54.6V
C_3 = 30μF	$V_3 = (Ceq/C_3) \times V$	(5.46/30) × 200 = 36.4V	36.4V

Mnemonic: "Smaller Capacitors get Larger Voltages"

Question 1(c) [7 marks]

Explain Node pair voltage method for graph theory.

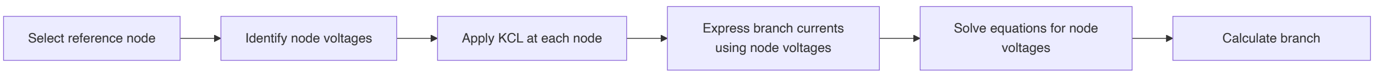
Answer:

Node pair voltage method is a systematic approach to analyze electrical networks.

Procedure:

1. Select a reference node (ground)
2. Identify the node voltages (N-1 unknowns for N nodes)
3. Apply KCL at each non-reference node
4. Express branch currents in terms of node voltages
5. Solve the equations for node voltages

Diagram:



Key advantages:

- **Fewer equations**: Only (n-1) equations for n nodes
- **Computational efficiency**: Reduces system complexity
- **Direct voltage solutions**: Provides node voltages directly
- **Systematic approach**: Works for any network topology

Mnemonic: "GARCS: Ground, Assign voltages, Relate with KCL, Calculate currents, Solve equations"

Question 1(c) OR [7 marks]

Explain voltage division method with necessary equations.

Answer:

Voltage division is a method to calculate how voltage distributes across series components.

Principle:
In a series circuit, voltage divides proportionally to component resistances/impedances.

Formula:
For a resistor R_1 in a series circuit with total resistance RT:
$V_1 = (R_1/RT) \times VS$

Diagram:

```
      +---+
VS ---|   |-- R1 --|
      +---+        |
                   |  V1
                   |
                   |
      +---+        |
      |   |-- R2 --|
      +---+
```

```
          |
          |
        -----
         ---
          -
```

Mathematical explanation:

- For resistors: $V_1 = (R_1/RT) \times VS$
- For capacitors: $V_1 = (1/C_1)/(1/CT) \times VS = (CT/C_1) \times VS$
- For inductors: $V_1 = (L_1/LT) \times VS$
- For complex impedances: $V_1 = (Z_1/ZT) \times VS$

Examples:

1. Voltage across a 1kΩ resistor in series with 4kΩ with 5V source = (1/5)×5V = 1V
2. Voltage across a 10μF capacitor in series with 40μF with 10V source = (1/10)/(1/8)×10V = 8V

Mnemonic: "The BIGGER the RESISTANCE, the BIGGER the VOLTAGE drop"

Question 2(a) [3 marks]

Write open circuit impedance parameters of Two port network.

Answer:

Open Circuit Impedance Parameters:

Parameter	Equation	Physical Meaning
Z_{11}	$Z_{11} = V_1/I_1$ (when I_2=0)	Input impedance with output open-circuited
Z_{12}	$Z_{12} = V_1/I_2$ (when I_1=0)	Transfer impedance from port 2 to port 1
Z_{21}	$Z_{21} = V_2/I_1$ (when I_2=0)	Transfer impedance from port 1 to port 2
Z_{22}	$Z_{22} = V_2/I_2$ (when I_1=0)	Output impedance with input open-circuited

Mnemonic: "ZIPO: Z-parameters with Inputs and outputs, Ports Open where needed"

Question 2(b) [4 marks]

Derive conversion from T-type network to ∏-type network.

Answer:

T to ∏ Network Conversion:

Diagram:

```
     T-Network           ∏-Network
        Z1                   Y1
   o---/\/\/---o       o---/\/\/---o
   |           |       |           |
   |           |       |           |
  Z3          Z2      Y3          Y2
   |           |       |           |
   |           |       |           |
   o-----------o       o-----------o
```

Conversion Equations:

∏-Parameter	Formula	Based on T-Parameters
$Y_1 = 1/Z_1$	$Y_1 = Z_2/(Z_1Z_2+Z_2Z_3+Z_3Z_1)$	Reciprocal of Z_1 modified by network
$Y_2 = 1/Z_2$	$Y_2 = Z_1/(Z_1Z_2+Z_2Z_3+Z_3Z_1)$	Reciprocal of Z_2 modified by network
$Y_3 = 1/Z_3$	$Y_3 = Z_3/(Z_1Z_2+Z_2Z_3+Z_3Z_1)$	Reciprocal of Z_3 modified by network

Derivation Steps:

1. Define determinant $\Delta = Z_1Z_2+Z_2Z_3+Z_3Z_1$
2. Use network theory to derive $Y_1 = Z_2/\Delta$
3. Similarly, $Y_2 = Z_1/\Delta$
4. And $Y_3 = Z_3/\Delta$

Mnemonic: "Delta Divides: Y_1 gets Z_2, Y_2 gets Z_1, Y_3 gets Z_3"

Question 2(c) [7 marks]

Three resistances of 1, 1 and 1 ohms are connected in Delta. Find equivalent resistances in star connection.

Answer:

Delta to Star Conversion:

Diagram:

```
    Delta Network          Star Network
        R1                      ra
    o---/\/\/--o           o---/\/\/---o
    |          |           |           |
    |          |           |           |
    |          |           |           |
    |          |          rb           rc
    |          |           |           |
   R3         R2           |           |
    |          |           |           |
    |          |           o-----------o
    o----------o
```

Conversion Formulas:

- ra = $(R_1 \times R_3)/(R_1+R_2+R_3)$
- rb = $(R_1 \times R_2)/(R_1+R_2+R_3)$
- rc = $(R_2 \times R_3)/(R_1+R_2+R_3)$

Calculation:
Given: $R_1 = R_2 = R_3 = 1\Omega$
Sum of resistances: $R_1+R_2+R_3 = 3\Omega$

Star Resistor	Formula	Calculation	Result
ra	$(R_1 \times R_3)/(R_1+R_2+R_3)$	(1×1)/3	0.333Ω
rb	$(R_1 \times R_2)/(R_1+R_2+R_3)$	(1×1)/3	0.333Ω
rc	$(R_2 \times R_3)/(R_1+R_2+R_3)$	(1×1)/3	0.333Ω

Mnemonic: "Product Over Sum: Each star arm gets the product of adjacent delta sides divided by the sum of all"

Question 2(a) OR [3 marks]

Define. (i) Transfer Impedance (ii) Image Impedance (iii) Driving point Impedance

Answer:

Term	Definition
Transfer Impedance	Ratio of output voltage at one port to input current at another port when all other ports are open-circuited ($Z_{21} = V_2/I_1$ when I_2=0)
Image Impedance	Input impedance at port when the output port is terminated with its own image impedance, creating infinite chain with same impedance at all points
Driving point Impedance	Input impedance seen when looking into a specified port or terminal pair ($Z_{11} = V_1/I_1$ for port 1)

Mnemonic: "TID: Transfer relates ports, Image creates reflections, Driving point looks inward"

Question 2(b) OR [4 marks]

Get the equation for characteristics impedance Z for a standard 'T' network.

Answer:

Characteristic Impedance of 'T' network:

Diagram:

```
     Z1/2           Z1/2
o---/\/\/----o---/\/\/---o
|            |           |
|            |           |
A           Z2           B
|            |           |
|            |           |
o------------o-----------o
```

Derivation:
For a symmetrical T-network with series impedance Z_1 (split as $Z_1/2$ on each side) and shunt impedance Z_2:

$Z_0 = \sqrt{(Z_1Z_2 + Z_1^2/4)}$

Steps:

1. ABCD parameters for T-network:
   - $A = 1 + Z_1/2Z_2$
   - $B = Z_1 + Z_1^2/4Z_2$
   - $C = 1/Z_2$
   - $D = 1 + Z_1/2Z_2$
2. From transmission line theory, $Z_0 = \sqrt{(B/C)}$
3. Substituting: $Z_0 = \sqrt{((Z_1 + Z_1^2/4Z_2)/(1/Z_2))}$
4. Simplifying: $Z_0 = \sqrt{(Z_1Z_2 + Z_1^2/4)}$

Mnemonic: "Square root of Z-products plus quarter-square"

Question 2(c) OR [7 marks]

Three resistances of 6, 15 and 10 ohms are connected in star. Find equivalent resistances in delta connection.

Answer:

Star to Delta Conversion:

Diagram:

```
   Star Network           Delta Network
       ra                      R1
   o---/\/\/--o           o---/\/\/---o
   |          |           |           |
   |          |           |           |
   |          |           |           |
   |          |          R3          R2
 rb          rc           |           |
   |          |           |           |
   |          |           |           |
   o----------o           o-----------o
```

Conversion Formulas:

- R_1 = (ra×rb + rb×rc + rc×ra)/ra
- R_2 = (ra×rb + rb×rc + rc×ra)/rb
- R_3 = (ra×rb + rb×rc + rc×ra)/rc

Calculation:
Given: ra = 6Ω, rb = 15Ω, rc = 10Ω
Sum of products = (6×15) + (15×10) + (10×6) = 90 + 150 + 60 = 300

Delta Resistor	Formula	Calculation	Result
R_1	(ra×rb + rb×rc + rc×ra)/ra	300/6	50Ω
R_2	(ra×rb + rb×rc + rc×ra)/rb	300/15	20Ω
R_3	(ra×rb + rb×rc + rc×ra)/rc	300/10	30Ω

Mnemonic: "Sum of Products Over Each: Delta side gets all products divided by opposite star arm"

Question 3(a) [3 marks]

Analyze the circuit (R1, R2 and R3 Connected in series with dc supply) to calculate loop current using KVL.

Answer:

KVL for Series Circuit:

Diagram:

```
      +---+
VS ---|   |-- R1 --+-- R2 --+-- R3 --+
      +---+        |        |        |
                   |        |        |
                   |        |        |
                  I|       I|       I|
                   |        |        |
                   |        |        |
                   +--------+--------+
                          -----
                           ---
                            -
```

KVL Equation: $VS - IR_1 - IR_2 - IR_3 = 0$
Loop Current: $I = VS/(R_1 + R_2 + R_3)$

Steps:

1. Identify all elements in the loop: VS, R_1, R_2, R_3
2. Apply KVL: Sum of voltage rises = Sum of voltage drops
3. Solve for I: $I = VS/RT$ where $RT = R_1 + R_2 + R_3$

Mnemonic: "KVL: Kirchhoff's Voltage Loop requires total resistance"

Question 3(b) [4 marks]

State Norton's theorem

Answer:

Norton's Theorem:

Any linear electrical network consisting of voltage sources, current sources, and resistances can be replaced by an equivalent circuit consisting of a current source IN in parallel with a resistance RN.

Diagram:

```
    Original Network          Norton Equivalent
         +-----+                   +-----+
         |     |                   |     |
         |  A  |                   | IN  |
         |     |                   |     |
         +--+--+                   +--+--+
            |                         |
      +-----+-----+             +-----+-----+
      |     |     |             |     |     |
      |     Z     |      =>     |    RN     |
      |     |     |             |     |     |
```

```
    +-----+-----+           +-----+-----+
          |                       |
       +--+--+                 +--+--+
       |     |                 |     |
       |  B  |                 |     |
       |     |                 |     |
       +-----+                 +-----+
```

How to find Norton equivalent:

1. **Norton Current (IN)**: Short-circuit current flowing through the load terminals
2. **Norton Resistance (RN)**: Input resistance seen at the terminals with all sources replaced by their internal resistances

Mnemonic: "SCIP: Short-Circuit current In Parallel with equivalent resistance"

Question 3(c) [7 marks]

Explain the steps to calculate the current in any branch of the ckt using superposition theorem

Answer:

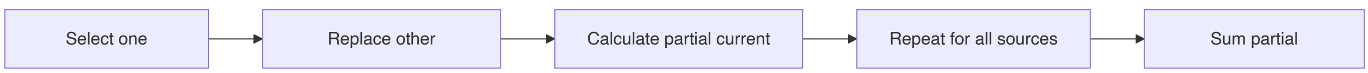
Superposition Theorem Application:

Principle:
In a linear circuit with multiple sources, the response in any element equals the sum of responses caused by each source acting alone.

Steps:

1. Consider only one source at a time
2. Replace other voltage sources with short circuits
3. Replace other current sources with open circuits
4. Calculate partial current for each source
5. Add all partial currents (algebraically) for final current

Diagram:



Mathematical Expression:
$I = I_1 + I_2 + I_3 + ... + In$
where I_1, I_2, etc. are partial currents due to individual sources

Example calculation:
For a branch with current contributions:
$I_1 = 2A$ (from source 1)
$I_2 = -1A$ (from source 2)
$I_3 = 0.5A$ (from source 3)

Total current = 2A + (-1A) + 0.5A = 1.5A

Mnemonic: "OSACI: One Source Active, Calculate and Integrate"

Question 3(a) OR [3 marks]

Analyze the circuit (R1, R2 and R3 Connected in parallel with dc supply) to calculate node voltage using KCL.

Answer:

KCL for Parallel Circuit:

Diagram:

```
                 I1
      +---+    +---+
VS ---|   |----| R1|----+
      +---+    +---+    |
                        |
                 I2     |
                +---+   |
                | R2|---+--- V (Node)
                +---+   |
                        |
                 I3     |
                +---+   |
                | R3|---+
                +---+   |
                        |
                       ---
                        -
```

KCL Equation: $I_1 + I_2 + I_3 = 0$
Node Voltage: V = VS (because parallel elements have same voltage)

Steps:

1. Identify node voltage V
2. Express branch currents: $I_1 = V/R_1$, $I_2 = V/R_2$, $I_3 = V/R_3$
3. Apply KCL: $V/R_1 + V/R_2 + V/R_3 = VS/RT$ where $1/RT = 1/R_1 + 1/R_2 + 1/R_3$

Mnemonic: "KCL: Kirchhoff's Current Law means parallel voltage equals source"

Question 3(b) OR [4 marks]

State Maximum power transfer theorem.

Answer:

Maximum Power Transfer Theorem:

For a source with internal resistance, maximum power is transferred to the load when the load resistance equals the source's internal resistance.

Diagram:

```
    +---+     Rsource      +---+
    |   |----/\/\/\/\------|   |
    | V |                  | RL|
    |   |                  |   |
    +---+                  +---+
     ---                    ---
      -                      -
```

Mathematical expression:

- Maximum power transfer occurs when RL = Rsource
- Maximum power: $P_{max} = V^2/(4 \times R_{source})$

Key points:

- **Efficiency**: Only 50% at maximum power transfer
- **AC Circuits**: Load impedance must be complex conjugate of source impedance
- **Applications**: Signal transmission, audio systems, RF circuits

Mnemonic: "MEET: Maximum Efficiency Equals when Thevenin-matched"

Question 3(c) OR [7 marks]

Explain the steps to calculate Vth, Rth and load current in the ckt using Thevenin's theorem

Answer:

Thevenin's Theorem Application:

Principle:
Any linear electrical network with voltage and current sources can be replaced by an equivalent circuit with a single voltage source Vth and a series resistance Rth.

Steps:

1. Remove the load resistance from the circuit
2. Calculate open-circuit voltage (Vth) across the load terminals
3. Replace all sources with their internal resistances (voltage sources as short circuits, current sources as open circuits)
4. Calculate equivalent resistance (Rth) seen from the load terminals
5. Draw the Thevenin equivalent circuit with Vth and Rth
6. Reconnect the load and calculate load current: $I_L = V_{th}/(R_{th} + R_L)$

Diagram:

Example calculation:

- If Vth = 12V
- Rth = 3Ω
- RL = 6Ω
- Then IL = 12V/(3Ω + 6Ω) = 12V/9Ω = 1.33A

Mnemonic: "VORTE: Voltage Open, Resistance with sources Transformed, Equivalent circuit"

Question 4(a) [3 marks]

Define resonance.

Answer:

Resonance:

Resonance is a phenomenon in which a circuit responds with maximum amplitude to an applied signal at a specific frequency called the resonant frequency.

Key characteristics:

- Impedance becomes purely resistive
- Inductive reactance equals capacitive reactance (XL = XC)
- Voltage and current are in phase
- Circuit stores and releases energy between L and C components

Applications:

- Tuning circuits
- Filters
- Oscillators
- Wireless communications

Mnemonic: "MAX-IN-PHASE: Maximum response when Inductive and capacitive reactances are equal and PHASEs cancel"

Question 4(b) [4 marks]

Derive an equation for Quality factor of coil.

Answer:

Quality Factor (Q) of a Coil:

Definition:
Q-factor is the ratio of energy stored to energy dissipated per cycle in a resonant circuit.

Derivation:
For a coil with inductance L and resistance R:

1. Energy stored in inductor: $W_L = \frac{1}{2}LI^2$
2. Power dissipated in resistance: $P = I^2R$
3. Time period: $T = 1/f = 2\pi/\omega$
4. Energy dissipated per cycle: $W_d = P \times T = I^2R \times (2\pi/\omega)$
5. Q = 2π(Energy stored/Energy dissipated per cycle)
6. $Q = 2\pi(\frac{1}{2}LI^2)/(I^2R \times 2\pi/\omega) = \omega L/R$

Final Equation:
$Q = \omega L/R = 2\pi fL/R$

Significance:

- Higher Q indicates lower energy loss
- Q increases with frequency
- Q decreases with resistance

Mnemonic: "Omega-L over R gives Quality"

Question 4(c) [7 marks]

An RLC series circuit has R=1 KΩ, L=100 mH and C=10μF. If a voltage of 100 V is applied across series combination, determine: (i) Resonance frequency (ii) 'Q' factor

Answer:

RLC Series Circuit Analysis:

Diagram:

```
          L=100mH
       +---uuuu---+
       |          |
       |          |
100V   R=1kΩ      C=10μF
       |          |
       |          |
       +-----------+
```

Calculations:

(i) **Resonance frequency:**

- Formula: $f_r = 1/(2\pi\sqrt{LC})$
- $f_r = 1/(2\pi\sqrt{100\times10^{-3} \times 10\times10^{-6}})$
- $f_r = 1/(2\pi\sqrt{1\times10^{-6}})$

- $f_r = 1/(2\pi \times 1\times10^{-3})$
- $f_r = 159.15$ Hz

(ii) **Quality factor (Q):**

- Formula: $Q = (1/R)\sqrt{(L/C)}$
- $Q = (1/1000)\sqrt{(100\times10^{-3}/10\times10^{-6})}$
- $Q = (1/1000)\sqrt{(10^4)}$
- $Q = (1/1000) \times 100$
- $Q = 0.1$

Parameter	Formula	Calculation	Result
Resonant frequency (fr)	$1/(2\pi\sqrt{(LC)})$	$1/(2\pi\sqrt{(1\times10^{-6})})$	159.15 Hz
Quality factor (Q)	$(1/R)\sqrt{(L/C)}$	$(1/1000)\sqrt{(10^4)}$	0.1

Mnemonic: "Frequency from LC, Quality from LCR"

Question 4(a) OR [3 marks]

Define Mutual Inductance.

Answer:

Mutual Inductance:

Mutual inductance is the property of a circuit whereby a change in current in one coil induces a voltage in another coil due to the magnetic coupling between them.

Mathematical expression:

- Voltage induced in coil 2: $V_2 = -M(dI_1/dt)$
- $M = k\sqrt{(L_1L_2)}$ where k is the coupling coefficient ($0\leq k\leq1$)
- Unit: Henry (H)

Key properties:

- Depends on coil geometry, distance and orientation
- Proportional to both inductances
- Basis for transformers and coupled circuits
- Can be positive or negative based on mutual flux direction

Mnemonic: "MICK: Mutual Inductance links Coils through K-coupling"

Question 4(b) OR [4 marks]

Derive equation of coefficient of coupling

Answer:

Coefficient of Coupling (k):

Definition:
The coefficient of coupling (k) is a measure of the magnetic coupling between two coils, ranging from 0 (no coupling) to 1 (perfect coupling).

Derivation:

1. Define mutual inductance: M = magnetic flux linkage / current
2. For two coils with self-inductances L_1 and L_2:
    - Flux linkage in coil 1 due to current in coil 1: $\lambda_{11} = L_1 I_1$
    - Flux linkage in coil 2 due to current in coil 2: $\lambda_{22} = L_2 I_2$
    - Flux linkage in coil 2 due to current in coil 1: $\lambda_{21} = MI_1$
3. The coupling coefficient k represents the fraction of flux from coil 1 that links with coil 2
4. From electromagnetic theory: $M = k\sqrt{(L_1 L_2)}$
5. Rearranging: $k = M/\sqrt{(L_1 L_2)}$

Final Equation:
$k = M/\sqrt{(L_1 L_2)}$

Key points:

- k = 0: No magnetic coupling
- 0 < k < 1: Partial coupling
- k = 1: Perfect coupling (all flux links both coils)

Mnemonic: "M divided by Geometric Mean of Ls"

Question 4(c) OR [7 marks]

Derive resonance frequency of parallel resonance circuit.

Answer:

Parallel Resonance Frequency Derivation:

Diagram:

```
            +---+
            |   |
         +--+---+--+
         |         |
         |         |
    L    |         |   C
  uuuuu  |         |  |||
         |         |  |||
         |         |  |||
         |         |  |||
```

```
           +----------+---+
              |   |
              +---+
               R
```

Derivation steps:

1. For a parallel RLC circuit, the admittance is:
   $Y = 1/Z = 1/R + 1/j\omega L + j\omega C$
2. At resonance, the imaginary part becomes zero:
   $Im(Y) = 0$
   $1/j\omega L + j\omega C = 0$
   $-j/\omega L + j\omega C = 0$
   $1/\omega L = \omega C$
   $\omega^2 LC = 1$
3. For the ideal case (with infinite resistance):
   $\omega_0 = 1/\sqrt{(LC)}$
   $f_0 = 1/(2\pi\sqrt{(LC)})$
4. For the real case (with resistance R):
   If R is in series with L, the resonant frequency becomes:
   $f_0 = (1/2\pi)\sqrt{(1/LC - R^2/L^2)}$

Final Equation:

- Ideal case: $f_0 = 1/(2\pi\sqrt{(LC)})$
- Real case (R in series with L): $f_0 = (1/2\pi)\sqrt{(1/LC - R^2/L^2)}$

Key characteristics of parallel resonance:

- Maximum impedance at resonance
- Minimum current drawn from source
- Current circulates between L and C
- Also called "anti-resonance" or "rejector circuit"

Mnemonic: "ONE over LC SQRT: The frequency where parallel paths balance"

Question 5(a) [3 marks]

Classify various types of attenuators.

Answer:

Types of Attenuators:

Type	Structure	Characteristics
T-type	Series-shunt-series	Symmetric, good for matching, widely used
∏-type	Shunt-series-shunt	Symmetric, alternative to T-type
Lattice	Balanced bridge	Symmetrical, used in balanced lines
L-type	Series-shunt	Asymmetric, simpler design
Bridged-T	T with bridged shunt	Better frequency response, complex
O-type	Series-shunt-series-shunt	Improved rejection characteristics

Mnemonic: "TL∏BO: Top attenuators Let ∏ signals Balance Output"

Question 5(b) [4 marks]

Derive relation between Decibel and Neper

Answer:

Decibel to Neper Conversion:

Definitions:

- **Decibel (dB)**: Power ratio logarithm using base 10 (common logarithm)
- **Neper (Np)**: Voltage/current ratio logarithm using base e (natural logarithm)

Derivation:

1. Power ratio in dB: Loss(dB) = 10 $\log_{10}(P_1/P_2)$
2. Voltage ratio in dB: Loss(dB) = 20 $\log_{10}(V_1/V_2)$
3. Voltage ratio in Nepers: Loss(Np) = $\ln(V_1/V_2)$
4. Converting between logarithm bases: $\log_{10}(x) = \ln(x)/\ln(10)$
5. Substitute: Loss(dB) = 20 $\ln(V_1/V_2)/\ln(10)$ = 20 Loss(Np)/ln(10)

Final Relation:

- 1 Neper = ln(10)/20 × 10 dB = 8.686 dB
- 1 dB = 0.115 Neper

Table:

Conversion	Formula	Value
Neper to dB	1 Np = (20/ln10) dB	1 Np = 8.686 dB
dB to Neper	1 dB = (ln10/20) Np	1 dB = 0.115 Np

Mnemonic: "8.686: Eight Point Six Nepers Buy Ten decibels"

Question 5(c) [7 marks]

Design T type attenuator which provides 20 dB attenuation and having characteristics Impedance of 600 ohm.

Answer:

T-Type Attenuator Design:

Diagram:

```
       Z1/2          Z1/2
    o---/\/\/---o---/\/\/---o
    |           |           |
    |           |           |
   R0          Z2          R0
    |           |           |
    |           |           |
    o-----------o-----------o
```

Design Steps:

1. Calculate attenuation ratio N from dB:
   N = 10^(dB/20) = 10^(20/20) = 10
2. Calculate R_1 and R_2 using formulas:
   - $R_1 = R_0 \times [(N^2 - 1)/(N^2 + 1)]$
   - $R_2 = R_0 \times [2N/(N^2 - 1)]$

Calculation:

Given:

- Attenuation = 20 dB
- Characteristic impedance = 600 Ω

Parameter	Formula	Calculation	Result
N	10^(dB/20)	10^(20/20)	10
R_1	$R_0[(N^2 - 1)/(N^2 + 1)]$	$600[(10^2 - 1)/(10^2 + 1)]$	588.2 Ω
$Z_1/2$	$R_1/2$	588.2/2	294.1 Ω
R_2	$R_0[2N/(N^2 - 1)]$	$600[2\times10/(10^2 - 1)]$	121.2 Ω

Final T-network values:

- Each series arm ($Z_1/2$): 294.1 Ω
- Shunt arm (Z_2): 121.2 Ω

Mnemonic: "N-squared minus ONE over N-squared plus ONE for series resistance"

Question 5(a) OR [3 marks]

State limitations of constant K low pass filters

Answer:

Limitations of Constant-K Low Pass Filters:

Limitation	Description
Poor cutoff transition	Gradual transition from pass band to stop band instead of sharp cutoff
Uneven impedance	Impedance varies with frequency, causing matching problems
Attenuation ripple	Non-uniform attenuation in both pass band and stop band
Phase distortion	Non-linear phase response causing signal distortion
Fixed termination	Designed for specific load impedance; performance deteriorates with other loads
Limited selectivity	Poor selectivity compared to modern filter designs

Mnemonic: "PUAPFL: Poor transition, Uneven impedance, Attenuation ripple, Phase distortion, Fixed termination, Limited selectivity"

Question 5(b) OR [4 marks]

Give classification of filters showing frequency response curves For each of them

Answer:

Classification of Filters:

Filter Type	Frequency Response Curve	Characteristics
Low Pass	```goat	

```
   |\\
   |  \\
   |    \\_________
   |
   +---------------
      fc
``` | Passes frequencies below cutoff fc, blocks higher frequencies |
```

| **High Pass** | `goat`

```
        | _________
        | /
        | /
```
```

```
        |  /
        |/
        +---------------
           fc
```
| Blocks frequencies below cutoff fc, passes higher frequencies |
| **Band Pass** | `goat`

```
        |      /\
        |     /  \
        |    /    \
        |   /      \
        |__/        \___
        +---------------
           f1     f2
```
| Passes frequencies between f1 and f2, blocks others |
| **Band Stop** | `goat`

```
        |___        ___
        |   \      /
        |    \    /
        |     \  /
        |      \/
        +---------------
           f1     f2
```
| Blocks frequencies between f1 and f2, passes others |

Mnemonic: "LHBS: Low lets low tones, High lets high tones, Band-pass selects middle, Band-Stop rejects middle"

Question 5(c) OR [7 marks]

Derive equation for designing a constant K low pass filters.

Answer:

Constant-K Low Pass Filter Design:

Diagram:

```
T-section:                π-section:


   L/2         L/2
o---uuu----o----uuu---o     o-----------o
|          |          |     |           |
|          |          |     |           |
|          C          |     C/2        C/2
|          |          |     |           |
|          |          |     |           |
o----------o----------o     o-----uuu---o
                                  L
```

Design Theory:
A constant-K filter has impedance product $Z_1Z_2 = k^2$ (constant) at all frequencies.

Derivation Steps:

1. For a T-section low-pass filter:
    - Series impedance $Z_1 = j\omega L$
    - Shunt impedance $Z_2 = 1/j\omega C$
2. Product Z_1Z_2 must be constant:
    - $Z_1Z_2 = j\omega L \times 1/j\omega C = L/C = k^2$
3. Characteristic impedance at zero frequency:
    - $R_0 = \sqrt{(L/C)}$
4. Cut-off frequency occurs when:
    - $Z_1 = 2Z_0$ at $\omega = \omega c$
    - $j\omega cL = 2R_0 = 2\sqrt{(L/C)}$
    - $\omega c^2 = 4/LC$
    - $\omega c = 2/\sqrt{(LC)}$
    - $fc = 1/\pi\sqrt{(LC)}$
5. Design equations:
    - $L = R_0/\pi fc$
    - $C = 1/(\pi fcR_0)$

Final Equations:

- Cut-off frequency: $fc = 1/\pi\sqrt{(LC)}$
- Inductance: $L = R_0/\pi fc$
- Capacitance: $C = 1/(\pi fcR_0)$

T-section values:

- Series inductance: L/2 each arm
- Shunt capacitance: C

π-section values:

- Series inductance: L
- Shunt capacitance: C/2 each arm

Mnemonic: "One over Pi-Root-LC: The frequency where we Cut"