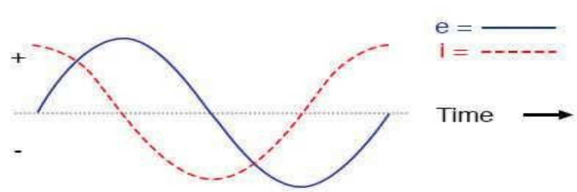
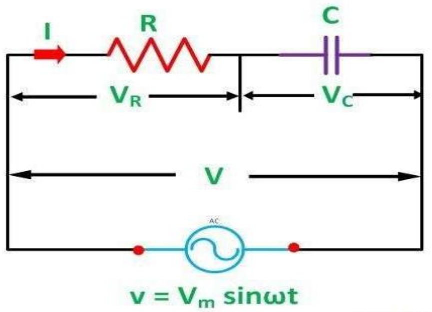
3^{rd} Semester, Electrical Engineering

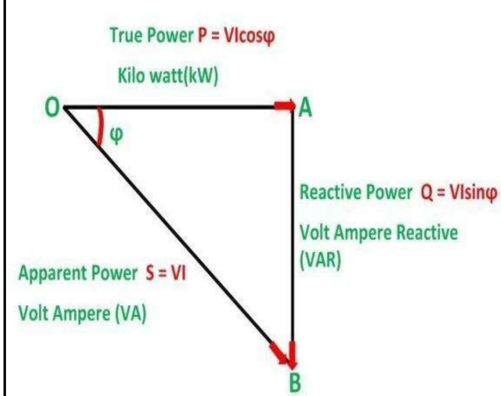
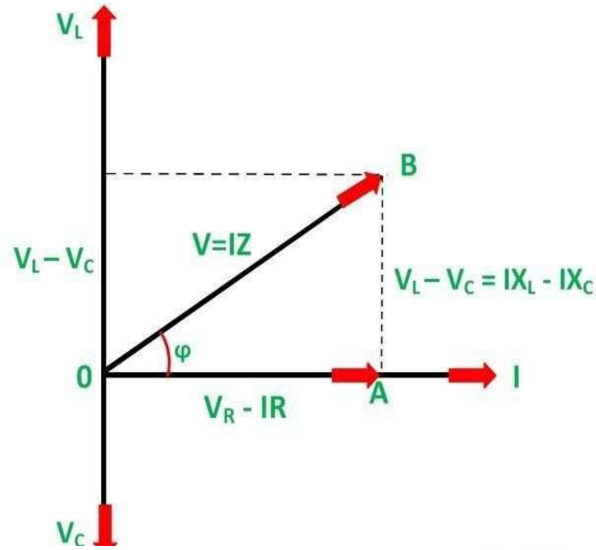
ELECTRICAL CIRCUITS (Th-2)

Unit I: Single Phase A.C Series Circuits

Question Type	Q.No.	Questions
2 Marks (10 Questions)	1	**Define Impedance and Reactance for an A.C. series circuit.** • ANS-Impedance (Z): The total opposition offered by a series A.C. circuit to the flow of alternating current. It is the vector sum of resistance (R) and reactance (X). $\boxed{Z = R + jX \text{(in rectangular form)}}$ $\mid Z \mid = \sqrt{R^2 + X^2}, \theta = \tan^{-1}(\frac{X}{R})$ • Reactance (X): The opposition due to inductance or capacitance (non-resistive part). $X = X_L - X_C$ where: $X_L = \omega L = 2\pi f L; X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$
	2	**State the relation between active power, reactive power, and apparent power.** ANS- V= RMS voltage • I= RMS current • ϕ= phase angle between V and I Active Power (P) $= VI\cos\phi$ (Watts) Reactive Power (Q) $= VI\sin\phi$ (VAR) Apparent Power (S) $= VI$ (VA) **Relation**: $\boxed{S^2 = P^2 + Q^2}$
	3	**What is the significance of the Power Triangle?** ANS- Significance: • Shows relationship between P, Q, S • $\cos\ \phi = \frac{P}{S} \rightarrow$ Power Factor • Helps in power factor correction (reducing Q to improve $\cos\phi$)
	4	**Define Quality Factor in a series R-L-C circuit.** ANS- Quality Factor (Q): Measure of sharpness of resonance or energy storage efficiency. $\boxed{Q = \frac{X_L}{R} = \frac{X_C}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} \text{ at resonance}}$ $Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}$ Higher $Q \rightarrow$ Sharper resonance peak, less damping.

	5	**What is Resonance in a series R-L-C circuit?** ANS- Resonance: Condition when inductive reactance equals capacitive reactance: $$\boxed{X_L = X_C \Rightarrow \omega L = \frac{1}{\omega C}}$$ Resonant frequency: $$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}; f_0 = \frac{1}{2\pi\sqrt{LC}}}$$ At resonance: • $Z = R$(minimum) • Current is maximum ($I = V/R$) • Voltage across $L$and Ccancel ($V_L = -V_C$) • Power factor = 1 (purely resistive)
	6	**Define Bandwidth for a resonant series circuit.** ANS- Bandwidth (BW): Frequency range where power is at least half of maximum (i.e., $P \geq \frac{P_{\max}}{2}$). $$\boxed{\text{BW} = f_2 - f_1 = \frac{R}{2\pi L}(\text{in Hz})}$$ Where $f_1$and $f_2$are half-power frequencies. Relation with Q: $$\boxed{Q = \frac{f_0}{\text{BW}}}$$ Narrow BW → High Q→ Sharp resonance
	7	**Explain the meaning of voltage magnification in a series R-L-C circui** ANS- Voltage Magnification: At resonance, voltage across inductor or capacitor can be much larger than source voltage. $$\boxed{V_L = IX_L = (\frac{V}{R})(\omega_0 L) = QV}$$ $$\boxed{V_C = IX_C = QV}$$ Magnification factor = QEven though $V_L + V_C = 0$(vector sum), individual magnitudes are Qtimes input.
	8	**What is the power factor in a purely inductive A.C. circuit?** ANS- In a purely inductive circuit ($R = 0$): • Current lags voltage by 90° • $\cos\phi = \cos 90° = 0$ $$\boxed{\text{Power Factor} = 0(\text{lagging})}$$ Active power $P = 0$, only reactive power exists.
	9	**Draw the voltage and current response waveforms for a purely capacitive circuit.** ANS-  ☐ Current leads voltage by 90° ☐ At zero crossing of V, current is maximum

	10	**Mention two characteristics of phasor representation of sinusoidal quantities.** ANS- 1. Rotating Vectors at Constant Speed: Phasors are vectors rotating counterclockwise at angular frequency ω, representing magnitude and phase of sinusoids. 2. Time-Invariant Relative Phase: The phase difference between two phasors is constant with time, even though they rotate. 3. Example: $v(t) = V_m \cos(\omega t) \rightarrow \vec{V} = V_m \angle 0° i(t) = I_m \cos(\omega t - 90°) \rightarrow \vec{I} = I_m \angle - 90°$
5 Marks **(5 Questions)**	1	**Explain the concept of Phasor representation of sinusoidal quantities.** ANS- A phasor is a rotating vector used to represent a sinusoid by its magnitude (RMS value) and phase angle. It converts time-domain sinusoidal analysis (using differential equations) into simple frequency-domain vector algebra, significantly simplifying A.C. circuit calculations.
	2	**Derive the expression for Impedance in an R-C series A.C. circuit.** **ANS-**  $V = \sqrt{(V_R)^2 + (V_C)^2} = \sqrt{(IR)^2 + (IX_C)^2}$ $V = I\sqrt{R^2 + X_C^2}$ or $I = \dfrac{V}{\sqrt{R^2 + X_C^2}} = \dfrac{V}{Z}$ $Z = \sqrt{R^2 + X_C^2}$ Where, • VR – voltage across the resistance R • VC – voltage across capacitor C • V – total voltage across the RC Series circuit

	3	**Draw and label the Impedance Triangle and Power Triangle for an R-L-C series circuit.** **ANS-** **<u>POWER TRAINGLE</u>** **<u>IMPEDANCE TRAINGLE</u>**  

Explain the phenomenon of Resonance in an R-L-C series circuit and state the condition for resonance.

ANS- Resonance in an R-L-C Series Circuit

1. Phenomenon of Resonance

In a series R-L-C circuit connected to an AC source $V = V_m \sin(\omega t)$, the total impedance is:

$$Z = R + j(\omega L - \frac{1}{\omega C}) = R + jX$$

where:

- $X = X_L - X_C = \omega L - \frac{1}{\omega C} \rightarrow$ net reactance

Resonance occurs when the inductive reactance (X_L) exactly cancels the capacitive reactance (X_C), i.e.,

$$X_L = X_C \Rightarrow \omega L = \frac{1}{\omega C}$$

At this condition:

- Net reactance $X = 0$
- Total impedance becomes purely resistive:
  $$Z = R \text{(minimum possible)}$$
- Current becomes maximum:
  $$I_{\text{max}} = \frac{V}{R}$$
- Power factor = 1 (circuit behaves as purely resistive)
- Voltage across L and C are equal in magnitude but 180° out of phase:
  $V_L = IX_L, V_C = IX_C \Rightarrow V_L = -V_C$ So, they cancel each other, and net voltage across L-C is zero.

Physical Insight: Energy oscillates between inductor (magnetic field) and capacitor (electric field) at the same frequency as the source → maximum energy transfer → **maximum current.**

2. Condition for Resonance

$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}} \text{(resonant angular frequency)}}$$

In terms of frequency:

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}} \text{(resonant frequency in Hz)}}$$

3. Key Effects at Resonance

4

Impedance	$Z = R$(minimum)
Current	$I = \frac{V}{R}$(maximum)
Phase angle	$\phi = 0°$
Power factor	$\cos\phi = 1$
$V_L$and V_C	$Q \times V$(can be much larger than source voltage)

This leads to voltage magnification by the quality factor$Q = \frac{\omega_0 L}{R}$.

Summary: Resonance is the tuning of the circuit to the source frequency such that reactive effects cancel, making the circuit purely resistive and allowing maximum current flow at minimum impedance. The condition is $\omega L = \frac{1}{\omega C}$, or $\omega_0 = \frac{1}{\sqrt{LC}}$.

5

A series circuit has R=10 Ω, L=0.1 H, and C=100 μF .Calculate the impedance and power factor at 50 Hz.

ANS-

Calculation of Impedance and Power Factor

Given:

- Resistance $R = 10\,\Omega$
- Inductance $L = 0.1\,\text{H}$
- Capacitance $C = 100\,\mu\text{F} = 100 \times 10^{-6}\,\text{F} = 10^{-4}\,\text{F}$
- Frequency $f = 50\,\text{Hz}$

Step 1: Calculate angular frequency

$$\omega = 2\pi f = 2\pi \times 50 = 100\pi \approx 314.159\,\text{rad/s}$$

Step 2: Calculate inductive reactance X_L

$$X_L = \omega L = 314.159 \times 0.1 = 31.416\,\Omega$$

Step 3: Calculate capacitive reactance X_C

$$X_C = \frac{1}{\omega C} = \frac{1}{314.159 \times 10^{-4}} = \frac{1}{0.031416} \approx 31.831\,\Omega$$

Step 4: Calculate net reactance X

$$X = X_L - X_C = 31.416 - 31.831 = -0.415\,\Omega$$

Step 5: Calculate impedance ZThe impedance of the series RLC circuit is:

$$Z = R + jX = 10 + j(-0.415) = 10 - j0.415\,\Omega$$

Magnitude:

$$|Z| = \sqrt{R^2 + X^2} = \sqrt{10^2 + (-0.415)^2} = \sqrt{100 + 0.172} = \sqrt{100.172} \approx 10.009\,\Omega$$

Phase angle:

$$\theta = \tan^{-1}(\frac{X}{R}) = \tan^{-1}(\frac{-0.415}{10}) \approx -2.377^\circ$$

Step 6: Calculate power factor The power factor is the cosine of the phase angle:

$$\text{Power Factor (PF)} = \cos\,\theta = \cos\,(-2.377^\circ) \approx 0.9991 \text{(leading, since } \theta < 0\text{)}$$

10 Marks
(2 Questions)

Derive the expression for the resonant frequency, Quality factor and Bandwidth of an R-L-C series A.C. circuit.

Ans-

1. Resonant Frequency (f_0 or ω_0)

Impedance of series RLC circuit:

$$Z = R + j(\omega L - \frac{1}{\omega C}) = R + jX$$

where:

- $X = X_L - X_C = \omega L - \frac{1}{\omega C}$

Resonance occurs when net reactance is zero:

$$X = 0 \Rightarrow \omega L = \frac{1}{\omega C}$$

$$\Rightarrow \omega^2 = \frac{1}{LC}$$

$$\boxed{\therefore \omega_0 = \frac{1}{\sqrt{LC}} \text{(resonant angular frequency)}}$$

In Hertz:

$$\boxed{f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}}$$

At $\omega = \omega_0$, $Z = R \rightarrow$ minimum impedance, maximum current.

2. Quality Factor (Q)

Definition: Ratio of energy stored to energy dissipated per cycle.

At resonance:

- Current: $I_0 = \frac{V}{R}$
- Voltage across inductor: $V_L = I_0 X_L = I_0(\omega_0 L)$
- Voltage across capacitor: $V_C = I_0 X_C = I_0(\frac{1}{\omega_0 C})$

But at resonance:

$$\omega_0 L = \frac{1}{\omega_0 C} \Rightarrow X_L = X_C$$

So:

$$V_L = V_C = \frac{V}{R} \cdot \omega_0 L$$

Quality factor:

$$\boxed{Q = \frac{\text{Voltage across reactive element}}{\text{Source voltage}} = \frac{V_L}{V} = \frac{I_0 \omega_0 L}{V} = \frac{(V/R) \cdot \omega_0 L}{V} = \frac{\omega_0 L}{R}}$$

Similarly:

$Q = \frac{1}{\omega_0 RC}$ Using $\omega_0 = \frac{1}{\sqrt{LC}}$: $\boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}}$

Higher $Q \rightarrow$ sharper resonance.

3. Bandwidth (Δf)

Bandwidth is the frequency range where power is ≥ half of maximum.

At resonance, power is maximum: $P_{\max} = I_0^2 R = (\frac{V}{R})^2 R = \frac{V^2}{R}$

Half-power occurs when: $P = \frac{P_{\max}}{2} \Rightarrow I = \frac{I_0}{\sqrt{2}}$

So impedance magnitude-

$$|Z| = \sqrt{R^2 + X^2} = R\sqrt{2}$$

$$\Rightarrow X^2 = R^2 \Rightarrow X = \pm R$$

$$\Rightarrow \omega L - \frac{1}{\omega C} = \pm R$$

Let ω_1, ω_2 be the two frequencies where $X = +R$ and $X = -R$.

$$\omega L - \frac{1}{\omega C} = R; \omega L - \frac{1}{\omega C} = -R$$

Multiply by ω:

$$\omega^2 L - \frac{1}{C} = \pm R\omega$$

$$\omega^2 L \mp R\omega - \frac{1}{C} = 0$$

Quadratic equation:

$$\omega = \frac{\pm R \pm \sqrt{R^2 + \frac{4L}{C}}}{2L}$$

Taking positive roots:

$$\omega_1 = \frac{R + \sqrt{R^2 + \frac{4L}{C}}}{2L}, \omega_2 = \frac{-R + \sqrt{R^2 + \frac{4L}{C}}}{2L}$$

For high Q circuits (R small), approximate:

$$\omega_2 - \omega_1 \approx \frac{R}{L}$$

Bandwidth in rad/s:

$$\Delta\omega = \omega_2 - \omega_1 = \frac{R}{L}$$

In Hz:

$$\boxed{\Delta f = f_2 - f_1 = \frac{\Delta\omega}{2\pi} = \frac{R}{2\pi L}}$$

2

A series R-L-C circuit with the following components
Resistance, R = 15 ohm Inductance, L = 0.05H, Capacitance = 120 microfarad is connected across a sinusoidal A.C. supply of 230 V, 50 Hz.
Calculate the following circuit parameters:
A.)Inductive Reactance (XL) and Capacitive Reactance (XC).
B.)Total Impedance (Z) of the circuit.
C.) Current (I) drawn from the supply.
D.)Power Factor (PF) of the circuit and state whether it is leading or lagging.
E.)Active Power (P), Reactive Power (Q), and Apparent Power (S).
F.)Draw the complete vector diagram showing the supply voltage (V), total current (I), and the individual voltage drops (VR, VL, VC).
Ans- Complete Solution: Series R-L-C Circuit
Given:

- $R = 15\,\Omega$
- $L = 0.05\,\text{H}$
- $C = 120\,\mu\text{F} = 120 \times 10^{-6}\,\text{F} = 1.2 \times 10^{-4}\,\text{F}$
- Supply: $V = 230\,\text{V(RMS)}$, $f = 50\,\text{Hz}$

A.) Inductive Reactance (X_L) and Capacitive Reactance (X_C)

$$\omega = 2\pi f = 2\pi \times 50 = 100\pi \approx 314.16\,\text{rad/s}$$

Inductive Reactance:

$$\boxed{X_L = \omega L = 314.16 \times 0.05 = 15.708\,\Omega}$$

Capacitive Reactance:

$$X_C = \frac{1}{\omega C} = \frac{1}{314.16 \times 1.2 \times 10^{-4}} = \frac{1}{0.0377} \approx 26.525\,\Omega$$
$$\boxed{X_C = 26.525\,\Omega}$$

B.) Total Impedance (Z)
Net Reactance:

$$X = X_L - X_C = 15.708 - 26.525 = -10.817\,\Omega$$

Impedance in rectangular form:

$$Z = R + jX = 15 - j10.817\,\Omega$$

Magnitude of Impedance:

$$|Z| = \sqrt{R^2 + X^2} = \sqrt{15^2 + (-10.817)^2} = \sqrt{225 + 116.9} = \sqrt{341.9} \approx 18.49\,\Omega$$

Phase angle:

$$\theta = \tan^{-1}(\frac{X}{R}) = \tan^{-1}(\frac{-10.817}{15}) = \tan^{-1}(-0.721) \approx -35.8^\circ$$
$$\boxed{Z = 18.49\,\Omega\angle -35.8^\circ}$$

C.) Current (I) drawn from the supply

$$\boxed{I = \frac{V}{|Z|} = \frac{230}{18.49} \approx 12.44\,\text{A (RMS)}}$$

D.) Power Factor (PF) and Nature

$$\text{PF} = \cos\theta = \cos(-35.8^\circ) \approx 0.811$$

Since $\theta < 0 \rightarrow$ Capacitive reactance dominates → Current leads voltage.

$$\boxed{\text{PF} = 0.811\text{(leading)}}$$

E.) Active Power (P), Reactive Power (Q), Apparent Power (S)
Apparent Power:

$$\boxed{S = V \cdot I = 230 \times 12.44 = 2861.2\,\text{VA}}$$

Active Power:

$$\boxed{P = VI\cos\phi = 230 \times 12.44 \times 0.811 \approx 2319\,\text{W}}$$

Reactive Power:

$$\boxed{Q = VI\sin\phi = 230 \times 12.44 \times \sin(-35.8^\circ)}$$
$$\sin(-35.8^\circ) \approx -0.585$$
$$\boldsymbol{Q = 230 \times 12.44 \times (-0.585) \approx -1673}\,\text{VAR(capacitive, negative)}$$

Note: Negative $\boldsymbol{Q}$indicates leading PF (capacitive circuit).

F.) Vector (Phasor) Diagram
Assume current $\vec{I}$as reference along +x axis (since current leads voltage in capacitive circuit):
text
VL

```
       ↑
       |
  VR ←---→ I (ref) ---→ VC
       |
       ↓
      V (supply)
```

Voltage Drops (Magnitudes):

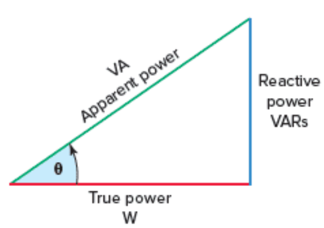
$$\boldsymbol{V_R = IR = 12.44 \times 15 = 186.6}\,\text{V}$$
$$\boldsymbol{V_L = IX_L = 12.44 \times 15.708 \approx 195.4}\,\text{V}$$
$$\boldsymbol{V_C = IX_C = 12.44 \times 26.525 \approx 329.9}\,\text{V}$$

Note: $\boldsymbol{V_C > V_L} \rightarrow$ capacitive dominance
Phasor Relations:
$\vec{V_R}$: in phase with $\vec{I} \rightarrow$ along +x
$\vec{V_L}$: leads $\vec{I}$by 90° → along +y
$\vec{V_C}$: lags $\vec{I}$by 90° → along -y

- $\vec{V} = \vec{V_R} + \vec{V_L} + \vec{V_C}$
- Vector Sum:

$$\boldsymbol{\vec{V} = V_R + j(V_L - V_C) = 186.6 + j(195.4 - 329.9) = 186.6 - j134.5}$$
$$|\vec{V}| = \sqrt{\boldsymbol{186.6^2 + 134.5^2}} \approx \boldsymbol{230}\,\text{V(matches supply)}$$

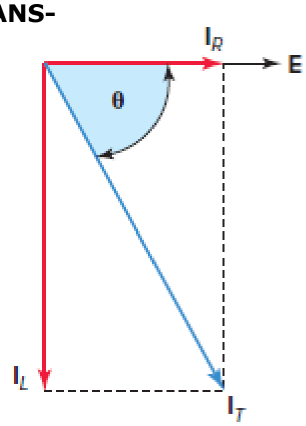
Unit II: Single Phase A.C Parallel Circuits

Question Type	Q.No.	Questions
2 Marks (10 Questions)	1	**Define Impedance and Reactance for an A.C. parallel circuit**. ANS-Impedance in A.C. Parallel Circuit Impedance (Z) is the total opposition to current flow in a parallel A.C. circuit, combining resistance and reactance effects. reactance (X) does not have a single value like in series circuits. Instead, we use Susceptance (B) — the imaginary part of admittance.
	2	What is the role of the phasor diagram in analyzing A.C. parallel circuits? ANS- **The phasor diagram is a powerful graphical tool for analyzing A.C. parallel circuits. It represents voltages and currents as rotating vectors (phasors) in the complex plane, enabling visual understanding of phase relationships, vector addition, and power components**.
	3	**State the condition for Resonance in a parallel R-L-C circuit**. ANS- Condition for Resonance in a Parallel R-L-C Circuit $\boxed{B = 0 \Rightarrow \omega C = \frac{1}{\omega L} \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}} \Rightarrow f_0 = \frac{1}{2\pi\sqrt{LC}}}$
	4	**Define the terms active power and apparent power in a parallel A.C. circuit**. ANS-Active Power (P): Real power consumed in the resistor, doing useful work. $\boxed{P = VI\cos\phi = \frac{V^2}{R}\,(\text{W})}$ Apparent Power (S): Total power supplied by the source. $\boxed{S = VI\ (\text{VA})}$
	5	**What is the significance of voltage magnification in an A.C. parallel circuit?** ANS- Voltage magnification at resonance in parallel R-L-C: $V_L = V_C \gg V(\text{supply}) \rightarrow$ High voltage across L & C despite low total current. Significance: • Used in tuned amplifiers and filters • Risk: Component damage if Q is high
	6	**How does a parallel R-L-C circuit at resonance behave electrically?** ANS- resonance, a parallel R-L-C circuit behaves as a pure resistor: • Net susceptance B = 0 $\rightarrow I_C = I_L$ • Total current minimum ($I = V/R$) • Impedance maximum ($\lvert Z \rvert = R$) • Power factor = 1 • Voltage across L and C much higher than supply voltage (magnification)
	7	**Sketch the Power Triangle for a parallel R-L circuit.** ANS- 
	8	**What are the units of Quality Factor and Bandwidth?** ANS-Quality Factor (Q): Unitless (dimensionless) Bandwidth (BW): Hertz (Hz)
	9	**State the difference between series and parallel resonance in terms of line current at resonance**. ANS-Series Resonance: Line current = Maximum Parallel Resonance: Line current = Minimum

10 **What is the power factor of a parallel R-L-C circuit operating at its resonant frequency?**
ANS-Power factor = 1 (unity)

5 Marks
(5 Questions)

1 **Draw the phasor diagram for an R-L parallel A.C. circuit.**
ANS-



2 **Explain the concept of resonance in a parallel R-L-C circuit.**
ANS-Resonance in a parallel R-L-C circuit occurs when:

- Capacitive susceptance $B_C = \omega C$equals Inductive susceptance $B_L = 1/(\omega L)$

$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}}$$

Effects at Resonance:

- Net susceptance = 0 → circuit is purely resistive
- Impedance = maximum ($|Z| = R$)
- Line current = minimum ($I = V/R$)
- Power factor = 1
- Voltage across L and C = high (magnified, $V_L = V_C \gg V$)

→ Behaves like a high-impedance tuned filter.

3 **Define and explain Bandwidth and Quality factor for a parallel R-L-C circuit.**
ANS- Bandwidth (BW): Frequency range where power ≥ half of maximum.

$$\boxed{\text{BW} = f_2 - f_1 = \frac{R}{2\pi L}\,(\text{Hz})}$$

Quality Factor (Q): Measure of sharpness of resonance.

$$\boxed{Q = \frac{f_0}{\text{BW}} = \frac{\omega_0 L}{R}\,(\text{dimensionless})}$$

Higher Q → narrower BW, sharper peak, better selectivity.

4 **Compare the characteristics of series R-L-C resonance and parallel R-L-C resonance.**
ANS-

Characteristic	Series R-L-C Resonance	Parallel R-L-C Resonance
Condition	$X_L = X_C$	$B_C = B_L (I_C = I_L)$
Resonant Frequency	$f_0 = \frac{1}{2\pi\sqrt{LC}}$	$f_0 = \frac{1}{2\pi\sqrt{LC}}$
Impedance at Resonance	Minimum ($$	Z
Line Current	Maximum $(\boldsymbol{I = V/R})$	Minimum $(\boldsymbol{I = V/R})$
Power Factor	1 **(unity)**	1 **(unity)**
Voltage across L & C	High ($V_L = V_C \gg V$)	High ($V_L = V_C \gg V$)
Circuit Behavior	Current amplifier	Voltage amplifier
Bandwidth	$\frac{R}{2\pi L}$	$\frac{R}{2\pi L}$
Q-Factor	$\frac{\omega_0 L}{R}$	$\frac{\omega_0 L}{R}$
Application	Power transfer, tuning	RF filters, tuned amplifiers

	5	**Two impedances Z_1 and Z_2 are connected in parallel. Explain how to find the total apparent power.** ANS- To find total apparent power (S) for Z_1 and Z_2 in parallel: 1. Common voltage V(RMS) across both. 2. Branch currents (RMS): $I_1 = \frac{V}{\lvert Z_1 \rvert}, I_2 = \frac{V}{\lvert Z_2 \rvert}$ 3. Branch apparent powers: $S_1 = VI_1, S_2 = VI_2$ 4. Total apparent power: $$\boxed{S = S_1 + S_2 = V(I_1 + I_2)}$$ Note: Apparent powers add algebraically only if in phase; otherwise, use phasor sum of currents for accurate I_{total}, then $S = VI_{\text{total}}$.

10 Marks (2 Questions)

1

Derive the expressions for impedance, power factor, and total current for an R-L and R-C parallel combination A.C. circuit, using phasor algebra.

ANS- **R-L and R-C Parallel A.C. Circuit**

Given:

- Branch 1: $R$and Lin series → Impedance $Z_L = R + j\omega L$
- Branch 2: $R$and Cin series → Impedance $Z_C = R - j/(\omega C)$
- Supply voltage: V(RMS, reference phasor)

1. Total Admittance Y

$$Y = Y_L + Y_C = \frac{1}{Z_L} + \frac{1}{Z_C}$$

$$Y_L = \frac{1}{R + j\omega L} = \frac{R - j\omega L}{R^2 + (\omega L)^2}$$

$$Y_C = \frac{1}{R - j/(\omega C)} = \frac{R + j/(\omega C)}{R^2 + 1/(\omega^2 C^2)}$$

$$\boxed{Y = \frac{R}{R^2 + (\omega L)^2} + \frac{R}{R^2 + 1/(\omega^2 C^2)} + j[\frac{-\omega L}{R^2 + (\omega L)^2} + \frac{1/(\omega C)}{R^2 + 1/(\omega^2 C^2)}]}$$

Let:

- Conductance: $G = \frac{R}{R^2+(\omega L)^2} + \frac{R}{R^2+1/(\omega^2 C^2)}$
- Susceptance: $B = \frac{-\omega L}{R^2+(\omega L)^2} + \frac{1/(\omega C)}{R^2+1/(\omega^2 C^2)}$

2. Total Impedance Z

$$\boxed{Z = \frac{1}{Y} = \frac{1}{G + jB} = \frac{G - jB}{G^2 + B^2}}$$

$$\boxed{|Z| = \frac{1}{|Y|} = \frac{1}{\sqrt{G^2 + B^2}}}$$

3. Total Current I

$$\boxed{I = V|Y| = V\sqrt{G^2 + B^2}}$$

4. Power Factor

$$\cos\phi = \frac{\text{Active Power}}{\text{Apparent Power}} = \frac{V^2 G}{V \cdot I} = \frac{G}{|Y|}$$

$$\boxed{\cos\phi = \frac{G}{\sqrt{G^2 + B^2}}}$$

$$\phi = \tan^{-1}(B/G)$$

- $B > 0$: Leading PF
- $B < 0$: Lagging PF

Summary (Phasor-Based)

Quantity	Expression
Admittance	$Y = G + jB$
Impedance	$\boxed{Z = \frac{G - jB}{G^2 + B^2}}$
Total Current	$\boxed{I = V\sqrt{G^2 + B^2}}$
Power Factor	$\boxed{\cos\phi = \frac{G}{\sqrt{G^2 + B^2}}}$

Phasor Insight:

- $I_R = VG$(in phase with V)
- $I_Q = VB$(90° to V)
- $I = \sqrt{I_R^2 + I_Q^2}$→ PF = I_R/I

	2	**Discuss the behavior of a parallel R-L-C circuit at frequencies below, at, and above resonance with respect to impedance, current, and power factor.** ANS- 1. Below Resonance ($f < f_0$) • Reactances: $X_C = 1/(\omega C) > X_L = \omega L \rightarrow$ Capacitive reactance dominates • Susceptance: $B_C = \omega C > B_L = 1/(\omega L) \rightarrow$ Net susceptance positive (capacitive) • Admittance: $\mid Y \mid$large → Impedance $\mid Z \mid = 1/\mid Y \mid$is LOW • Current: Total $I = V \mid Y \mid \rightarrow$ HIGH current • Phase: Capacitive current leads voltage → Current leads voltage → Leading Power Factor • Circuit Behavior: Acts like a capacitor → draws leading reactive current **2.** At Resonance ($f = f_0 = 1/(2\pi\sqrt{LC})$) • Reactances: $X_C = X_L \rightarrow$ Net reactance = 0 • Susceptance: $B_C + B_L = 0 \rightarrow$ Net susceptance = 0 • Admittance: $Y = G = 1/R$(pure conductance) → |Y| minimum • Impedance: $\mid Z \mid = 1/G = R \rightarrow$ MAXIMUM • Current: $I = V/R \rightarrow$ MINIMUM • Phase: Current in phase with voltage → Power Factor = 1 (unity) • Voltages: $V_L = IX_L$, $V_C = IX_C \rightarrow V_L = V_C \gg V$(voltage magnification) • Circuit Behavior: Purely resistive, minimum current, maximum impedance, no reactive power **3.** Above Resonance ($f > f_0$) • Reactances: $X_L = \omega L > X_C = 1/(\omega C) \rightarrow$ Inductive reactance dominates • Susceptance: $B_L > B_C \rightarrow$ Net susceptance negative (inductive) • Admittance: $\mid Y \mid$large → Impedance $\mid Z \mid$is LOW • Current: $I = V \mid Y \mid \rightarrow$ HIGH current • Phase: Inductive current lags voltage → Current lags voltage → Lagging Power Factor • Circuit Behavior: Acts like an inductor → draws lagging reactive current

Unit III: Three Phase Circuits

<table>
<tr><th>Question Type</th><th>Q.No.</th><th>Questions</th></tr>
<tr><td>2 Marks
(10 Questions)</td><td>1</td><td>Define Phase Sequence in a three-phase supply.
ANS- Phase Sequence in a three-phase supply is the order in which the three phase voltages reach their positive maximum values.
• Positive (R-Y-B): R peaks → Y peaks → B peaks
• Negative (R-B-Y): R peaks → B peaks → Y peaks
It determines motor rotation direction and system compatibility.</td></tr>
<tr><td></td><td>2</td><td>What are the two main types of three-phase connections?
ANS- Two main types of three-phase connections:
1. Star (Y) Connection
2. Delta (Δ) Connection</td></tr>
<tr><td></td><td>3</td><td>Distinguish between Phase quantities and Line quantities in a star (Y) system.
ANS-
<table><tr><td>Quantity</td><td>Phase (Line-to-Neutral)</td><td>Line (Line-to-Line)</td></tr><tr><td>Voltage</td><td>$V_{ph} = \frac{V_L}{\sqrt{3}}$</td><td>$V_L = \sqrt{3}\, V_{ph}$</td></tr><tr><td>Current</td><td>$I_{ph} = I_L$</td><td>$I_L = I_{ph}$</td></tr><tr><td>Power Formula</td><td>$P_{ph} = V_{ph} I_{ph} \cos \phi$</td><td>Total $P = \sqrt{3} V_L I_L \cos \phi$</td></tr></table>Key:
• Voltage: Line is √3 times Phase
• Current: Line = Phase</td></tr>
</table>

	4	Write the relationship between Line Voltage and Phase Voltage in a delta connection. ANS- In Delta (Δ) Connection: Quantity Relationship Line Voltage $\boxed{V_L = V_{ph}}$ Line Current $\boxed{I_L = \sqrt{3}\, I_{ph}}$ Phase Angle Line current lags phase current by 30°
	5	**Define a Balanced Load in a three-phase system.** ANS- ☐ Equal phase currents (I_{ph}) ☐ Equal line currents ☐ 120° phase difference ☐ Neutral current = **0** (in star)
	6	**What is Neutral Shift in an unbalanced three-phase load?** ANS- Neutral Shift (2 Marks) When a three-phase star-connected load is unbalanced (i.e., phase impedances are unequal), the neutral point of the load shifts from the supply neutral. Reason: Unequal phase currents cause a non-zero neutral current, producing voltage drop in the neutral conductor, thus displacing the load neutral. Effect: Phase voltages become unequal while line voltages remain equal.
	7	**Write the formula for Total Active Power in a three-phase system.** ANS- Total Active Power (P) in a three–phase system: $\boxed{P = \sqrt{3}\, V_L I_L \cos\,\phi}$ Where: • V_L= Line voltage (RMS) • I_L= Line current (RMS) • $\cos\phi$= Power factor
	8	**Define Apparent Power in a three-phase system**. ANS- **Apparent Power (S)** in a three-phase system: **Total power supplied** by the source. $\boxed{S = \sqrt{3}\, V_L I_L}$ **Unit**: Volt-Amperes (VA)
	9	**What is the function of the neutral wire in a three-phase star system with an unbalanced load?** ANS- Function of Neutral Wire (Unbalanced Load): Carries the unbalanced current back to the source to prevent neutral shift and maintain balanced phase voltages. Key: • $I_N = I_R + I_Y + I_B$(phasor sum ≠ 0) • Without neutral → voltage imbalance • With neutral → phase voltages stabilized
	10	**Explain the significance of Phasor and complex representation of a three-phase supply.** ANS-Significance of Phasor & Complex Representation in 3-Phase Supply: 1. Simplifies Analysis: ○ Represents sinusoidal voltages/currents as rotating vectors (phasors) or complex numbers. 2. Handles Phase Difference: ○ 120° phase shift → $1, a, a^2$where $a = e^{j120^\circ}$ 3. Enables Symmetrical Components: ○ Decomposes unbalanced system into positive, negative, zero sequences. 4. Power Calculation: ○ $P = \Re(V \cdot I^*)$Using complex form. 5. Fault & Stability Studies: ○ Essential for short-circuit, stability, and protection analysis.

<table>
<tr>
<td>5 Marks
(5 Questions)</td>
<td>1</td>
<td>
Explain the concept of Phase Sequence and Polarity in a three-phase supply.
ANS- Phase Sequence and Polarity in a Three-Phase Supply

1. Phase Sequence
Definition: Phase sequence is the order in which the three phase voltages attain their positive maximum values.
Types:
• Positive sequence (R-Y-B): $V_R$peaks first → $V_Y$after 120° → $V_B$after 240°
• Negative sequence (R-B-Y): $V_R$peaks first → $V_B$after 120° → $V_Y$after 240°
Phasor Representation:
$$V_R = V_m\angle 0^\circ, V_Y = V_m\angle 240^\circ, V_B = V_m\angle 120^\circ \text{(R-Y-B)}$$
Significance:
• Determines direction of rotation of three-phase motors.
• Ensures correct paralleling of generators/transformers.
• Affects power flow and protection relay operation.
Detection:
• Using phase sequence indicator or two-lamp method.

2. Polarity
Definition: Polarity refers to the correct terminal marking (start/finish) of phase windings in transformers or generators.
Types:
• Additive polarity: High-voltage terminal and adjacent low-voltage terminal have same polarity.
• Subtractive polarity: High-voltage and low-voltage terminals on same side have opposite polarity.
Significance:
• Essential for correct parallel operation of transformers.
• Prevents circulating currents and short circuits.
• Ensures proper vector grouping (e.g., Dy11, Yy0).
Testing:
• DC kick test or AC voltage test across windings.
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<td>2</td>
<td>
Derive the relationship between Line current and Phase current for a three-phase delta connected load.
ANS- In a delta-connected three-phase load, each phase impedance is connected directly between two line terminals, so the phase voltage equals the line voltage: $V_{ph} = V_L$. The phase current I_{ph}flows through each phase impedance. To find the line current I_L, apply Kirchhoff's Current Law (KCL) at any line junction, say between lines R and Y. The line current entering the junction equals the sum of the two phase currents connected to it: $I_L = I_{RY} + I_{BR}$, where $I_{RY}$is the current in the R-Y phase and $I_{BR}$is the current in the B-R phase.
Using phasor representation with $I_{RY} = I_{ph}\angle 0^\circ$, the current I_{BR}lags by 240° (or leads by 120°), so $I_{BR} = I_{ph}\angle 240^\circ$. The phasor sum is:
$$I_L = I_{ph} + I_{ph}(\cos\ 240^\circ + j\sin\ 240^\circ) = I_{ph} + I_{ph}(-\frac{1}{2} - j\frac{\sqrt{3}}{2})$$
$$= I_{ph}(1 - \frac{1}{2}) + jI_{ph}(-\frac{\sqrt{3}}{2}) = \frac{I_{ph}}{2} - j\frac{\sqrt{3}}{2}I_{ph}$$
The magnitude of $I_L$is:
$$|\ I_L\ |= \sqrt{(\frac{I_{ph}}{2})^2 + (\frac{\sqrt{3}}{2}I_{ph})^2} = \sqrt{\frac{I_{ph}^2}{4} + \frac{3I_{ph}^2}{4}} = \sqrt{I_{ph}^2} = I_{ph}\sqrt{3}$$
Thus, the line current is √3 times the phase current:
$$\boxed{I_L = \sqrt{3}\, I_{ph}}$$
Additionally, the line current lags the corresponding phase current by 30°, which is crucial for power and phasor diagram analysis in delta systems.
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</table>

	3	**Explain the significance of Neutral Shift in an unbalanced three-phase star connected load**. ANS- In a three-phase star-connected load with unbalanced impedances ($Z_R \neq Z_Y \neq Z_B$), the phase currents become unequal in magnitude and/or phase. The vector sum of phase currents is non-zero, resulting in a neutral current $I_N = I_R + I_Y + I_B \neq 0$. This neutral current flows through the neutral conductor, causing a voltage drop $V_N = I_N \cdot Z_N$(where $Z_N$is neutral impedance). Consequently, the load neutral point (N) shifts away from the supply neutral (N'), a phenomenon called Neutral Shift. Key Effects: 1. Unequal Phase Voltages: $V_{RN} \neq V_{YN} \neq V_{BN} \rightarrow$ Some phases get overvoltage, others undervoltage. 2. Equipment Stress: ○ Motors: Uneven torque, overheating ○ Lamps: Flickering or burnout ○ Electronics: Malfunction or failure 3. Increased Losses: Higher I^2Rloss in neutral and phases. 4. Protection Issues: Incorrect tripping of relays/breakers. Importance: • Must be minimized using proper neutral sizing (1.5–2× phase conductor) or load balancing. • In delta systems, no neutral → no shift, but circulating currents possible. Conclusion: Neutral shift distorts voltage distribution, affects system reliability, and increases losses — critical in distribution and industrial loads.
	4	**Briefly explain how active, reactive, and apparent power are calculated for a three-phase system.** ANS- Three-Phase Power Calculations (Brief) For balanced or unbalanced system: • Active Power (P): $\boxed{P = \sqrt{3}\, V_L I_L \cos\, \phi}$(W) • Reactive Power (Q): $\boxed{Q = \sqrt{3}\, V_L I_L \sin\, \phi}$(VAR) • Apparent Power (S): $\boxed{S = \sqrt{3}\, V_L I_L}$(VA) $\cos\phi$= power factor $S = \sqrt{P^2 + Q^2}$
	5	**A balanced star connected load has an impedance of (6+j8) Ω per phase. If the line voltage is 400V, calculate the line current.** ANS- **Given**: • Balanced star load • Phase impedance: $Z_{ph} = 6 + j8\,\Omega$ • Line voltage: $V_L = 400\,\text{V}$ **Step 1: Phase Voltage** $$\boxed{V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} \approx 230.94\,\text{V (RMS)}}$$ **Step 2: Magnitude of Z_{ph}** $$\mid Z_{ph} \mid = \sqrt{6^2 + 8^2} = \sqrt{36 + 64} = \sqrt{100} = \boxed{10\,\Omega}$$ **Step 3: Phase Current = Line Current (in star)** $$\boxed{I_L = I_{ph} = \frac{V_{ph}}{\mid Z_{ph} \mid} = \frac{230.94}{10} = \boxed{23.094\,\text{A}}}$$ **Final Answer**: $$\boxed{I_L = 23.09\,\text{A}}$$

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<td>10 Marks
(2 Questions)</td>
<td>1</td>
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Explain the different types of three-phase connections (Star and Delta). Derive the relationship between Line and Phase quantities (Voltage and Current) for both connections

ANS-1. Star (Y) Connection

In star connection, one end of each phase winding is connected to a common neutral point (N), and the other ends form the three line terminals.

Phasor Diagram & Relationships

- Phase voltage (V_{ph}): Voltage between line and neutral (V_{RN}, V_{YN}, V_{BN})
- Line voltage (V_L): Voltage between two lines (V_{RY}, V_{YB}, V_{BR})

Using phasor addition:

$$\vec{V}_{RY} = \vec{V}_{RN} + \vec{V}_{NY}$$

Since $\vec{V}_{NY} = -\vec{V}_{YN}$ and $V_{RN} = V_{YN} = V_{ph}$, with 120° phase shift:

$$V_L = \sqrt{V_{ph}^2 + V_{ph}^2 + 2V_{ph}V_{ph}\cos 120^\circ} = \sqrt{2V_{ph}^2 + 2V_{ph}^2(-\frac{1}{2})} = \sqrt{3V_{ph}^2}$$

$$\boxed{V_L = \sqrt{3}\,V_{ph}} \Rightarrow V_{ph} = \frac{V_L}{\sqrt{3}}$$

Current: Each line carries only one phase current →

$$\boxed{I_L = I_{ph}}$$

2. Delta (Δ) Connection

In delta connection, the three phase windings are connected end-to-end forming a closed loop. Each junction is a line terminal.

Phasor Diagram & Relationships

- Phase voltage = voltage across one phase = Line voltage

$$\boxed{V_{ph} = V_L}$$

Current: At each line junction, two phase currents combine. Apply KCL at junction (say R):

$$\vec{I}_L = \vec{I}_{RY} + \vec{I}_{BR}$$

Let $I_{RY} = I_{ph}\angle 0^\circ$, then $I_{BR} = I_{ph}\angle 240^\circ$

$$I_L = I_{ph} + I_{ph}(-\frac{1}{2} - j\frac{\sqrt{3}}{2}) = \frac{I_{ph}}{2} - j\frac{\sqrt{3}}{2}I_{ph}$$

$$|I_L| = \sqrt{(\frac{I_{ph}}{2})^2 + (\frac{\sqrt{3}}{2}I_{ph})^2} = \sqrt{\frac{I_{ph}^2}{4} + \frac{3I_{ph}^2}{4}} = I_{ph}\sqrt{3}$$

$$\boxed{I_L = \sqrt{3}\,I_{ph}} \Rightarrow I_{ph} = \frac{I_L}{\sqrt{3}}$$

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2

Explain Balanced and Unbalanced three-phase loads. Derive the formula for Total Active Power in a three-phase star and delta connected system.

ANS-Balanced and Unbalanced Three-Phase Loads Derivation of Total Active Power (Star & Delta)

1. Balanced Load (
A balanced three-phase load has equal impedance per phase in magnitude and phase angle:

$$Z_R = Z_Y = Z_B = Z_{ph}$$

Characteristics:

- Phase currents equal: $I_R = I_Y = I_B = I_{ph}$
- 120° phase difference
- Neutral current = 0 (in star)
- Line voltages/currents symmetrical

2. Unbalanced Load
An unbalanced load has unequal phase impedances:

$$Z_R \neq Z_Y \neq Z_B$$

Characteristics:

- Unequal phase currents
- Neutral current ≠ 0 (in star) → Neutral shift
- Voltage imbalance across phases
- Increased losses, overheating

3. Total Active Power – Star Connection
Per Phase Power:

$$P_{ph} = V_{ph} I_{ph} \cos\,\phi$$

where $V_{ph} = \frac{V_L}{\sqrt{3}}$, $I_{ph} = I_L$

$$P_{ph} = (\frac{V_L}{\sqrt{3}}) I_L \cos\,\phi$$

Total Power (3 phases):

$$\boxed{P = 3P_{ph} = 3 \cdot \frac{V_L I_L \cos\,\phi}{\sqrt{3}} = \sqrt{3}\,V_L I_L \cos\,\phi}$$

4. Total Active Power – Delta Connection
Per Phase Power:

$$P_{ph} = V_{ph} I_{ph} \cos\,\phi$$

where $V_{ph} = V_L$, $I_{ph} = \frac{I_L}{\sqrt{3}}$

$$P_{ph} = V_L \cdot \frac{I_L}{\sqrt{3}} \cos\,\phi$$

Total Power (3 phases):

$$\boxed{P = 3P_{ph} = 3 \cdot \frac{V_L I_L \cos\,\phi}{\sqrt{3}} = \sqrt{3}\,V_L I_L \cos\,\phi}$$

Conclusion: **Same formula for both connections** (balanced or unbalanced, if $V_L, I_L, \cos\,\phi$ are measured):

$$\boxed{P = \sqrt{3}\,V_L I_L \cos\,\phi}$$

Valid for: Balanced systems, or **average power** in unbalanced (using line values). **Unbalanced**: Use **per-phase summation** for accurate analysis.

Unit IV: Network Reduction and Principles of Circuit Analysis

Question Type	Q.No.	Questions
2 Marks (10 Questions)	1	**Define Source transformation technique.** ANS- Source transformation is a circuit analysis method that converts a voltage source in series with an impedance into an equivalent current source in parallel with the same impedance, or vice versa, without changing the terminal voltage-current relationship. Formulas: 1. Voltage → Current Source: $$\boxed{I_S = \frac{V_S}{R}, R_{\text{parallel}} = R}$$ 2. Current → Voltage Source: $$\boxed{V_S = I_S R, R_{\text{series}} = R}$$
	2	**What is the main purpose of Star/delta and delta/star transformation?** ANS- To simplify complex resistive networks by converting a three-terminal star (Y) network into an equivalent delta (Δ) network, or vice versa, without changing the external terminal behavior.
	3	**What is the role of a reference node in nodal analysis?** ANS- Role of Reference Node in Nodal Analysis The reference node (usually the ground node, marked with 0 V) is a common voltage reference point chosen in the circuit to: 1. Simplify KCL equations by setting its voltage to zero ($V_{ref} = 0$). 2. Express all other node voltages relative to it ((e.g., V_1, V_2become $V_1 - 0, V_2 - 0$). 3. Enable writing KCL at non-reference nodes in terms of unknown node voltages only.
	4	**Convert a voltage source of 20 V in series with a 5 Ω resistor into an equivalent current source.** ANS- Source Transformation Voltage → Current Source Given: • Voltage source: $V_S = 20\,\text{V}$ • Series resistor: $R = 5\,\Omega$ Step 1: $$\boxed{I_S = \frac{V_S}{R} = \frac{20}{5} = 4\,\text{A}}$$ Step 2: The resistor is now in parallel with the current source. Equivalent Current Source: Current source: $4\,\text{A}$ ∥ Resistor: $5\,\Omega$ Final Answer: 4 A current source in parallel with 5 Ω resistor
	5	**State the formula to convert a Star network resistance R_A to a Delta network resistance R_{AB}** ANS-. Star to Delta Transformation Formula (For resistance $R_A$in star connected to terminals A, B, C) $$\boxed{R_{AB} = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C}}$$ Where: • R_A, R_B, R_C= Star resistances from common node to A, B, C • R_{AB}= Delta resistance between terminals A and B

	6	**Write the matrix equation format for Mesh Analysis.**
		ANS- **Mesh Analysis – Matrix Equation Format**
		For a circuit with n meshes:
		$\begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1n} \\ Z_{21} & Z_{22} & \cdots & Z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{n1} & Z_{n2} & \cdots & Z_{nn} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_n \end{bmatrix}$
		Or in compact form:
		$[Z][I] = [V]$
		Where:
		• $[Z]$: Impedance matrix
		  ○ Diagonal: Z_{ii}= Sum of impedances in mesh i
		  ○ Off-diagonal: $Z_{ij} = -$(shared impedance between mesh $i$and j)
		• $[I]$: Column vector of mesh currents $(I_1, I_2, \ldots)$
		• $[V]$: Column vector of net voltage sources in each mesh (with sign based on direction)

	7	**Write the matrix equation format for Node Analysis.**
		ANS-Nodal Analysis – Matrix Equation Format
		For a circuit with n non-reference nodes:
		$\begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1n} \\ Y_{21} & Y_{22} & \cdots & Y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{n1} & Y_{n2} & \cdots & Y_{nn} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_n \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{bmatrix}$
		Or in compact form:
		$[Y][V] = [I]$
		Where:
		• $[Y]$: Admittance matrix
		  ○ Diagonal: Y_{ii}= Sum of admittances connected to node i
		  ○ Off-diagonal: $Y_{ij} = -$(admittance between node $i$and j)
		• $[V]$: Column vector of node voltages $(V_1, V_2, \ldots)$ w.r.t. reference (0 V)
		• $[I]$: Column vector of net current sources entering each node (positive if entering)

	8	**Explain the condition for an ideal current source to be converted into an ideal voltage source using Source Transformation.** ANS-Condition for Ideal Current Source → Ideal Voltage Source Conversion An ideal current source (with infinite internal resistance) cannot be converted into an equivalent ideal voltage source using source transformation. **Reason:** • **Ideal current source**: I_S, $R_{\text{int}} = \infty$ • **Transformation formula**: $V_S = I_S \cdot R$But $R = \infty \rightarrow V_S = \infty$(undefined) **Conclusion:** Ideal current source ↮ Ideal voltage source
	9	**What is a supernode? When is it used in nodal analysis?** ANS-A supernode is a conceptual node used in nodal analysis that encompasses an ideal voltage source (independent or dependent) and the two non-reference nodes it is connected between. The supernode technique is used when an ideal voltage source is connected between two non-reference nodes, as you cannot determine the current through the ideal voltage source using Ohm's Law (I=V/R) to write a standard KCL equation at those nodes. The method requires writing two equations: 1. A KCL equation for the entire supernode boundary (treating the entire region as a single node). 2. A Constraint Equation using KVL, which relates the two node voltages to the value of the internal voltage source.

	10	**State the condition under which source transformation is valid.**
		ANS- The condition under which source transformation is valid is that the transformation must be performed on an ideal voltage source in series with an impedance or an ideal current source in parallel with the same impedance. The transformation is valid only between these two equivalent forms.
		More specifically:
		1. Voltage Source to Current Source: An ideal voltage source (V_S) in series with an impedance (Z) can be transformed into an ideal current source (I_S) in parallel with the same impedance (Z).
		    ○ The value of the current source must be $I_S = V_S / z_s$
		2. Current Source to Voltage Source: An ideal current source (I_S) in parallel with an impedance (Z) can be transformed into an ideal voltage source V_S in series with the same impedance (Z).
		    ○ The value of the voltage source must be $V_S = I_S \backslash z_s$
		The transformation is valid because the two circuit configurations maintain the same V_S- I_S characteristics at the terminals to which they are connected, meaning they deliver the same voltage and current to the rest of the circuit.

5 Marks (5 Questions)	1	**Explain the procedure for Source Transformation with a suitable diagram.**
		Ans-Explain the procedure for Source Transformation with a suitable diagram.
		Source Transformation is a technique used to simplify electrical circuits by converting a voltage source in series with a resistor into an equivalent current source in parallel with a resistor (or vice versa). This helps in analyzing complex networks using methods like nodal or mesh analysis.
		Procedure:
		1. Identify the source-resistor pair: Locate a voltage source $V_s$in series with a resistor R.
		2. Convert voltage to current source:
		    ○ The equivalent current source $I_s = \frac{V_s}{R}$
		    ○ The parallel resistor remains R
		3. Reverse transformation (current to voltage):
		    ○ $V_s = I_s \times R$
		    ○ The series resistor remains R
		4. Ensure terminal behavior is identical: The voltage-current relationship at the terminals must remain the same before and after transformation.
		5. Repeat as needed to simplify the circuit.

	2	**Derive the formulas for converting a Star network to an equivalent Delta network.** Ans-A **Star (Y)** network has three resistors connected to a common node. A **Delta (Δ)** network has three resistors forming a triangle. Let the star resistors be: R_1(from node A to center), R_2(from node B to center), R_3(from node C to center). We need to find delta resistors: R_{AB}, R_{BC}, R_{CA} **Derivation:** To find R_{AB}, short nodes B and C, and measure resistance between A and the shorted B-C. • Resistors $R_2$and $R_3$are in parallel (since B and C are shorted). • This parallel combination is in series with R_1. $$R_{AB} = R_1 + (R_2 \parallel R_3) = R_1 + \frac{R_2 R_3}{R_2 + R_3}$$ Similarly: $$R_{BC} = R_2 + \frac{R_1 R_3}{R_1 + R_3}$$ $$R_{CA} = R_3 + \frac{R_1 R_2}{R_1 + R_2}$$ **Final Delta Resistor Formulas (Star to Delta):** $$\boxed{\begin{aligned} R_{AB} &= R_1 + \frac{R_2 R_3}{R_2 + R_3} \\ R_{BC} &= R_2 + \frac{R_1 R_3}{R_1 + R_3} \\ R_{CA} &= R_3 + \frac{R_1 R_2}{R_1 + R_2} \end{aligned}}$$ Alternatively, a compact form: $$R_{AB} = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_2 + R_3}$$

	3	**Outline the steps involved in solving an electrical network using Mesh Analysis**. Ans-Mesh Analysis uses KVL on closed loops (meshes) to solve for loop currents. Steps: 1. Identify meshes: Define independent closed loops (usually the smallest windows in the circuit). 2. Assign mesh currents: Label each mesh current (e.g., I_1, I_2) in clockwise direction. 3. Apply KVL to each mesh: ○ Start at a point, go around the loop. ○ Voltage drop across resistor: $+R \cdot I$(if current in same direction). ○ Voltage rise: subtract source voltage if going from – to +. 4. Write KVL equations for each mesh. 5. Solve the system of equations for mesh currents. 6. Find required quantities: Use mesh currents to compute branch currents, voltages, power, etc. For shared resistors: $(I_m - I_n) \cdot R$
	4	**Outline the steps involved in solving an electrical network using Node Analysis.** Ans-Node Analysis uses KCL at nodes to solve for node voltages. Steps: 1. Select a reference node (ground): Usually the node with most connections. 2. Assign node voltages: Label unknown node voltages $V_1, V_2, \ldots$w.r.t. ground. 3. Apply KCL at each non-reference node: ○ Sum of currents leaving = 0. ○ Current through resistor: $\frac{V_i - V_j}{R}$ ○ Current sources: directly included. 4. Write KCL equations for each unknown node. 5. Solve the system for node voltages. 6. Find currents and other quantities using node voltages. Use conductances $G = 1/R$for cleaner equations.

5

Convert a delta network with R_{AB}=20 Ω R_{BC}=10 Ω, and R_{CA}=30 Ω to an equivalent star network.

ans- We are given **Delta** resistors and need **Star** resistors R_1, R_2, R_3.

Delta to Star Transformation Formulas:

Let:

- $R_{AB} = R_c = 20\,\Omega$
- $R_{BC} = R_a = 10\,\Omega$
- $R_{CA} = R_b = 30\,\Omega$

Standard formula:

$$\boxed{\begin{aligned} R_1 &= \frac{R_{CA} \cdot R_{AB}}{R_{AB} + R_{BC} + R_{CA}} \\ R_2 &= \frac{R_{AB} \cdot R_{BC}}{R_{AB} + R_{BC} + R_{CA}} \\ R_3 &= \frac{R_{BC} \cdot R_{CA}}{R_{AB} + R_{BC} + R_{CA}} \end{aligned}}$$

Where:

- R_1: Resistor connected to node A
- R_2: to node B
- R_3: to node C

Calculation:

Sum of delta resistors:

$$\Sigma R = 20 + 10 + 30 = 60\,\Omega$$

Now:

$$R_1 = \frac{R_{CA} \cdot R_{AB}}{\Sigma R} = \frac{30 \times 20}{60} = \frac{600}{60} = 10\,\Omega$$
$$R_2 = \frac{R_{AB} \cdot R_{BC}}{\Sigma R} = \frac{20 \times 10}{60} = \frac{200}{60} = \frac{10}{3} \approx 3.333\,\Omega$$
$$R_3 = \frac{R_{BC} \cdot R_{CA}}{\Sigma R} = \frac{10 \times 30}{60} = \frac{300}{60} = 5\,\Omega$$

Final Star Network:

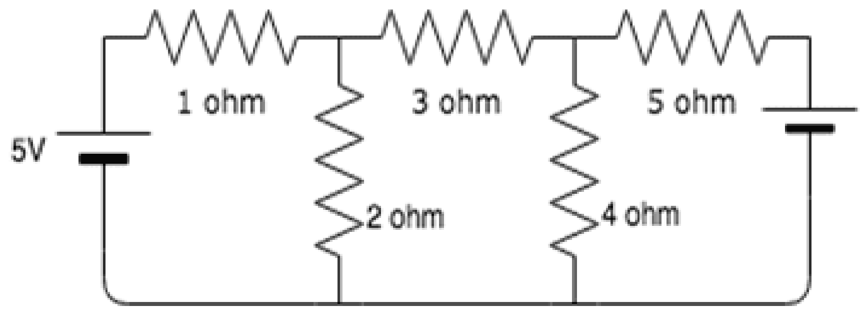
$$\boxed{\begin{aligned} R_A &= 10\,\Omega \\ R_B &= \frac{10}{3}\,\Omega \\ R_C &= 5\,\Omega \end{aligned}}$$

(or exactly: $R_B = 3.\bar{3}\,\Omega$)

10 Marks
(2 Questions)

1

Explain the detailed procedure for solving a circuit using Mesh Analysis. Find the current in 3 Ohm resistor by using Mesh analysis.



Ans-Detailed Procedure for Mesh Analysis

Mesh Analysis is a systematic method to solve planar electrical circuits by applying Kirchhoff's Voltage Law (KVL) to each independent mesh (closed loop). It is most effective for circuits with voltage sources and resistors.

Step-by-Step Procedure:

1. Verify the circuit is planar
   - A circuit is planar if it can be drawn on a plane without crossing branches.
   - Non-planar circuits require other methods.
2. Identify all independent meshes
   - A mesh is the smallest closed loop (window) in the circuit.
   - Number of independent meshes $N_m = B - N + 1$(where $B =$ branches, $N =$ nodes), or count windows.
3. Assign mesh currents
   - Label each mesh with a clockwise current: $I_1, I_2, I_3, \dots$
   - Assume all mesh currents flow clockwise for consistency.
4. Write KVL for each mesh
   - Start from any point in the mesh and go clockwise.
   - Voltage drop across resistor: $+R \cdot I$if current is in the same direction.
   - Shared resistor between two meshes: $R(I_m - I_n)$
   - Voltage source:
     - If going from − to +: +V (rise)
     - If going from + to −: −V (drop)
5. Form the system of equations
   - One KVL equation per mesh.
6. Solve the equations
   - Use substitution, elimination, or matrix method.
7. Find branch currents
   - Current in a resistor = algebraic sum of mesh currents passing through it.

Step 1: Identify Meshes

There are 3 independent meshes:

Step 2: Assign Mesh Currents (Clockwise)

- I_1: Left mesh
- I_2: Middle mesh
- I_3: Right mesh

Step 3: Apply KVL to Each Mesh

Step 4: Solve the System of Equations

$$\{\begin{matrix} (1) & 3I_1 - I_2 = 5 \\ (2) & -I_1 + 8I_2 - 3I_3 = 0 \\ (3) & 3I_2 - 8I_3 = 10 \end{matrix}$$

Step 5: Current in 3 Ω Resistor

The 3 Ω resistor is shared between Mesh 2 and Mesh 3.

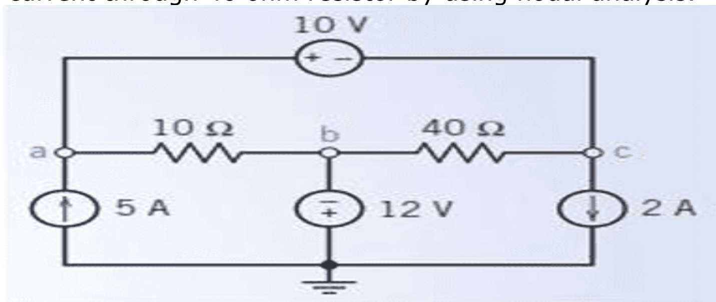
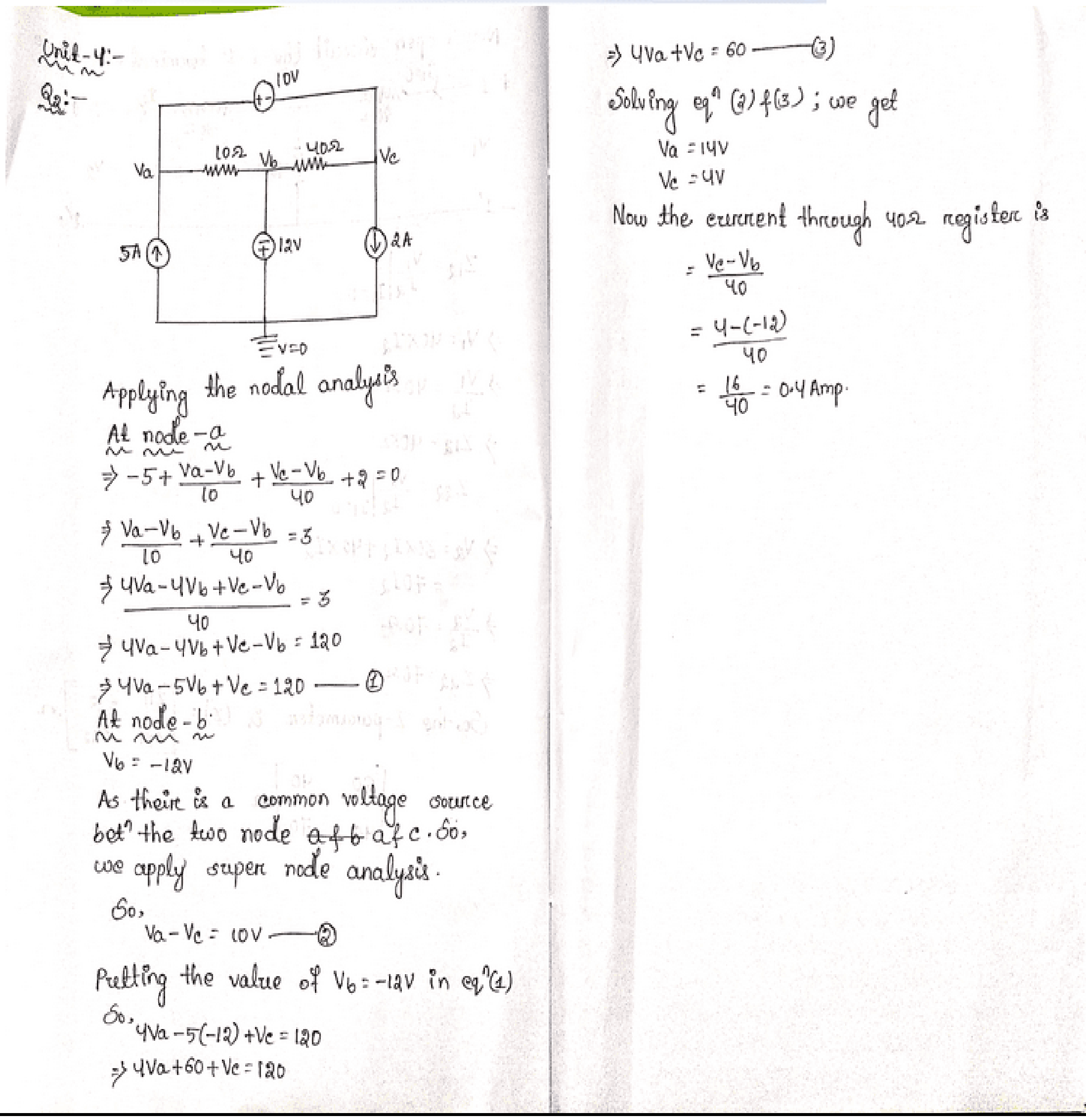
Current direction:

- I_2flows left to right
- I_3flows right to left → Net current from left to right = $I_2 - I_3$

$$I_{3\Omega} = I_2 - I_3 = -\frac{50}{157} - (-\frac{215}{157}) = \frac{-50 + 215}{157} = \frac{165}{157} \approx 1.051 \text{ A}$$

Final Answer

$$\boxed{I_{3\Omega} = \frac{165}{157} \text{ A} \approx 1.051 \text{ A(from left to right)}}$$

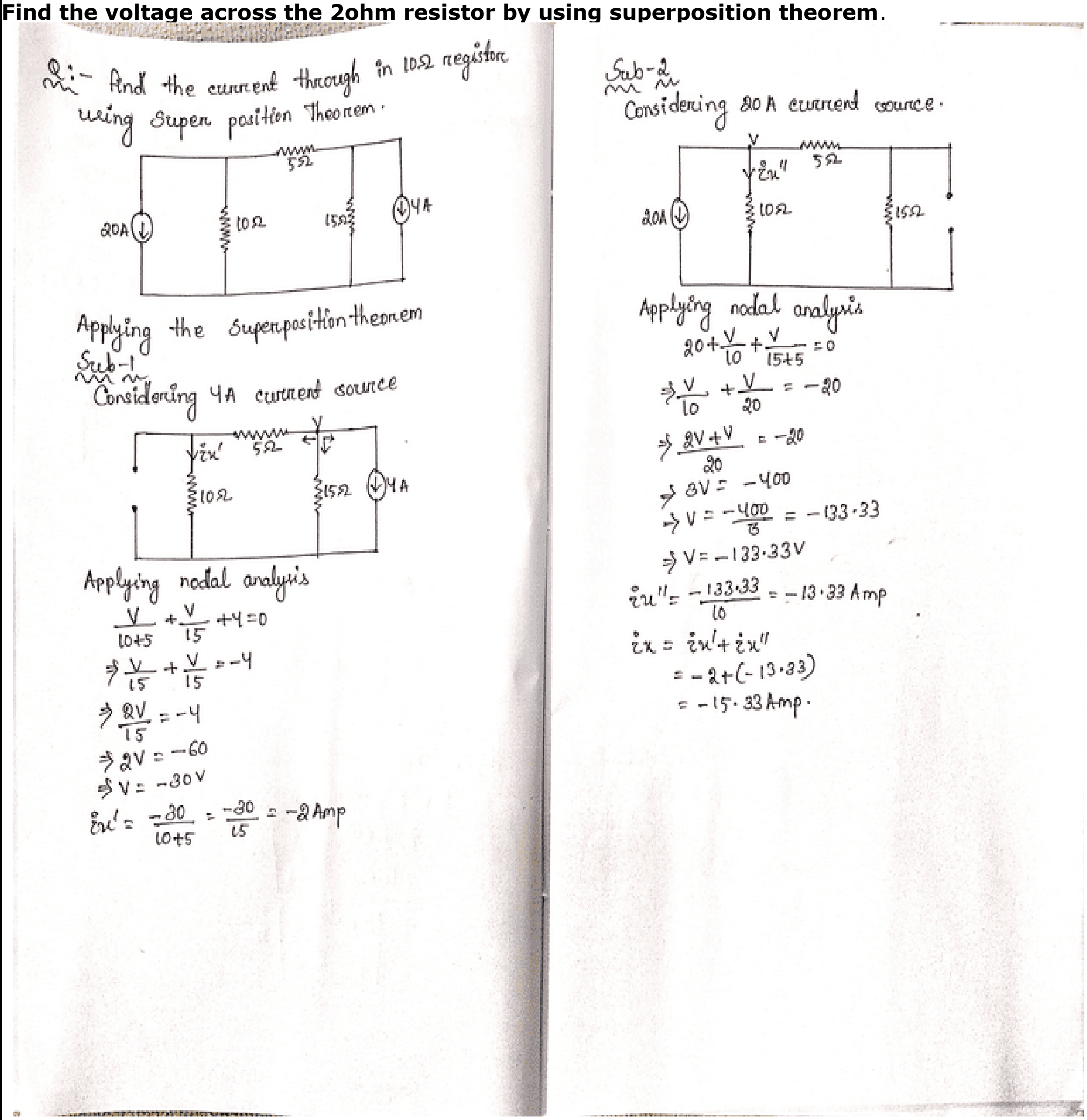
	2	Find the current through 40 ohm resistor by using nodal analysis.   Unit-4:- Q2:- Applying the nodal analysis At node-a ⇒ $-5+\frac{V_a-V_b}{10}+\frac{V_c-V_b}{40}+2=0$ ⇒ $\frac{V_a-V_b}{10}+\frac{V_c-V_b}{40}=3$ ⇒ $\frac{4V_a-4V_b+V_c-V_b}{40}=3$ ⇒ $4V_a-4V_b+V_c-V_b=120$ ⇒ $4V_a-5V_b+V_c=120$ —— (1) At node-b $V_b=-12V$ As their is a common voltage source bet^n the two node ~~a & b~~ a & c. So, we apply super node analysis. So, $V_a-V_c=10V$ —— (2) Putting the value of $V_b=-12V$ in eq^n (1) So, $4V_a-5(-12)+V_c=120$ ⇒ $4V_a+60+V_c=120$ ⇒ $4V_a+V_c=60$ —— (3) Solving eq^n (2) & (3); we get $V_a=14V$ $V_c=4V$ Now the current through 40Ω register is $=\frac{V_c-V_b}{40}$ $=\frac{4-(-12)}{40}$ $=\frac{16}{40}=0.4$ Amp.

Unit V: Network Theorems

Question Type	Q. No.	Questions
2 Marks (10 Questions)	1	**State the Superposition theorem**. Ans-The Superposition theorem states that in a linear bilateral network containing more than one independent source, the voltage across (or current through) any element is the algebraic sum of the voltages (or currents) caused by each source acting alone, with all other independent sources replaced by their internal resistances (voltage sources shorted, current sources opened).
	2	**State Thevenin's theorem.** Ans-Thevenin's theorem states that any linear bilateral network with terminals A and B can be replaced by an equivalent circuit consisting of a single voltage source V_{th} in series with a single resistance R_{th}, where: • V_{th}= open-circuit voltage across A-B • R_{th}= equivalent resistance seen from A-B with all independent sources deactivated.

	3	**State Norton's theorem.** Ans-Norton's theorem states that any linear bilateral network with terminals A and B can be replaced by an equivalent circuit consisting of a single current source $I_N$in parallel with a single resistance R_N, where: • I_N= short-circuit current from A to B • R_N= equivalent resistance seen from A-B with sources deactivated.
	4	**Define the condition for Maximum power transfer for an AC circuit**. Ans-In an AC circuit, maximum power is transferred from the source to the load when the load impedance $Z_L$is the complex conjugate of the source (Thevenin) impedance Z_{th}: $\boxed{Z_L = Z_{th}^* = R_{th} - jX_{th}}$ i.e., $R_L = R_{th}$and $X_L = -X_{th}$.
	5	**State the Reciprocity Theorem.** Ans-The Reciprocity theorem states that in a linear bilateral network, the ratio of excitation to response is the same if the positions of excitation and response are interchanged. Mathematically: If a voltage Vin branch A produces current Iin branch B, then the same voltage Vin branch B will produce current Iin branch A.
	6	**Define Thevenin's Equivalent Voltage (V_{th}).** Ans-$V_{th}$is the open-circuit voltage appearing across the two terminals of the network when no load is connected. It is the voltage that would be measured across the terminals with an ideal voltmeter.
	7	**Define Norton's Equivalent Resistance (R_N).** Ans-$R_N$is the equivalent resistance seen across the two terminals of the network when all independent sources are deactivated (voltage sources replaced by short circuits, current sources by open circuits).
	8	**Mention one limitation of the Superposition Theorem**. Ans-it cannot be applied to circuits containing nonlinear elements (e.g., diodes, transistors) because the response is not proportional to the excitation.
	9	**Which theorem is used to replace a complex network with a single voltage source and a series resistance/impedance?** Ans-Thevenin's theorem
	10	**Can Thevenin's theorem be applied to all types of circuits? State its primary limitation**. Ans- Thevenin's theorem cannot be applied to nonlinear circuits. Primary limitation: The network must be linear and bilateral.

5 Marks (5 Questions)	1	**Find the voltage across the 2ohm resistor by using superposition theorem.**



Q:- Find the current through in 10Ω resistor using Super position Theorem.

Applying the Superposition theorem

Sub-1

Considering 4A current source

Applying nodal analysis

$\frac{V}{10+5} + \frac{V}{15} + 4 = 0$

$\Rightarrow \frac{V}{15} + \frac{V}{15} = -4$

$\Rightarrow \frac{2V}{15} = -4$

$\Rightarrow 2V = -60$

$\Rightarrow V = -30V$

$i_x' = \frac{-30}{10+5} = \frac{-30}{15} = -2 Amp$

Sub-2

Considering 20A current source.

Applying nodal analysis

$20 + \frac{V}{10} + \frac{V}{15+5} = 0$

$\Rightarrow \frac{V}{10} + \frac{V}{20} = -20$

$\Rightarrow \frac{2V+V}{20} = -20$

$\Rightarrow 3V = -400$

$\Rightarrow V = \frac{-400}{3} = -133.33$

$\Rightarrow V = -133.33V$

$i_x'' = \frac{-133.33}{10} = -13.33 Amp$

$i_x = i_x' + i_x''$

$= -2 + (-13.33)$

$= -15.33 Amp.$

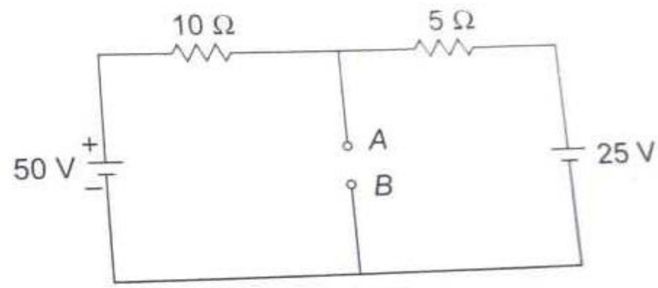
	2	**Outline the steps to find the Thevenin's equivalent circuit across a load terminal.**

Ans-Step-by-Step Procedure:

Step	Action
1	Identify the load terminals (A and B) across which the equivalent is required. Remove the load (if any) connected between A and B.
2	Find V_{th}(Thevenin Voltage): → Calculate the open-circuit voltage across terminals A and B (with load removed). → Use KVL, KCL, Mesh, Node, or source transformation. → $V_{th} = V_{AB}$ (open circuit).
3	Find R_{th}(Thevenin Resistance): → Deactivate all independent sources: • Voltage sources → replace with short circuit (0 V) • Current sources → replace with open circuit (0 A) → Dependent sources remain active. → Calculate the equivalent resistance seen from terminals A and B (with load removed). → Use series-parallel combination or test source method if needed.
4	Draw the Thevenin equivalent: → V_{th} in series with R_{th}, positive terminal of V_{th} at the same polarity as V_{AB} in Step 2.
5	Reconnect the load (if required) to find current, power, etc

3

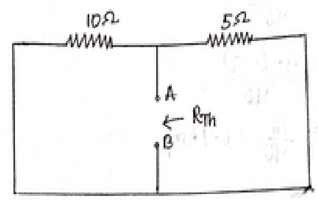
Determine the Thevenin's equivalent circuit across 'AB' for the given circuit.



Unit-5

Q3:-

Thevenin's Resistance is calculated across the target terminal by short circuiting the voltage source & open circuiting the current source. So, the circuit becomes as below.

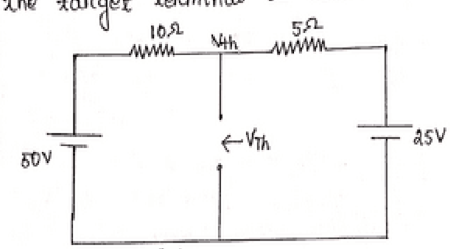


$R_{Th} = 10\Omega // 5\Omega$

$\Rightarrow \frac{10\times5}{10+5} = \frac{50}{15} = 3.34\Omega$

$\Rightarrow R_{Th} = 3.34\Omega$

Thevenin's Voltage is calculated across the target terminal as below.



Applying nodal analysis;

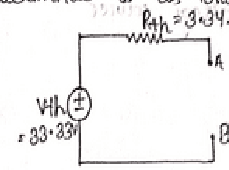
$\frac{V_{Th}-50}{10} + \frac{V_{Th}-25}{5} = 0$

$\Rightarrow \frac{V_{Th}-50+2V_{Th}-50}{10} = 0$

$\Rightarrow 3V_{Th} = 100$

$\Rightarrow V_{Th} = \frac{100}{3} = 33.33V.$

The thevenin's equivalent circuit across A-B terminal is as follow.



	No.	
	4	**Explain the condition and significance of the Maximum power transfer theorem**.

Ans-**Maximum Power Transfer Theorem**

Statement:

Maximum power is delivered from a source to a load when the load impedance Z_L is equal to the complex conjugate of the source (Thevenin) impedance Z_{th}.

$$\boxed{Z_L = Z_{th}^* = R_{th} - jX_{th}}$$

Condition for Maximum Power Transfer (AC Circuits):

1. Magnitude of impedance must be equal:

$$| Z_L |=| Z_{th} | \Rightarrow \sqrt{R_L^2 + X_L^2} = \sqrt{R_{th}^2 + X_{th}^2}$$

2. Reactances must be opposite in sign (conjugate):

$$X_L = -X_{th}$$

3. Resistances must be equal:

$$R_L = R_{th}$$

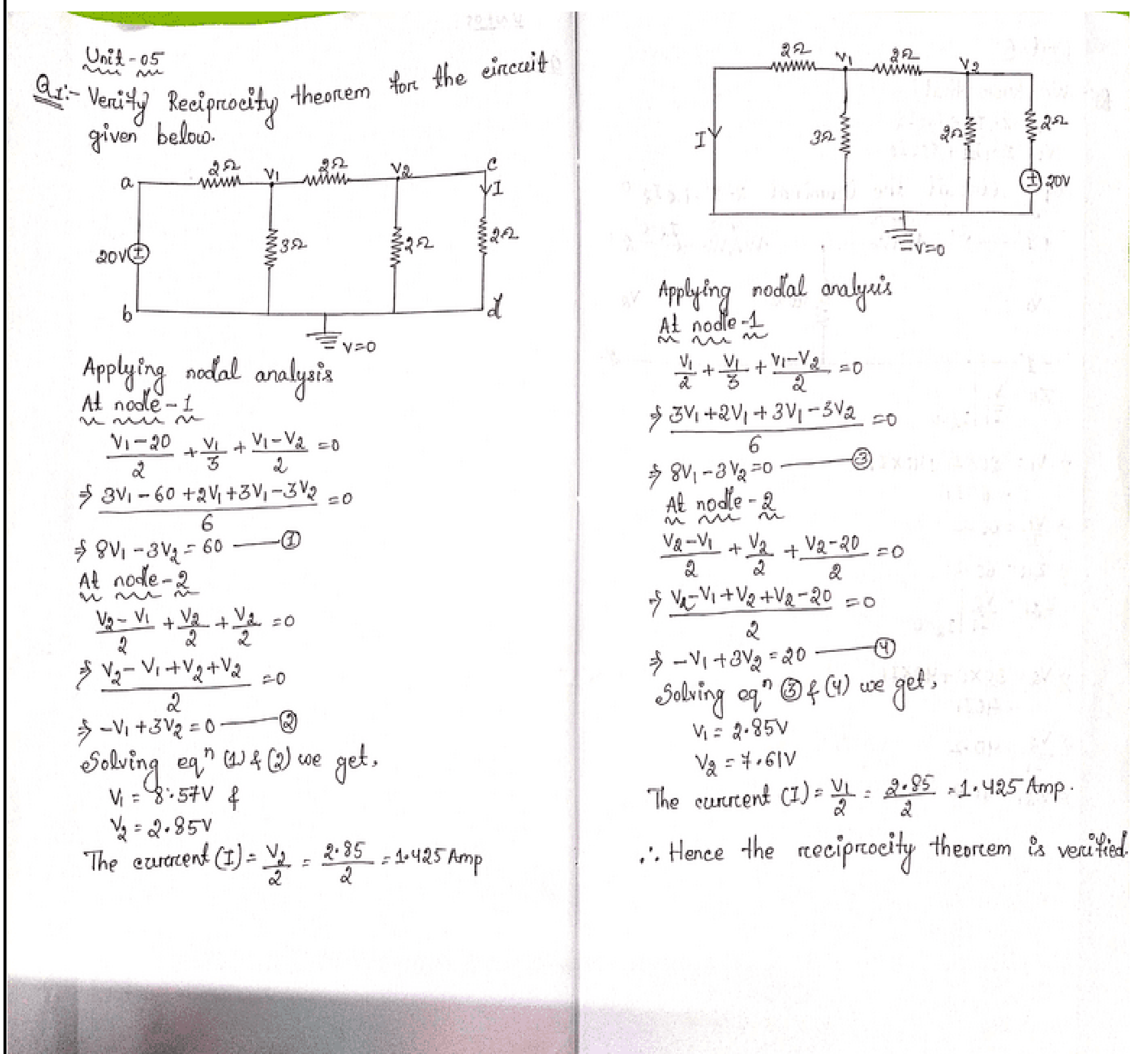
Final Condition:

$$Z_L = R_{th} + jX_L = R_{th} - jX_{th} \text{(Conjugate Match)}$$

For DC (Resistive) Circuits (Special Case):

$$\boxed{R_L = R_{th}}$$

	No.	
	5	**Verify the Reciprocity Theorem for the network Shown.**


Unit-05

Q1:- Verify Reciprocity theorem for the circuit given below.

Applying nodal analysis

At node-1

$\frac{V_1-20}{2} + \frac{V_1}{3} + \frac{V_1-V_2}{2} = 0$

$\Rightarrow \frac{3V_1 - 60 + 2V_1 + 3V_1 - 3V_2}{6} = 0$

$\Rightarrow 8V_1 - 3V_2 = 60$ ——(1)

At node-2

$\frac{V_2-V_1}{2} + \frac{V_2}{2} + \frac{V_2}{2} = 0$

$\Rightarrow \frac{V_2 - V_1 + V_2 + V_2}{2} = 0$

$\Rightarrow -V_1 + 3V_2 = 0$ ——(2)

Solving eq^n (1) & (2) we get,

$V_1 = 8.57V$ &

$V_2 = 2.85V$

The current $(I) = \frac{V_2}{2} = \frac{2.85}{2} = 1.425$ Amp

Applying nodal analysis

At node-1

$\frac{V_1}{2} + \frac{V_1}{3} + \frac{V_1-V_2}{2} = 0$

$\Rightarrow \frac{3V_1 + 2V_1 + 3V_1 - 3V_2}{6} = 0$

$\Rightarrow 8V_1 - 3V_2 = 0$ ——(3)

At node-2

$\frac{V_2-V_1}{2} + \frac{V_2}{2} + \frac{V_2-20}{2} = 0$

$\Rightarrow \frac{V_2 - V_1 + V_2 + V_2 - 20}{2} = 0$

$\Rightarrow -V_1 + 3V_2 = 20$ ——(4)

Solving eq^n (3) & (4) we get,

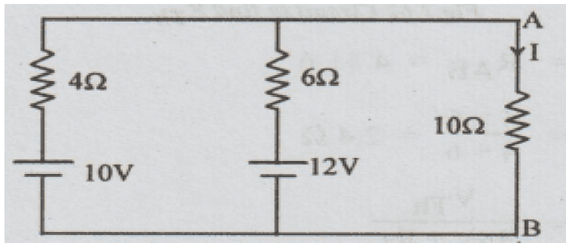
$V_1 = 2.85V$

$V_2 = 7.61V$

The current $(I) = \frac{V_1}{2} = \frac{2.85}{2} = 1.425$ Amp.

∴ Hence the reciprocity theorem is verified.

10 Marks (2 Questions)	1	**State and explain Thevenin's Theorem. Apply the theorem to find the current through a load resistor 10 ohm by using Thevenin's Theorem.**



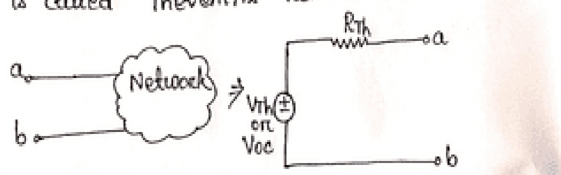
Unit-5

Q1:-

Statement:-

In any linear bilateral active network consisting of number of energy sources, resistances etc. with a define opened output circuit terminals can be converted into a simple circuit consisting of a voltage source in series with a resistance across this defined terminals.

This voltage source is called as Thevenin's voltage source which is open circuit voltage source and the resistance is called Thevenin's resistance.



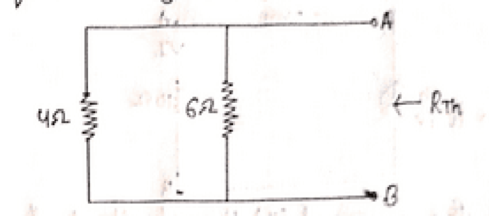
Steps to calculate Thevenin's Resistance:-

(i) Identity to target terminal across which Thevenin's equivalent resistance has to be determine.

(ii) Remove any element present betn these two terminals.

(iii) Short circuit the voltage source & open circuit the current source simultaneously and the resistance appearing across the target terminal is are Thevenin.

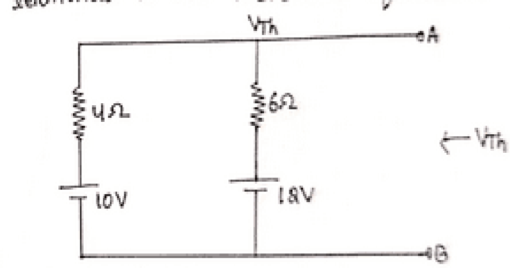
Short circuit the voltage source then; Re across the load terminal is the Theveni equivalent registance (R_{Th}).



$R_{Th} = 4\Omega \,//\, 6\Omega$

$= \frac{4 \times 6}{4+6} = \frac{24}{10} = 2.4\Omega$

The voltage across the load that is targ terminal is the Thevenin's equivalent V



Applying Nodal analysis;

$\frac{V_{Th}-10}{4} + \frac{V_{Th}-12}{6} = 0$

$\Rightarrow \frac{3V_{Th}-30+2V_{Th}-24}{12} = 0$

$\Rightarrow 5V_{Th} = 54$

$\Rightarrow V_{Th} = \frac{54}{5} = 10.8V$

$\Rightarrow V_{Th} = 10.8V$

	2	**State and explain the Maximum Power Transfer Theorem. Derive the condition for maximum power transfer in a DC resistive network.**

Ans- Ans-
Maximum Power Transfer Theorem

Statement:
In a linear electrical network, the maximum power is transferred from the source to the load when the load resistance R_L is equal to the Thevenin equivalent resistance R_{th} of the network as seen from the load terminals.

$$\boxed{R_L = R_{th}}$$

For AC circuits: $Z_L = Z_{th}^*$ (complex conjugate) For DC circuits: $R_L = R_{th}$ (resistive only)

Explanation:

- The theorem simplifies a complex network into its Thevenin equivalent:
  V_{th} in series with R_{th}
- The load R_L is connected across the output terminals.
- Power delivered to the load is:
  $P_L = I_L^2 R_L$ where $I_L = \frac{V_{th}}{R_{th}+R_L}$
- We need to maximize P_L with respect to R_L.

Derivation of Condition for Maximum Power in DC Resistive Network
Step 1: Express Power in Load

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$
$$P_L = I_L^2 R_L = (\frac{V_{th}}{R_{th} + R_L})^2 R_L$$
$$\boxed{P_L = \frac{V_{th}^2 R_L}{(R_{th} + R_L)^2}} (1)$$

Step 2: Maximize P_L w.r.t. R_L
Take derivative of P_L with respect to R_L and set to zero.
Let $f(R_L) = \frac{R_L}{(R_{th}+R_L)^2}$ (We maximize f, since V_{th}^2 is constant)

$$\frac{d}{dR_L}[\frac{R_L}{(R_{th} + R_L)^2}] = 0$$

Use **quotient rule**:
Let $u = R_L$, $v = (R_{th} + R_L)^2$

$$\frac{du}{dR_L} = 1, \frac{dv}{dR_L} = 2(R_{th} + R_L)$$
$$\frac{df}{dR_L} = \frac{v \cdot 1 - u \cdot 2(R_{th} + R_L)}{v^2}$$
$$= \frac{(R_{th} + R_L)^2 - R_L \cdot 2(R_{th} + R_L)}{(R_{th} + R_L)^4}$$

Numerator:

$$(R_{th} + R_L)^2 - 2R_L(R_{th} + R_L) = 0$$
$$(R_{th} + R_L)[(R_{th} + R_L) - 2R_L] = 0$$
$$(R_{th} + R_L)(R_{th} - R_L) = 0$$
$$\Rightarrow R_L = R_{th} (\text{since } R_L \neq -R_{th})$$

Step 3: Confirm Maximum (Second Derivative Test)
At $R_L = R_{th}$, check behavior:

- If $R_L = 0$: $P_L = 0$
- If $R_L \to \infty$: $P_L \to 0$
- At $R_L = R_{th}$: P_L has a peak → **maximum**

Step 4: Maximum Power Value
Substitute $R_L = R_{th}$ in (1):

$$P_{L,\max} = \frac{V_{th}^2 R_{th}}{(R_{th} + R_{th})^2} = \frac{V_{th}^2 R_{th}}{4R_{th}^2} = \frac{V_{th}^2}{4R_{th}}$$
$$\boxed{P_{max} = \frac{V_{th}^2}{4R_{th}}}$$

Circuit Diagram

Unit VI: Two Port Network

Question Type	Q.No.	Questions
2 Marks (10 Questions)	1	**Write the equations for Open Circuit Impedance Parameters (z-parameters).** Ans-Open Circuit Impedance Parameters (z-parameters) $V_1 = z_{11}I_1 + z_{12}I_2$ $V_2 = z_{21}I_1 + z_{22}I_2$ Matrix Form: $\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$
	2	**Write the equations for Short Circuit Admittance Parameters (y-parameters).** Ans-Short Circuit Admittance Parameters (y-parameters) $I_1 = y_{11}V_1 + y_{12}V_2$ $I_2 = y_{21}V_1 + y_{22}V_2$ Matrix Form: $\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$
	3	**Write the equations for Transmission Parameters (ABCD parameters).** Ans-Transmission Parameters (ABCD parameters) $V_1 = AV_2 + B(-I_2)$ $I_1 = CV_2 + D(-I_2)$ Or (standard form): $\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$ Note: $I_2$is outgoing from port 2 → hence $-I_2$
	4	Write the equations for Hybrid Parameters (h-parameters). Ans-Hybrid Parameters (h-parameters) $V_1 = h_{11}I_1 + h_{12}V_2$ $I_2 = h_{21}I_1 + h_{22}V_2$ Matrix Form: $\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}\begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$
	5	**Define Z_{12} (Reverse Transfer Impedance) for a two-port network**. Ans-Define z_{12}(Reverse Transfer Impedance) $z_{12} = \frac{V_1}{I_2} \big\vert_{I_1=0}$ Meaning: The voltage at port 1 per unit current at port 2, when port 1 is open-circuited ($I_1 = 0$).
	6	**Define y_{21} (Forward Transfer Admittance) for a two-port network**. Ans-Define y_{21}(Forward Transfer Admittance) $y_{21} = \frac{I_2}{V_1} \big\vert_{V_2=0}$ Meaning: The current at port 2 per unit voltage at port 1, when port 2 is short-circuited ($V_2 = 0$).
	7	**What is the purpose of the Interrelationship of Two Port Network parameters?** Ans-The purpose of interrelationship of two-port network parameters is to convert between different parameter sets (z, y, h, ABCD) to facilitate analysis, enable cascading of networks, support transistor modeling, and match measurement or simulation conditions.

<table>
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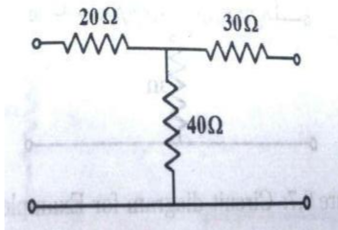
For the network shown find the Z parameters.



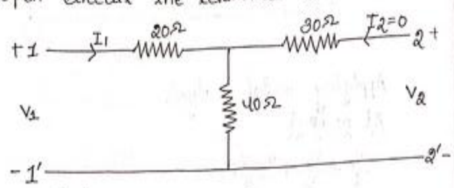
Unit-6

Q:- We know that,

$V_1 = Z_{11}I_1 + Z_{12}I_2$

$V_2 = Z_{21}I_1 + Z_{22}I_2$

Open circuit the terminal 2-2', i.e $I_2=0$



$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0}$

$\Rightarrow V_1 = 20\times I_1 + 40\times I_1$
$= 60I_1$

$\Rightarrow \frac{V_1}{I_1} = 60\,\Omega$

$\Rightarrow Z_{11} = 60\,\Omega$

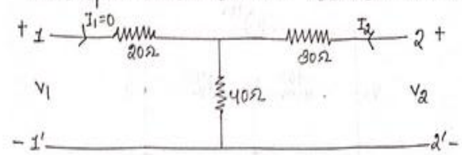
$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$

$\Rightarrow V_2 = 30\times 0 + 40\times I_1$
$= 40I_1$

$\Rightarrow \frac{V_2}{I_1} = 40\,\Omega$

$\Rightarrow Z_{21} = 40\,\Omega$

Now, open circuit the 1-1' terminal, i.e $I_1=0$



$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$

$\Rightarrow V_1 = 40\times I_2$

$\Rightarrow \frac{V_1}{I_2} = 40\,\Omega$

$\Rightarrow Z_{12} = 40\,\Omega$

$Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0}$

$\Rightarrow V_2 = 30\times I_2 + 40\times I_2$
$= 70I_2$

$\Rightarrow \frac{V_2}{I_2} = 70\,\Omega$

$\Rightarrow Z_{22} = 70\,\Omega$

So, the Z-parameter is $(Z) = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}\Omega$

$= \begin{bmatrix} 60 & 40 \\ 40 & 70 \end{bmatrix}\Omega$

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<tr><td></td><td>9</td><td>

State the condition for a two-port network to be reciprocal in terms of z-parameters.
Ans-Condition for a two-port network to be reciprocal in terms of z-parameters: A two-port network is reciprocal if $z_{12} = z_{21}$.

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<tr><td></td><td>10</td><td>

Which parameters are determined by open-circuit tests and which by short-circuit tests?
Ans-Parameters determined by open-circuit tests and short-circuit tests:

- Open-circuit tests: Determine the z-parameters (open-circuit impedance parameters).
- Short-circuit tests: Determine the y-parameters (short-circuit admittance parameters).

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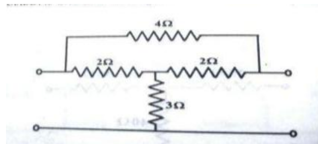
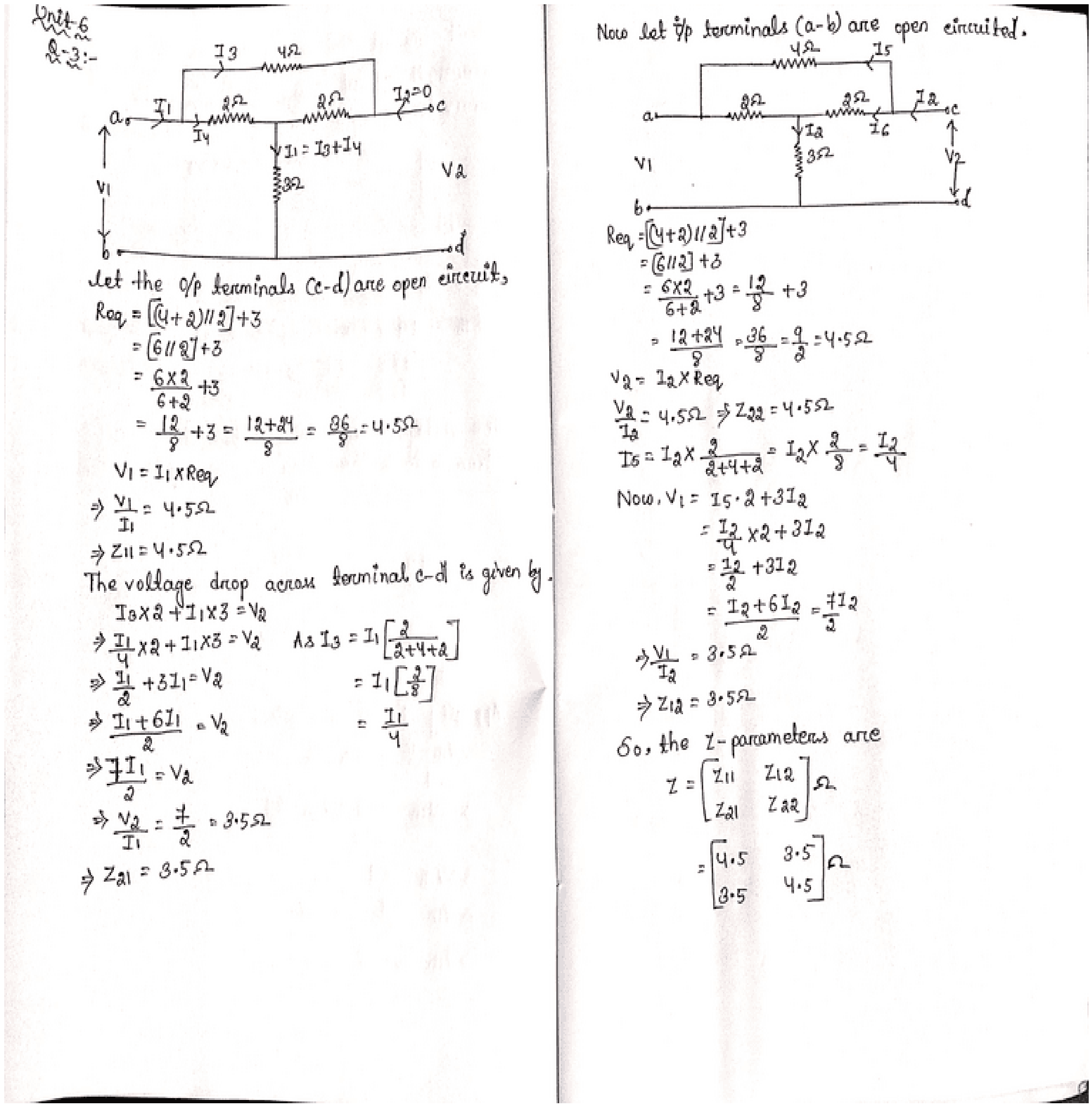
</table>

5 Marks (5 Questions)	1	**Explain the procedure to find the Open Circuit Impedance Parameters (z-parameters) of a two-port network.** Ans- Procedure to find the Open Circuit Impedance Parameters (z-parameters): The z-parameters are defined as: $$V_1 = z_{11}I_1 + z_{12}I_2; V_2 = z_{21}I_1 + z_{22}I_2$$ To measure them: 1. Find z_{11} and z_{21}: ○ Leave port 2 open-circuited ($I_2 = 0$). ○ Apply a known current I_1 at port 1. ○ Measure V_1 and V_2. ○ Then: $$z_{11} = \frac{V_1}{I_1}; z_{21} = \frac{V_2}{I_1}$$ 2. Find z_{12} and z_{22}: ○ Leave port 1 open-circuited ($I_1 = 0$). ○ Apply a known current I_2 at port 2. ○ Measure V_1 and V_2. ○ Then: $$z_{12} = \frac{V_1}{I_2}; z_{22} = \frac{V_2}{I_2}$$
	2	**Explain the procedure to find the Short Circuit Admittance Parameters (y-parameters) of a two-port network.** Ans- Procedure to find the Short Circuit Admittance Parameters (y-parameters): The y-parameters are defined as: $$I_1 = y_{11}V_1 + y_{12}V_2; I_2 = y_{21}V_1 + y_{22}V_2$$ To measure them: 1. Find y_{11} and y_{21}: ○ Short-circuit port 2 ($V_2 = 0$). ○ Apply a known voltage V_1 at port 1. ○ Measure I_1 and I_2. ○ Then: $$y_{11} = \frac{I_1}{V_1}; y_{21} = \frac{I_2}{V_1}$$ 2. Find y_{12} and y_{22}: ○ Short-circuit port 1 ($V_1 = 0$). ○ Apply a known voltage V_2 at port 2. ○ Measure I_1 and I_2. ○ Then: $$y_{12} = \frac{I_1}{V_2}; y_{22} = \frac{I_2}{V_2}$$

3

For the network shown find the Z parameters.





Unit-6

Q-3:-

Let the o/p terminals (c-d) are open circuit,

$R_{eq} = [(4+2) \| 2] + 3$
$= [6 \| 2] + 3$
$= \frac{6 \times 2}{6+2} + 3$
$= \frac{12}{8} + 3 = \frac{12+24}{8} = \frac{36}{8} = 4.5\Omega$

$V_1 = I_1 \times R_{eq}$

$\Rightarrow \frac{V_1}{I_1} = 4.5\Omega$

$\Rightarrow Z_{11} = 4.5\Omega$

The voltage drop across terminal c-d is given by.

$I_3 \times 2 + I_1 \times 3 = V_2$ As $I_3 = I_1\left[\frac{2}{2+4+2}\right] = I_1\left[\frac{2}{8}\right] = \frac{I_1}{4}$

$\Rightarrow \frac{I_1}{4} \times 2 + I_1 \times 3 = V_2$

$\Rightarrow \frac{I_1}{2} + 3I_1 = V_2$

$\Rightarrow \frac{I_1 + 6I_1}{2} = V_2$

$\Rightarrow \frac{7I_1}{2} = V_2$

$\Rightarrow \frac{V_2}{I_1} = \frac{7}{2} = 3.5\Omega$

$\Rightarrow Z_{21} = 3.5\Omega$

Now let i/p terminals (a-b) are open circuited.

$R_{eq} = [(4+2) \| 2] + 3$
$= [6 \| 2] + 3$
$= \frac{6 \times 2}{6+2} + 3 = \frac{12}{8} + 3$
$= \frac{12+24}{8} = \frac{36}{8} = \frac{9}{2} = 4.5\Omega$

$V_2 = I_2 \times R_{eq}$

$\frac{V_2}{I_2} = 4.5\Omega \Rightarrow Z_{22} = 4.5\Omega$

$I_5 = I_2 \times \frac{2}{2+4+2} = I_2 \times \frac{2}{8} = \frac{I_2}{4}$

Now, $V_1 = I_5 \cdot 2 + 3I_2$
$= \frac{I_2}{4} \times 2 + 3I_2$
$= \frac{I_2}{2} + 3I_2$
$= \frac{I_2 + 6I_2}{2} = \frac{7I_2}{2}$

$\Rightarrow \frac{V_1}{I_2} = 3.5\Omega$

$\Rightarrow Z_{12} = 3.5\Omega$

So, the Z-parameters are

$$Z = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \Omega = \begin{bmatrix} 4.5 & 3.5 \\ 3.5 & 4.5 \end{bmatrix} \Omega$$

	4	**Explain the process of finding Hybrid Parameters (h-parameters) for a given two-port network.**

Ans-Process of finding Hybrid Parameters (h-parameters) for a two-port network:
The h-parameters (hybrid parameters) are defined by the following equations:

$$V_1 = h_{11}I_1 + h_{12}V_2; I_2 = h_{21}I_1 + h_{22}V_2$$

These represent a mixed combination of voltage and current at input and output ports.
To determine the h-parameters experimentally:

1. Find $h_{11}$and h_{21}
(Input impedance and forward current gain with output short-circuited)

- Short-circuit port 2 ($V_2 = 0$).
- Apply a known input current I_1at port 1.
- Measure:
  - V_1(input voltage)
  - I_2(output current)

Then:

$$h_{11} = \frac{V_1}{I_1} |_{V_2=0} \text{ (input impedance, output shorted)}$$
$$h_{21} = \frac{I_2}{I_1} |_{V_2=0} \text{ (forward current transfer ratio)}$$

2. Find $h_{12}$and h_{22}
(Reverse voltage gain and output admittance with input open-circuited)

- Open-circuit port 1 ($I_1 = 0$).
- Apply a known output voltage V_2at port 2.
- Measure:
  - V_1(input voltage)
  - I_2(output current)

Then:

$$h_{12} = \frac{V_1}{V_2} |_{I_1=0} \text{ (reverse voltage feedback ratio)}$$
$$h_{22} = \frac{I_2}{V_2} |_{I_1=0} \text{ (output admittance, input open)}$$

Summary of Test Conditions:

Parameter	Condition at Port 2	Condition at Port 1	Measured Ratio
h_{11}	Short-circuited ($V_2 = 0$)	Apply I_1	V_1/I_1
h_{21}	Short-circuited ($V_2 = 0$)	Apply I_1	I_2/I_1
h_{12}	Apply V_2	Open-circuited ($I_1 = 0$)	V_1/V_2
h_{22}	Apply V_2	Open-circuited ($I_1 = 0$)	I_2/V_2

	5	**Briefly explain the Interrelationship of Two Port Network parameters, specifically z to h.**

Ans-interrelationship between z-parameters and h-parameters (z to h conversion):
Given z-parameters:

$$\begin{bmatrix}V_1\\V_2\end{bmatrix} = \begin{bmatrix}z_{11} & z_{12}\\z_{21} & z_{22}\end{bmatrix}\begin{bmatrix}I_1\\I_2\end{bmatrix}$$

We need to express in h-form:

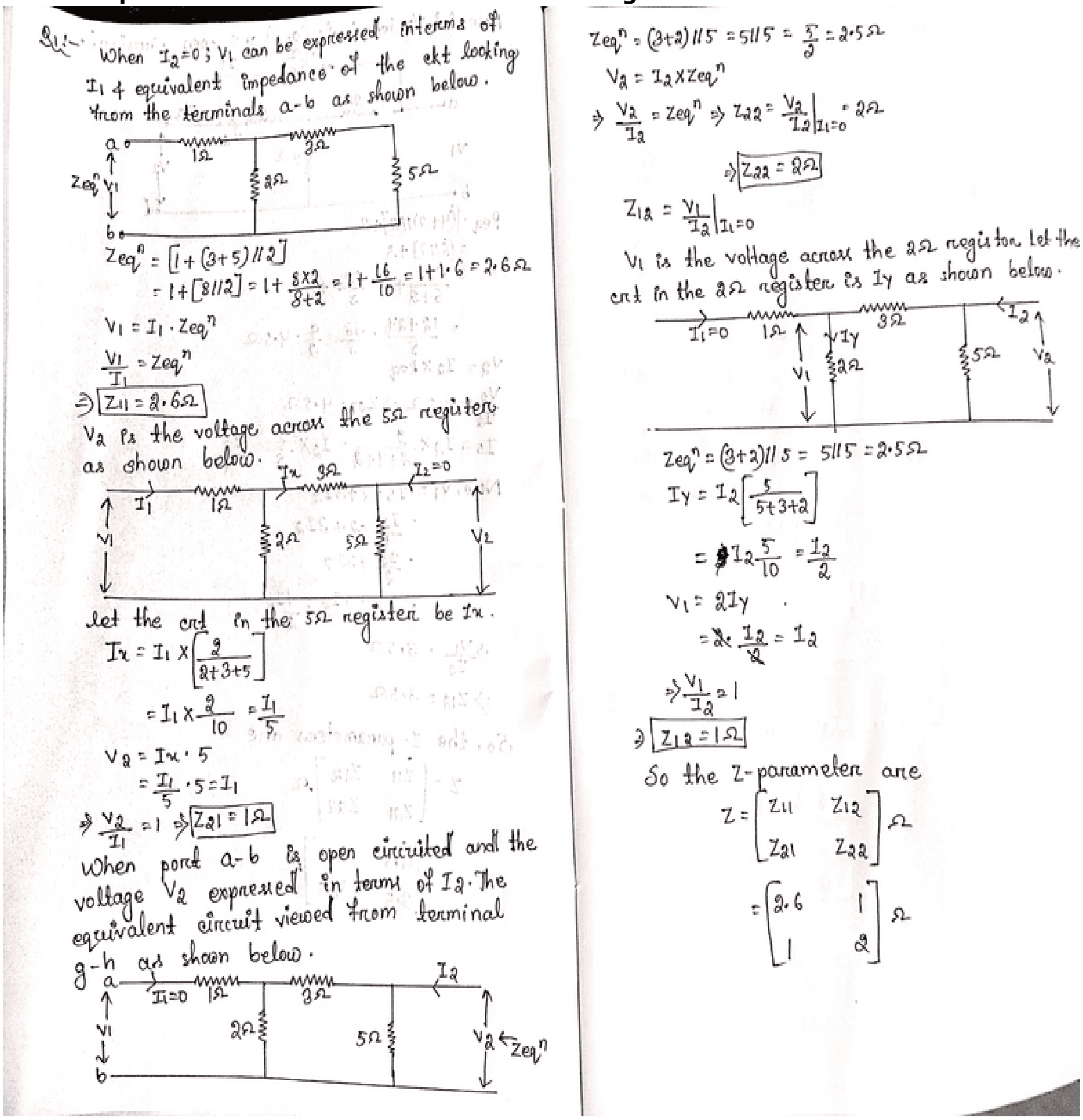
$$\begin{bmatrix}V_1\\I_2\end{bmatrix} = \begin{bmatrix}h_{11} & h_{12}\\h_{21} & h_{22}\end{bmatrix}\begin{bmatrix}I_1\\V_2\end{bmatrix}$$

Conversion formulas (from z to h):

h_{11}	$= \frac{\det(Z)}{z_{22}} = \frac{z_{11}z_{22} - z_{12}z_{21}}{z_{22}}$
h_{12}	$= \frac{z_{12}}{z_{22}}$
h_{21}	$= -\frac{z_{21}}{z_{22}}$
h_{22}	$= \frac{1}{z_{22}}$

Note: $\det(Z) = z_{11}z_{22} - z_{12}z_{21}$is the determinant of the z-matrix. For reciprocal networks, $z_{12} = z_{21}$, so $h_{12} = -h_{21}$.

10 Marks (2 Questions)	1	**Find the Z parameter for the circuit Shown in the figure.**



Q:- When $I_2 = 0$; V_1 can be expressed interms of I_1 & equivalent impedance of the ckt looking from the terminals a-b as shown below.

$Zeq^n = [1 + (3+5) \| 2]$

$= 1 + [8 \| 2] = 1 + \frac{8 \times 2}{8+2} = 1 + \frac{16}{10} = 1 + 1.6 = 2.6\Omega$

$V_1 = I_1 \cdot Zeq^n$

$\frac{V_1}{I_1} = Zeq^n$

$\Rightarrow \boxed{Z_{11} = 2.6\Omega}$

V_2 is the voltage across the 5Ω register as shown below.

let the crt in the 5Ω register be I_x.

$I_x = I_1 \times \left[\frac{2}{2+3+5}\right]$

$= I_1 \times \frac{2}{10} = \frac{I_1}{5}$

$V_2 = I_x \cdot 5$

$= \frac{I_1}{5} \cdot 5 = I_1$

$\Rightarrow \frac{V_2}{I_1} = 1 \Rightarrow \boxed{Z_{21} = 1\Omega}$

When port a-b is open circuited and the voltage V_2 expressed in terms of I_2. The equivalent circuit viewed from terminal g-h as shown below.

$Zeq^n = (3+2) \| 5 = 5 \| 5 = \frac{5}{2} = 2.5\Omega$

$V_2 = I_2 \times Zeq^n$

$\Rightarrow \frac{V_2}{I_2} = Zeq^n \Rightarrow Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0} = 2\Omega$

$\Rightarrow \boxed{Z_{22} = 2\Omega}$

$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$

V_1 is the voltage across the 2Ω register. Let the crt in the 2Ω register is I_y as shown below.

$Zeq^n = (3+2) \| 5 = 5 \| 5 = 2.5\Omega$

$I_y = I_2 \left[\frac{5}{5+3+2}\right]$

$= I_2 \frac{5}{10} = \frac{I_2}{2}$

$V_1 = 2I_y$

$= 2 \cdot \frac{I_2}{2} = I_2$

$\Rightarrow \frac{V_1}{I_2} = 1$

$\Rightarrow \boxed{Z_{12} = 1\Omega}$

So the Z-parameter are

$$Z = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \Omega$$

$$= \begin{bmatrix} 2.6 & 1 \\ 1 & 2 \end{bmatrix} \Omega$$

	2	see below

Define the Transmission (ABCD) parameters and Hybrid (h) parameters. Discuss the concept of Inter Connection of Two Port Network (e.g., cascade and series).

Ans- Definition of Transmission (ABCD) Parameters

The Transmission parameters (also called ABCD parameters) describe a two-port network in terms of input voltage/current on the left and output voltage/current on the right, assuming power flows from left to right (port 1 → port 2).

They are defined as:

$$\boxed{\begin{aligned} V_1 &= AV_2 + B(-I_2) \\ I_1 &= CV_2 + D(-I_2) \end{aligned}}$$

Or in matrix form:

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

Physical Meaning:

Parameter	Unit	Meaning
A	—	Voltage ratio $(\frac{V_1}{V_2})$ when $I_2 = 0$(open-circuit reverse voltage gain)
B	Ω	Reverse transfer impedance $(\frac{V_1}{-I_2})$ when $V_2 = 0$
C	S	Reverse transfer admittance $(\frac{I_1}{V_2})$ when $I_2 = 0$
D	—	Current ratio $(\frac{I_1}{-I_2})$ when $V_2 = 0$(short-circuit reverse current gain)

For reciprocal networks: $AD - BC = 1$

Definition of Hybrid (h) Parameters

The h-parameters (hybrid parameters) express the input voltage and output current in terms of input current and output voltage:

$$\boxed{\begin{aligned} V_1 &= h_{11}I_1 + h_{12}V_2 \\ I_2 &= h_{21}I_1 + h_{22}V_2 \end{aligned}}$$

Or in matrix form:

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}\begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

Physical Meaning:

Parameter	Unit	Meaning
h_{11}	Ω	Input impedance $(\frac{V_1}{I_1})$ with output shorted ($V_2 = 0$)
h_{12}	—	Reverse voltage feedback ratio $(\frac{V_1}{V_2})$ with input open ($I_1 = 0$)
h_{21}	—	Forward current gain $(\frac{I_2}{I_1})$ with output shorted
h_{22}	S	Output admittance $(\frac{I_2}{V_2})$ with input open

For reciprocal networks: $h_{12} = -h_{21}$

Interconnection of Two-Port Networks

Two-port networks can be interconnected in different configurations. The most common are:

1. Cascade (Series) Connection

- Networks are connected in series along the transmission path (output of first → input of second).
- ABCD parameters are multiplied.

Cascade of Two Networks:

Let network A have ABCD matrix:

$$\mathrm{T_A} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}$$

Let network B have ABCD matrix:

$$\mathrm{T_B} = \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}$$

Then, overall ABCD matrix for cascade $A \to B$:

$$\boxed{\mathrm{T} = \mathrm{T_A} \cdot \mathrm{T_B} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} A_1A_2 + B_1C_2 & A_1B_2 + B_1D_2 \\ C_1A_2 + D_1C_2 & C_1B_2 + D_1D_2 \end{bmatrix}}$$

2. Series Connection (of Impedances)

- Both ports of two networks are connected in series (same current through both).
- z-parameters add.

Series Connection:

If two networks have z-matrices:

$$\mathrm{Z_1} = \begin{bmatrix} z_{11a} & z_{12a} \\ z_{21a} & z_{22a} \end{bmatrix}, \mathrm{Z_2} = \begin{bmatrix} z_{11b} & z_{12b} \\ z_{21b} & z_{22b} \end{bmatrix}$$

Then, total z-matrix:

$$\boxed{\mathrm{Z_{total}} = \mathrm{Z_1} + \mathrm{Z_2} = \begin{bmatrix} z_{11a} + z_{11b} & z_{12a} + z_{12b} \\ z_{21a} + z_{21b} & z_{22a} + z_{22b} \end{bmatrix}}$$

$$\mathbf{T} = \begin{bmatrix} 2 & 3 \\ 1 & 2 \end{bmatrix}$$