

## WEEK-5 : IDEAL VOLTAGE AND CURRENT SOURCES

### Ideal Voltage Source — Definition and Explanation

#### Definition:

An **ideal voltage source** is a theoretical electrical source that **maintains a constant voltage across its terminals**, regardless of the amount of current drawn from it or supplied to a load.

#### Explanation

An ideal voltage source has the following key characteristics:

##### 1. Constant Output Voltage

- The terminal voltage remains fixed and does **not change** with load current.
- Example: A 10 V ideal source always provides 10 V, whether the load draws 1 A or 10 A.

##### 2. Zero Internal Resistance

- It has **no internal resistance**.
- Therefore, there is **no internal voltage drop**, and all the voltage appears across the load.

##### 3. Unlimited Current Capability

- In theory, it can supply **any amount of current** required by the load.
- For a short circuit (load resistance = 0), the current becomes infinite (theoretical only).

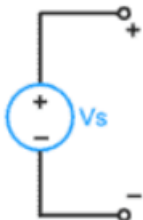
##### 4. Independent of External Conditions

Its voltage is unaffected by changes in temperature, load, or time.

#### Symbol:

An ideal voltage source is represented by a **circle with polarity marks**

(+ and -) indicating the direction of voltage.



## IDEAL CURRENT SOURCE:

### Definition:

An **ideal current source** is a theoretical electrical source that **supplies a constant current** to a load, **irrespective of the voltage across its terminals** or the resistance of the load.

### Explanation

An ideal current source has the following important characteristics:

#### 1. Constant Current Output

- The current remains **fixed** even if the load resistance changes.
- Example: A 5 A ideal current source always supplies 5 A.

#### 2. Infinite Internal Resistance

- It has **infinite internal resistance**.
- This prevents any internal current leakage and ensures constant current delivery.

#### 2. Unlimited Voltage Capability

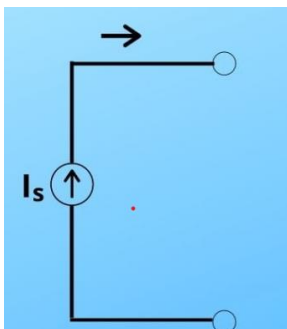
- It can develop **any voltage across its terminals** as required by the load to maintain the constant current.
- For an open circuit, the voltage becomes infinite (theoretical case).

#### 3. Independent of Load Conditions

- The output current does not change with variation in load, temperature, or time.

### Symbol

An ideal current source is represented by a **circle with an arrow** inside it, showing the direction of current flow.



## Conversion from Voltage Source to Current Source

This conversion is also called **source transformation** and is widely used to simplify electrical circuit analysis.

### Definition

A **practical voltage source** consisting of a **voltage source**  $V$  in **series with resistance**  $R$  can be converted into an **equivalent current source** consisting of a **current source**  $I$  in **parallel with the same resistance**  $R$ , without changing the external circuit behavior.

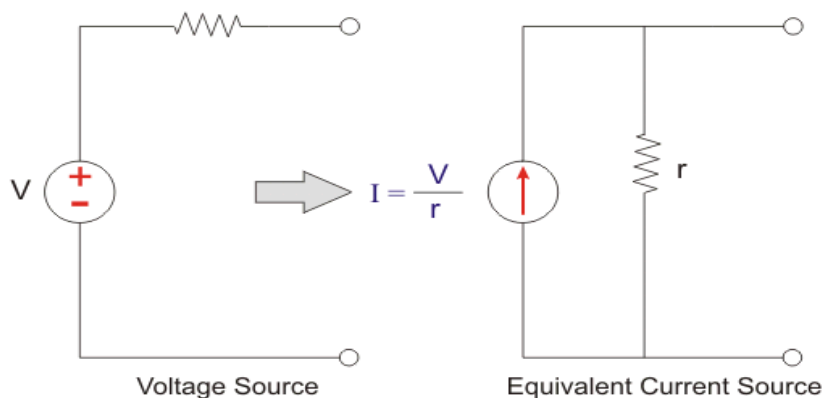
### Conversion Rule

If a voltage source  $V$  is in series with resistance  $R$ :

$$I = \frac{V}{R}$$

- The **current source value**  $I = V/R$
- The **resistance remains the same** but is connected in **parallel** with the current source

EXAMPLE:



## Conversion of Current Source to Voltage Source

This process is known as **source transformation** and is used to simplify circuit analysis.

### Definition

A **practical current source** consisting of a **current source**  $I$  in **parallel with resistance**  $R$  can be converted into an **equivalent voltage source** consisting of a **voltage source**  $V$  in **series with the same resistance**  $R$ , without changing the behavior of the external circuit.

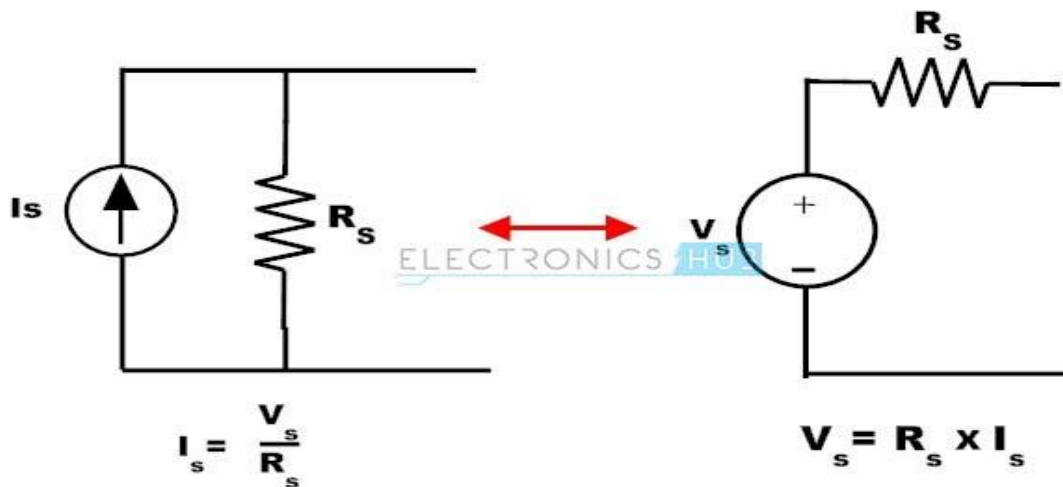
## Conversion Rule

If a current source  $I$  is in parallel with resistance  $R$ :

$$V = I \times R$$

- The **voltage source value**  $V = IR$
- The **resistance remains the same** but is connected in **series** with the voltage source

EXAMPLE:



## SIMPLE PROBLEMS ON SOURCE TRANSFORMATION:

### Problem 1: Voltage Source $\rightarrow$ Current Source

Given

A **12 V voltage source** in series with a **6  $\Omega$  resistor**.

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Conversion

$$I = \frac{V}{R} = \frac{12}{6} = 2 \text{ A}$$

Load

Answer

Equivalent **current source** = **2 A**

Resistance = **6  $\Omega$  in parallel**

### **Problem 2: Current Source → Voltage Source**

#### **Given**

A **4 A current source** in parallel with a **5 Ω resistor**.

#### **Conversion**

$$V = I \times R = 4 \times 5 = 20 \text{ V}$$

#### **Answer**

Equivalent **voltage source = 20 V**

Resistance = **5 Ω in series**

### **Problem 3: Find Load Current Using Source Transformation**

#### **Given**

- Voltage source = **10 V**
- Series resistance = **2 Ω**
- Load resistance = **3 Ω**

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#### **Step 1: Convert Voltage Source to Current Source**

$$I = \frac{10}{2} = 5 \text{ A}$$

#### **Step 2: Find Load Current**

Using current division:

$$I_L = 5 \times \frac{2}{2+3} = 2 \text{ A}$$

**Load current = 2 A**

### **Problem 4: Find Load Voltage Using Source Transformation**

#### **Given**

- Current source = **6 A**
- Parallel resistance = **4 Ω**

- Load resistance = **8 Ω**

### Step 1: Convert to Voltage Source

$$V = I \times R = 6 \times 4 = 24 \text{ V}$$

### Step 2: Find Load Voltage

Total resistance:

$$R_T = 4 + 8 = 12\Omega$$

Current:

$$I = \frac{24}{12} = 2 \text{ A}$$

Load voltage:

$$V_L = I \times 8 = 16 \text{ V}$$

**Answer**

**Load voltage = 16 V**

## Delta (Δ) to Star (Y) Conversion

**Delta–Star (Δ–Y) conversion** is used in electrical circuit analysis to simplify complex resistor networks that cannot be reduced using simple series–parallel methods.

### 1. Delta (Δ) Network

A **delta network** has three resistances connected in a triangular form.

Let the delta resistances be:

- $R_{AB}$
- $R_{BC}$
- $R_{CA}$

## 2. Star (Y) Network

A **star network** has three resistances connected to a common central point.

Let the star resistances be:

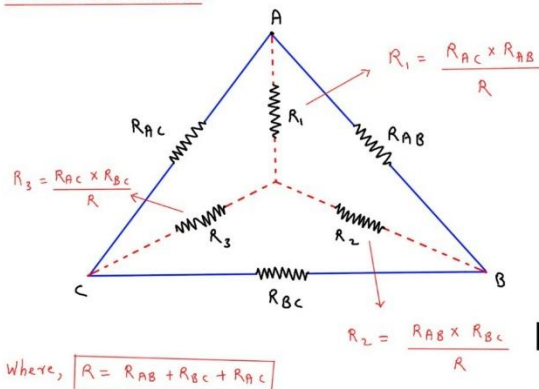
- $R_A$
- $R_B$
- $R_C$

### Delta to Star Conversion Formula:

Each star resistance is equal to the **product of the two adjacent delta resistances divided by the sum of all three delta resistances**.

$$R_A = \frac{R_{AB} \times R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$
$$R_B = \frac{R_{AB} \times R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$
$$R_C = \frac{R_{BC} \times R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

Delta to Star network :



**How to  
Convert  
Delta to  
Star  
Network ?**

### Key Points for Exams

- Used to simplify **non-series-parallel** resistor networks
- Applicable to **resistors, impedances, and conductances**
- Opposite conversion is **Star to Delta (Y- $\Delta$ )**

## 6. Example (Quick)

If

$$R_{AB} = 6 \Omega, R_{BC} = 3 \Omega, R_{CA} = 9 \Omega$$

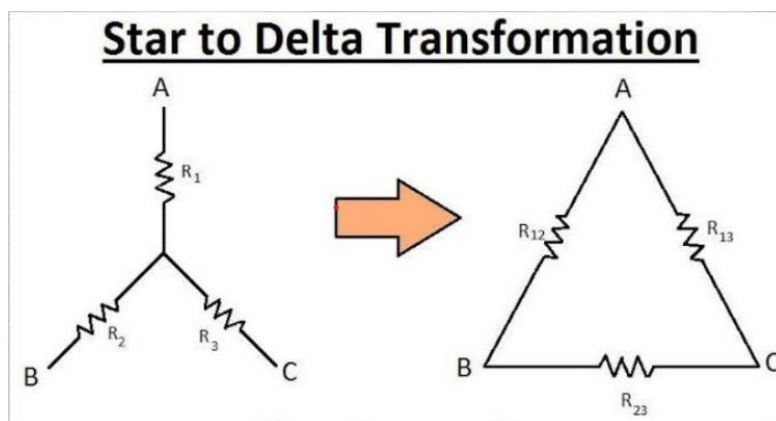
$$\text{Sum} = 6 + 3 + 9 = 18$$

$$R_A = \frac{6 \times 9}{18} = 3 \Omega$$

$$R_B = \frac{6 \times 3}{18} = 1 \Omega$$

$$R_C = \frac{3 \times 9}{18} = 1.5 \Omega$$

**Star to Delta Conversion Formula:**



$$R_A = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

$$R_B = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$

$$R_C = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

Delta-Star	Star-Delta
<p>Given delta</p> <p>Equivalent star</p>	<p>Given star</p> <p>Equivalent delta</p>
$R_1 = \frac{R_{12}R_{31}}{R_{12} + R_{23} + R_{31}}$	$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$
$R_2 = \frac{R_{12}R_{23}}{R_{12} + R_{23} + R_{31}}$	$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$
$R_3 = \frac{R_{23}R_{31}}{R_{12} + R_{23} + R_{31}}$	$R_{31} = R_3 + R_1 + \frac{R_1 R_3}{R_2}$

**Star-Delta and Delta-Star Transformations**

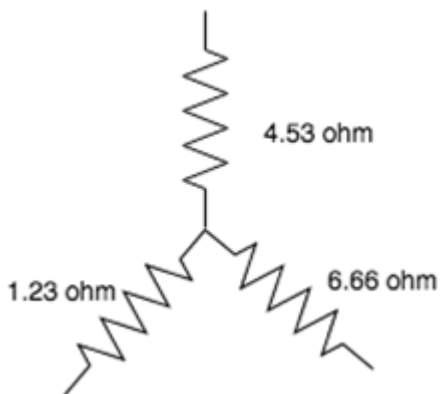
Let us look at the difference between delta and star connection

Parameter	Star Connection	Delta Connection
Presence of Node	In this type of circuit the all the three branches have a common node and branches initiate form this node.	In this type of circuit the three are connected in way that they form a loop and no common node is present.
Common Terminal	One terminal is common for all the branches in the circuit.	For every two branches one terminal remains common.
Relation between line and phase current	$I_L = I_{ph}$	$I_L = \sqrt{3} I_{ph}$
Relation between line	$V_L = \sqrt{3} V_{ph}$	$V_L = V_{ph}$

Parameter	Star Connection	Delta Connection
and phase voltage		
Presence of neutral point	There is a neutral point present in the circuit	No neutral point is present in this type of circuit
Power Supply	It receives less power than the supply.	It receives the full power.
Used in	Used in power transmission networks	Used in power distribution networks
Load Type	It can have both balanced and unbalanced load	It can only have balanced load.

#### PROBLEMS:

1. Find the equivalent delta circuit.



Answer:

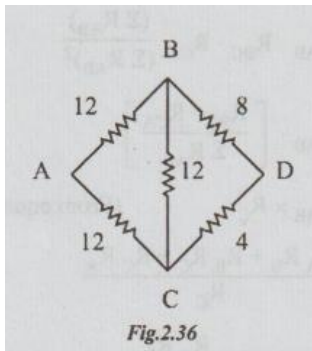
Explanation: Using the star to delta conversion:

$$R_1 = 4.53 + 6.66 + \frac{4.53 \times 6.66}{1.23} = 35.71 \text{ ohm}$$

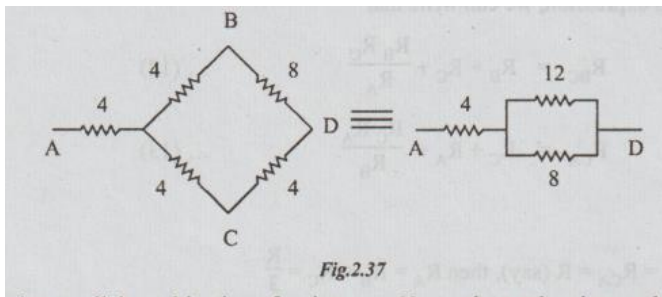
$$R_2 = 4.53 + 1.23 + \frac{4.53 \times 1.23}{6.66} = 6.59 \text{ ohm}$$

$$R_3 = 1.23 + 6.66 + \frac{1.23 \times 6.66}{4.53} = 9.69 \text{ ohm.}$$

2. For the passive circuit consisting of resistances (in ohms) as shown, calculate the equivalent resistance between the terminals A and D.



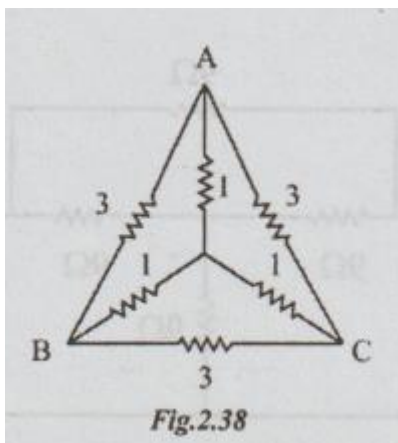
**Solution:** Between the terminals A and D in the circuit given, the combination is neither series nor parallel. Hence, simplification is not possible as it is. So, we can convert the delta between A, B and C into equivalent star. As a result, the circuit becomes as drawn below:

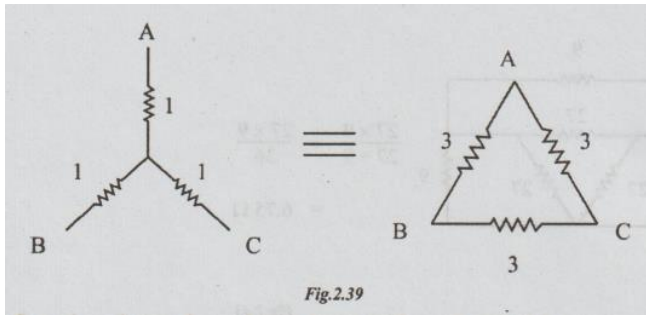


Now, it is series parallel combination of resistances. Hence the total resistance between A and D is equal to

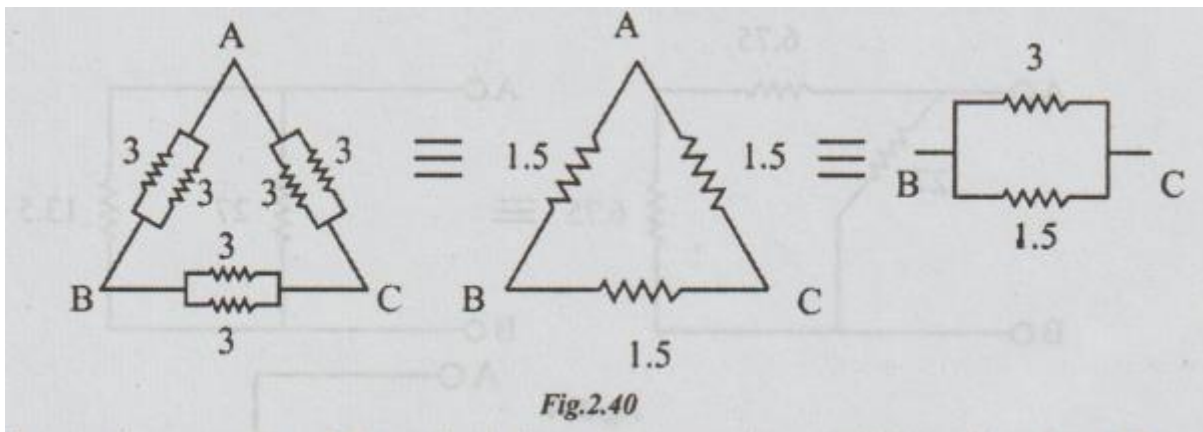
$$\begin{aligned}
 R_{AD} &= 4 + \frac{12 \times 8}{12 + 8} \\
 &= 4 + 4.8 \\
 &= 8.8 \Omega
 \end{aligned}$$

3. For the network shown in the figure below, find the equivalent resistance between the terminals B and C.





The given figure is re-drawn after replacing the star by its equivalent Delta.



The resistance between B and C terminals is equivalent to the parallel combination of 3 and 1.5 ohms.

