

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Symbols and Abbreviations

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

أولاً: مقدمة عن أساسيات الكهرباء

الكهرباء هي أحد أهم أشكال الطاقة المستخدمة في الحياة اليومية وفي التطبيقات الهندسية المختلفة. تعتمد دراسة الكهرباء على فهم بعض الكميات الفيزيائية الأساسية مثل الجهد والتيار والمقاومة والقدرة، بالإضافة إلى الرموز والاختصارات التي تستخدم في المعادلات والدوائر الكهربائية. تُستخدم الرموز والاختصارات لتسهيل كتابة المعادلات الكهربائية ورسم الدوائر وتحليلها بشكل واضح ومنظم.

ثانياً: أهمية الرموز والاختصارات الكهربائية

1. تكمن أهمية الرموز والاختصارات في أنها:
2. تسهل فهم وتحليل الدوائر الكهربائية.
3. توحد طريقة التعبير عن الكميات الكهربائية في جميع أنحاء العالم.
4. تختصر كتابة المعادلات والقوانين.
5. تسهل قراءة المخططات الكهربائية.
6. تستخدم في الكتب العلمية والبحوث الهندسية.

ثالثاً: الكميات الكهربائية الأساسية ورموزها

رمز الوحدة	وحدة القياس	الرمز	الكمية الفيزيائية
C	كولوم	Q	الشحنة الكهربائية
A	أمبير	I	التيار الكهربائي
V	فولت	V	الجهد الكهربائي
Ω	أوم	R	المقاومة
W	واط	P	القدرة الكهربائية
J	جول	E	الطاقة الكهربائية
Hz	هرتز	f	التردد
F	فاراد	C	السعة
H	هنري	L	الحث

رابعاً: تعريف الكميات الكهربائية

1- الشحنة الكهربائية (Charge)

هي خاصية فيزيائية للمادة تسبب حدوث قوة كهربائية بين الأجسام.

قانون الشحنة:

$$Q = I \times t \quad \text{حيث:}$$

$$Q = \text{الشحنة الكهربائية}$$

$$I = \text{التيار الكهربائي}$$

$$t = \text{الزمن}$$

2- التيار الكهربائي (Electric Current)

هو معدل تدفق الشحنات الكهربائية خلال موصل.

$$I = Q \ / \ t \quad \text{القانون:}$$

وحدة القياس: الأمبير (A)

3- الجهد الكهربائي (Voltage)

هو الفرق في الطاقة الكهربائية بين نقطتين في الدائرة.

$$V = W \ / \ Q \quad \text{القانون:}$$

حيث:

$$V = \text{الجهد}$$

$$W = \text{الطاقة}$$

$$Q = \text{الشحنة}$$

4- المقاومة الكهربائية (Resistance)

هي خاصية في الموصل تعيق مرور التيار الكهربائي.

$$R = V \ / \ I \quad \text{القانون:}$$

وحدة القياس: الأوم (Ω)

خامساً: قانون أوم (Ohm's Law)

يعد من أهم القوانين في الكهرباء.

$$\text{القانون: } V = I \times R$$

حيث:

$$V = \text{الجهد}$$

$$I = \text{التيار}$$

$$R = \text{المقاومة}$$

سادساً: القدرة الكهربائية (Electric Power)

القدرة هي معدل استهلاك الطاقة الكهربائية.

$$\text{القانون: } P = V \times I$$

$$P = I^2 R, \quad P = V^2 / R$$

كما يمكن كتابتها أيضاً:

وحدة القياس: الواط (W)

سابعاً: الاختصارات الشائعة في الكهرباء

الاختصار	المعنى
AC	التيار المتناوب
DC	التيار المستمر
RMS	القيمة الفعالة
EMF	القوة الدافعة الكهربائية
KVL	قانون كيرشوف للجهد
KCL	قانون كيرشوف للتيار

ثامناً : قانون كيرشوف

1- قانون كيرشوف للتيار (KCL)

ينص على أن:

مجموع التيارات الداخلة إلى نقطة يساوي مجموع التيارات الخارجة منها

2- قانون كيرشوف للجهد (KVL)

ينص على أن:

مجموع الجهود في أي حلقة مغلقة يساوي صفر

تاسعاً : تطبيقات الكهرباء في الهندسة الميكانيكية

الكهرباء لها دور مهم في الهندسة الميكانيكية مثل:

تشغيل المحركات الكهربائية

أنظمة التحكم الصناعية

أنظمة التبريد والتكييف

الروبوتات والأنظمة الميكانيكية الذكية

أنظمة الطاقة في المصانع

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

The direct current networks, Ohm law

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

First: What is Direct Current (DC)?

Direct Current (DC) is an electric current that flows in one direction only, and its magnitude remains constant over time.

Examples:

- Batteries
- Power supplies

Second: Components of an Electrical Circuit

Any DC circuit consists of:

1. **Voltage Source**, such as a battery, measured in volts (V)
2. **Resistance**: An element that opposes current flow, measured in ohms (Ω)
3. **Current**: The flow of electric charge, measured in amperes (A)
4. **Conductors (Wires)**: Used to connect circuit components

Third: Ohm's Law

One of the most important laws in electricity, relating voltage, current, and resistance:

Where:

$$V = I R$$

V: Voltage (Volt)

I: Current (Ampere)

R: Resistance (Ohm)

Derived Forms of Ohm's Law

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

Fourth: Interpretation of Ohm's Law

Increasing voltage → increases current

Increasing resistance → decreases current

Current is directly proportional to voltage

Current is inversely proportional to resistance

Fifth: Electrical Power

The power consumed in a circuit is given by:

$$P = V I$$

Using Ohm's Law:

$$P = I^2 R \quad , \quad P = \frac{V^2}{R}$$

Unit: Watt (W)

Sixth: Types of DC Circuits

1- Series Circuit

- Current is the same through all components
- Voltage is divided across resistors

2- Parallel Circuit

- Voltage is the same across all branches
- Current is divided among branches

Seventh: Measuring Instruments

- **Ammeter** → measures current (connected in series)
- **Voltmeter** → measures voltage (connected in parallel)
- **Ohmmeter** → measures resistance

HW//

What is the difference between series and parallel circuits?

What happens to current when resistance increases?

Calculate current if voltage = 20V and resistance = 5Ω ?

What is the unit of electrical power?

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Series Circuits (Resistances in Series) Voltage Divider Rule

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Introduction

Series connection is one of the fundamental methods of connecting electrical components such as resistors in circuits.

In this type of connection, components are connected one after another so that the same current flows through all of them.

Definition of Series Connection

A series connection is defined as connecting two or more components in such a way that there is only one path for electric current to flow.

Characteristics of the Series Connection

1- The current is the same throughout the entire circuit:

$$I_T = I_1 = I_2 = I_3 = \dots = I_n$$

2- The voltage is divided among the components:

$$V_T = V_1 + V_2 + V_3 + \dots + V_n$$

3- The total resistance equals the sum of all resistances:

$$R_{eq} = R_1 + R_2 + R_3 + \dots + R_n$$

4- If one component fails, the entire circuit is interrupted.

General Formula — Equivalent Resistance

In a series connection, the equivalent resistance is calculated by summing all resistances:

$$R_{total} = R_1 + R_2 + R_3 + \dots$$

Example (Solved)

Example: $R_1 = 10\Omega$, $R_2 = 20\Omega$, $R_3 = 30\Omega$, $V = 12V \rightarrow$ Find R_{eq} and I_T

Solution:

$$R_t = R_{eq} = R_1 + R_2 + R_3 = 10\Omega + 20\Omega + 30\Omega = 60\Omega$$

$$R = V/I \rightarrow I = V/R = 12V / 60\Omega$$

$$\therefore I = 0.2 \text{ A } \checkmark$$

Advantages of Series Connection

- 1- Simple and easy to understand.**
- 2- Useful for voltage control.**
- 3- Used in some applications like older lighting systems.**

Disadvantages of Series Connection

- 1- Failure of one component stops the entire circuit.**
- 2- Devices cannot operate independently.**
- 3- Voltage drops across each component.**

Applications of Series Connection

Series connection is used in:

- 1- Light strings.**
- 2- Electrical measuring instruments.**
- 3- Simple educational circuits.**

Conclusion

Series connection is a simple system where the same current flows through all components. It is easy to analyze but suffers from low reliability if one component fails.

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Parallel Circuits (Resistances in Parallel) Current Divider Rule

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Introduction

Parallel connection is one of the fundamental methods of connecting electrical components, where resistors are connected so that each component has its own independent path for current, making it widely used in practical applications.

Definition of Parallel Connection

A parallel connection is defined as connecting two or more components such that their terminals are connected to the same two voltage points, allowing current to flow through multiple paths.

Characteristics of the Parallel Connection

1- Voltage is the same across all components:

$$V_T = V_1 = V_2 = V_3 = \dots = V_n$$

2- Current is divided among branches:

$$I_T = I_1 + I_2 + I_3 + \dots + I_n$$

3- Total resistance is less than the smallest resistance.

$$1/R_T = 1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 + \dots + 1/R_n$$

4- Failure of one branch does not affect the others.

General Formula — Equivalent Resistance

In a parallel connection, the equivalent resistance is calculated using:

$$1/R_{total} = 1/R_1 + 1/R_2 + 1/R_3 + \dots$$

Example (Solved)

Given: $R_1 = 10\Omega$, $R_2 = 20\Omega$, $V = 10V$

Find: R_{eq} and I_T

Solution (1) — Finding R_{eq} :

$$1/R_{eq} = 1/R_1 + 1/R_2 = 1/10 + 1/20$$

$$1/R_{eq} = (2+1)/20 = 3/20 \rightarrow R_{eq} = 20/3 = 6.67\Omega$$

Solution (2) — Finding I_T :

When R in parallel $\rightarrow V_T = V_1 = V_2 = V = 10V$

$$I_1 = V/R_1 = 10V / 10\Omega = 1 A$$

$$I_2 = V/R_2 = 10V / 20\Omega = 0.5 A$$

$$I_{total} = I_1 + I_2 = 1 + 0.5 = 1.5 A \quad (\text{because } I_T = I_1 + I_2)$$

Or by Ohm's Law:

$$R = V/I \rightarrow I = V/R = 10V / 6.67\Omega$$

$$\therefore I = 1.499 \approx 1.5 A \quad \checkmark$$

Advantages of Parallel Connection

- 1- Devices operate independently.**
- 2- Circuit continues working even if one branch fails.**
- 3- Suitable for household use.**

Disadvantages of Parallel Connection

- 1- Requires more wiring.**
- 2- Relatively more complex design.**
- 3- Higher total current.**

Applications of Parallel Connection

Parallel connection is used in:

- 1- Household electrical wiring.**
- 2- Power distribution systems.**
- 3- Modern electrical devices.**

Conclusion

Parallel connection allows current to be distributed across multiple paths while maintaining constant voltage, making it more efficient and reliable than series connection in practical applications.

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Series-Parallel Circuits Transformation

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Introduction

A mixed resistor connection is a combination of series and parallel connections in the same electrical circuit, where some parts are connected in series and others in parallel.

Basic Concept of Mixed Connection

In a mixed connection, the circuit contains both series and parallel resistors, and it must be simplified step by step to obtain a single equivalent resistance.

Solution Steps

- 1- Identify which resistors are in series and which are in parallel.**
- 2- Start by simplifying the easiest part of the circuit (series or parallel) and replace it with an equivalent resistor.**
- 3- After each simplification step, redraw the circuit in a simpler form.**
- 4- Repeat the process until you obtain a single equivalent resistance.**
- 5- After finding the total resistance, current or voltage can be calculated using Ohm's Law:**

$$V = I \times R$$

Important Notes

- 1- In series: current is constant.**
- 2- In parallel: voltage is constant.**
- 3- Simplification must be done step by step.**

Example 1 (Solved)

Circuit contains: $R_1=1\Omega$, $R_2=3\Omega$, $R_3=6\Omega$, $R_4=12\Omega$, $R_5=12\Omega$, $R_6=12\Omega$,
 $V=14V \rightarrow$ Find R_{eq}

Step 1: R_2 and R_3 are in parallel (between points a and b):

$$1/R_{eq} = 1/R_2 + 1/R_3 = 1/3 + 1/6 = (2+1)/6 = 3/6$$

$$\rightarrow R_A = 2\Omega$$

Step 2: R_4 , R_5 , R_6 are in parallel (between points c and d):

$$1/R_{eq} = 1/R_4 + 1/R_5 + 1/R_6 = 1/12 + 1/12 + 1/12 = 3/12$$

$$\rightarrow R_B = 4\Omega$$

Step 3: Final circuit — R_1 , R_A , R_B are now in series:

$$R_{eq} = R_1 + R_A + R_B = 1\Omega + 2\Omega + 4\Omega$$

$$\therefore R_T = 7\Omega \checkmark$$

Example 2 (Solved)

Circuit contains: $R_1=2\Omega$, $R_2=3\Omega$, $R_3=4\Omega$, $R_4=6\Omega$, $R_5=8\Omega$, $R_6=12\Omega$, $V=30V$
 \rightarrow Find R_{eq}

Step 1: R_1 and R_2 are in series (between points a and b):

$$R_{eq_{se}} = R_1 + R_2 = 2\Omega + 3\Omega = 5\Omega \rightarrow R_A = 5\Omega$$

Step 2: R_3 and R_4 are in series (between points a and b):

$$R_{eq_{se}} = R_3 + R_4 = 4\Omega + 6\Omega = 10\Omega \rightarrow R_B = 10\Omega$$

Step 3: R_A , R_B , R_5 , R_6 are all in parallel:

$$1/R_{eq} = 1/R_A + 1/R_B + 1/R_5 + 1/R_6$$

$$1/R_{eq} = 1/5 + 1/10 + 1/8 + 1/12$$

$$1/R_{eq} = (24+12+15+10)/120 = 61/120$$

$$\therefore R_{eq} = 120/61 \approx 1.967 \Omega \checkmark$$

Applications

Mixed connections are used in:

- 1- Electrical devices.**
- 2- Electronic circuits.**
- 3- Power distribution systems.**

Common Mistakes

- 1- Confusing series with parallel.**
- 2- Not redrawing the circuit after each simplification.**
- 3- Using the wrong formula.**

Conclusion

Mixed circuits require understanding both series and parallel connections and are solved through step-by-step simplification.

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Open and Short Circuits & Source Transformation)

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Open Circuits

An open circuit is a circuit where the path is broken, so no current flows.

Characteristics:

- **Current = 0 A**
- **Voltage may exist across the open terminals**
- **No energy transfer**

Short Circuits

A short circuit is a circuit with very low (almost zero) resistance.

Characteristics:

- **Very high current**
- **Voltage ≈ 0 V**
- **Dangerous and may damage components**

Comparison between open circuit and short circuit

Property	Current	Voltage
Current	0	Very high
Voltage	Exists	≈ 0
Resistance	Very high	Very low
Danger	Low	High

Source Transformation

Converting:

Voltage source ↔ Current source

While maintaining the same external behavior.

1- Voltage → Current:

$$\mathbf{I = V \ / \ R}$$

Series resistor becomes parallel

2- Current → Voltage:

$$\mathbf{V = I \times R}$$

Parallel resistor becomes series

Importance:

- **Simplifies circuit analysis**
- **Helps apply Ohm's Law and Kirchhoff's Laws**

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Kirchhoff's Current law (KCL)

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Kirchhoff's current law (KCL) and their use in network analysis.

Kirchhoff's current law (KCL) is one of the fundamental law used in electrical circuit analysis, and it states that :-

The sum of currents entering any node in a circuit is equal to the sum of currents leaving it.

In simpler terms :-

A node does not store electric charge, so every current entering it must leave it.

Mathematical form

$$\sum I_{in} = \sum I_{out}$$

$$\sum I = 0$$

Considering incoming currents as positive and outgoing currents as negative, or vice versa depending on convention.

What is a Node?

It is a point where two or more conductors meet in an electrical circuit.

ex //

If three resistors meet at one point → this point is a node.

Kirchhoff's law of current is based on an important principle in physics:-

"law of conservation of charge"

That means :-

- Charge is neither created nor destroyed.
- Therefore, it cannot accumulate at a node.

ex // We have a node where :

Current $I_1 = 5$ A enters

Current $I_2 = 3$ A enters

Current $I_3 = ?$ is leaves.

So I_1 and I_2 are enters :-

$$I_1 + I_2 = I_3 \rightarrow 5A + 3A = I_3$$

$$I_3 = 8 \text{ A}$$

Therefore, the outgoing current = 8A

ex // At a node $I_1 = 10\text{A}$ entering

$I_2 = 4\text{A}$ leaving

$I_3 = ?$ leaving

Sol // $I_{in} = I_{out} \rightarrow I_1 = I_2 + I_3$

$$10\text{A} = 4\text{A} + I_3$$

$$I_3 = 10\text{A} - 4\text{A} = 6\text{A}$$

The Kirchhoff's law of current used in :

1- Simple circuits

2- Network analysis

3- Along with Kirchhoff's Voltage law.

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Kirchhoff's Voltage law (KVL)

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Kirchhoff's Voltage law is a fundamental rule in circuit analysis stating that the algebraic sum of all voltages in any closed loop equals zero.

$$\sum V = 0$$

This equation means that the sum of all Voltages within a loop equals zero.

Kirchhoff's Voltage law is based on an important principle in physics :-

"law of conservation of energy"

Kirchhoff's Voltage law is based on the principle of energy conservation, where the energy consumed by circuit elements.

The solution uses Kirchhoff's potential law :-

Select a closed loop, choose a direction, start from a point, sum the Voltages considering signs, then apply the law and solve the equation.

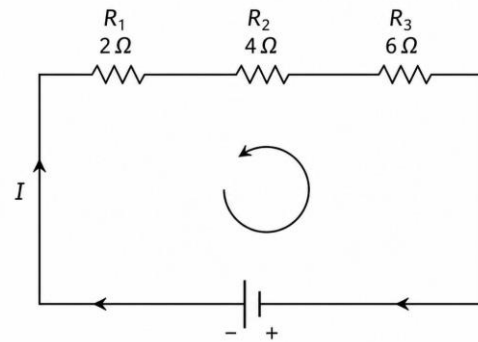
The Kirchhoff's law of Voltage used in :-

- 1- Analyzing complex circuits**
- 2- Finding unknown Values.**
- 3- Designing electrical systems.**

ex // If we have an electrical circuit containing three resistors in series, find the solution by using Kirchhoff's law?

R₁	R₂	R₃
~ ~	~ ~	~ ~
2Ω	4Ω	6Ω

12V



Sol //

$$\begin{aligned} \mathbf{R_{eq}} &= \mathbf{R_1 + R_2 + R_3} \\ &= \mathbf{2\Omega + 4\Omega + 6\Omega} \\ &= \mathbf{12\Omega} \end{aligned}$$

$$\mathbf{I = V/R = 12V / 12\Omega = 1 A}$$

$$V_1 = I \times R_1 = 1A \times 2\Omega = 2V$$

$$V_2 = I \times R_2 = 1A \times 4\Omega = 4V$$

$$V_3 = I \times R_3 = 1A \times 6\Omega = 6V$$

$$V_{out} = V_{in}$$

$$12V = 2V + 4V + 6V$$

$$\sum V = 0$$

$$12V - 2V - 4V - 6V$$

$$12V - 12V = 0$$

$$\text{or } // 2 + 4 + 6 - 12 \rightarrow 12 - 12 = 0$$

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Parallel and series circuit transformation

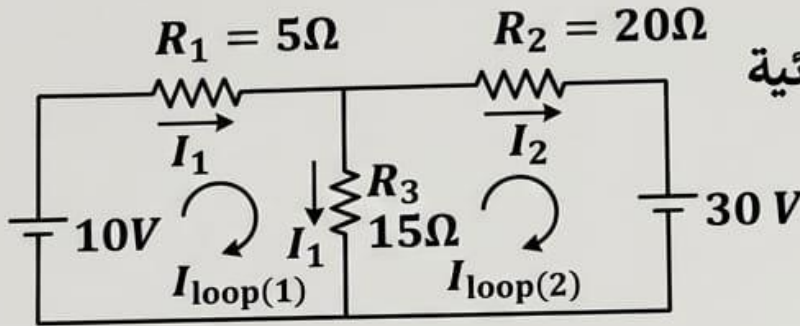
By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026



نفترض أن لدينا دائرة كهربائية توجد فيها نقطة أو عقدة وتكون هناك ثلاث تيارات موجودة في هذه العقدة اثنان منها داخلان والثالث خارج من العقدة.

(I_1, I_2) enters
 (I_3) leaves

(1) نطبق قانون كيرشوف للتيار للعقدة (1)
~~KCL~~ // $T_{in} = T_{out}$ that mean $I_1 + I_2 = I_3$

$$\therefore \boxed{I_1 + I_2 - I_3 = 0} \quad \text{-- (1)}$$

(2) نطبق قانون كيرشوف لقية وتحصل على معادلتين ويفضل أن تكون العلاقة باتجاه التيار.

KVL // Loop (1) /

$$\begin{aligned} V_{in} &= V_{out} \Rightarrow V_{in} - V_{out} = 0 \\ V_{out} &= V_{in} \Rightarrow V_{out} - V_{in} = 0 \end{aligned}$$

$$-10 + 5I_1 + 15I_3 = 0 \Rightarrow \boxed{5I_1 + 15I_3 = 10} \quad \text{-- (2)}$$

KVL / Loop (2) /

$$-30 + 20I_2 + 15I_3 = 0 \Rightarrow \boxed{20I_2 + 15I_3 = 30} \quad \text{-- (3)}$$

$$[5I_1 + 15I_3 = 10] \div 5 \quad \text{تبسيط معادلة (1)}$$

$$I_1 + 3I_3 = 2 \quad \Rightarrow \quad \boxed{I_1 = 2 - 3I_3} \quad (A)$$

تبسيط معادلة (2)

$$[20I_2 + 15I_3 = 30] \div 5$$

$$[4I_2 + 3I_3 = 6] \div 4 \quad \Rightarrow \quad I_2 + \frac{3}{4}I_3 = \frac{6}{4}$$

$$I_2 + 0.75 I_3 = 1.5 \quad \Rightarrow \quad \boxed{I_2 = 1.5 - 0.75 I_3}$$

(B)

نعوض في معادلة (A) و (B) في معادلة (1)

$$I_1 + I_2 = I_3$$

$$2 - 3I_3 + 1.5 - 0.75 I_3 = I_3$$

$$3.5 - 3.75 I_3 = I_3$$

$$I_3 + 3.75 I_3 = 3.5$$

$$4.75 I_3 = 3.5$$

$$I_3 = \frac{3.5}{4.75} = 0.777 \quad (A)$$

$$I_1 = 2 - 3I_3$$

نعوض قيمة I_3 في معادلة (A)

$$I_1 = 2 - 3(0.777)$$

$$I_1 = 2 - 2.331 \quad \Downarrow$$

$$\boxed{I_1 = -0.211} \quad (A)$$

Date: ___/___/___

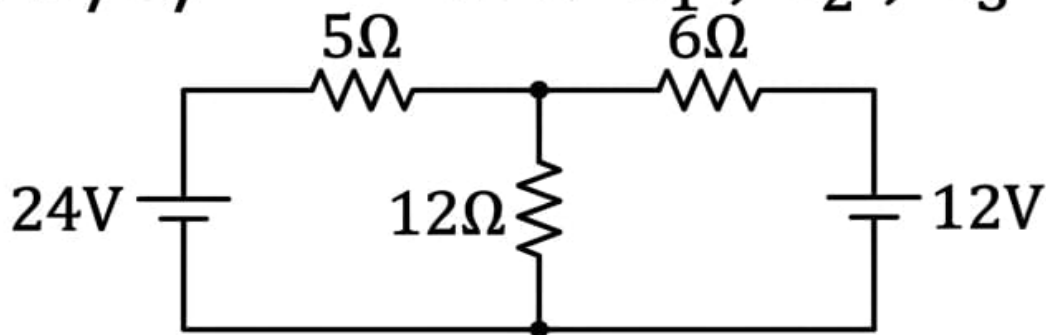
تعويض قيمة I_3 في معادلة (3)

$$I_2 = 1.5 - 0.75 I_3$$

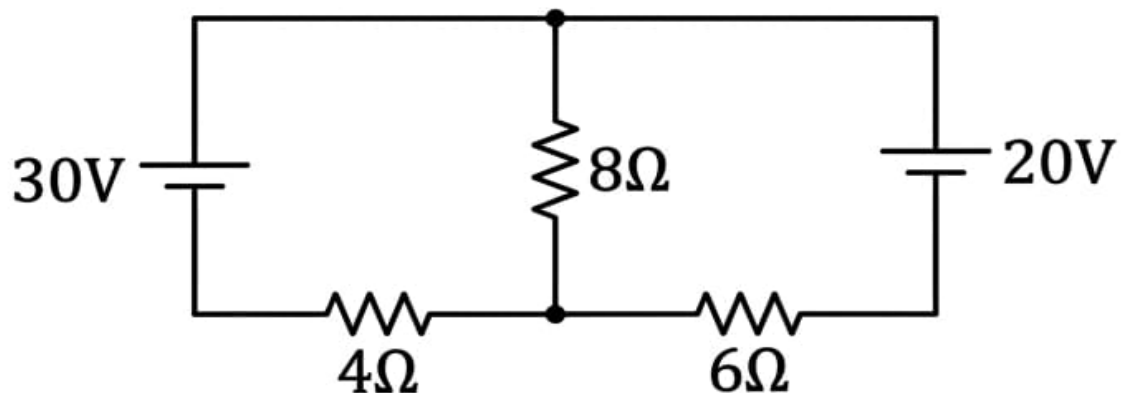
$$I_2 = 1.5 - 0.75 (0.777)$$

$$I_2 = 1.5 - 0.777 = 0.723 \text{ (A)}$$

HW/1/ find I_1, I_2, I_3 ?



HW/2/ find I_1, I_2, I_3 ?



Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Star to Delta conversion and Delta to Star conversion

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

conversion Delta to star connection and conversion star to Delta conversion.

التحويل من ستار إلى دلتا ومن دلتا إلى ستار

(Delta – star and star – Delta) transformations ✓

Is used to simplify the analysis of electrical circuits and solve related problems.

The name comes from the shapes of the electrical circuit connections, which resemble the letter Y and the greek letter Δ .

The idea is that within an electrical circuit, a network may appear either in a Y form or a Δ .

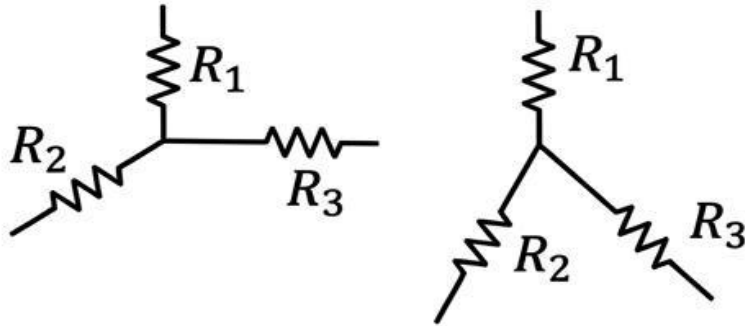
We convert the network from one form to another total current entering the circuit, or to determine any other required electrical quantity.

This transformation is purely mathematical, meaning that no physical changes are made to the actual circuit.

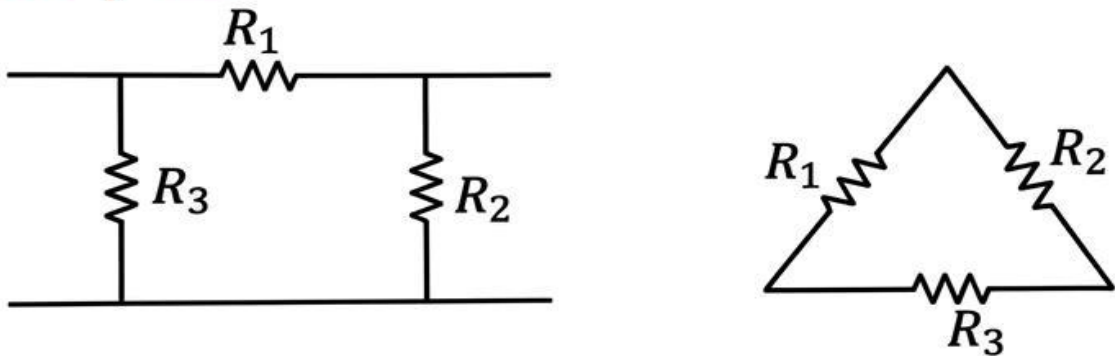
At the same time, the total impedance of resistance of the circuit does not change.

Therefore, the current entering the circuit and the Voltage measured across any two terminals remain unchanged.

star / Y



Delta / Δ



$\Delta \rightarrow Y$

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

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

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

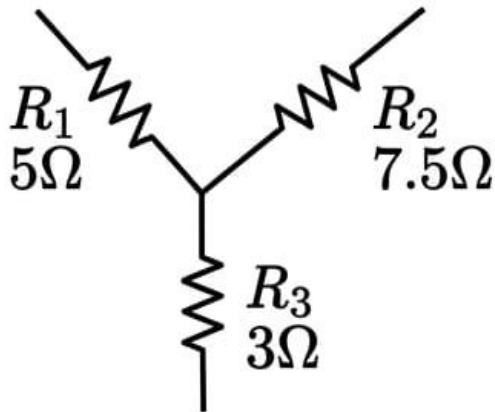
$Y \rightarrow \Delta$

$$R_A = \frac{(R_1 \cdot R_2) + (R_1 \cdot R_3) + (R_2 \cdot R_3)}{R_3}$$

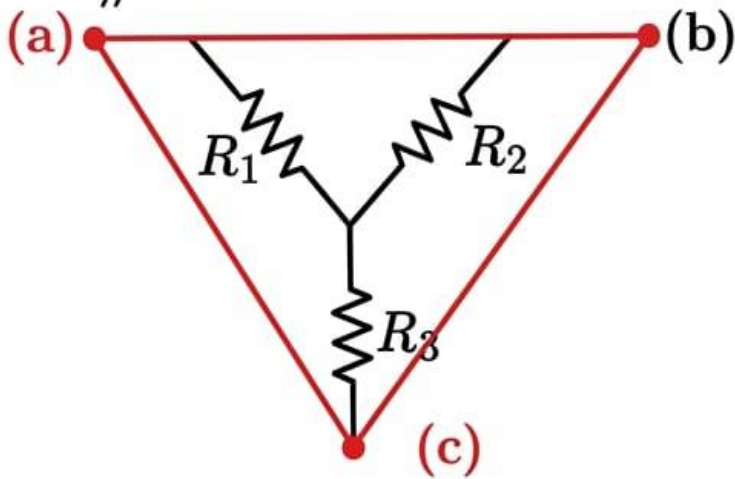
$$R_B = \frac{(R_1 \cdot R_2) + (R_1 \cdot R_3) + (R_2 \cdot R_3)}{R_2}$$

$$R_C = \frac{(R_1 \cdot R_2) + (R_1 \cdot R_3) + (R_2 \cdot R_3)}{R_1}$$

~ex//~ Convert the Y network to an equivalent Δ network ?



Sol//

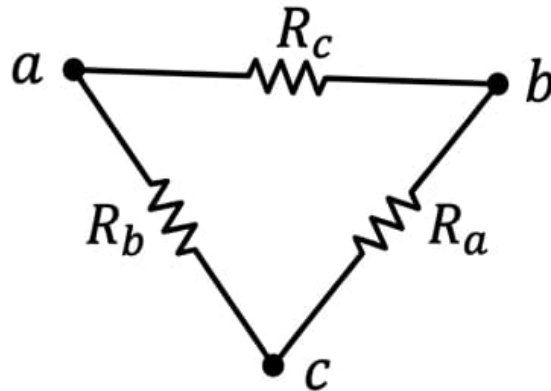


$$R_a = 7.5 + 5 + \frac{7.5 * 5}{3} = 25\Omega$$

$$R_b = 7.5 + 3 + \frac{7.5 * 3}{5} = 15\Omega$$

$$R_c = 5 + 3 + \frac{5 * 3}{7.5} = 10\Omega$$

Ex Convert the Δ network to an equivalent star network ?

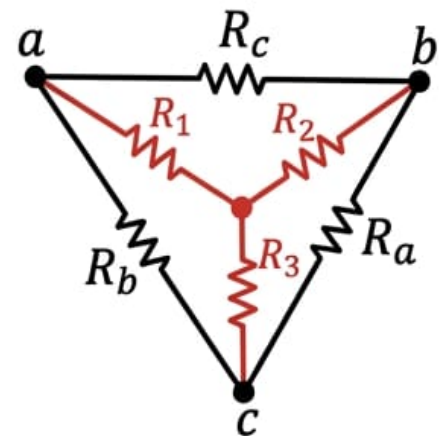


Sol//

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} = \frac{10 * 25}{15 + 10 + 25} = 5 \Omega$$

$$R_2 = \frac{R_b R_c}{R_a + R_b + R_c} = \frac{25 * 15}{50} = 7.5 \Omega$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} = \frac{15 * 10}{50} = 3 \Omega$$



Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Superposition Theorem

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Introduction

The Superposition Theorem is one of the most important theorems used in analyzing linear electrical circuits that contain more than one independent voltage or current source. This theorem simplifies the analysis of complex circuits by studying the effect of each source separately and then summing the results to obtain the total circuit response.

Definition of the theory of separation

The Superposition Theorem states that the total response (voltage or current) in any element of a linear circuit containing multiple independent sources is equal to the algebraic sum of the responses produced by each independent source acting alone while all other independent sources are deactivated.

Conditions for applying the separation theory

The Superposition Theorem can only be applied to linear circuits, which satisfy the principles of proportionality and additivity. These circuits include ideal resistors, capacitors, and inductors. The theorem cannot be directly used to calculate electrical power because power is not a linear quantity.

How to disable sources

First: Source of voltage

When deactivating an independent voltage source, it is replaced by a short circuit, which is equivalent to a wire having zero resistance.

Second: Source of current

When deactivating an independent current source, it is replaced by an open circuit, meaning that the current path is completely removed.

Steps for applying the separation theory

- 1- Select the first source and keep it active.**
- 2- Deactivate all other independent sources.**
- 3- Calculate the required voltage or current due to the first source.**
- 4- Repeat the process for each independent source in the circuit.**
- 5- Add all responses algebraically to obtain the final response.**

Advantages of the separation theory

- 1- Simplifies the analysis of complex circuits.**
- 2- Helps understand the effect of each source separately.**
- 3- Useful for circuits containing multiple sources.**
- 4- Can be combined with Kirchhoff's Laws and Ohm's Law.**

Disadvantages of the separation theory

- 1- Requires repeated calculations for each source.**
- 2- Takes more time for large circuits.**
- 3- Cannot be directly applied to power calculations.**

Summary

The Superposition Theorem states that the effect of multiple independent sources in a linear electrical circuit can be analyzed by considering each source separately and then adding the results algebraically. It is one of the most widely used tools in circuit analysis, especially when multiple voltage or current sources are present.

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Thevenin's Theorem, Norton's Theorem

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Introduction

First: Thevenin's Theorem

Any linear electrical network containing voltage sources, current sources, and resistors can be replaced by an equivalent circuit consisting of a single voltage source in series with a single equivalent resistance.

Components of the Thevenin Equivalent Circuit

- 1- Thevenin Voltage (V_{th}).**
- 2- Thevenin Resistance (R_{th}).**
- 3- Load Resistance (R_L).**

Second: Norton's Theorem

Norton's theorem states that any linear electrical circuit can be replaced by an equivalent circuit consisting of a single current source called the Norton current (I_N) in parallel with a single resistance called the Norton resistance (R_N).

Components of the Norton Equivalent Circuit

- 1- Norton Current (I_N).**
- 2- Norton Resistance (R_N).**
- 3- Load Resistance (R_L).**

Importance of Thevenin's and Norton's Theorems

- 1- Simplifying complex electrical circuits.**
- 2- Reducing the amount of calculations required.**
- 3- Facilitating the analysis of load variations.**
- 4- Assisting in electronic system design.**
- 5- Improving the efficiency of circuit analysis.**

Difference in Importance

Thevenin's theorem is more useful when the focus is on voltages.

Norton's theorem is more useful when the focus is on currents

Relationship Between Thevenin and Norton

The two equivalent circuits can be converted into each other using the following relationships:

- 1- Thevenin resistance equals Norton resistance.**
- 2- Thevenin voltage equals Norton current multiplied by Norton resistance.**
- 3- Norton current equals Thevenin voltage divided by Thevenin resistance.**

Conclusion

Thevenin's and Norton's theorems are used to transform complex electrical circuits into simple equivalent circuits. Thevenin's theorem is based on a voltage source and a series resistance, while Norton's theorem is based on a current source and a parallel resistance. These theorems are essential tools that every electrical engineering student should master to analyze circuits effectively.

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Maximum Power Transfer Theorem

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Introduction

The Maximum Power Transfer Theorem is one of the important theories in electrical and electronic engineering. It is used to determine the load value that receives the maximum possible power from a source. This theorem is widely applied in electronic circuit design, communication systems, and signal amplifiers to achieve optimal power transfer.

**The Maximum Power Transfer Theorem states that:
Maximum electrical power is transferred from the source to the load when the load resistance is equal to the Thevenin equivalent resistance of the source.**

Application

- 1- Loudspeaker systems.**
- 2- Wireless communication systems.**
- 3- Radio circuits.**
- 4- Impedance matching.**
- 5- Antenna design.**

Advantages:

- 1- Achieves maximum possible power transfer.**
- 2- Simplifies circuit design.**
- 3- Improves communication system performance.**

Important Notes:

- 1- At maximum power transfer, efficiency is only 50%.**
- 2- Half of the power is dissipated in the source resistance.**
- 3- In power systems, high efficiency is usually preferred over maximum power transfer.**

Summary:

The Maximum Power Transfer Theorem states that a load receives maximum power when its resistance equals the Thevenin equivalent resistance of the source. This theorem is fundamental in electronics, communication systems, and impedance matching applications.

Republic of Iraq

Ministry of Higher Education and Scientific Research

AL-Furat AL-Awsat Technical University – Iraq



Kerbela Polytechnic College

Department of Mechanical Engineering Technology

Fundamentals of Electricity

Reciprocity Theorem

By

Assist. Lectures

Zahraa S. Alkhfajy

MS.C Physics Science

2025-2026

Introduction

The Reciprocity Theorem is one of the fundamental theorems in the analysis of electrical circuits and linear networks. It helps engineers and students simplify circuit analysis and verify results by utilizing the interchangeability between the excitation source and the response point within the circuit.

Definition of Reciprocity Theorem

The Reciprocity Theorem states:

In any linear bilateral network containing a single independent source, the current flowing through one branch due to a voltage source in another branch remains unchanged when the positions of the source and the current measurement branch are interchanged.

Basic Idea of the Theorem

If an electrical circuit contains a voltage source at point (A) that produces a current at point (B), then moving the source to point (B) and measuring the current at point (A) will result in the same current value.

Conditions for applying the Reciprocity Theorem

1. The Circuit Must Be Linear

This means that the relationship between voltage and current follows Ohm's Law, and the superposition principle is applicable.

2. The Circuit Elements Must Be Bilateral

This means that the characteristics of the element do not change when the direction of current or voltage is reversed.

Examples:

Resistors , Inductors , Capacitors .

However, non-bilateral elements such as diodes do not satisfy this condition.

3. Only One Independent Source Must Exist

The circuit should contain only one excitation source while applying the theorem.

4. No Nonlinear Elements

Such as diodes and transistors operating in the nonlinear region.

Simplified Mathematical Proof

Using Kirchhoff's Laws and Ohm's Law, the network equations can be expressed in matrix form. In linear bilateral networks, the coefficient matrix is symmetric, which leads directly to the reciprocity property.

The importance of Reciprocity theory

1. Simplifying Circuit Analysis

Only one part of the circuit may need to be analyzed, and the interchange property can then be used.

2. Verifying Solutions

It serves as a method for checking the correctness of results.

3. Communication Network Analysis

It is used in the study of transmission and reception networks.

4. Reducing Calculations

It reduces the number of equations needed for analysis.

5. Antenna Analysis

It is widely used in antenna engineering.

Advantages of the Theorem

- 1- Easy to apply.**
- 2- Saves time and effort.**
- 3- Helps verify results.**
- 4- Useful in large and complex circuits.**

Limitations of the Theorem

- 1- It cannot be applied in the following cases:**
- 2- Nonlinear circuits.**
- 3- Circuits with more than one independent source.**
- 5- Unilateral elements.**
- 6- Nonlinear transistor and diode circuits.**

Conclusion

The Reciprocity Theorem is an important theorem in the analysis of linear bilateral electrical circuits. It states that the effect of a voltage source at one point on the current in another branch remains the same when the positions of the source and the response are interchanged. It is widely used to simplify circuit analysis and verify engineering solutions.