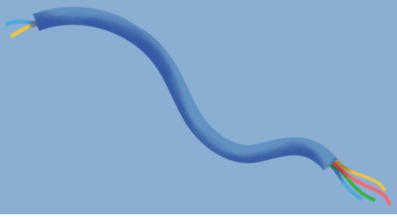




# Fundamental of Electrical Circuit : Volume 1

Omar J, Ilmi Ariffin




Fundamental of Electrical Circuit : Volume 1

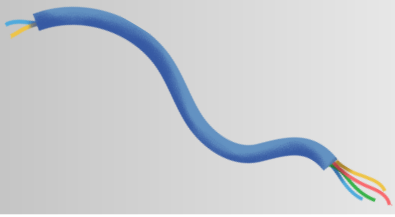
Writers :
Julaiha Omar
Ilmi Ariffin

Editor :
Julaiha Omar
Ilmi Ariffin
Mariana Rosdi

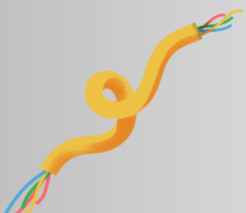
First Publication 2024

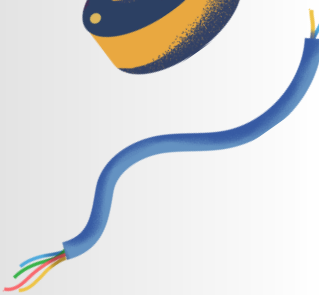
eISBN No: 978 629 7667 28 7

Published by:
UNIT PENERBITAN
Politeknik Sultan Salahuddin Abdul Aziz Shah
Persiaran Usahawan, Seksyen U1,
40150 Shah Alam Selangor
Telephone No : +603 5163 4000
Fax No : +603 5569 1609



# Fundamental of Electrical Circuit : Volume 1





# Preface

Welcome to the electrifying journey into the heart of modern technology and innovation! This book, is designed to be your companion as you embark on a fascinating exploration of the principles that power our modern, connected world.

As technology continues to advance at an unprecedented pace, understanding the fundamentals of electric circuits becomes increasingly crucial. Whether you're a curious beginner or a seasoned enthusiast, this book aims to demystify the complexities of electric circuits, making them accessible and engaging for all readers.

Our journey will take us from the basics of voltage and current to the intricacies of resistors, capacitors, and inductors. Along the way, we'll discover how these circuits are the lifeblood of countless devices that shape our daily lives.

Through clear explanations, vivid examples, and hands-on activities, we aim to make the study of electric circuits not only informative but also enjoyable. Join us as we flip the switch on discovery and illuminate the path to a brighter, electrified future.

Let the journey begin!

# The team

"Dream big and fly high! Success is waiting just ahead!"

**Mrs Julaiha binti Omar**
**Lecturer of Diploma Medical Electronic Engineering**
**julaiha@psa.edu.my**
**Bach of Education with Honour**
**Diploma electrical Engineering with Education**

**Mr Mohammad Ilmi Ariffin**
**Lecturer of Control Electronic Engineering**
**iliariffin@psa.edu.my**
**Msc. Mechanical Engineering, UiTM**
**Bsc electrical engineering, UTM**
**Diploma Electrical Engineering, UTM**

"Every day is a new chance! Rise up, fight, and show your best self!"

# By the end of the lesson, you'll be able to:

- Define current, voltage and resistance.
- Explain the relationship of current and charge.
- Explain the complete circuit
- Use Ohm's law to calculate for current, voltage or resistance.
- Explain the relationship between current, voltage and resistance through Ohm's law
- Apply series, parallel and series-parallel connections to dc circuit.

# Introduction to Electricity

## Other Circuit Components

Shown below are other circuit components and their corresponding electrical symbols:

battery

closed switch

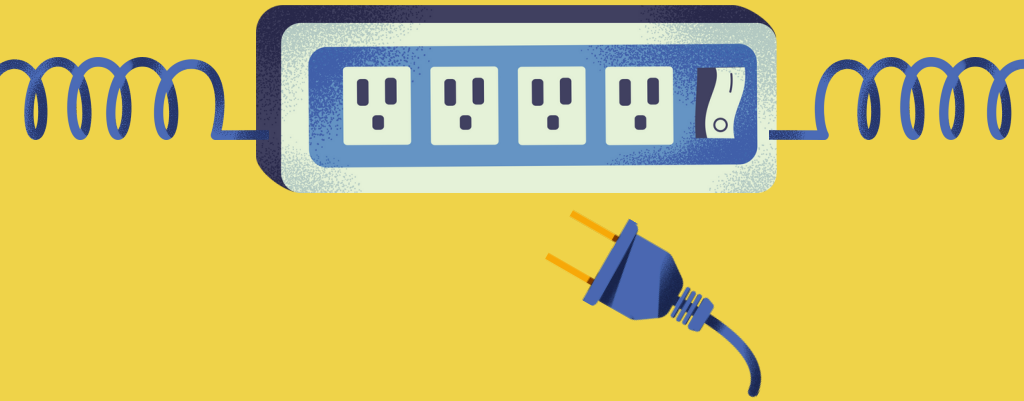
open switch

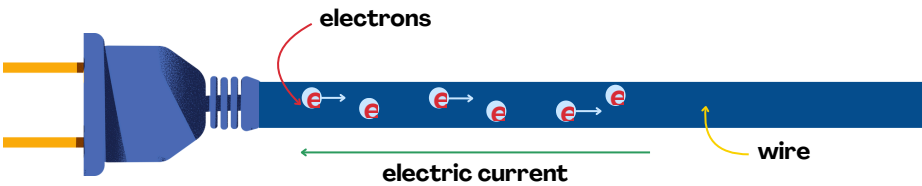
resistor


motor

fuse

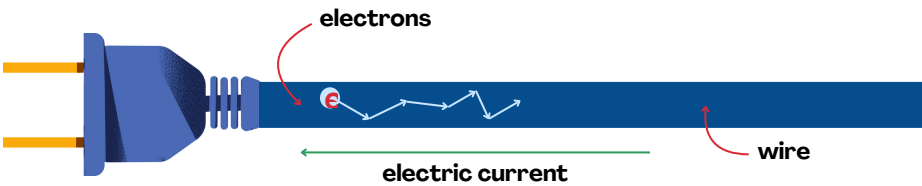
**Have you ever wondered**
**how your phone charges**
**when you plug it into a socket?**






When a charger is plugged in, negatively charged particles called **electrons,** which are already present inside the wires, start moving in the same net direction.

This flow of electrons is what we call **electric current**. The **voltage**, or **electrical pressure** pushes these electrons along the wires.




Free electrons move along a zigzag path, colliding with each other and with fixed atoms within the material, creating **resistance**.

This **resistance** makes the wire and any connected devices, like your phone charger, **heat up**.

# Key Elctrical Quantity

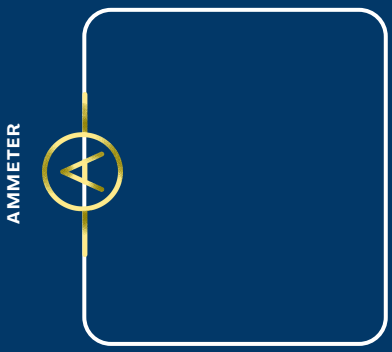
BATTERY

## Current

**Current** (**measured in amps or amperes, A**) is the rate of flow of charge in a circuit.

This flow is in the form of electrons flowing through a circuit.

An **ammeter** is used to measure current. It is always **connected in series** with the circuit.



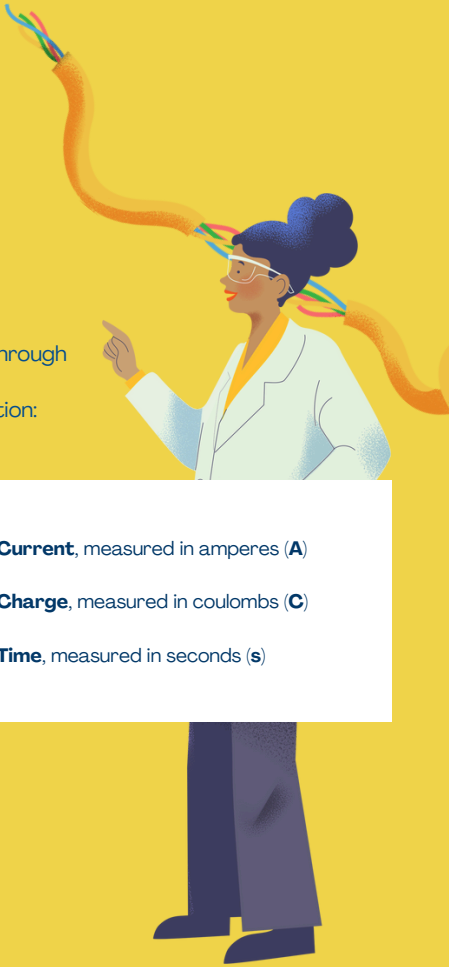

BULB

# Calculating Current

**Electric current** is the amount of charge passing through a component per second. This relationship between current, charge, and time is expressed by the equation:

$$\text{current}\ (i) = \frac{\text{charge}\ (Q)}{\text{time}\ (t)}$$

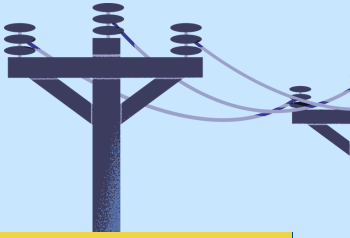
- **i** — **Current**, measured in amperes (**A**)
- **Q** — **Charge**, measured in coulombs (**C**)
- **t** — **Time**, measured in seconds (**s**)



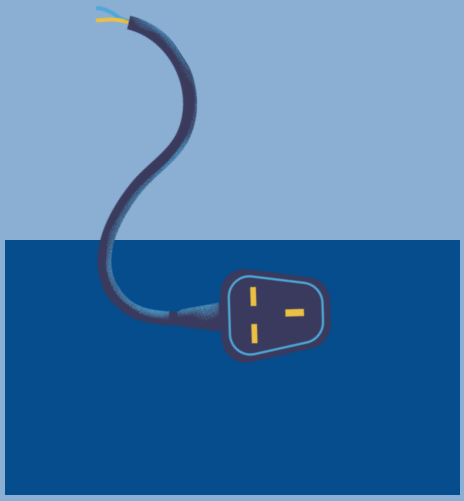
EXAMPLE

# Calculating Current

Calculate the current in an air conditioning unit that has a charge of 18,400 C flowing through it every hour.

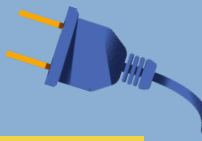


| STEP 1: WHAT ARE THE GIVEN AND MISSING VALUES? | STEP 2: WHICH FORMULA WILL WE BE USING? |
| --- | --- |
| i **Current** (**A**) = ?<br>Q **Charge** (**Q**) = 18,400 C<br>t **Time** (**t**) = 1 hour = 3,600 s | $\text{current}\,(i) = \frac{\text{charge}\,(Q)}{\text{time}\,(t)}$ |



EXAMPLE

# Calculating Current



Calculate the current in an air conditioning unit that has a charge of 18,400 C flowing through it every hour.

**STEP 3: SUBSTITUTE THE VALUES.**

$$\text{current (i)} = \frac{18{,}400 \text{ C } (\mathbf{Q})}{3{,}600 \text{ s } (\mathbf{t})}$$

**STEP 4: SOLVE.**

$$\text{current (i)} = \frac{18{,}400 \text{ C}}{3{,}600 \text{ s}} = \mathbf{5.1\ A}$$

**Answer:**
The current in an air conditioning unit that has a charge of 18,400 C flowing through it every hour is **5.1 A**.

# Try this!

A current of 4.8 A flows through a circuit for 45 seconds. How much electric charge passes through the circuit during this time?

# Try this!

A current of 4.8 A flows through a circuit for 45 seconds.

How much electric charge passes through the circuit during this time?

**ANSWER:**

| | |
|---|---|
| **Step 1:** What are the given and missing values? | **Current** (**A**) = 4.8 A<br>**Charge** (**Q**) = ?<br>**Time** (**t**) = 45 s |
| **Step 2:** Which formula will we be using? | $i = \frac{Q}{t}$ → $Q = i \times t$ |
| **Steps 3 & 4:** Substitute the values, then solve. | $Q = i \times t = 4.8\ A \times 45\ s =$ **216 C**<br>The electric charge that passes through the circuit is **216 C**. |

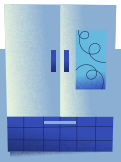
# What can electric circuits do?

Electric circuits play a crucial role in our daily lives.

It allows specific devices to produce heat and sound.

It allows light bulbs to light up.

It helps trains move and makes travelling to work or school easier.

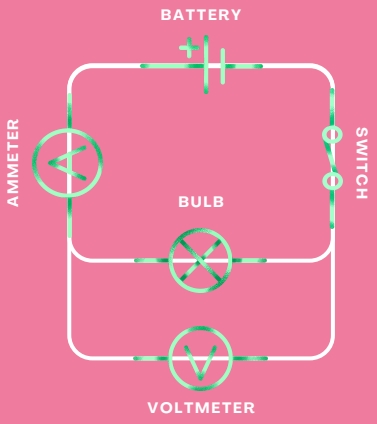


It enables the cooling system of a refrigerator to work.

# Voltage

**Voltage** (**measured in volts, V**) is the pressure or push behind the flow of current. It is also referred to as potential difference.

A **voltmeter** is used to measure voltage. It is **placed parallel** to the component(s) to measure the voltage in a circuit.



# Resistance

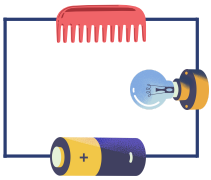
**Resistance** (**measured in ohms, Ω**) is a measure of how much a material opposes the flow of electric current going through it.

The greater the resistance, the more energy is needed to push the current through the component, which can affect the overall performance of electrical circuits.

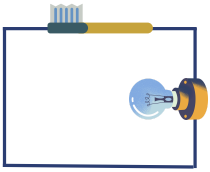
An **ohmmeter** is used to measure the amount of resistance present when a current is passed through a particular component.

# Electric Circuit

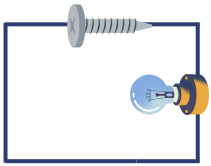
Which of these circuits would work?



A



B

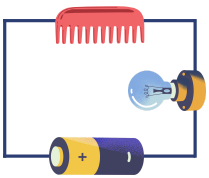


C

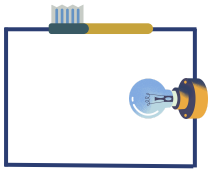
# Electric Circuit

Which of these circuits would work?

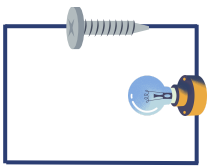
ANSWER KEY



A plastic comb is not a conductor of electricity.



A plastic toothbrush is not a conductor of electricity, and a power source is missing.

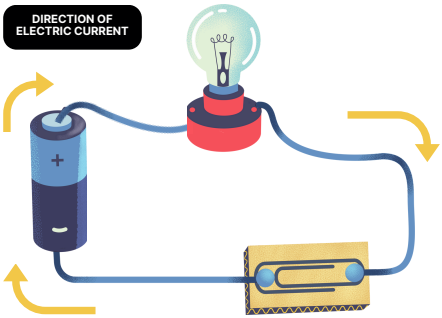


A metal screw is a conductor of electricity, but the power source is missing.

# What is an electric circuit?

It is a complete path through which electric current flows.

It should be constructed in an unbroken loop.

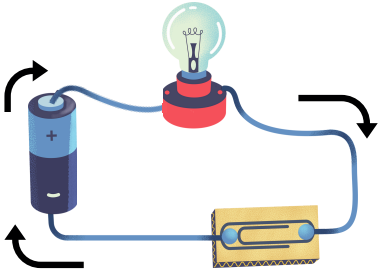


## What makes an electric circuit complete?

A simple circuit consists of a battery (or other source), a light bulb (or other load) and conducting wires.

| | | | |
|---|---|---|---|
| COMPONENT |  |  |  |
| SYMBOL |  |  |  |

# What happens in a circuit?

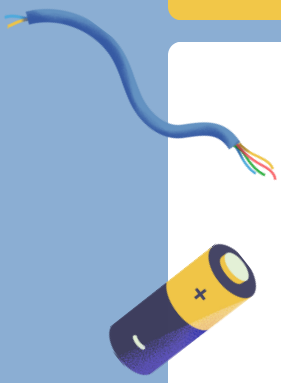


A dry cell provides the ‘push’ needed for electrons to flow in the loop.

These electrons are already present in the wires.

When these electrons pass through a load or a receiver, electrical energy can change into other forms, such as light, heat and sound.

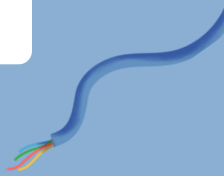
# Completing the Circuit



Given a bulb, a wire and a cell, can you suggest:

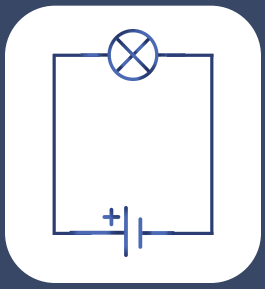
- 1 way to connect them to get the bulb to light up?
- 1 way to connect them such that the bulb does not light up?

Use the electrical symbols when drawing the circuits.

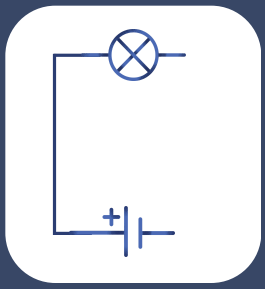


# Completing the Circuit

**SAMPLE ANSWER**



Bulb lights up



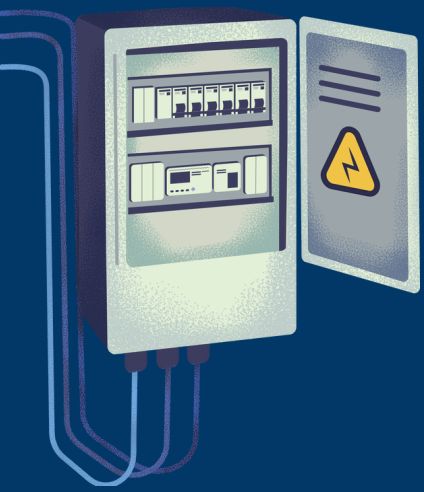
Bulb does not light up

# Completing the Circuit

**EXTENSION ACTIVITY**

With the help of your teacher or carer, test whether your suggestions and diagrams will make the bulb light using actual batteries, a small lightbulb and wires.

# Ohm’s Law



## Ohm’s Law

**Ohm's Law** states that the **current through a conductor is directly proportional to the potential difference across it**, provided the temperature remains constant.

$$\text{current}\,(i) = \frac{\text{Voltage}\,(V)}{\text{Resistance}\,(\Omega)}$$

EXAMPLE

# Ohm's Law

Calculate the voltage, or potential difference, through a resistor with a resistance of 40 Ω with a current of 0.6 A flowing through it.

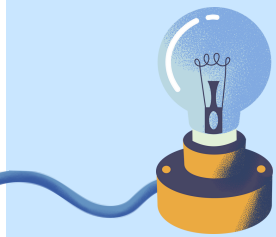
| STEP 1: WHAT ARE THE GIVEN AND MISSING VALUES? | STEP 2: WHICH FORMULA WILL WE BE USING? |
| --- | --- |
| i **Current (A)** = 0.6 A<br>Ω **Resistance (Ω)** = 0 Ω<br>V **Voltage (V)** = ? | $\text{current (i)} = \frac{\text{Voltage (V)}}{\text{Resistance (Ω)}}$<br>↓<br>**Voltage (V)** = Current (i) × Resistance (Ω) |

# Try this!

If the current is increased from 0.6 A to 2.2 A while maintaining the same voltage of 24 V, what will be the new resistance required?

# Try this!

If the current is increased from 0.6 A to 2.2 A while maintaining the same voltage of 24 V, what will be the new resistance required?



**ANSWER:**

| | |
|---|---|
| **Step 1:** What are the given and missing values? | **Current** (**A**) = 2.2 A<br>**Voltage** (**V**) = 24 V<br>**Resistance** (**Ω**) = ? |
| **Step 2:** Which formula will we be using? | $i = \frac{V}{\Omega}$ → $\Omega = \frac{V}{i}$ |
| **Steps 3 & 4:** Substitute the values, then solve. | $\Omega = \frac{V}{i} = \frac{24\ V}{2.2\ A} =$ **10.9 Ω.**<br>The new resistance required will be **10.9 Ω.** |

# Review

What is an electric circuit?

It is a complete path through which electric current flows.

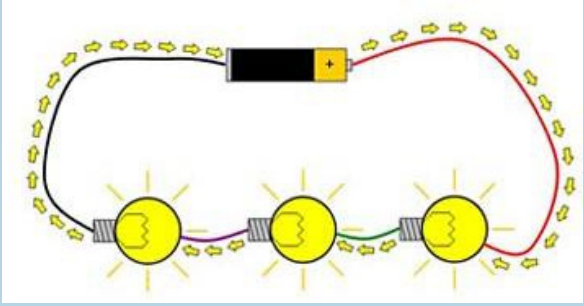
Some of its components include wires, a bulb and a power source (cell or battery).

A complete circuit features an unbroken loop where charges can flow.

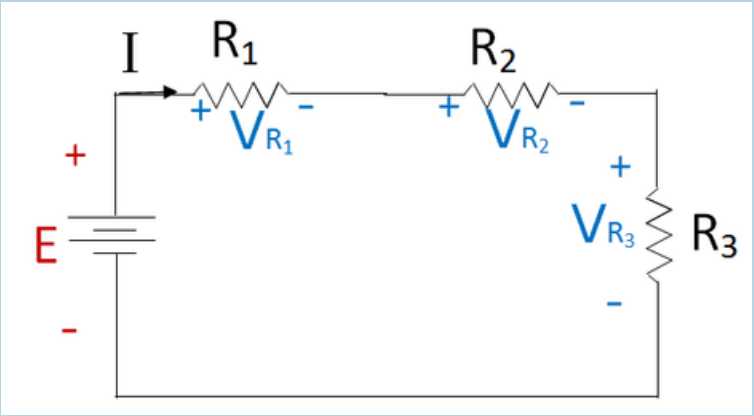
# Types of Circuit

## Series Circuit

- Is formed when any number of devices are connected end-to-end so that there is only one path for current to flow.



# Series Circuit Characteristics



# Series Circuit Characteristics

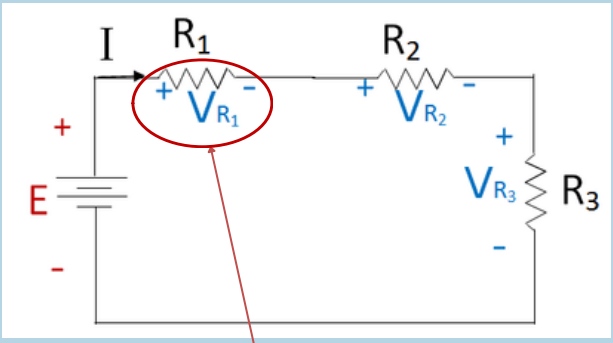
1. Resistances are additive
   $R_T = R_1 + R_2 + R_3$

2. The current flows throughout the circuit is same.
   $I = I_{R1} = I_{R2} = I_{R3}$

3. Different resistors have their individual voltage drop
   $V_{R1} \neq V_{R2} \neq V_{R3}$

4. Total e.m.f equals to the sum of voltage drops across each resistor
   $E = V_{R1} + V_{R2} + V_{R3}$

# Voltage Divider Rule




$$V_{R1} = \frac{R_1}{R_1 + R_2 + R_3} \times E$$

# Series Circuit (Example)

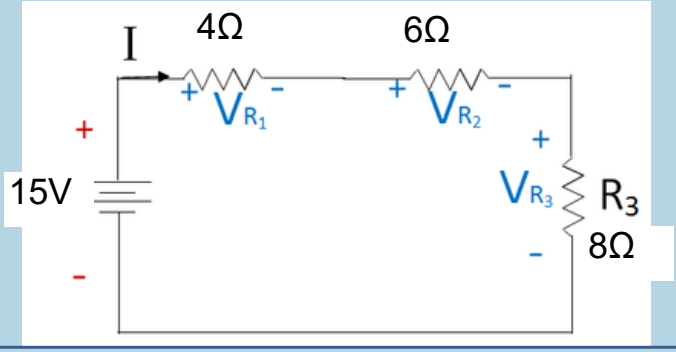
Example 1.9

By referring to the circuit above, calculate:

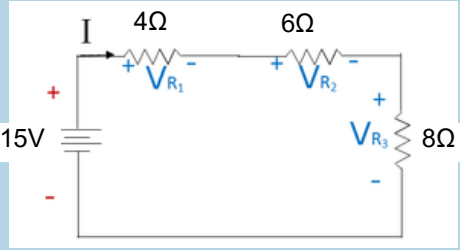
i. Total resistance of the circuit,

ii. Current, I

iii. Voltage drop across resistor 6Ω,



# Series Circuit (Example)




i) $R_{total} = 4 + 6 + 8$
$= 18\Omega$

ii) $I = \frac{E}{R} = \frac{15}{18} = 0.833A$

$V_{R2} = IR_2 = 0.833 \times 6 = 5V$

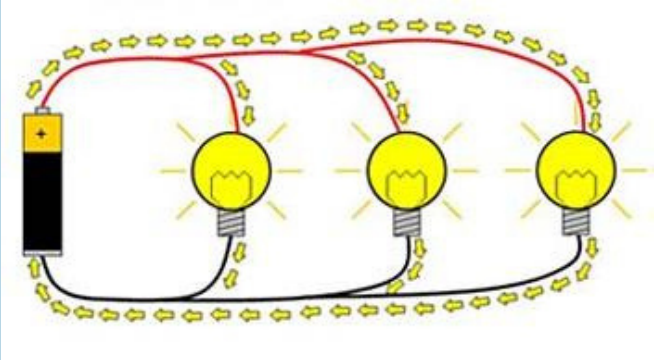
or

use VDR

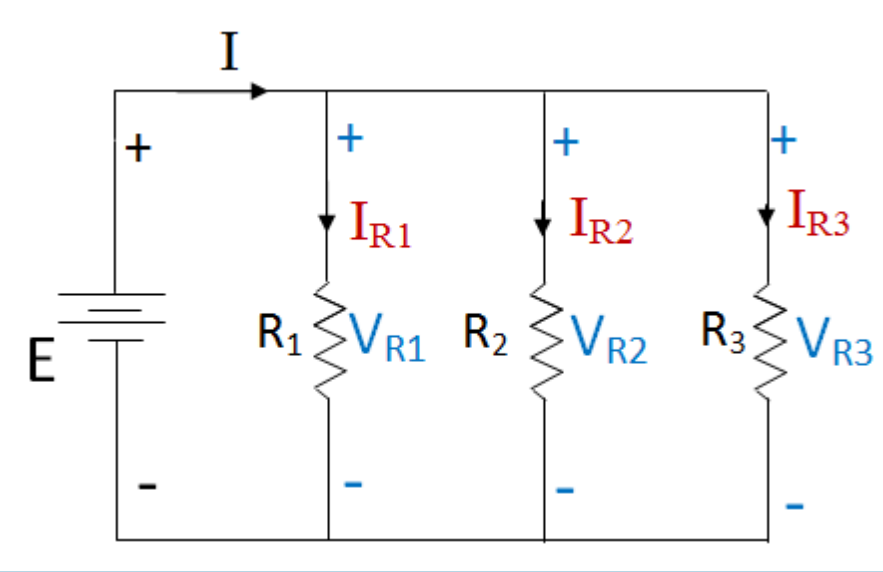
$$V_{R2} = \frac{R_2}{R_1 + R_2 + R_3} \times E = \frac{6}{4 + 6 + 8} \times 15 = 5V$$

# Parallel Circuit

- Is formed when two or more devices are arranged in a circuit side by side so that current can flow through more than one path



# Parallel Circuit Characteristic



# Parallel Circuit Characteristic

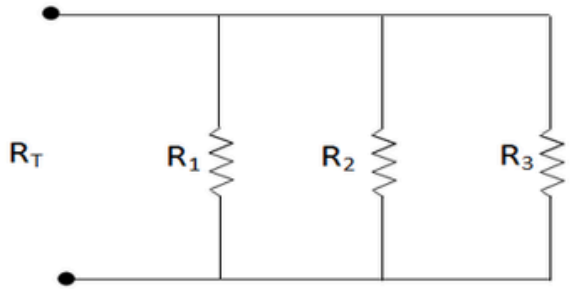
1. Total resistance can be determined from:
   $RT = 1/(1/R1 + 1/R2 + 1/R3)$

2. Different resistors have their individual current.
   $IR1 \neq IR2 \neq IR3$

3. Same voltage acts across all parts of the circuit
   $E = VR1 = VR2 = VR3$

4. Supplied current equals to the sum of different current flows through each resistor.
   $I = IR1 + IR2 + IR3$

# Equivalent resistance in parallel

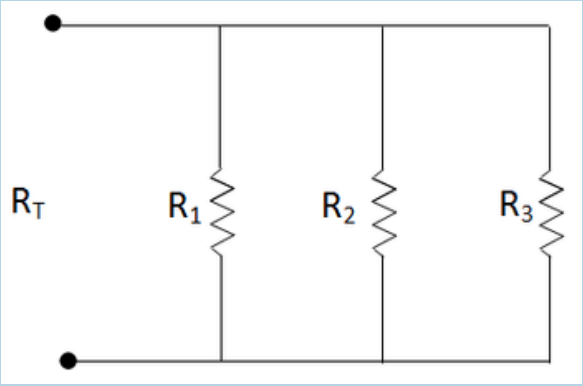



$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Equ. 1

- Applicable to any means of resistors.
- Standard equation of parallel connection resistors.

# Equivalent resistance in parallel

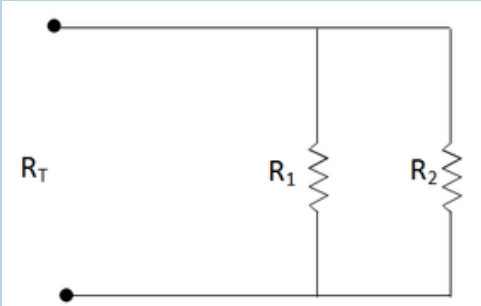



$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Equ. 1

- Applicable to any means of resistors.
- Standard equation of parallel connection resistors.

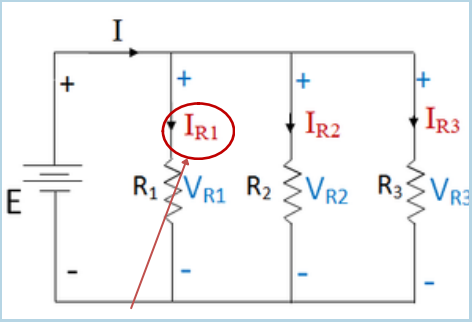
# Equivalent resistance in parallel (2 resistors case)




$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$ Equ. 2

- Applicable for 2 resistors connection only.

# Current Divider Rule (CDR)

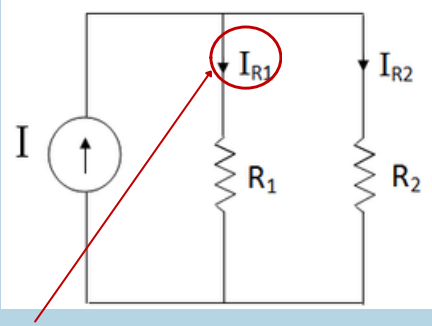



$$I_{R1} = \frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \times I$$

Equ. 1

- Applicable to any means of resistors.
- Standard equation of current divider rule

# Current Divider Rule (2 Resistors case)




$$I_{R1} = \frac{R_2}{R_1+R_2} \times I$$

Equ. 2

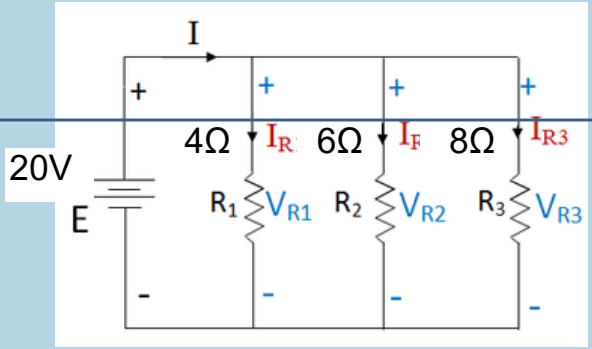
- Applicable for 2 resistors connection only.

# Parallel Circuit (Example)

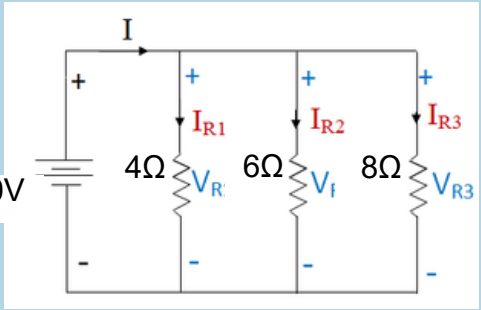
Example 1.10

QUESTION: By referring to the circuit above, calculate:

i. Total resistance of the circuit,
ii. Current, I
iii. Voltage drop across resistor 8Ω,
iv) Current through resistor 4Ω,



# Parallel Circuit (Example)




i) $R_{total} = \frac{1}{\frac{1}{4}+\frac{1}{6}+\frac{1}{8}} = 1.846\Omega$

ii) $I = \frac{E}{R} = \frac{20}{1.846} = 10.83A$

iii) $V_{R3} = E = 20V$

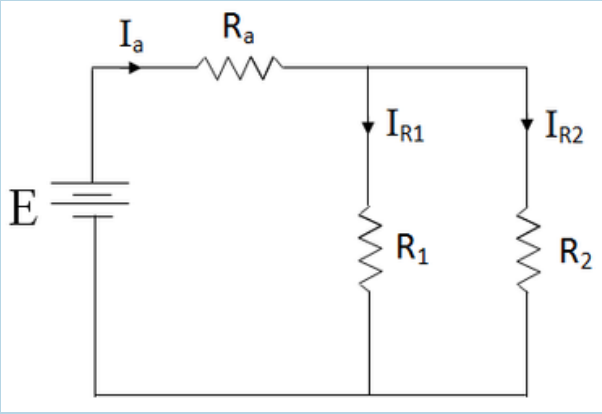
iv) $I_{R1} = \frac{V}{R} = \frac{20}{4} = 5A$

or

CDR

$$I_{R1} = \frac{\frac{1}{R_1}}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} \times I = \frac{\frac{1}{4}}{\frac{1}{4}+\frac{1}{6}+\frac{1}{8}} \times 10.83 = 5A$$

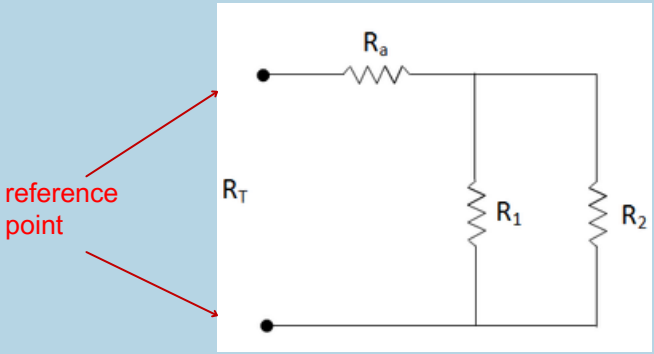
# Series-Parallel Circuit




For this diagram:

- R1 is parallel with R2.
- Ra is series with equivalent resistance of R1 and R2.

# Total Resistance of Series-Parallel Circuit

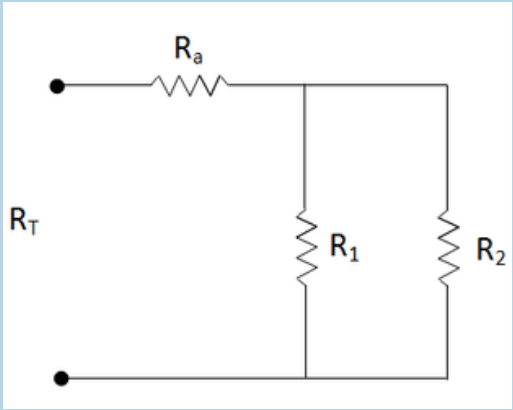



- RT is the equivalent resistance of Ra, R1 and $R_2$
- Start solving by calculating the total resistance of parts located farthest away from the reference point.
- *Exception: if there are any series/parallel connection resistors at any part of circuit which is not farthest from the reference point, solve the total resistance of the series/parallel connection first. Then you can use the tips mentioned above to solve your problem.*

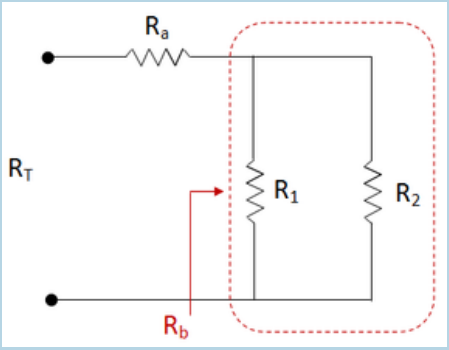
# Total Resistance of Series–Parallel Circuit (Example )

Example 1.11

Calculate equivalent resistance,  of the circuit below.



# Total Resistance of Series-Parallel Circuit (Example )




Rb =

# Summary

## Current

**Current** is the rate of flow of charge in a circuit. This flow is in the form of electrons flowing through a circuit. Current is measured in amperes (A) using an ammeter.

## Voltage

**Voltage** is the pressure or push behind the flow of current. It is measured in volts (V) using a voltmeter. Voltage is also referred to as potential difference.

## Resistance

**Resistance** opposes current flow and is measured in ohms (Ω). It can be calculated by dividing the voltage by the current.

## Circuit

**Electrical circuit** can be constructed in series, parallel and combination of series-parallel connection.

# Practical Application

## Video Practical Work 1

## Video Practical Work 2

## Video Practical Work 3

# References


1)John Bird. Electrical Circuit Theory & Technology. Fourth Edition. Newness. (ISBN: 978-0-08-089056-2)

2)Allan R. Hambley. Electrical Engineering, Principles and Applications, Fifth Edition. Prentice Hall. (ISBN-13: 978-0-13-213006-6)

3)B.L. Theraja.Textbook of Electrical Technology .S Chand & Co Ltd. (ISBN: 978-8121924900)

4)Allan R. Hambley. Electrical Engineering, Principles and Applications, Fifth Edition. Prentice Hall. (ISBN-13: 978-0-13-213006-6)

5)Darren Ashby. Electrical Engineering 101, (3rd Ed ) [Paperback] Elsevier Inc. (ISBN: 978-0123860019)

6)John Bird. Electrical And Electronic Principles And Technology. Fourth Edition. Newness. (ISBN: 978-1-85617-770-2)

7)Meizhong Wang. Understandable Electric Circuits First edition © 2005 Higher Education Press, China, English translation ©2010 The Institution of Engineering and Technology. (ISBN 978-0-86341-952-2)

8)V. K. Mehta. Principles of Electrical Engineering and Electrical [Paperback] S Chand & Co Ltd. (ISBN: 978-8121927291)