



**EDO UNIVERSITY IYAMHO**  
**Department of Physics**  
**PHY 213 - Electric Circuit & Electronics (3 Credit Unit)**



**Instructor:** Dr A.S. OLAYINKA  
**Email:** [akinola.olayinka@edouniversity.edu.ng](mailto:akinola.olayinka@edouniversity.edu.ng)  
**Phone:** +234- 8062447411  
**Lectures:** Wednesday, 10.00am – 12.00 pm  
Thursday, 8.00 - 9.00am  
**Venue:** PHYSICS LAB., Faculty of Science  
**Office:** Faculty of Science, New Building, Room  
**Office hours:** Wednesday: 12.00 - 2.00 pm

**Description:** This course is intended to give the students a thorough knowledge of direct current (D.C) circuits, alternating current (A.C) circuits and introduction to basic electronics. This course covers advanced topics in semiconductors, the p-n junction, field effect transistors, bipolar transistors, characteristics and equivalent circuits, amplifiers, feedback, and oscillators.

**Prerequisites:** PHY 121 is a prerequisite to this course. Students are expected to be familiar with the concepts the basic electricity and magnetism.

**Assignments:** Assignments are due for submission on Wednesday at 8.00am the next week, unless otherwise noted. Assignment There We expect to have five individual homework assignments throughout the course in addition to a mid-semester Test and a final examination.

**Grading:** We will assign 10% of this class grade to home works and assignments, 05% for attendance, 15% for the mid-semester test and 70% for the final examination. The final examination is comprehensive.

**Course Materials:**

Lecture notes and presentation are available at the [EUI-LMS](#).

**Learning outcomes:** At the completion of this course, students (learners) are expected to:

- i. Appreciate that electrical systems may be represented by circuit diagram
- ii. Identify basic electrical circuit symbols
- iii. Understand the units of electrical current, potential difference (p.d) and resistance to be amperes (A), volt (v) and ohm ( $\Omega$ ) respectively
- iv. Understand sources of EMF
- v. Understand Network theorems and use the same for network analysis and calculation
- vi. Understand the principle of transformer
- vii. Understand Basic Electronics
- viii. Understand Semiconductor theory and its application to electronics

- ix. Understand principles of PN junction, BJT and FET
- x. Design a simple circuit e.g. Voltage divider, power supply

**Software Requirement:**

MATLAB, JAVA

**Reference Books:**

The recommended and referenced textbooks for this class are:

Title: **Electrical and Electronic Principles and Technology** (available in [library](#))  
Author: John Bird  
ISBN: 978-0-75-068556-6  
Publisher: Newnes, UK, USA  
Edition: 3<sup>rd</sup> Edition, 2007

Title: **Electronic Devices and Circuits** (available in [library](#))  
Author: Dr. K. Lal Kishore  
ISBN: 81-7800-167-5  
Publisher: BS Publications, Hyderabad

Title: **A Textbook of Electrical Technology**  
Authors: B.L. Theraja and A.K. Theraja  
ISBN: 81-219-2441-3  
Publisher: S. Chand & Company Ltd.

## **MODULE 1 - D.C. CIRCUITS; KIRCHHOFF'S LAWS, SOURCES OF EMF**

### **Intended Learning Outcome:**

At the end of this module, the students (learners) are expected to:

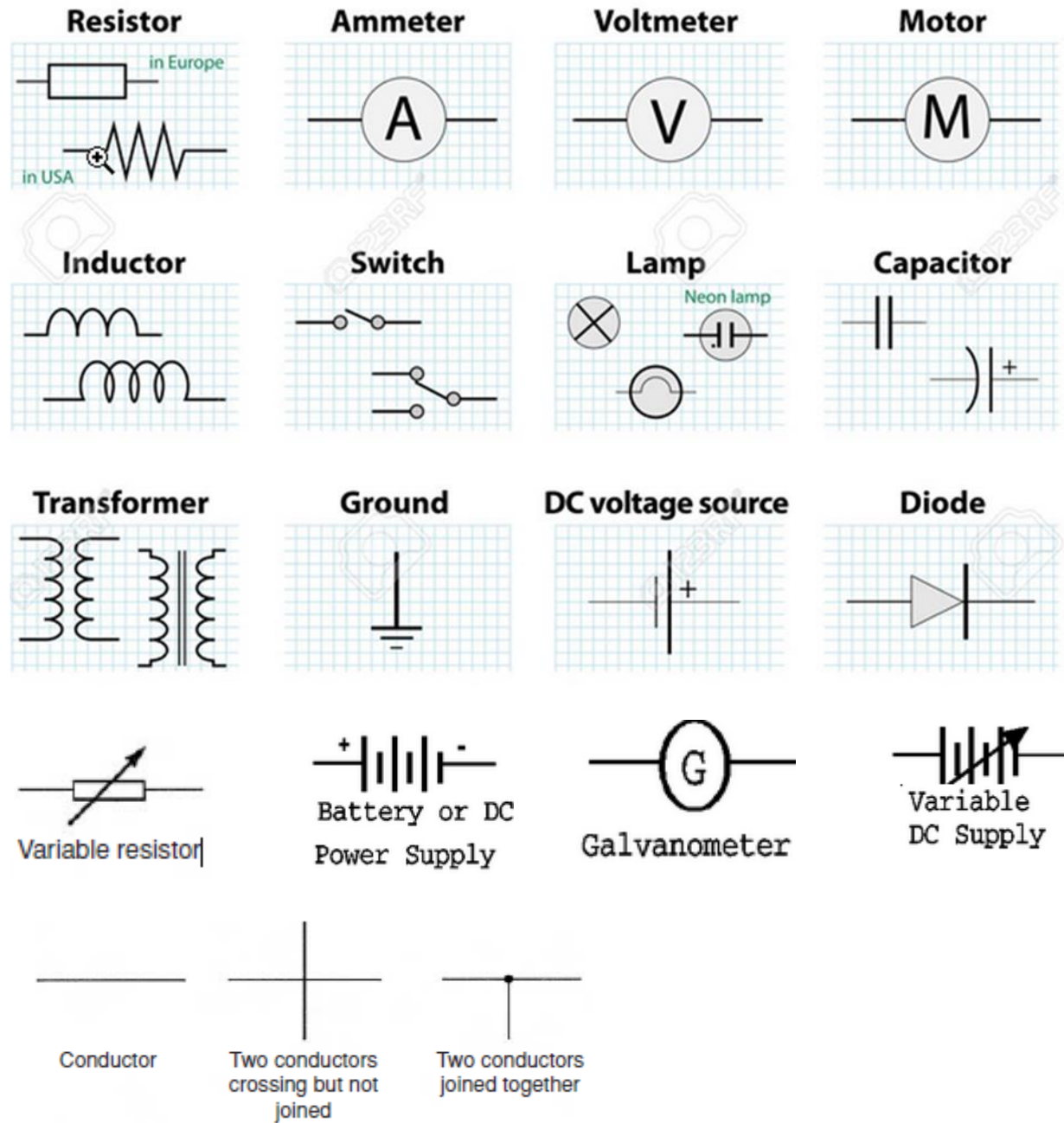
- Appreciate that electrical systems may be represented by circuit diagram
- Identify basic electrical circuit symbols
- Understand the units of electrical current, potential difference (p.d) and resistance to be amperes (A), volt (v) and ohm ( $\Omega$ ) respectively
- Understand sources of EMF
- Appreciate that the unit of charge is the coulomb
- Understand that a potential difference between two points in a circuit is required for current to flow
- Recognise that resistance opposes current flow and is measured in ohms
- Appreciate what an ammeter, a voltmeter, an ohmmeter, a multimeter and an oscilloscope measure
- State Ohm's law mathematically as  $V = IR$  or  $I = V/R$  or  $R = V/I$
- Use Ohm's law in circuit analysis and calculations
- State Kirchhoff's circuit laws
- Use Kirchhoff's circuit laws in circuit analysis and calculations
- Appreciate that electrical power  $P$  is given by  $P = VI = I^2R = V^2/R$  with unit in watts

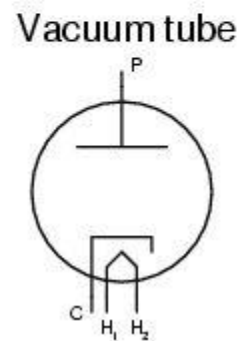
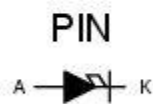
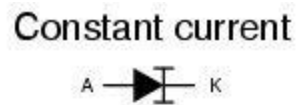
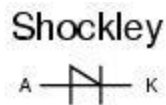
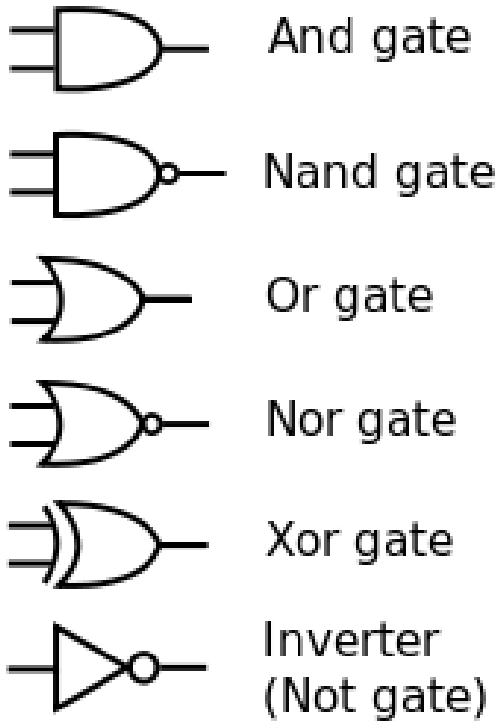
### **1.1 D.C. Circuit**

A Direct Current (DC) circuit is an electric circuit in which Current (I) flows through in one direction. DC circuits are usually found in many low-voltage applications, especially where these are powered by Battery.

Most electronic circuits require a DC power supply for their operations. Common devices / gadgets that use DC power supply are Television, Laptop, Mobile phones, Tablets, Computers, etc.

## 1.1.1 Electrical Circuit Symbols





<p>A = Anode          K = Cathode</p>
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### International System of Units (SI):

Dimension	Unit	Symbol	Relationship
Length	Meter	m	
Mass	Kilogram	kg	
Time	Seconds	s	
Temperature	Kelvin	K	
Voltage	Volt	V	
Current	Ampere	A	
Charge	Coulomb	C	$= (A)(s)$
Resistance	Ohm	$\Omega$	$= V / A$
Capacitance	Farad	F	$= C / V$
Inductance	Henry	H	$= (V)(s) / A$
Power	Watt	W	$= (V)(A)$
Frequency	Hertz	Hz	$= 1 / s$

## Prefixes & Scientific Notation

Prefix	Symbol	Magnitude	Prefix	Symbol	Magnitude
exa	E	$10^{18}$	atto	a	$10^{-18}$
peta	P	$10^{15}$	femto	f	$10^{-15}$
tera	T	$10^{12}$	pico	p	$10^{-12}$
giga	G	$10^9$	nano	n	$10^{-9}$
mega	M	$10^6$	micro	$\mu$	$10^{-6}$
kilo	k	$10^3$	milli	m	$10^{-3}$

Rewrite the following as indicated:

(a)  $1000 \text{ pF} = \dots \text{ nF}$

(b)  $0.02 \text{ } \mu\text{F} = \dots \text{ pF}$

(c)  $5000 \text{ kHz} = \dots \text{ MHz}$

(d)  $47 \text{ k}\Omega = \dots \text{ M}\Omega$

(e)  $0.32 \text{ mA} = \dots \text{ } \mu\text{A}$  ]

## 1.2 Charge and quantity of electricity:

The unit of charge is the coulomb (C) where one coulomb is one ampere second. (1 coulomb =  $6.24 \times 10^{18}$  electrons).

Coulomb is defined as the quantity of electricity which flows past a given point in an electric circuit when a current of one ampere is maintained for one second.

Charge,  $Q=It$

where I is the current in amperes (A) and t is the time in Seconds (s) .

### Example:

If a current of 6A flows for 4 minutes in a circuit, find the quantity of electricity transferred.

### Solution:

$$I = 6A, t = 4 \times 60 = 240 \text{ s}$$

$$Q = 6 \times 240 = 1440C = 1.44 \times 10^3C = 1.44kC$$

## 1.3 Electrical potential and e.m.f.:

- The unit of electric potential is the volt (V), where one volt is one joule per coulomb.
- One volt is defined as the difference in potential between two points in a conductor which, when carrying a current of one ampere, dissipates a power of one watt, i.e.

$$\text{volts} = \frac{\text{watts}}{\text{amperes}} = \frac{\text{joules/second}}{\text{amperes}} = \frac{\text{joules}}{\text{amperes second}} = \frac{\text{joules}}{\text{coulombs}}$$

- A change in electric potential between two points in an electric circuit is called a potential difference.



- The electromotive force (e.m.f.) provided by a source of energy such as a battery or a generator is measured in volts.

## 1.4 Resistance and conductance

The unit of electric resistance is the ohm( $\Omega$ )

One ohm is one volt per ampere.

$1\Omega$  is defined as the resistance between two points in a conductor when a constant electric potential of one volt, applied at the two points produces a current flow of one ampere in the conductor.

$$R = V / I$$

The reciprocal of resistance is called conductance,  $G$  and is measured in siemens (S).

$$G = 1 / R = I / V$$

Example: Find the conductance of a conductor of resistance:

(a)  $100\ \Omega$  (b)  $50\ \text{k}\ \Omega$  (c)  $150\text{m}\ \Omega$ .

## 1.5 Electrical power and energy

- When a direct current of  $I$  amperes is flowing in an electric circuit and the voltage across the circuit is  $V$  volts, then power, in watts  $P = VI$
- Electrical energy = Power  $\times$  time =  $VI$ t joules
- Although the unit of energy is the joule, when dealing with large amounts of energy, the unit used is the kilowatt hour (kWh) where
- $1\ \text{kWh} = 1000\text{watt hour} = 1000 \times 3600\ \text{watt seconds or joules} = 3\ 600\ 000\ \text{J}$

**Example:**

A source e.m.f. of 5V supplies a current of 3A for 10 minutes. How much energy is provided in this time?

**Solution:**

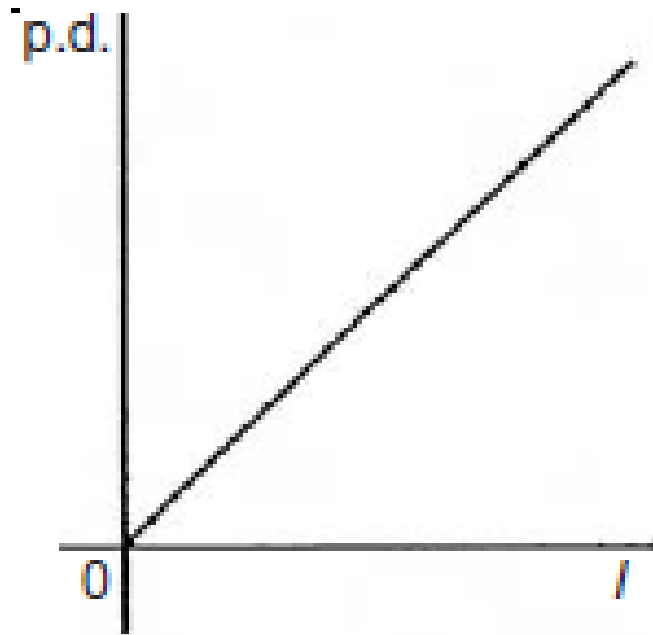
Energy = power×time, and power=voltage×current.

$$\begin{aligned}\text{Energy} &= VIt = 5 \times 3 \times (10 \times 60) \\ &= 9000 \text{ Ws or J} = 9\text{kJ}\end{aligned}$$

**1.6 Linear and non-linear devices**

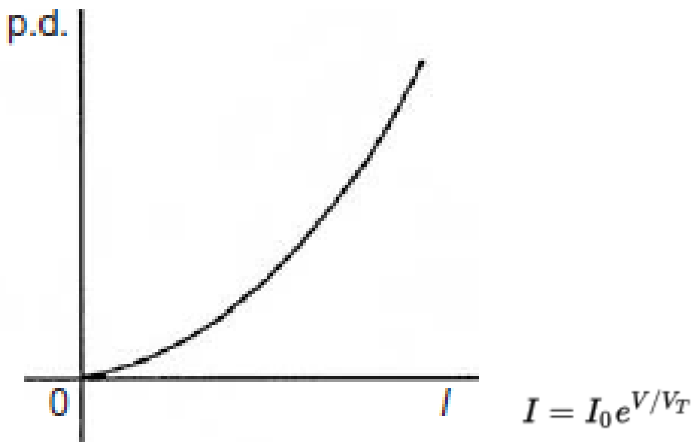
**A linear device/element** is an electrical element which has a linear relationship between current and voltage as in figure below. Obey Ohm's Law  $V=IR$

Examples are resistors, capacitors, and air core inductors



**A non-linear element / device** is an electrical element which does not have a linear relationship between current and voltage. Does not obey Ohm's law

- Examples are diode, transistor, iron-core inductors, vacuum tubes.



### 1.7 Ohm's law

- Ohm's law states that the current  $I$  flowing in a circuit is directly proportional to the applied voltage  $V$  and inversely proportional to the resistance  $R$ , provided the temperature remains constant. Thus,
- $I = V / R$  or  $V = IR$  or  $R = V / I$

**Example:** A 100W electric light bulb is connected to a 250V supply. Determine (a) the current flowing in the bulb, and (b) the resistance of the bulb.

**Solution:**

(a)  $I = P/V = 100/250 = 0.4\text{A}$

(b)  $R = V / I = 250 / 0.4 = 625\Omega$

## 1.8 Conductor and Insulator

- A conductor is a material having a low resistance which allows electric current to flow in it.
- All metals are conductors
- Examples are copper, aluminium, brass, platinum, silver, gold and carbon.
- An insulator is a material having a high resistance which does not allow electric current to flow in it.
- Example are plastic, rubber, glass, porcelain, air, paper, cork, mica, ceramics and certain oils.

## 1.9 Sources of EMF

A battery is a device that converts chemical energy to electricity.

The electromotive force (e.m.f.),  $E$ , of a cell is the p.d. between its terminals when it is not connected to a load (i.e. the cell is on 'no load').

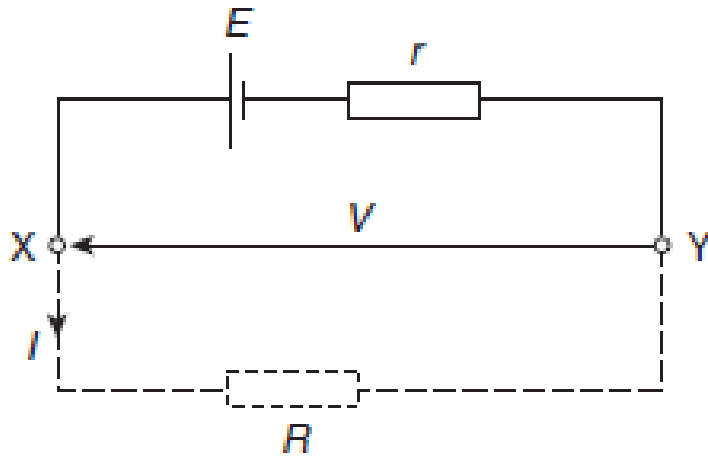
The e.m.f. of a cell is measured by using a high resistance voltmeter connected in parallel with the cell.

The voltmeter must have a high resistance otherwise it will pass current and the cell will not be on 'no-load'

The voltage available at the terminals of a cell falls when a load is connected. This is caused by the internal resistance of the cell which is the opposition of the material of the cell to the flow of current.

The internal resistance acts in series with other resistances in the circuit.

The fig shows a cell of e.m.f.  $E$  volts and internal resistance,  $r$ , and  $XY$  represents the terminals of the cell



When a load (shown as resistance  $R$ ) is not connected, no current flows and the terminal p.d.,  $V = E$ . When  $R$  is connected a current  $I$  flows which causes a voltage drop in the cell, given by  $Ir$ . The p.d. available at the cell terminals is less than the e.m.f. of the cell and is given by  $V = E - Ir$

Since  $V = E - Ir$  then the internal resistance may be calculated using

$$r = (E - V) / I$$

A battery is a combination of more than one cell. The cells in a battery may be connected in series or in parallel

- **For cells connected in series:**

Total e.m.f. = sum of cell's e.m.f.s

Total internal resistance = sum of cell's internal resistances

- **For cells connected in parallel:**

If each cell has the same e.m.f. and internal resistance:

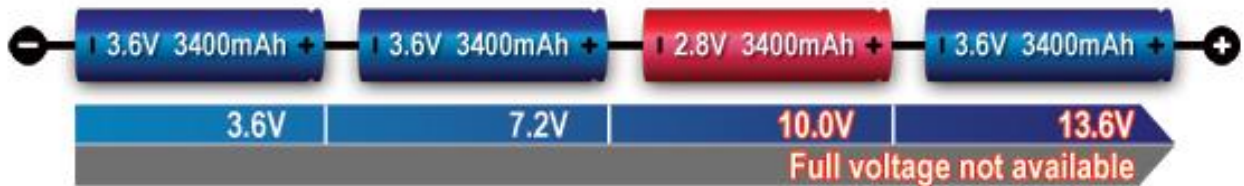
Total e.m.f. = e.m.f. of one cell

Total internal resistance of  $n$  cells =  $(1 / n) \times$  internal resistance of one cell.

**For cells connected in series: (Positive to Negative)**

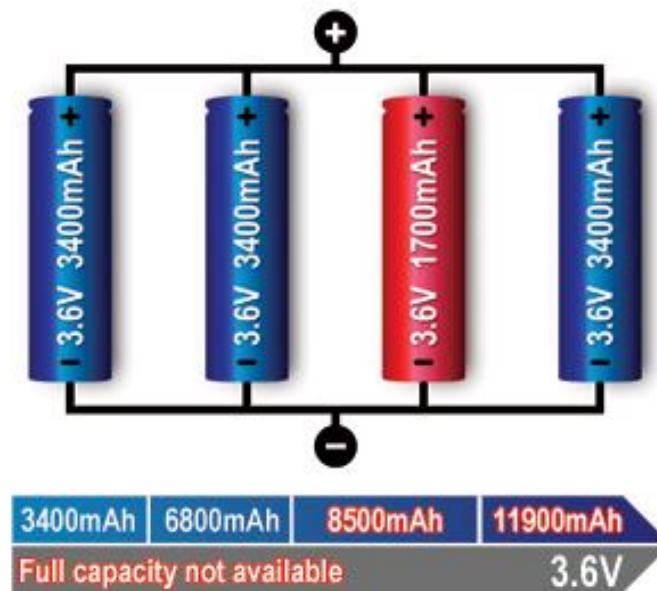
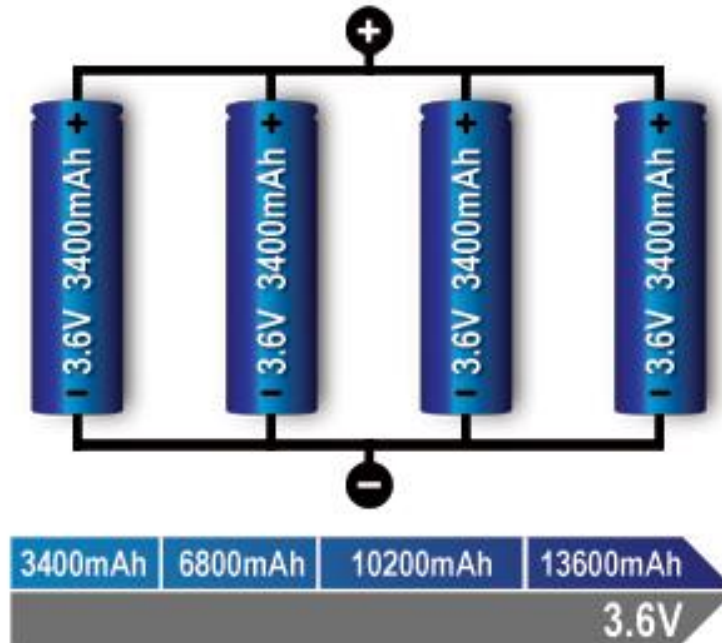


**For cells in series with a faulty cell the full voltage supply will be disrupted.**

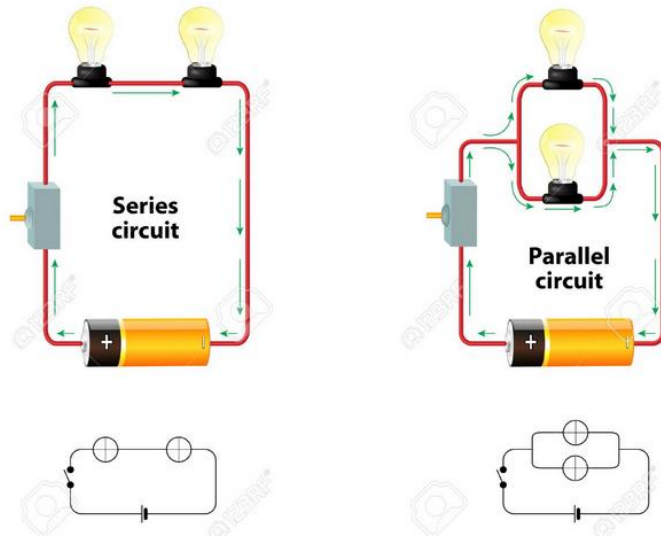


**For cells connected in parallel: (Positive to Positive and Negative to Negative)**

**With parallel cells, capacity in Ah and runtime increases while the voltage stays the same.**



## 1.10 Series and Parallel Circuit



### Series and Parallel Circuit

#### Parallel Circuit: Application - Current Division

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

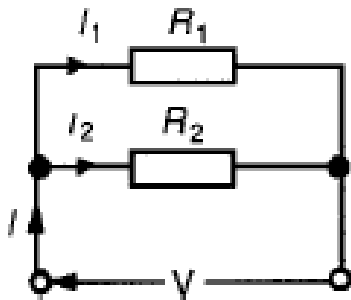
and

$$V = IR_T = I \left( \frac{R_1 R_2}{R_1 + R_2} \right)$$

Current

$$I_1 = \frac{V}{R_1} = \frac{I}{R_1} \left( \frac{R_1 R_2}{R_1 + R_2} \right)$$

$$= \left( \frac{R_2}{R_1 + R_2} \right) (I)$$



current

$$I_2 = \frac{V}{R_2} = \frac{I}{R_2} \left( \frac{R_1 R_2}{R_1 + R_2} \right)$$

$$= \left( \frac{R_1}{R_1 + R_2} \right) (I)$$

$$I_1 = \left( \frac{R_2}{R_1 + R_2} \right) (I)$$

$$I_2 = \left( \frac{R_1}{R_1 + R_2} \right) (I)$$



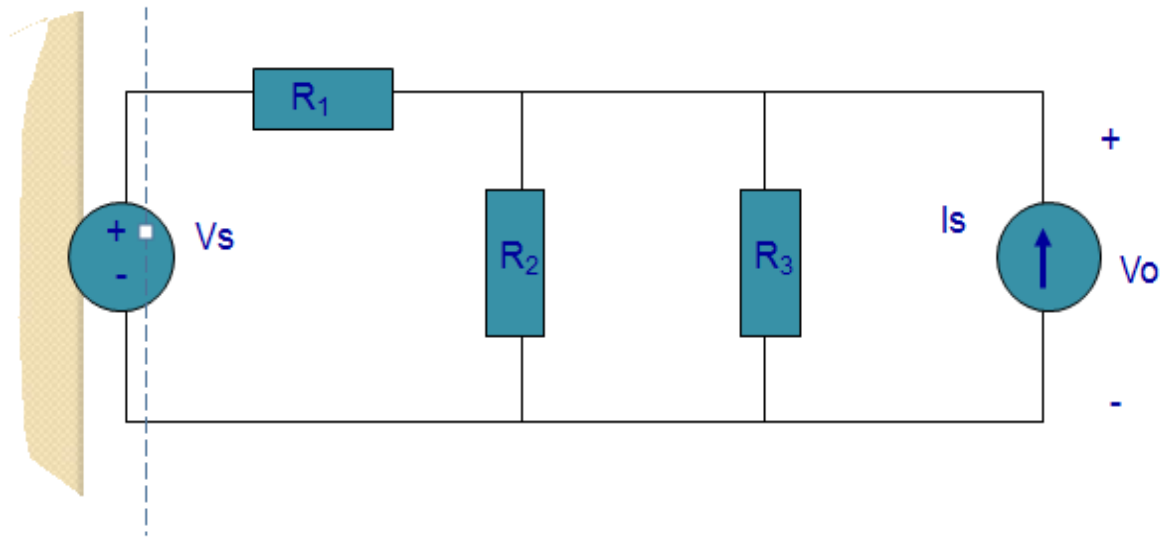
## 1.11 Kirchhoff's Law

We have Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL)

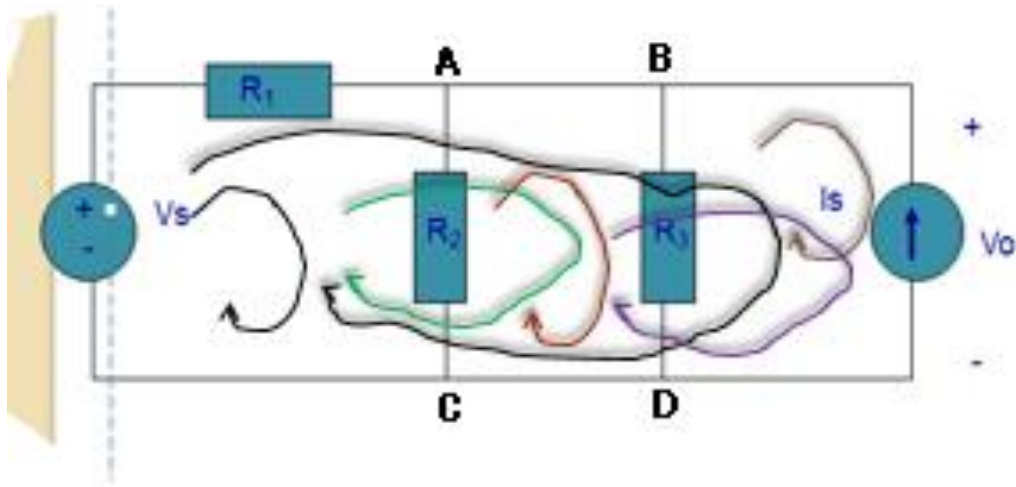
- In understanding the Laws, we define:

1. **Node** – a point or junction where 2 or more elements connect.
2. **Branch** – a single element such as voltage source or a resistor. *Branches are the connections between nodes. A branch is an element (resistor, capacitor, source, etc.). The number of branches in a circuit is equal to the number of elements.*
3. **Loop** – is any closed path in a circuit.

How many nodes & loops?

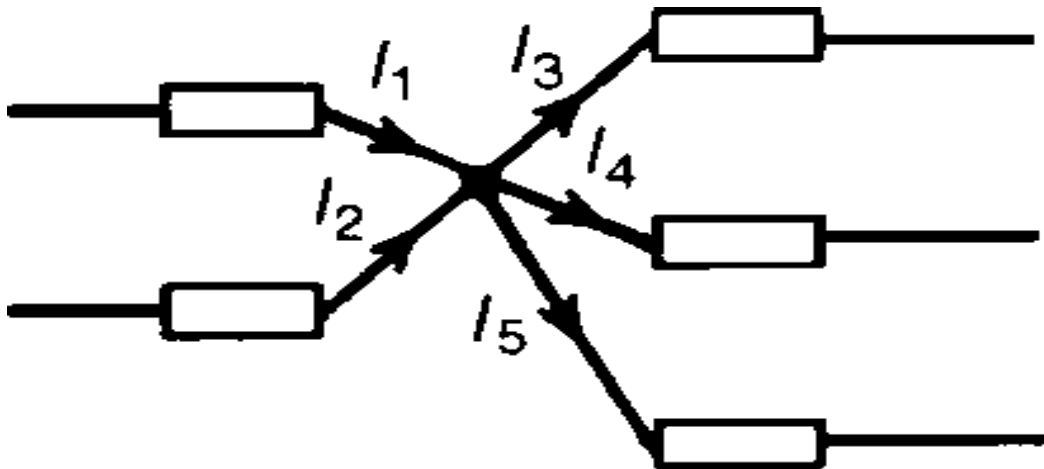


We have 6 loops, and 4 nodes (A, b, C, D)



### 1.11.1 Kirchhoff's Current Law (KCL)

KCL states that at any junction/point in an electric circuit the total current flowing towards that junction is equal to the total current flowing away from the junction.

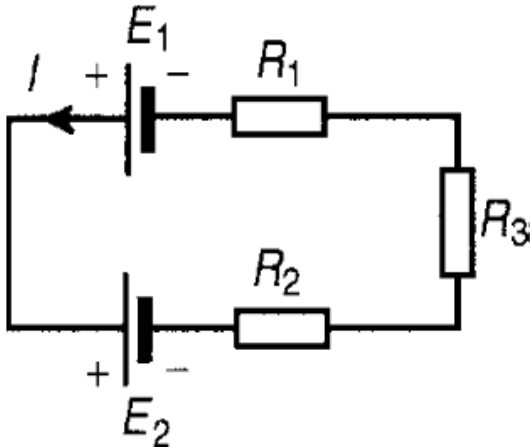


$$I_1 + I_2 = I_3 + I_4 + I_5$$

$$I_1 + I_2 - I_3 - I_4 - I_5 = 0$$

### 1.11.2 Kirchhoff's Voltage Law (KVL)

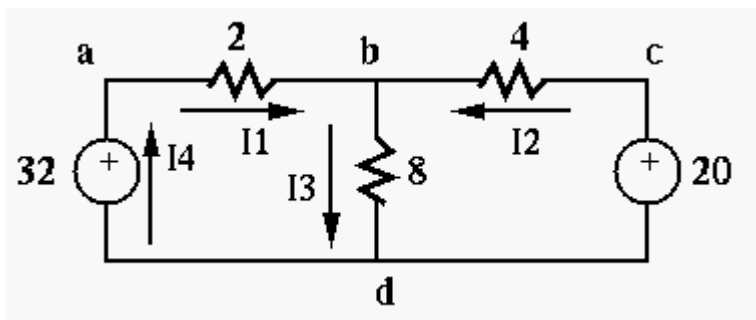
In any closed loop in a network, the algebraic sum of the voltage drops (i.e. products of current and resistance) taken around the loop is equal to the resultant e.m.f. acting in that loop.



$$E_1 - E_2 = IR_1 + IR_2 + IR_3$$

### Examples

Find the three unknown currents ( $I_1, I_2, I_3$ ) and three unknown voltages ( $V_{ab}, V_{bd}, V_{cb}$ ) in the circuit below:



### Note:

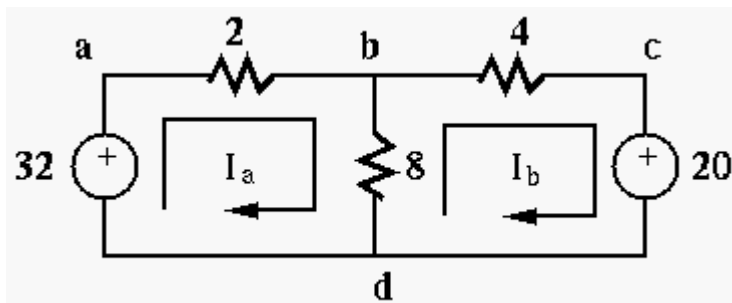
- The direction of a current and the polarity of a voltage source can be assumed arbitrarily.

- To determine the actual direction and polarity, the sign of the values also should be considered. For example, a current labeled in left-to-right direction with a negative value is actually flowing right-to-left.

All voltages and currents in the circuit can be found by either of the following two methods, based on either the KVL or KCL.

**The loop-current method based on KVL:**

1. For each of the  $\ell$  independent loops in the circuit, define a loop current around the loop in clockwise (or counter clockwise) direction. These  $\ell$  loop currents are the unknown variables to be obtained.
2. Apply KVL around each of the loops in the same clockwise direction to obtain  $\ell$  equations. While calculating the voltage drop across each resistor shared by two loops, both loop currents (in opposite positions) should be considered.
3. Solve the equation system with  $\ell$  equations for the  $\ell$  unknown loop currents.



Find currents  $I_1$  from a to b,  $I_2$  from c to b, and  $I_3$  from b to d.

Assume two loop currents  $I_a$  and  $I_b$  around loops abda and bcdb and apply the KVL to them:

$$\begin{aligned} \sum V_{abda} &= -32 + 2I_a + 8(I_a - I_b) = 0 \\ \sum V_{bcdb} &= 8(I_b - I_a) + 4I_b + 20 = 0 \end{aligned}$$

We rewrite these as:

$$\begin{cases} 10I_a & -8I_b & = & 32 \\ -8I_a & +12I_b & = & -20 \end{cases} \implies \begin{cases} I_a = 4 \\ I_b = 1 \end{cases}$$

and then get  $I_1 = I_a = 4$ ,  $I_2 = -I_b = -1$ , and  $I_3 = I_a - I_b = 3$ . Having found

$I_a$  and  $I_b$ , we can easily find all voltages in the circuit:  $V_a = 32V$ ,

$V_b = 32 - 2 \times 4 = 24V$ ,  $V_c = 20V$ .

### ALTERNATIVELY

We could also apply KVL around the third loop of abcda with a loop current  $I_c$  to get three equations:

$$\begin{aligned} \sum V_{abda} &= -32 + 2(I_a + I_c) + 8(I_a - I_b) = 0 \\ \sum V_{bcdb} &= 8(I_b - I_a) + 4(I_b + I_c) + 20 = 0 \\ \sum V_{abcda} &= -32 + 2(I_a + I_c) + 4(I_b + I_c) + 20 = 0 \end{aligned}$$

However, it is clear that the third equation is the sum of the first two, i.e., it is not independent.

- Alternatively, consider the two loop currents  $I_a$  and  $I_c$  around loops abda and bcdb:

$$\begin{aligned} \sum V_{abda} &= -32 + 2(I_a + I_c) + 8I_a = 0 \\ \sum V_{bcdb} &= -32 + 2(I_a + I_c) + 4I_c + 20 = 0 \end{aligned}$$

i.e.,

$$\begin{cases} 10I_a + 2I_c = 32 \\ 2I_a + 6I_c = 12 \end{cases} \implies \begin{cases} I_a = 3 \\ I_c = 1 \end{cases}$$

and we get  $I_1 = I_a + I_c = 4$  and  $I_2 = -I_c = -1$ , same as the previous results.

**References:**

John Bird . **Electrical and Electronic Principles and Technology**. Newnes, UK, USA. 3<sup>rd</sup> Edition, 2007

Dr. K. Lal Kishore. **Electronic Devices and Circuits** .BS Publications, Hyderabad

B.L. Theraja and A.K. Theraja. **Textbook of Electrical Technology**. S. Chand & Company Ltd.

<http://fourier.eng.hmc.edu/e84/lectures/ch2/node2.html>