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Introduction

➢ Electrical systems pervade our lives; they are found in home, school, workplaces, factories, and transportation vehicles—everywhere.

➢ A circuit model is used to connect our visualization to our analysis of a physical system.

➢ The challenge is to develop models that will predict the physical behaviour of real components accurately and result in mathematical equations that can be solved.
Basic Electrical Quantities

Basic quantities: current, voltage and power.

**Electric current:**
Electric current in a wire is defined as the net amount of charge that passes through the wire per unit time, and is measured in amperes (A).

\[ i = \frac{dq}{dt} \]

where
- \( i \) = current in amperes
- \( q \) = charge in coulombs
- \( t \) = time in sec.

- 1 Ampere = 1 Coulomb per second (C/s)
- Current in circuits physically realized by movement of electrons.
- Direction of current must be specified by an arrow.
- By convention, current direction defined as flow of positive charge.
- Note that positive charge is not flowing physically.
- Electrons have negative charge.
- They move in the opposite direction of current.

In general, current can be an arbitrary function of time. Constant current is called direct current (DC). Current that can be represented as a sinusoidal function of time (or in some contexts a sum of sinusoids) is called alternating current (AC).
Voltage
Voltage is the energy absorbed or expended as a unit charge moves from one point to the other.

- Analogous to pressure in hydraulic system.
- Sometimes called potential difference.
- Can be created by a separation of charge.
- Is a measure of the potential between two points.
- Voltage pushes charge in one direction.
We use polarity (+ and – on batteries) to indicate which direction the charge is being pushed.

Voltage is the energy required to move a unit charge through an element, measured in volts (V):

\[ v = \frac{d\omega}{dq} \]

where

- \( v \) = voltage in volts
- \( \omega \) = energy in Joules
- \( q \) = charge in coulombs
Voltage ~ Pressure
Electric Current ~ Water Current
Sponge ~ Resistance
**Electrical Power**

Time rate of expending or absorbing energy and is measured by Watts.

\[ p = \frac{d\omega}{dt} \]

\[ p = \left( \frac{d\omega}{dq} \right) \left( \frac{dq}{dt} \right) = vi \]

where

- \( p \) = power in watts
- \( \omega \) = energy in Joules
- \( t \) = time in seconds
- \( q \) = charge in coulombs
- \( i \) = current in apperbes
- \( v \) = voltage in volts

By convention

- Circuit elements that absorb power have a positive value of \( p \).
- Circuit elements that produce power have a negative value of \( p \).
Elements of electrical circuits

Active elements

Active elements are the elements that can generate energy or power, such as voltage and current sources.

- Ideally, a voltage source produces $V_s$ volts regardless of the current absorbed or produced by the connected device.

- Ideally, a current source produces $I_s$ amps regardless of the current in the connected device.

- In a particular circuit, there can be active elements that absorb power – for example, a battery being charged.
Passive elements

Passive elements are the elements that can not generate energy, such as resistors, capacitors, and inductors.

Resistors

- The ability of a material to resist (impede, obstruct) the flow of charge is called its resistivity. It is represented by the letter R.
- A resistor is a circuit element that dissipates electrical energy (usually as heat).
- Real-world devices that are modeled by resistors: incandescent light bulbs, heating elements, long wires.
- Resistance is measured in Ohms (Ω).
- Resistor is indicated by the symbol. 

Diagram of passive elements and resistors.
Resistance of a wire depends on some factors like as length \((L)\), cross-sectional area \((A)\) and resistivity of material \((\rho)\).

\[
R = \frac{\rho L}{A}
\]

Where \(\rho\) resistivity in \(\Omega \cdot m\)
\(L\) length in m
\(A\) cross-section area in \(m^2\)

The conductance \((G)\) of a pure resistor is the reciprocal of its resistance. The unit of conductance is the siemens \((S)\) or mho \((\Omega)\).

\[
G = \frac{1}{R}
\]
Ohm’s Law

Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them.

The mathematical equation that describes this relationship is:

\[ i = \frac{v}{R} \]

where \( v \) is the potential difference measured across the resistance in units of volts; \( i \) is the current through the resistance in units of amperes and \( R \) is the resistance of the conductor in units of ohms.
Two elements are in series if the current that flows through one must also flow through the other.

- If we wish to replace the two series resistors with a single equivalent resistor whose voltage-current relationship is the same, the equivalent resistor has a value given by

\[ R_{eq} = R_1 + R_2 \]
For N resistors in series, the equivalent resistor has a value given by:

\[ R_{eq} = R_1 + R_2 + R_3 + \Lambda + R_N \]
Consider two resistors in series with a voltage $v$ across them:

Voltage division:

$$v_1 = v \frac{R_1}{R_1 + R_2}$$

$$v_2 = v \frac{R_2}{R_1 + R_2}$$
Resistors in Parallel

- When the terminals of two or more circuit elements are connected to the same two nodes, the circuit elements are said to be in **parallel**.

- If we wish to replace the two parallel resistors with a single **equivalent** resistor whose voltage-current relationship is the same, the **equivalent** resistor has a value given by

\[ R_{eq} = \frac{R_1 \cdot R_2}{R_1 + R_2} \]
Consider two resistors in parallel with a voltage $v$ across them:

$$i_1 = i \frac{R_2}{R_1 + R_2}$$

$$i_2 = i \frac{R_1}{R_1 + R_2}$$