Basic Concepts of Electrical Circuit-I

Electric Circuit: An electric circuit is an interconnection of electrical elements.

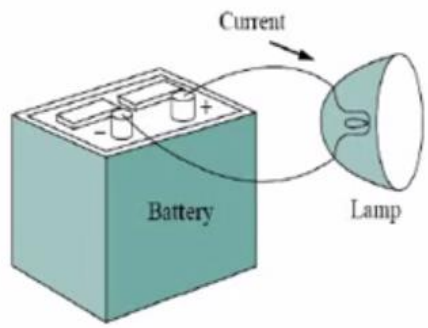

Fig 1: A simple electric circuit

Charge (q): The most basic quantity in an electric circuit is the electric charge. Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

We also know that the charge e on an electron is negative and equal in magnitude to $1.602\times10-19$ C, while a proton carries a positive charge of the same magnitude as the electron.

Current (I): Electric current is the time rate of change of charge, measured in amperes (A).

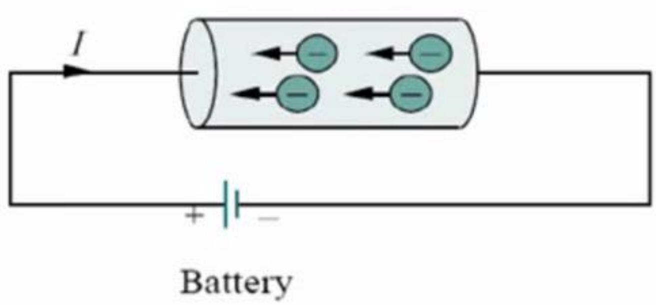

Fig 2: Electric current due to flow of electronic charge in a conductor

Mathematically, the relationship between current i, charge q, and time t is -

$$i = \frac{dq}{dt}$$

Direct Current (DC): A direct current (dc) is a current that remains constant with time.

Alternating Current (AC): An alternating current (ac) is a current that varies sinusoidally with time.

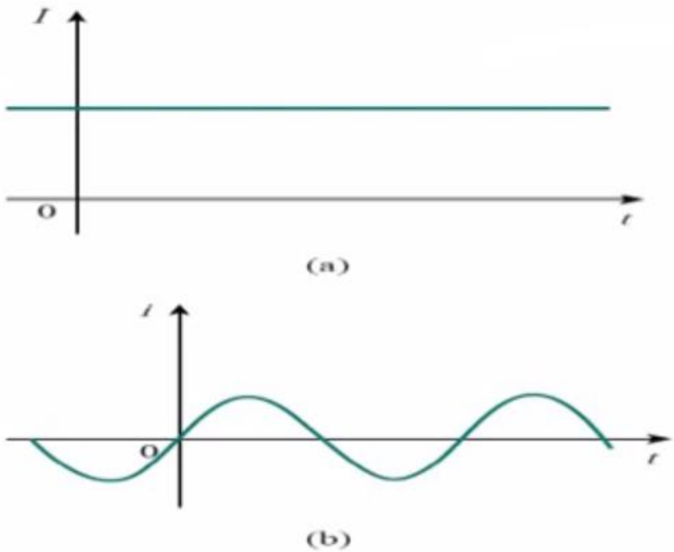

Fig 3: Two common types of current: (a) direct current (dc), (b) alternating current (ac).

<u>Voltage (V):</u> Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

Like electric current, a constant voltage is called **a dc voltage** and is represented by V, whereas a sinusoidally time-varying voltage is called an **ac voltage** and is represented by v.

<u>Energy and Power:</u> **Energy** is the capacity to do work, measured in joules (J).

The electric power utility companies measure energy in watt-hours (Wh), where

$$1 \text{ Wh} = 3{,}600 \text{ J}$$

Power is the time rate of expending or absorbing energy, measured in watts (W).

We write this relationship as

$$p = \frac{dw}{dt}$$

where p is power in watts (W), w is energy in joules (J), and t is time in seconds (s).

Or we can say that $$p = vi$$

The power p is a time-varying quantity and is called the instantaneous power. Thus, the power absorbed or supplied by an element is the product of the voltage across the element and the current through it. If the power has a + sign, power is being delivered to or absorbed by the element. If, on the other hand, the power has a − sign, power is being supplied by the element.

Current direction and voltage polarity play a major role in determining the sign of power.

It is therefore important that we pay attention to the relationship between current i and voltage v in Fig. 4(a).

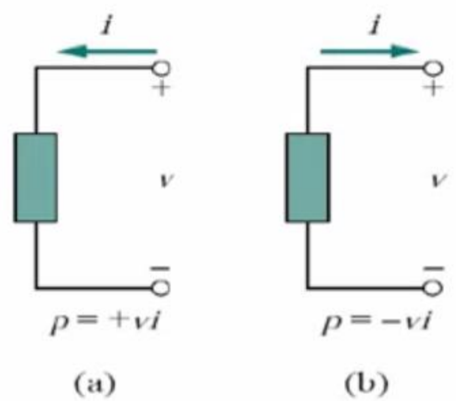

Fig 4: Reference polarities for power using the passive sign convention : (a) absorbing power,(b) supplying power

The voltage polarity and current direction must conform with those shown in Fig. 4(a) in order for the power to have a positive sign. This is known as the ***passive sign convention***. By the passive sign convention, current enters through the positive polarity of the voltage. In this case, $p = +vi$ or $vi > 0$ implies that the element is absorbing power.

However, if $p = -vi$ or $vi < 0$, as in Fig. 4(b), the element is releasing or supplying power.

Passive sign convention is satisfied when the current enters through the positive terminal of an element and $p = +vi$. If the current enters through the negative terminal, $p = -vi$.

Unless otherwise stated, we will follow the passive sign convention throughout this text. For example, the element in both circuits of Fig. 5 has an absorbing power of +12 W because a positive current enters the positive terminal in both cases. In Fig. 6, however, the element is supplying power of −12Wbecause a positive current enters the negative terminal. Of course, an absorbing power of +12 W is equivalent to a supplying power of −12 W. In general,

Power absorbed = −Power supplied

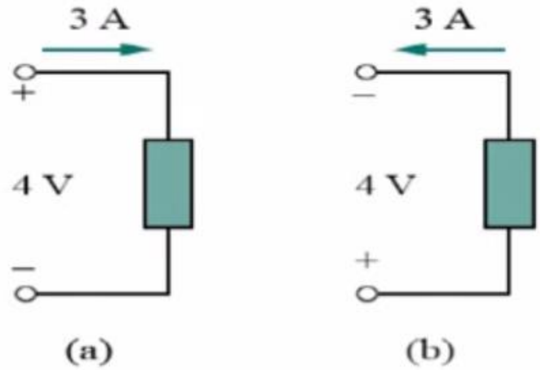

Fig.5: One case of an element with an absorbing power of 12 W: (a) $p = 4 \times 3 = 12$ W, (b) $p = 4 \times 3 = 12$ W

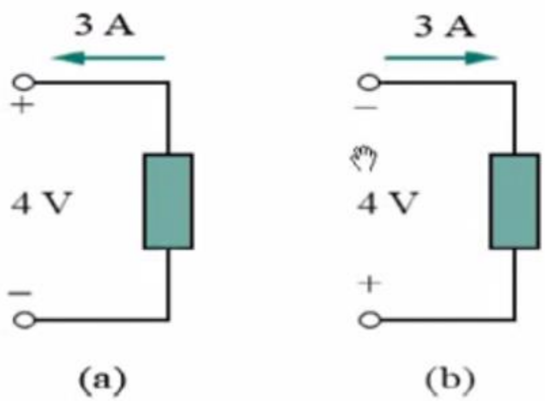

Fig.6: Another case of an element with an absorbing power of 12 W: (a) $p = 4 \times (-3) = -12$ W,

(b) $p = 4 \times (-3) = -12$ W

In fact, the law of conservation of energy must be obeyed in any electric circuit. For this reason, the algebraic sum of power in a circuit, at any instant of time, must be zero:

$$\sum p = 0$$

This again confirms the fact that the total power supplied to the circuit must balance the total power absorbed.

<u>Circuit Elements:</u> There are two types of elements found in electric circuits: **passive elements** and **active elements**.

An active element is capable of generating energy while a **passive element is** not.

Examples of passive elements are **resistors, capacitors, and inductors**. Typical active elements include **generators, batteries, and operational amplifiers.**

The most important active elements are voltage or current sources that generally deliver power to the circuit connected to them. There are two kinds of sources:

1. **Independent Source:** An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit variables.

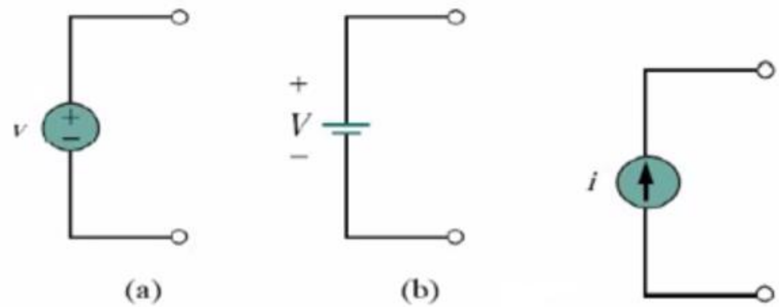

Fig.7. Symbols for independent voltage sources: (a) used for constant or time-varying voltage, (b) used for constant voltage (dc), (c) symbol for independent current source

2. **Dependent Source:** An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.

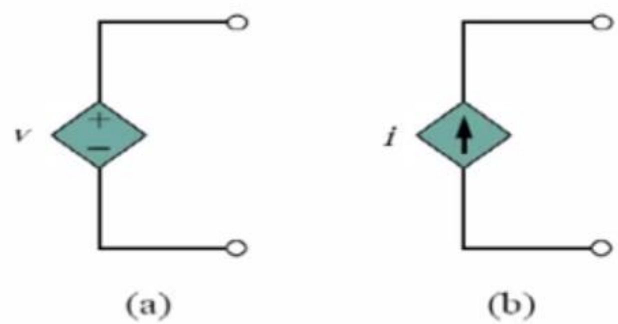

Fig.8. Symbols for: (a) dependent voltage source, (b) dependent current source

There are four possible types of dependent sources, namely:

1. A voltage-controlled voltage source (VCVS).
2. A current-controlled voltage source (CCVS).
3. A voltage-controlled current source (VCCS).
4. A current-controlled current source (CCCS).

Short Circuit: An element with R = 0 is called a short circuit as shown in Fig 9. A short circuit is a circuit element with resistance approaching zero.

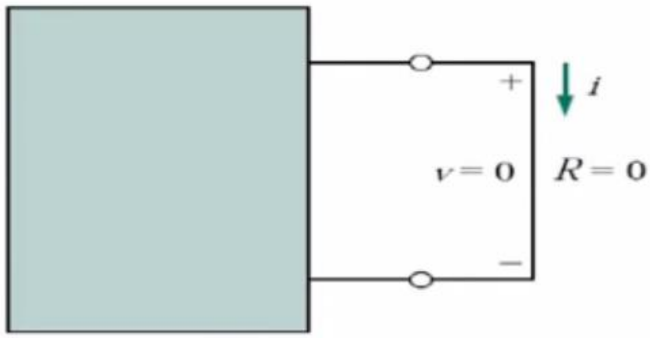

Fig.9. Short Circuit

For a short circuit, $$v = iR = 0$$

We see that the voltage is zero but the current could be anything. In practice, a short circuit is usually a connecting wire assumed to be a perfect conductor.

Open Circuit: An element with R =∞ is known as an open circuit as shown in Fig. 10.

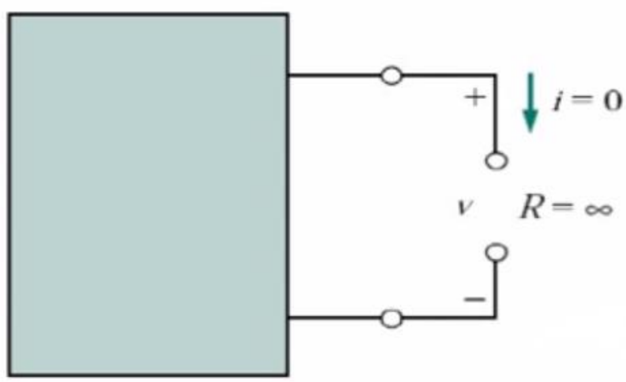

Fig.10. Open Circuit

For an open circuit,

$$i = \lim_{R \to \infty} \frac{V}{R} = 0$$

The above equation indicating that the current is zero though the voltage could be anything.

Branches, Nodes and Loops:

A **branch** represents a single element such as a voltage source or a resistor.
A **node** is the point of connection between two or more branches.
A **loop** is any closed path in a circuit.

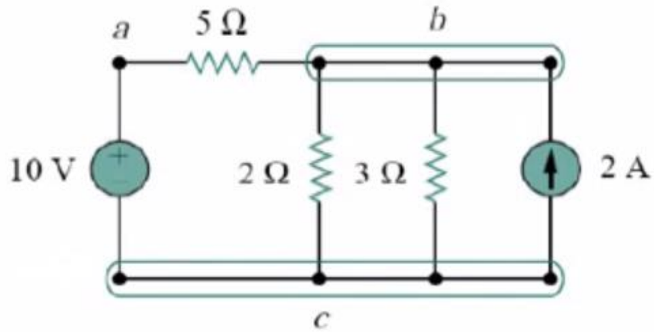

Fig.11. Branches, Nodes and Loops

Series Connection: Two or more elements are in series if they are cascaded or connected sequentially and consequently carry the same current. Two elements are in series if they share one common node and no other element is connected to that common node.

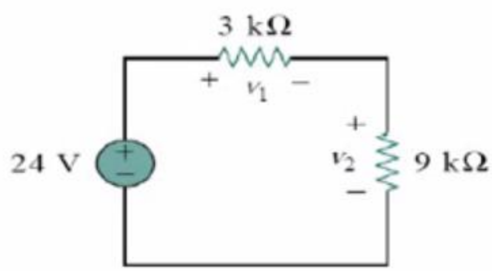

Fig.12. Series Circuit

Parallel connection: Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them. Elements in parallel are connected to the same pair of terminals.

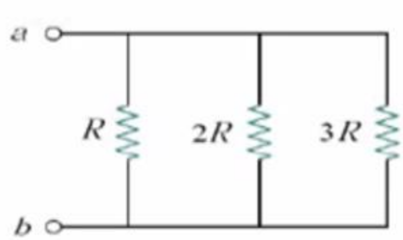

Fig.13. Parallel Circuit