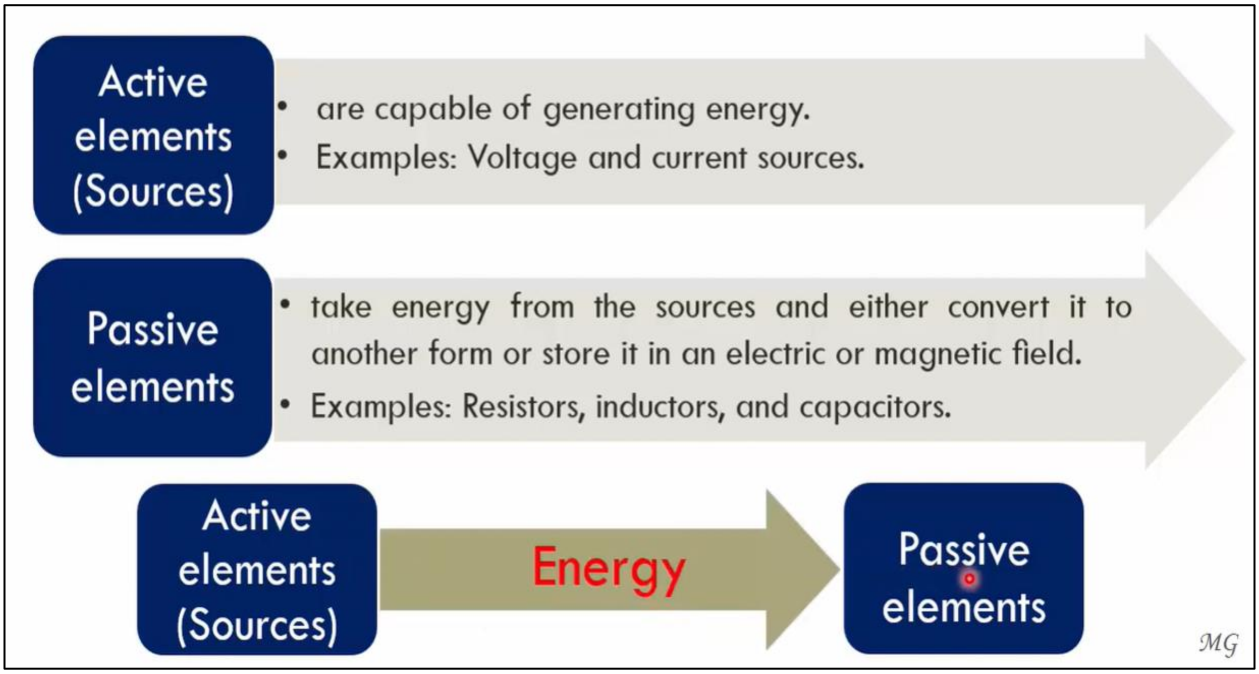
Ministry of High Education and Scientifics Research
Al-Farahidi University
College of Technical Engineering

AC Electrical Circuits
A. AC Circuit Elements
For students of 1nd Stage

By:

Lec. Dr. Hiba M. Isam

AC Circuit Elements



- **Electric current (I):** is the rate of movement of charge through a conductor.

$$I = \frac{Q}{t}$$

I: is the current in amperes
t*:* the time in seconds during which the current flows
Q: the quantity of electrical charge in coulombs

- **potential difference (p.d.) or voltage (V):** For a continuous current to flow between two points in a circuit a **potential difference (p.d.)** or **voltage**, *V*, is required between them.

Volt (v): is the unit of **voltage**.

- **Resistance (R)**: The flow of electric current is subject to friction. This friction, or opposition, is the property of a conductor that limits current.

  Ohm (Ω): is the unit of resistance.

- **Conductance (G):** is the reciprocal of resistance.

  measured in Mho or siemens (S).

$$G = \frac{1}{R}$$

- **Power (P):** is defined as the rate of doing work or transferring energy.

Watt (W): is the unit of power.

POWER

$$P = \frac{W}{t}$$

Power (watts) — P; *Work* (joules) — W; *Time* (seconds) — t

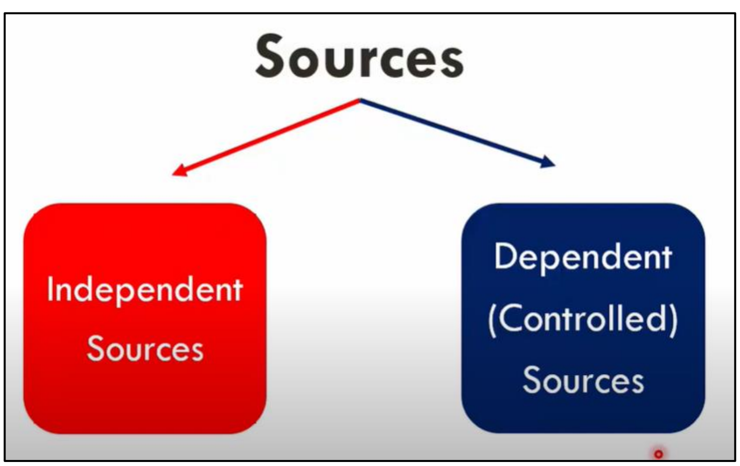
Multiples and submultiples of units:

SI units may be made larger or smaller by using prefixes which denote multiplication or division by a particular amount. The eight most common multiples and submultiples, with their meaning, are listed below:

Prefix	Name	Meaning
T	tera	multiply by 1 000 000 000 000 (i.e.$\times 10^{12}$)
G	gega	multiply by 1 000 000 000 (i.e.$\times 10^{9}$)
M	mega	multiply by 1 000 000 (i.e.$\times 10^{6}$)
k	kilo	multiply by 1000 (i.e. $\times 10^{3}$)
m	milli	divide by 1000 (i.e. $\times 10^{-3}$)
μ	micro	divide by 1 000 000 (i.e. $\times 10^{-6}$)
N	nano	divide by 1 000 000 000 (i.e. $\times 10^{-9}$)
P	pico	divide by 1 000 000 000 000 (i.e. $\times 10^{-12}$)

Sources

Ideal voltage and current sources can be further described as either independent sources or dependent sources.



- ***Independent source:*** in which the value of the voltage or current supplied is specified by the value of the independent source alone.

- ***Independent voltage source:*** An ideal voltage source is independent of the current through it. If a copper wire were connected across its ends the current through it would be infinite. The symbol for an ideal voltage source is shown in Figure.1.

- **An ideal current source** is independent of the voltage across it and if its two ends are not connected to an external circuit the potential difference across it would be infinite. The symbol for a current generator is shown in Figure 1.

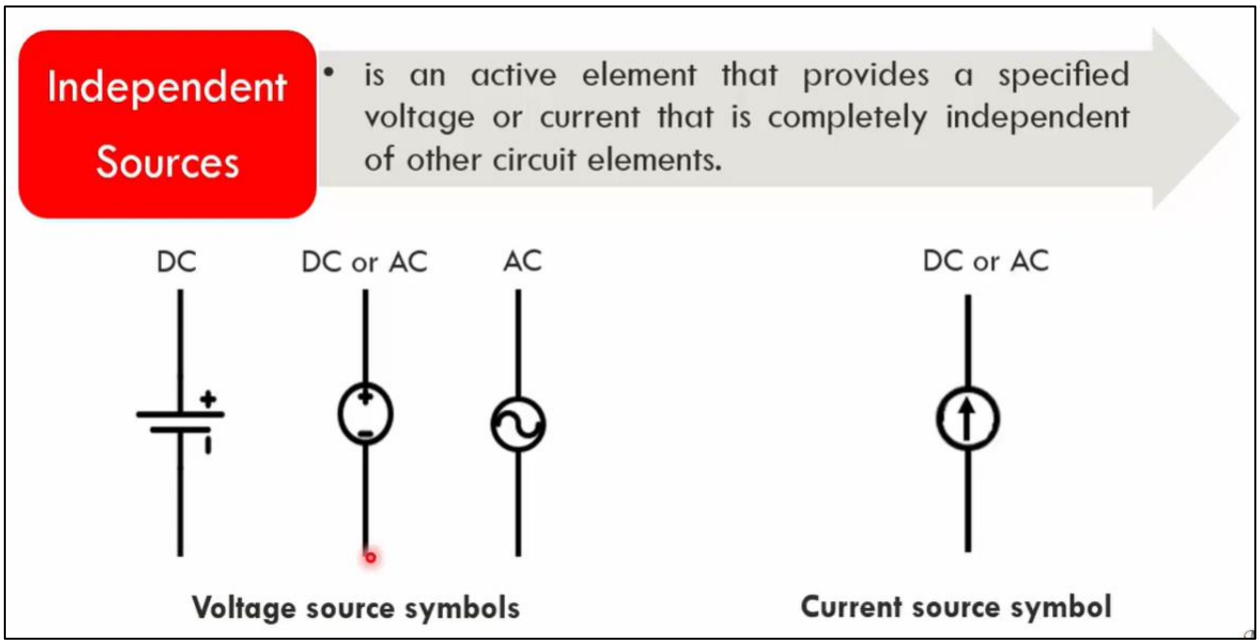


Figure. 1

- **Dependent source (or controlled source):** in which the value of the voltage or current cannot be specified unless we know the value of the voltage or current on which it depends in the circuit.
  - Dependent voltage source: The symbol for a dependent voltage source is shown in Figure2
  - Dependent current source: The symbol for a dependent current source is shown in Figure 2.

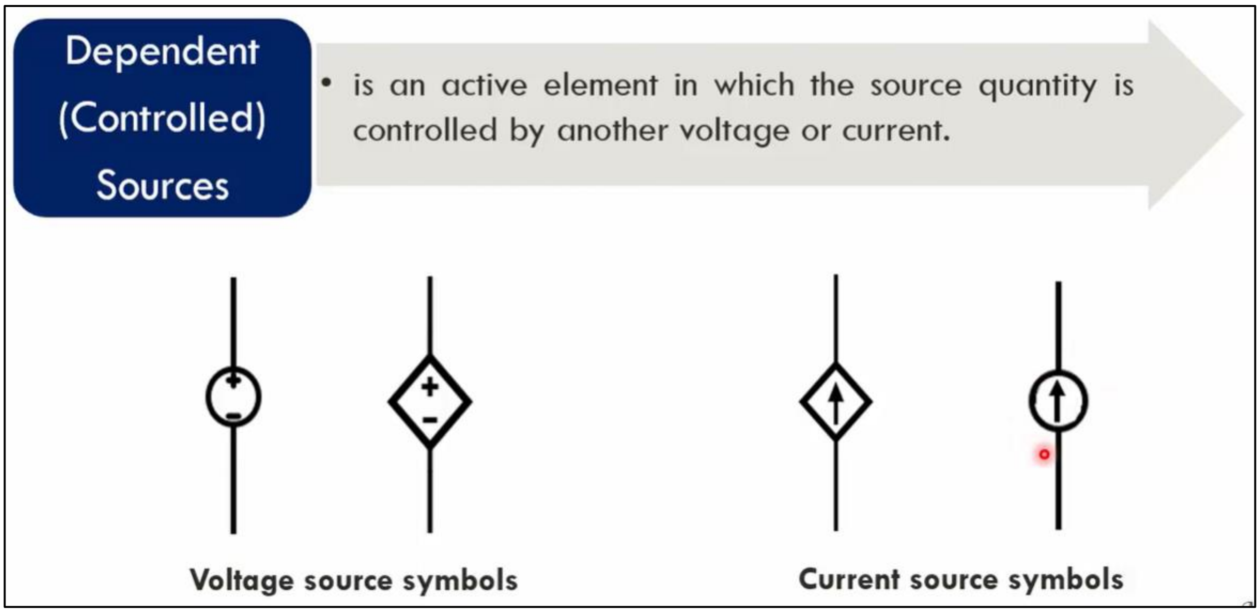


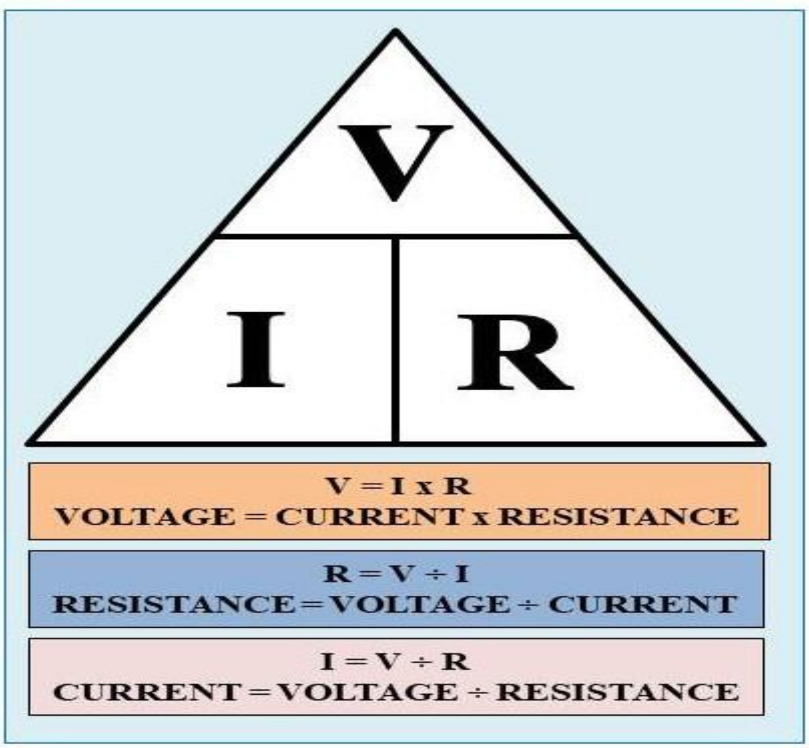
Figure. 2

1- Ohms law

1.1 Ohms 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.

$$I = \frac{V}{R} \quad \text{or} \quad V = IR \quad \text{or} \quad R = \frac{V}{I}$$



Example (1): The current flowing through a resistor is 0.8A when a p.d. of 20V is applied. Determine the value of the resistance.

Solution:

$$\text{resistance } R = \frac{V}{I} = \frac{20}{0.8} = \frac{200}{8} = \mathbf{25\ \Omega}$$

Example2: Determine the p.d. which must be applied to a 2 kΩ resistor in order that a current of 10mA may flow.

Solution:

$$\text{Resistance } R = 2\,k\Omega = 2 \times 10^3 = 2000\ \Omega$$

$$\text{Current I} = 10\,\text{mA} = 10 \times 10^{-3}\text{A}$$

$$V = IR = (0.01)(2000) = \mathbf{20\ V}$$

Example 3: A coil has a current of 50mA flowing through it when the applied voltage is 12V. What is the resistance of the coil?

Solution:

$$\text{Resistance, } R = \frac{V}{I} = \frac{12}{50 \times 10^{-3}}$$

$$= \frac{12 \times 10^3}{50} = \frac{12\,000}{50} = \mathbf{240\ \Omega}$$

Homework: A 100V battery is connected across a resistor and causes a current of 5mA to flow. Determine the resistance of the resistor. If the voltage is now reduced to 25V, what will be the new value of the current flowing?

Solution:

1.2 Electrical power:

Power (*P*): in an electrical circuit is given by the product of potential difference V and current I.

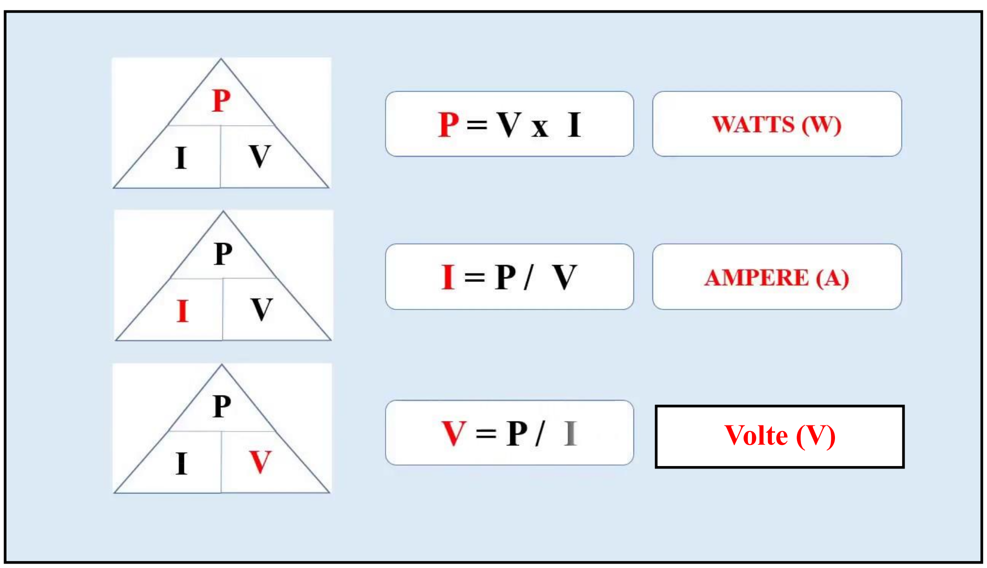
Watt (W): is the unit of power.

$$P = V * I \ \text{(Watt)}$$

Note: From Ohm's law, $V = IR$.

$$P = \frac{V^2}{R}$$

Voltage, Current & Power- Relationship



Example 4: A 100W electric light bulb is connected to a 250V supply. Determine:

(a) the current flowing in the bulb
(b) the resistance of the bulb.

Solution:

Power $P = V \times I$, from which, current $I = \frac{P}{V}$

(a) Current $I = \frac{100}{250} = \frac{10}{25} = \frac{2}{5} = \mathbf{0.4\,A}$

(b) Resistance $R = \frac{V}{I} = \frac{250}{0.4} = \frac{2500}{4} = \mathbf{625\,\Omega}$

Example 5 : Calculate the power dissipated when a current of 4mA flows through a resistance of 5 kΩ.

Solution:

$$\begin{aligned} \text{Power } P = I^2R &= (4 \times 10^{-3})^2(5 \times 10^3) \\ &= 16 \times 10^{-6} \times 5 \times 10^3 \\ &= 80 \times 10^{-3} \\ &= \mathbf{0.08\,W} \text{ or } \mathbf{80\,mW} \end{aligned}$$

OR

Alternatively, since $I = 4 \times 10^{-3}$ and $R = 5 \times 10^3$ then from Ohm's law, voltage

$$V = IR = 4 \times 10^{-3} \times 5 \times 10^3 = 20\,V$$

Hence,

$$\begin{aligned} \text{power } P = V \times I &= 20 \times 4 \times 10^{-3} \\ &= \mathbf{80\,mW} \end{aligned}$$

Example 6: A current of 5A flows in the winding of an electric motor, the resistance of the winding being 100Ω Determine:

(a) the p.d. across the winding
(b) the power dissipated by the coil.

Solution:

(a) Potential difference across winding,

$$V = IR = 5 \times 100 = \mathbf{500\,V}$$

(b) Power dissipated by coil,

$$P = I^2R = 5^2 \times 100$$
$$= \mathbf{2500\,W} \text{ or } \mathbf{2.5\,kW}$$

(Alternatively, $P = V \times I = 500 \times 5$
$= \mathbf{2500\,W}$ or $\mathbf{2.5\,kW}$)

OR

1.3 Electrical energy:

Energy = Power x Time

- If the power is measured in watts and the time in seconds, then the unit of energy is watt-seconds or joules.

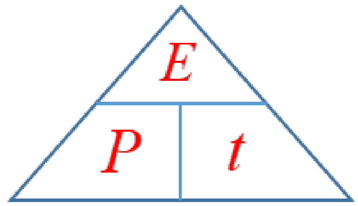
- If the power is measured in kilowatts and the time in hours, then the unit of energy is kilowatt-hours.

Electrical Energy

The following formula gives the relationship between Electrical Energy and Power

$$E = Pt$$

$$P = \frac{E}{t}$$



E = Energy in Joules (J)
P = Power in Watts (W)
t = Time in Seconds (s)

Example 7: A 12V battery is connected across a load having a resistance of 40Ω, Determine the current flowing in the load, the power consumed, and the energy dissipated in 2 minutes.

Solution:

$$\text{Current } I = \frac{V}{R} = \frac{12}{40} = \mathbf{0.3\,A}$$

$$\text{Power consumed, } P = VI = (12)(0.3) = \mathbf{3.6\,W}.$$

$$\begin{aligned}\text{Energy dissipated} &= \text{power} \times \text{time}\\ &= (3.6\,\text{W})(2 \times 60\,\text{s})\\ &= \mathbf{432\,J} \text{ (since 1 J = 1 Ws)}\end{aligned}$$

Homework: Electrical equipment in an office takes a current of 13A from a 240V supply. Estimate the cost per week of electricity if the equipment is used for 30 hours each week and 1 kWh of energy costs 12.5dinar.

1.4 Resistance and resistivity

The resistance of an electrical conductor depends on four factors, these being:

- the length of the conductor (l)
- the cross-sectional area of the conductor (a)
- the type of material
- the temperature of the material.

$$R = \frac{\rho L}{A}$$

ρ = resistivity
L = length
A = cross sectional area

Example 8: Calculate the resistance of a 2 km length of aluminum overhead power cable if the cross-sectional area of the cable is $100 mm^2$. Take the resistivity of aluminum to $0.03\times10_{-6}\ \Omega.m$.

Solution:

Length $l = 2\ km = 2000\ m$,
area $a = 100\ mm^2 = 100 \times 10^{-6}\ m^2$
and resistivity $\rho = 0.03 \times 10^{-6}\ \Omega\ m$.

1 مليمتر مربع = 1.0×10^{-6} متر مربع

$$\text{Resistance } R = \frac{\rho l}{a} = \frac{(0.03 \times 10^{-6}\ \Omega\ m)(2000\ m)}{(100 \times 10^{-6}\ m^2)} = \frac{0.03 \times 2000}{100}\ \Omega = \mathbf{0.6\ \Omega}$$

Example 9: Calculate the cross-sectional area, in mm^2, of a piece of copper wire, 40m in length and having a resistance of 0.25Ω. Take the resistivity of copper as 0.02×10-6 Ω.m.

Solution:

Resistance $R = \rho l / a$ hence cross-sectional area

$$a = \frac{\rho l}{R} = \frac{(0.02 \times 10^{-6}\ \Omega\,\text{m})(40\,\text{m})}{0.25\,\Omega}$$
$$= 3.2 \times 10^{-6}\,\text{m}^2$$
$$= (3.2 \times 10^{-6}) \times 10^{6}\,\text{mm}^2 = \mathbf{3.2\,mm^2}$$

Homework: The resistance of 1.5 km of wire of cross-sectional area $0.17mm^2$ is 150Ω. Determine the resistivity of the wire.

Solution: