Ministry of Higher Education and Scientific Research
Tikrit University
Engineering Collage –Al shirqat

LECTURE 1
FUNDAMENTALS OF ELECTRICAL ENGINEERING

PREPARED BY
TEACHING ASSISTANT

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General Objectives:

- **Understanding Theoretical Foundations:**

Mastering the fundamental principles related to electric current, voltage, energy, and power.

- **Practical Application:**

Utilizing electrical laws and theories to analyze and design electrical circuits.

- **Mathematical Analysis:**

Applying basic and advanced mathematics to analyze electrical circuits accurately.

- **Logical Thinking and Problem-Solving:**

Enhancing the ability to think logically to solve complex electrical circuit problems..

- **Preparation for Advanced Courses:**

Preparing students for studying advanced topics such as electronics, power systems, and control.

Specific Objectives:

➢**Understanding Basic Terminology:**
Introducing students to electrical terms such as Voltage, Current, Resistance, and Capacitors.
➢**Applying Circuit Laws:**
Training students on **Kirchhoff's Laws** and **Ohm's Law**.
➢**Analyzing Simple and Complex Systems:**
Learning circuit analysis methods, including:
- **Nodal Analysis**
- **Mesh Analysis**

➢**Studying Electrical Components:**
Understanding the function of elements such as resistors, capacitors, inductors, and electrical sources.

What is electricity and what are its types?

Introduction

Electric circuit theory and electromagnetic theory are the two fundamental theories upon which all branches of electrical engineering are built. Many branches of electrical engineering, such as power, electric machines, control, electronics, communications, and instrumentation, are based on electric circuit theory. Circuit theory is also valuable to students specializing in other branches of the physical sciences because circuits are a good model for the study of energy systems in general, and because of the applied mathematics, physics, and topology involved.

In electrical engineering, we are often interested in communicating or transferring energy from one point to another. To do this requires an interconnection of electrical devices. Such interconnection is referred to as an electric circuit, and each component of the circuit is known as an element.

An electric circuit is an interconnection of electrical elements.

A simple electric circuit is shown in Fig. 1.1. It consists of three basic elements: a battery, a lamp, and connecting wires. Such a simple circuit can exist by itself; it has several applications, such as a flash light, a search light, and so forth.

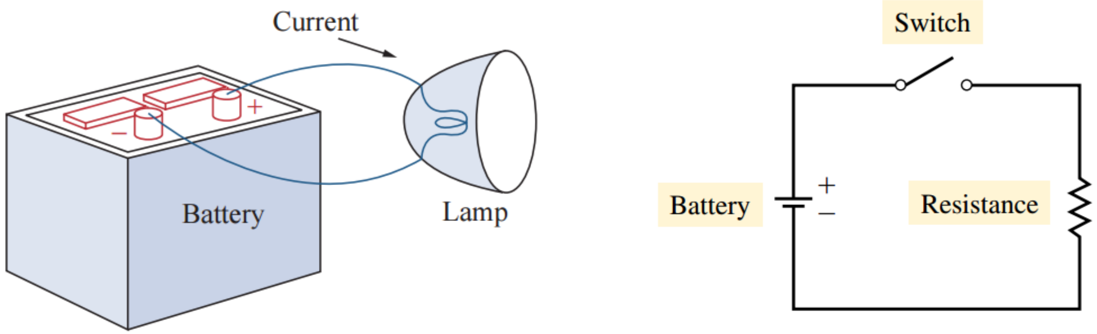


Figure 1.1
A simple electric circuit.

Systems of Units

As electrical engineers, we deal with measurable quantities. Our measurement, however, must be communicated in a standard language that virtually all professionals can understand, irrespective of the country where the measurement is conducted. Such an international measurement language is the International System of Units (SI), adopted by the General Conference on Weights and Measures in 1960. In this system, there are seven principal units from which the units of all other physical quantities can be derived. Table 1.1 shows the six units and one derived unit that are relevant to this text.

TABLE 1.1

Six basic SI units and one derived unit relevant to this text.

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Charge	coulomb	C

Systems of Units

One great advantage of the SI unit is that it uses prefixes based on the power of 10 to relate larger and smaller units to the basic unit. Table 1.2 shows the SI prefixes and their symbols. For example, the following are expressions of the same distance in meters (m):

600,000,000 mm   600,000 m   600 km

TABLE 1.2

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Charge and Current

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

$$q = N_e \times e$$
$$e = -1.602 \times 10^{-19}$$

q = charge measured in coulombs (C).

N_e= number of electron.

e = electronic charge.

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

1 ampere =1 coulomb/second

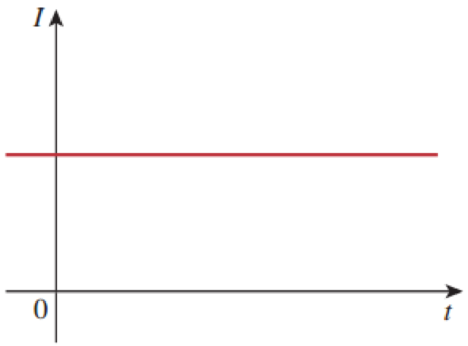
$$i = \frac{dq}{dt}$$
$$q = \int_{t_0}^{t_1} i\,dt + q(0)$$
$$q = it$$

Charge and Current

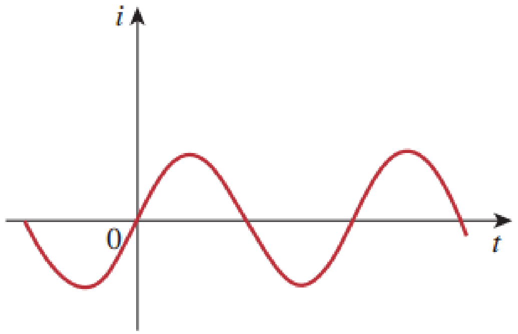
Electric current

A direct current (dc) is a current that remains constant with time.

An alternating current (ac) is a current that varies sinusoidally with time.



(a)



(b)

Figure 1.4
Two common types of current: (a) direct current (dc), (b) alternating current (ac).

Examples

Example 1.1

How much charge is represented by 4,600 electrons?

Solution:

$$\boldsymbol{q = N_e \times e}$$
$$q = 4600 \times -1.602 \times 10^{-19} = -7.369 \times 10^{-19}\text{C}$$

Example 1.2

The total charge entering a terminal is given by $q = 5t \sin 4\pi t$ mC. Calculate the current at $t = 0.5$ s.

Solution:

$$i = \frac{dq}{dt} = \frac{d}{dt}(5t \sin 4\pi t) = (5 \sin 4\pi t + 20\pi t \cos 4\pi t)$$

At t=0.5

$$i(0.5) = [5 \sin 4\pi(\frac{1}{2}) + 20\pi(\frac{1}{2}) \cos(\frac{4\pi 1}{2})]$$

$$i(0.5) = 5 \sin 2\pi + 10\pi \cos 2\pi = 0 + 10\pi = 31.42 \text{ mA}$$

مشتقة حاصل ضرب دالتين:

الدالة الأولى مضروبة في مشتقة الثانية + الدالة الثانية مضروبة في مشتقة الأولى. أي أن :

$$\frac{d}{dx}(uv) = u\frac{dv}{dx} + v\frac{du}{dx}$$

Examples

Example 1.3 Determine the total charge entering a terminal between $t = 1$ s and $t = 2$ s if the current passing the terminal is $i = (3t^2 - t)$ A.

$$Q = \int_{t=1}^{2} i\,dt = \int_{1}^{2} (3t^2 - t)\,dt$$

$$\int [f(x) \pm g(x)]\,dx = \int f(x)\,dx \pm \int g(x)\,dx$$

$$Q = \left[\frac{3}{3}t^3 - \frac{1}{2}t^2\right]_1^2 = \{[2^3 - 2^2/2] - [1 - 1/2]\}$$

$$Q = 8 - 2 - 1 + \frac{1}{2} = 5.5\ C$$

Voltage or potential difference

To move the electron in a conductor in a particular direction requires some work or energy transfer. This work is performed by an external electromotive force (emf), typically represented by the battery in Fig. 1.3. This emf is also known as **voltage or potential difference**. The voltage between two points **a** and **b** in an electric circuit is the energy (or work) needed to move a unit charge from **a** to **b**; mathematically:

$$v = \frac{dw}{dq}$$

Derivative of work with respect to charge

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

1 volt = 1 joule/coulomb =1 newton-meter/coulomb

$$v_{ab} = -v_{ba} = v_a - v_b$$

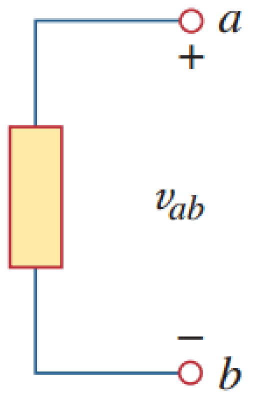


Figure 1.6
Polarity of voltage v_{ab}.

Power and Energy

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

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

$$\boldsymbol{p = \frac{w}{t}}$$

$$\boldsymbol{p = vi}$$

p → Power
w → Energy

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, $p = -vi$.

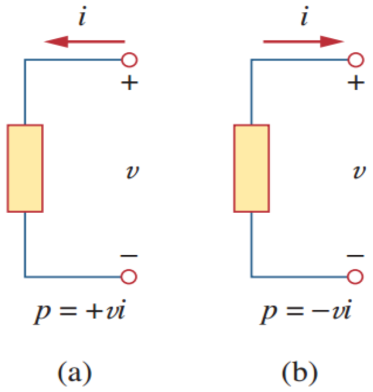


Figure 1.8
Reference polarities for power using the passive sign convention: (a) absorbing power, (b) supplying power.

+Power absorbed = - Power supplied

- Voltage and current → supply power.
- Resistors → absorb power.

Power and Energy

Energy is the capacity to do work, measured in joules (J).

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

Example 1.4

An energy source forces a constant current of 2 A for 10 s to flow through a light bulb. If 2.3 kJ is given off in the form of light and heat energy, calculate the voltage drop across the bulb.

Solution:

The total charge is

$$\Delta q = i\,\Delta t = 2 \times 10 = 20 \text{ C}$$

The voltage drop is

$$v = \frac{\Delta w}{\Delta q} = \frac{2.3 \times 10^3}{20} = 115 \text{ V}$$

Example 1.6 How much energy does a 100-W electric bulb consume in two hours?

Solution:

$$\begin{aligned} w = pt &= 100\ \text{(W)} \times 2\ \text{(h)} \times 60\ \text{(min/h)} \times 60\ \text{(s/min)} \\ &= 720{,}000\ \text{J} = 720\ \text{kJ} \end{aligned}$$

This is the same as

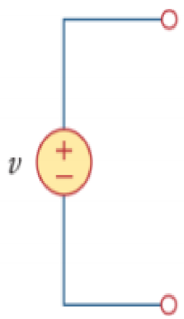
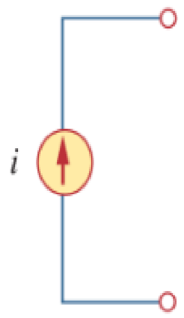
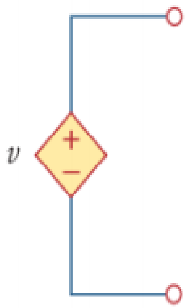
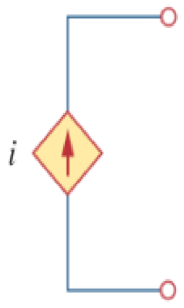
$$w = pt = 100\ \text{W} \times 2\ \text{h} = 200\ \text{Wh}$$

Electric Source

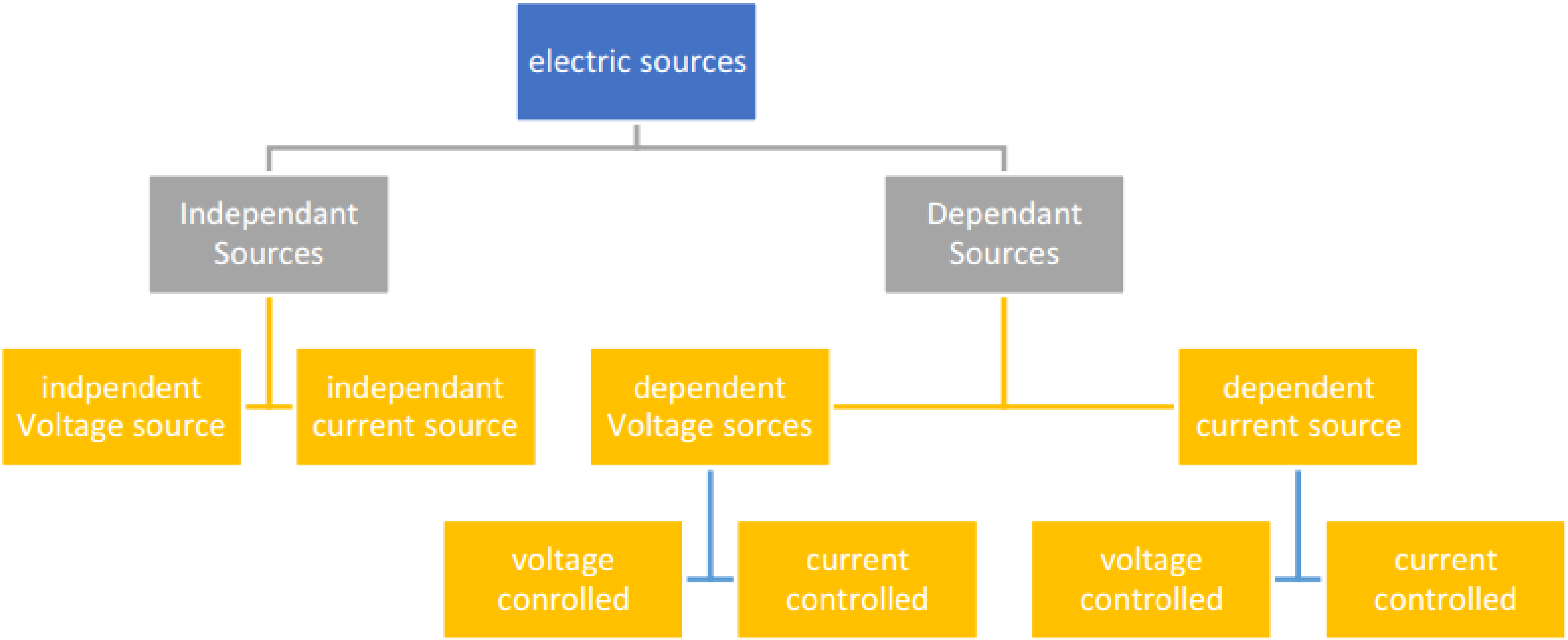
Type of electric sources:

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.

An ideal dependent source (also called a controlled source) is one where the output (voltage or current) depends on another voltage or current elsewhere in the circuit.

independent Voltage source	independent Current source	dependent Voltage source	dependent Current source
			

Type of electric sources:



- A voltage-controlled voltage source (VCVS).
- A current-controlled voltage source (CCVS).
- A voltage-controlled current source (VCCS).
- A current-controlled current source (CCCS).

Circuit Elements

There are two types of elements found in electric circuits:

- passive elements
- active elements.

Passive elements عناصر غير فعالة	Active elements عناصر فعالة
An active element can NOT generate energy. العناصر غير الفعالة: هي عناصر غير قادرة علي توليد الطاقة	An active element can generate energy. العناصر الفعالة: هي عناصر قادرة علي توليد الطاقة
Examples of passive elements are: ▪ Resistors ▪ Capacitors ▪ inductors.	Examples of passive elements are: ▪ Generators ▪ Batteries ▪ operational amplifiers .

Circuit Elements