ELECTRIC FIELD
General information

General electrical engineering
with basic electronics
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Outline

- Systems of Units;
- Electric Circuits and Current;
- Voltage;
- Power and Energy;
- Literature;
- Q&A;

Systems of Units

In representing a circuit and its elements, we must define a consistent system of units for the quantities occurring in the circuit. At the 1960 meeting of the General Conference of Weights and Measures, the representatives modernized the metric system and created the Systeme International d'Unites, commonly called SI units.

SI is Systeme International d'Unites or the International System of Units.

The fundamental, or base, units of SI are shown in Table 1.3-1. Symbols for units that represent proper (persons') names are capitalized; the others are not. Periods are not used after the symbols, and the symbols do not take on plural forms. The derived units for other physical quantities are obtained by combining the fundamental units. Table 1.3-2 shows the more common derived units along with their formulas in terms of the fundamental units or preceding derived units. Symbols are shown for the units that have them.

Systems of Units

Table 1.3-1 SI Base Units

QUANTITY	SI UNIT: NAME	SI UNIT: SYMBOL
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Table 1.3-3 SI Prefixes

MULTIPLE	PREFIX	SYMBOL
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

Systems of Units

Table 1.3-2 Derived Units in SI

QUANTITY	UNIT NAME	FORMULA	SYMBOL
Acceleration — linear	meter per second per second	m/s^2	
Velocity — linear	meter per second	m/s	
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or stress	pascal	N/m^2	Pa
Density	kilogram per cubic meter	kg/m^3	
Energy or work	joule	$N \cdot m$	J
Power	watt	J/s	W
Electric charge	coulomb	$A \cdot s$	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	$V \cdot s$	Wb
Inductance	henry	Wb/A	H

Electric Circuits and Current

The outstanding characteristics of electricity when compared with other power sources are its mobility and flexibility. Electrical energy can be moved to any point along a couple of wires and, depending on the user's requirements, converted to light, heat, or motion.

An electric circuit or electric network is an interconnection of electrical elements linked together in a closed path so that an electric current may flow continuously.

Consider a simple circuit consisting of two well-known electrical elements, a battery and a resistor, as shown in Figure 1.2-1. Each element is represented by the two-terminal element shown in Figure 1.2-2. Elements are sometimes called devices, and terminals are sometimes called nodes.

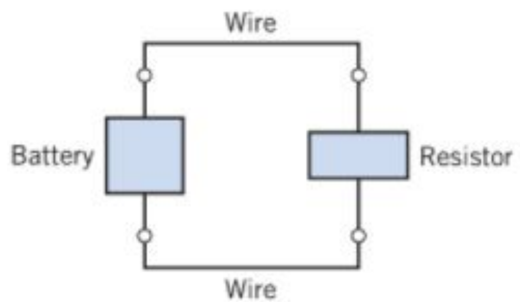


FIGURE 1.2-1 A simple circuit.

FIGURE 1.2-2 A general two-terminal electrical element with terminals a and b.

Electric Circuits and Current

Charge may flow in an electric circuit. Current is the time rate of change of charge past a given point. Charge is the intrinsic property of matter responsible for electric phenomena. The quantity of charge q can be expressed in terms of the charge on one electron, which is - 1.602 * 10^{-19} coulombs. Thus, -1 coulomb is the charge on 6.24 * 10^{18} electrons. The current through a specified area is defined by the electric charge passing through the area per unit of time. Thus, q is defined as the charge expressed in coulombs (C).

> ***Charge*** *is the quantity of electricity responsible for electric phenomena.*

Then we can express current as:

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

The unit of current is the ampere (A); an ampere is 1 coulomb per second.

> ***Current*** *is the time rate of flow of electric charge past a given point.*

Electric Circuits and Current

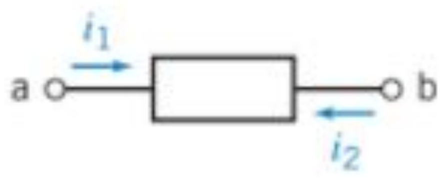


FIGURE 1.2-3 Current in a circuit element.

Figure 1.2-3 shows the notation that we use to describe a current. There are two parts to this notation: a value (perhaps represented by a variable name) and an assigned direction. As a matter of vocabulary, we say that a current exists in or through an element. Figure 1.2-3 shows that there are two ways to assign the direction of the current through an element.

The current i_1 is the rate of flow of electric charge from terminal a to terminal b. On the other hand, the current i_2 is the flow of electric charge from terminal b to terminal a. The currents i_1 and i_2 are similar but different. They are the same size but have different directions. Therefore, i_2 is the negative of i_1 and

$$i_1 = -i_2$$

Electric Circuits and Current

We always associate an arrow with a current to denote its direction. A complete description of current requires both a value (which can be positive or negative) and a direction (indicated by an arrow).

If the current flowing through an element is constant, we represent it by the constant I, as shown in Figure 1.2-4. A constant current is called a *direct current (dc)*.

*A **direct current** (dc) is a current of constant magnitude.*

FIGURE 1.2-4 A direct current of magnitude *I*.

Electric Circuits and Current

A time-varying current i(t) can take many forms, such as a ramp, a sinusoid, or an exponential, as shown in Figure 1.2-5. The sinusoidal current is called an alternating current (ac).

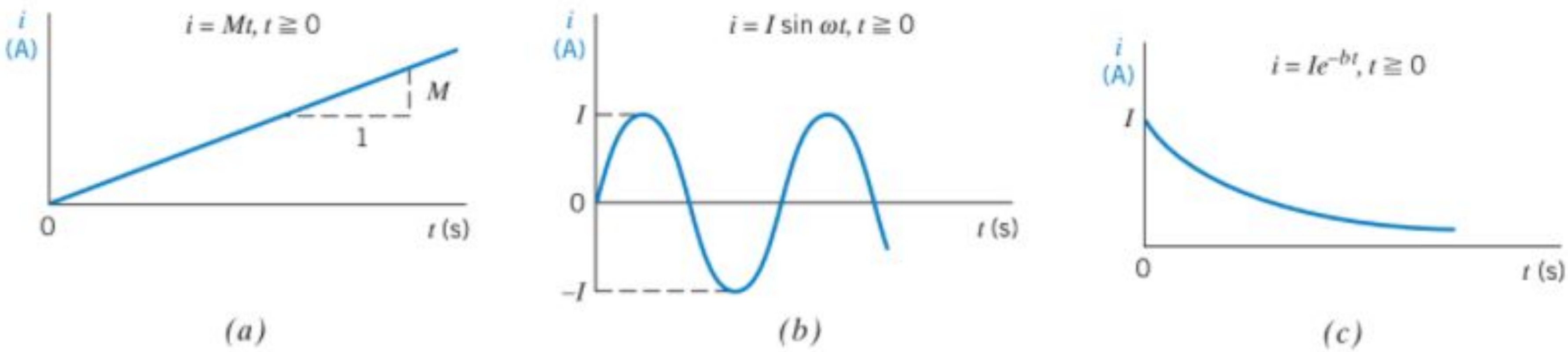


FIGURE 1.2-5 (*a*) A ramp with a slope M. (*b*) A sinusoid. (*c*) An exponential. I is a constant. The current i is zero for $t < 0$.

If the charge q is known, the current i is readily found using Eq. 1. Alternatively, if the current i is known, the charge q is readily calculated. Note that from Eq. 1, we obtain

$$q = \int_{-\infty}^{t} i \, d\tau = \int_{0}^{t} i \, d\tau + q(0)$$

where $q(0)$ is the charge at $t = 0$.

Voltage

The basic variables in an electrical circuit are current and voltage. These variables describe the flow of charge through the elements of a circuit and the energy required to cause charge to flow. Figure 1.4-1 shows the notation we use to describe a voltage. There are two parts to this notation: a value (perhaps represented by a variable name) and an assigned direction. The value of a voltage may be positive or negative. The direction of a voltage is given by its polarities (+,-).

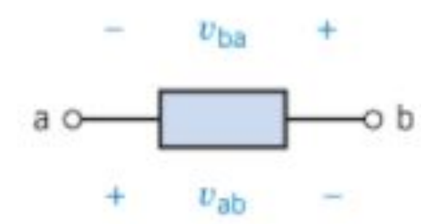


FIGURE 1.4-1 Voltage across a circuit element.

As a matter of vocabulary, we say that a voltage exists across an element. Figure 1.4-1 shows that there are two ways to label the voltage *across* an element. The voltage vba is proportional to the work required to move a positive charge from terminal a to terminal b. On the other hand, the voltage v_{ab} is proportional to the work required to move a positive charge from terminal b to terminal a. We sometimes read v_{ba} as "the voltage at terminal b with respect to terminal a." Similarly, v_{ab} can be read as "the voltage at terminal a with respect to terminal b." Alternatively, we sometimes say that v_{ba} is the voltage drop from terminal a to terminal b. The voltages v_{ab} and v_{ba} are similar but different. They have the same magnitude but different polarities. This means that

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

Voltage

When considering v_{ba}, terminal b is called the “+ terminal” and terminal a is called the “ - terminal.” On the other hand, when talking about v_{ab}, terminal a is called the “+ terminal” and terminal b is called the

“- terminal.”

> *The **voltage** across an element is the work (energy) required to move a unit positive charge from the terminal to the þ terminal. The unit of voltage is the volt, V.*

The equation for the voltage across the element is:

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

where v is voltage, w is energy (or work), and q is charge. A charge of 1 coulomb delivers an energy of 1 joule as it moves through a voltage of 1 volt.

Power and Energy

The power and energy delivered to an element are of great importance. For example, the useful output of an electric lightbulb can be expressed in terms of power. We know that a 300-watt bulb delivers more light than a 100-watt bulb.

Power *is the time rate of supplying or receiving power.*

Thus, we have the equation:

$$p = \frac{dw}{dt} \tag{1}$$

where p is power in watts, w is energy in joules, and t is time in seconds. The power associated with the current through an element is

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = v \cdot i \tag{2}$$

Power and Energy

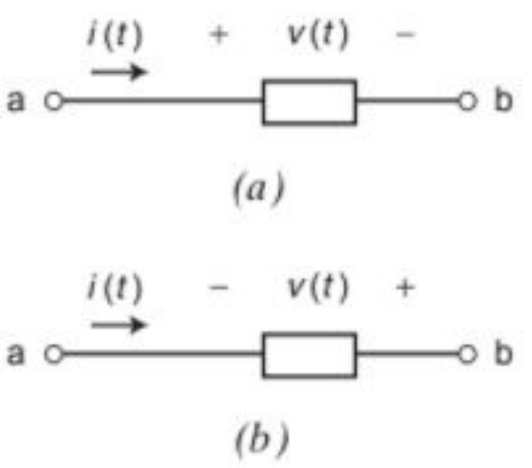


FIGURE 1.5-1 (*a*) The element voltage and current **adhere** to the passive convention. (*b*) The element voltage and current **do not adhere** to the passive convention.

From Eq.2, we see that the power is simply the product of the voltage across an element times the current through the element. The power has units of watts. Two circuit variables are assigned to each element of a circuit: a voltage and a current. Figure 1.5-1 shows that there are two different ways to arrange the direction of the current and the polarity of the voltage. In Figure 1.5-1a, the current is directed from the + toward the - of the voltage polarity. In contrast, in Figure 1.5-1b, the current is directed from the - toward the + of the voltage polarity.

First, consider Figure 1.5-1a. When the current enters the circuit element at the + terminal of the voltage and exits at the - terminal, the voltage and current are said to "adhere to the passive convention." In the passive convention, the voltage pushes a positive charge in the direction indicated by the current. Accordingly, the power calculated by multiplying the element voltage by the element current

$$\boxed{p = vi}$$

Power and Energy

is the power received by the element. (This power is sometimes called “the power absorbed by the element” or “the power dissipated by the element.”) The power received by an element can be either positive or negative. This will depend on the values of the element voltage and current.

Next, consider Figure 1.5-1b. Here the passive convention has not been used. Instead, the current enters the circuit element at the terminal of the voltage and exits at the þ terminal. In this case, the voltage pushes a positive charge in the direction opposite to the direction indicated by the current. Accordingly, when the element voltage and current do not adhere to the passive convention, the power calculated by multiplying the element voltage by the element current is the power supplied by the element. The power supplied by an element can be either positive or negative, depending on the values of the element voltage and current.

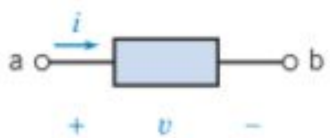
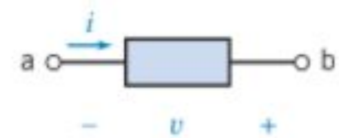
The power received by an element and the power supplied by that same element are related by

$$\boxed{power\ received = -power\ supplied}$$

The rules for the passive convention are summarized in Table 1.5-1. When the element voltage and current adhere to the passive convention, the energy received by an element can be determined

Power and Energy

Table 1.5-1 Power Received or Supplied by an Element

POWER RECEIVED BY AN ELEMENT	POWER SUPPLIED BY AN ELEMENT
	
Because the reference directions of v and i adhere to the passive convention, the power $p = vi$ is the power received by the element.	Because the reference directions of v and i do not adhere to the passive convention, the power $p = vi$ is the power supplied by the element.

from Eq. 1. by rewriting it as

$$dw = p\,dt$$

On integrating, we have

$$w = \int_{-\infty}^{t} p\,d\tau$$

If the element only receives power for $t \geq t_0$ and we let $t_0=0$, then we have

$$w = \int_{0}^{t} p\,d\tau$$

Literature

THANK YOU !

Do you have any questions?

Examples

Example 1.2-1 Current from Charge

Find the current in an element when the charge entering the element is

$$q = 12t \text{ C}$$

where t is the time in seconds.

Solution

Recall that the unit of charge is coulombs, C. Then the current, from Eq. 1.2-1, is

$$i = \frac{dq}{dt} = 12 \text{ A}$$

where the unit of current is amperes, A.

Examples

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EXAMPLE 1.2-2 Charge from Current

Find the charge that has entered the terminal of an element from $t = 0$ s to $t = 3$ s when the current entering the element is as shown in Figure 1.2-6.

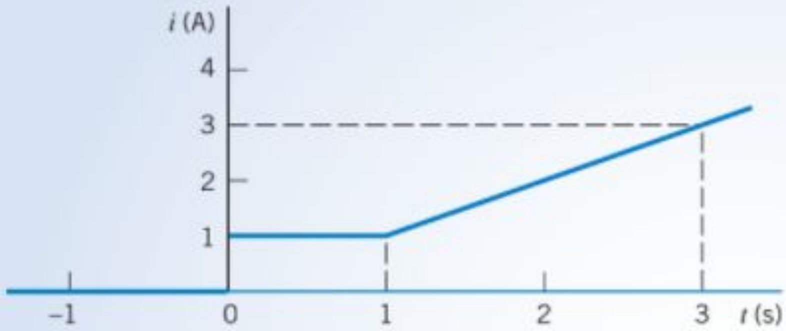

FIGURE 1.2-6 Current waveform for Example 1.2-2.

Solution

From Figure 1.2-6, we can describe $i(t)$ as

$$i(t) = \begin{cases} 0 & t < 0 \\ 1 & 0 < t \le 1 \\ t & t > 1 \end{cases}$$

Using Eq. 1.2-2, we have

$$\begin{aligned} q(3) - q(0) &= \int_0^3 i(t)dt = \int_0^1 1\,dt + \int_1^3 t\,dt \\ &= t\Big|_0^1 + \frac{t^2}{2}\Big|_1^3 = 1 + \frac{1}{2}(9 - 1) = 5\,\text{C} \end{aligned}$$

Examples

Example 1.5-1 Electrical Power and Energy

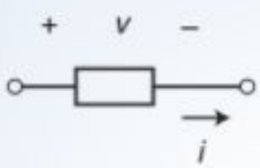

FIGURE 1.5-2 The element considered in Example 1.5-1.

Let us consider the element shown in Figure 1.5-2 when $v = 8$ V and $i = 25$ mA. Find the power received by the element and the energy received during a 10-ms interval.

Solution

In Figure 1.5-2 the current i and voltage v adhere to the passive convention. Consequently the power

$$p = vi = 8\,(0.025) = 0.2\text{ W} = 200\text{ mW}$$

is the power *received* by the circuit element. Next, the energy received by the element is

$$w = \int_0^t p\,dt = \int_0^{0.010} 0.2\,dt = 0.2(0.010) = 0.002\text{ J} = 2\text{ mJ}$$

Examples

EXAMPLE 1.5-2 Electrical Power and the Passive Convention

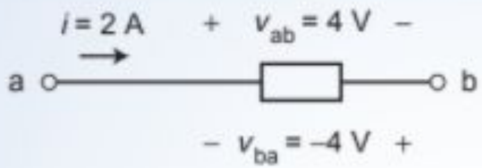

FIGURE 1.5-3 The element considered in Example 1.5-2.

Consider the element shown in Figure 1.5-3. The current i and voltage v_{ab} adhere to the passive convention, so

$$i \cdot v_{ab} = 2 \cdot (-4) = -8 \text{ W}$$

is the power *received* by this element. The current i and voltage v_{ba} do not adhere to the passive convention, so

$$i \cdot v_{ba} = 2 \cdot (4) = 8 \text{ W}$$

is the power *supplied* by this element. As expected

$$\text{power received} = -\text{power supplied}$$

Examples

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EXAMPLE 1.5-3 Power, Energy, and the Passive Convention

Consider the circuit shown in Figure 1.5-4 with $v(t) = 12e^{-8t}$ V and $i(t) = 5e^{-8t}$ A for $t \geq 0$. Both $v(t)$ and $i(t)$ are zero for $t < 0$. Find the power supplied by this element and the energy supplied by the element over the first 100 ms of operation.

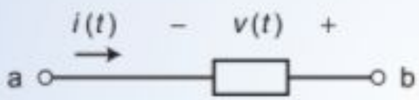

FIGURE 1.5-4 The element considered in Example 1.5-3.

Solution

The power

$$p(t) = v(i)\, i(t) = \left(12e^{-8t}\right)\left(5e^{-8t}\right) = 60e^{-16t} \text{ W}$$

is the power *supplied* by the element because $v(t)$ and $i(t)$ do not adhere to the passive convention. This element is supplying power to the charge flowing through it.

The energy supplied during the first 100 ms = 0.1 seconds is

$$w(0.1) = \int_0^{0.1} p\, dt = \int_0^{0.1} \left(60e^{-16t}\right) dt$$

$$= 60 \frac{e^{-16t}}{-16}\bigg|_0^{0.1} = -\frac{60}{16}\left(e^{-1.6} - 1\right) = 3.75\left(1 - e^{-1.6}\right) = 2.99 \text{ J}$$