# Chapter 1
## Electric Circuit Variables


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# Electric Circuits and Current

- **Electric circuit (or Electric network)**
  - An interconnection of electrical elements linked together in a closed path so that an electric current may flow continuously.

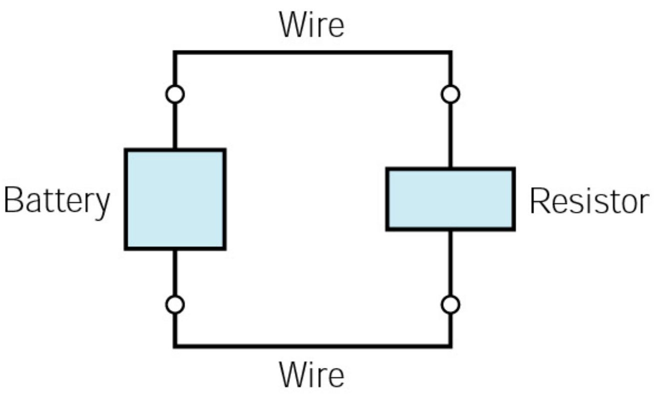



**Figure 1.2-1 (p. 2)**
A simple circuit

- **Charge**
  - Charge: The quantity of electricity responsible for electric phenomena.
  - Quantity of charge; $q$
    - $q = -1.602 \times 10^{-19}$ C (coulombs)
    - -1 C (Coulomb) is the charge on $6.24 \times 10^{18}$ electrons.

# Electric Circuits and Current (cont'd)

- **Current**
  - Current: The time rate of flow of electric charge past a given point.
  - The unit of current: ampere (A)

$$i = \frac{dq}{dt} \qquad \left\{ \begin{array}{l} i\text{: current} \\ q\text{: charge} \\ t\text{: time} \end{array} \right.$$

(*e.g.* 1A is 1C per second.)

$$i_1 = -i_2$$

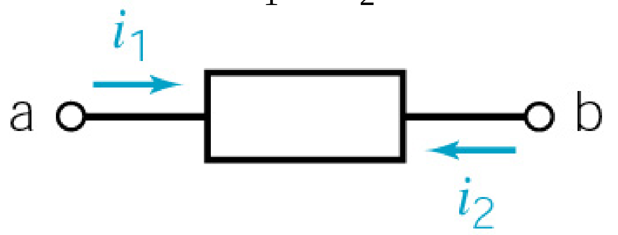



**Figure 1.2-3 (p. 2)**
Current in a circuit element.

# Electric Circuits and Current (cont'd)

- **DC; Direct current**
  - A current of constant magnitude.


**Figure 1.2-4 (p. 3)**
A direct current of magnitude *I*.

- **AC; Alternating current**
  - Alternating current = sinusoidal current

$$i = I \sin \omega t, t \geq 0$$

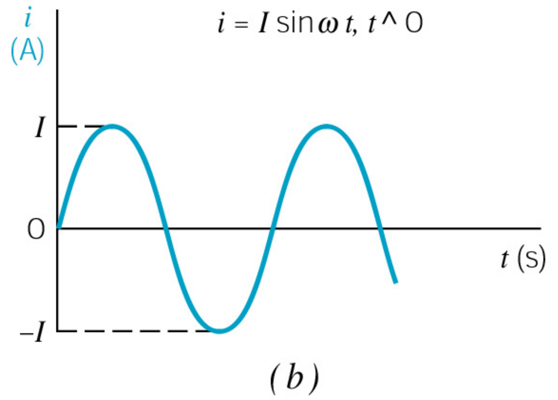



**Figure 1.2-5 (p. 3)**
**(b)** A sinusoid.

# 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

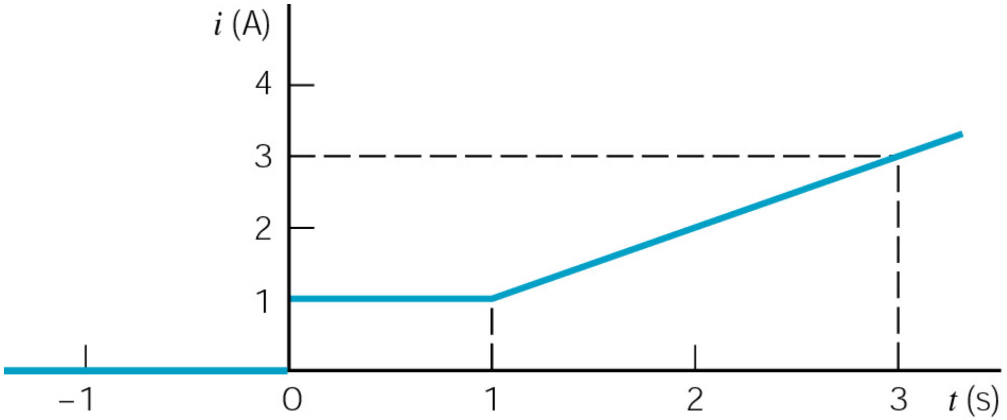
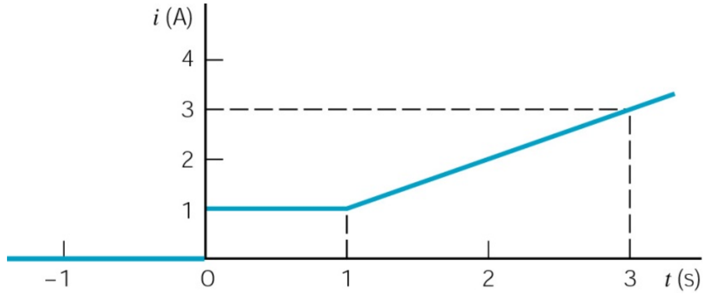



**Figure 1.2-6 (p. 4)**
Current waveform for Example 1.2-2

# 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. 1.3-2, we have

$$q=\int_0^3 i(t)dt=\int_0^1 1\,dt+\int_1^3 t dt$$

$$=t\Big|_0^1+\frac{t^2}{2}\Big|_1^3$$

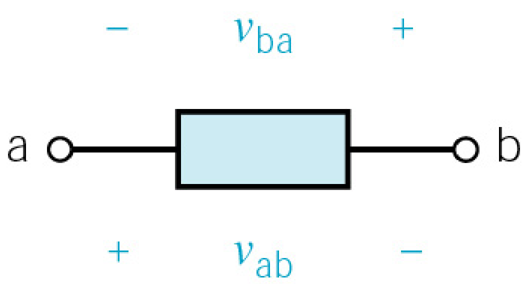
$$=1+\frac{1}{2}(9-1)=5 \quad C$$

- Alternatively, we node that integration of i(t) from t=0 to t=3 s simply requires the calculation of the area under the curve shown in Figure 1.3-6. Then, we have

$$q=1+2x2=5\,C$$

# Voltage

- Voltage: Difference of electrical potential between two points of an electrical or electronic circuit.
- The **voltage** across an element is work (energy) required to move a unit positive charge from the – terminal to the + terminal.




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

Voltage across the element

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

**Figure 1.4-1 (p. 7)**
**Voltage across a circuit element.**

- The unit of voltage: volt (V)

# Power and Energy

- **Energy**: The capacity to do work.
- **Power**: The time rate of expanding or absorbing energy.

$$p = \frac{dw}{dt} \qquad \begin{cases} p\text{: power (W)} \\ w\text{: energy (J)} \\ t\text{: time (s)} \end{cases}$$

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

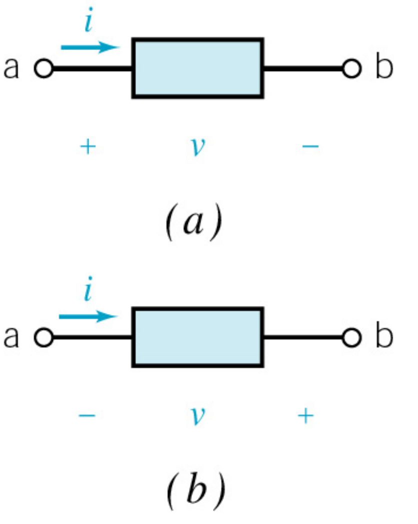
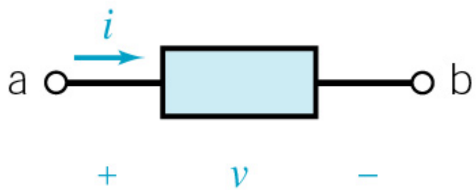
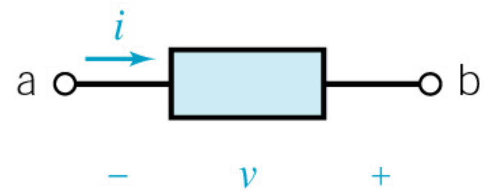



**Figure 1.5-1 (p. 8)**
(*a*) The passive convention is used for element voltage and current.
(*b*) The passive convention is not used.

# Power and Energy

Table 1.5-1 **Power Absorbed or Supplied by an Element**

| POWER ABSORBED BY AN ELEMNET | POWER SUPPLIED BY AN ELEMENT |
|---|---|
|  |  |
| Since the reference directions of v and i adhere to the passive convention, the power p=vi is the power absorbed by the element. | Since 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. |

power absorbed = - power supplied

$$w = \int_{-\infty}^{t} p\,d\tau \quad \left( w = \int_{0}^{t} p\,d\tau \qquad , t \geq 0 \right)$$

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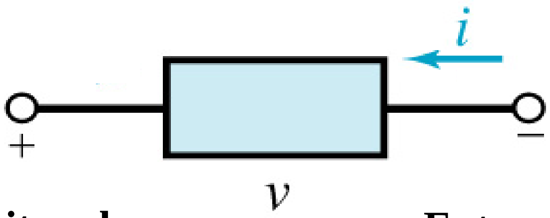
# Active and Passive Circuit Elements

An **active element** is capable of supplying energy.

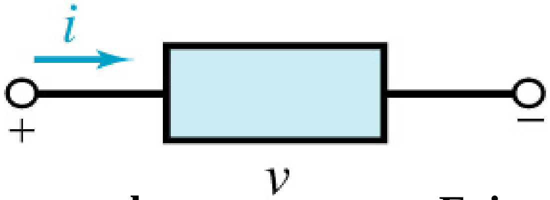



**Exit node** **Entry node**

Active element는 아래 수식을 만족하는 시간 $t$가 적어도 1개 있다.

$$w = \int_{-\infty}^{t} vi \, d\tau \ \geq \ 0$$

A **passive element** is not capable of supplying energy. It simply absorbs energy.




**Entry node** **Exit node**

Passive element는 모든 시간 $t$에 대하여 아래 수식을 만족한다.

$$w = \int_{-\infty}^{t} vi \, d\tau \ \geq \ 0$$

# Example 1.5-1 *Electrical Power and Energy*

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

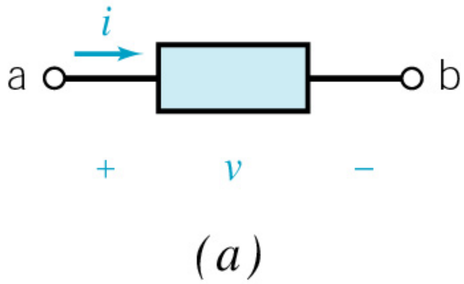
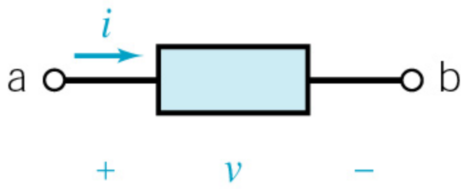



**Figure 1.5-2 (p. 9)**

# Solution




(a)

- The power absorbed by the element is

$$p = vi = 8 \cdot 0.025 = 0.2W = 200mW$$

- The energy absorbed by the element is

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

# Example 1.5-2 *Electrical Power and the Passive Convention*

- Consider the element shown in Figure 1.5-3. The current *i* and voltage $v_{ab}$ adhere to the passive convention, so the power *absorbed* by this element is

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

  The current *i* and voltage $v_{ab}$ do not adhere to the passive convention, so the power *supplied* by this element is

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

  As expected

  $$\text{Power absorbed} = -\text{Power supplied}$$

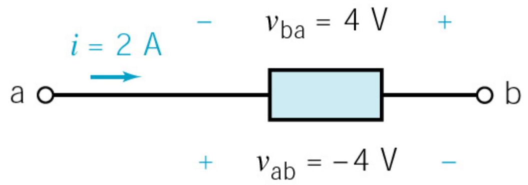



**Figure 1.5-3 (p. 9)**
The element considered in Example 1.5-2.

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# Example 1.5-3 *Electrical Power and the Passive Convention*

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

## Solution

- The power supplied is

$$p = vi = (12e^{-8t})(5e^{-8t}) = 60e^{-16t} W$$

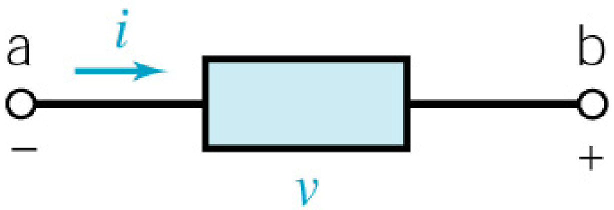


**Figure 1.5-4 (p. 10)**
An element with the current flowing into the terminal with a negative voltage sign.

- This element is providing energy to the charge flowing through it.
  The energy supplied during the first second is

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

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

# Example 1.7-1 *How Can We Check Power and the Passive Convention*

- A laboratory report states that the measured values of ***v*** and ***i*** for the circuit element shown in Figure 1.7-1 are -5V and -2A, respectively. The report also states that the power absorbed by the element is 10W. **How can we check** the reported value of the power absorbed by this element?

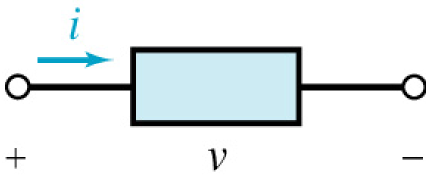


**Figure 1.7-1 (p. 13)**
A circuit element with a measured current and voltage.

## Solution

- The power absorbed is

$$p = vi$$

- Substituting ***v*** and ***i***, we have

$$p = (-5)(-2) = 10W$$

- **Thus, we have verified that the circuit element is absorbing 10W.**