Chapter 2: Basic Components and Electric Circuits

1. Units and scales
2. Basic electric components: charge, current, voltage, power and energy
3. Voltage and current sources
4. Ohm's law

The SI System

- Base units:
  - meter [m], kilogram [kg], second [s], ampere [A]
- Derived units:
  - work or energy: joule [J]
  - power (rate of doing work): watt [W]
  - 1 [W] = 1 [J/s]

SI: Units and Prefixes

FACTOR	NAME	SYMBOL
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{3}	kilo	k
10^{6}	mega	M

- Example:

$$12.3\ [\mathrm{mW}] = 0.0123\ [\mathrm{W}] = 1.23 \times 10^{-2}\ [\mathrm{W}]$$

Basic circuits: Assumptions

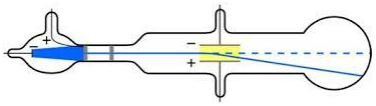
- Lumped parameter circuit (집중정수회로)
  - Attributes of the circuit, resistance, capacitance, and inductance, are concentrated into idealized electrical components (without any physical dimension): resistors, capacitors, and inductors, joined by a network of perfectly conducting wires.
  - This assumption is valid, whenever the physical length of the device is much less than the circuit's operating wavelength.
  - Distributed parameter circuit (분포정수회로)
- Charge is conserved: neither created nor destroyed. (전하보존의 원칙).
- No magnetic coupling between components.

Charge: 전하

- Charge is conserved: neither created nor destroyed.
  - units are coulomb [C].
  - Two types of charge: proton (양자) or electron (전자)
  - Electric charges exist in discrete quantities, integral multiple of 1.6022×10^{-12} [C].
  - Electrical effects are attributed to
    - Separation of charges, creating an electric force (voltage: 전압)
    - Charges in motion, creating current (전류)

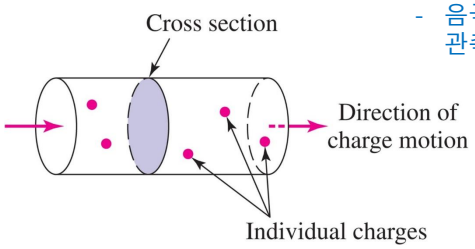
Current & Charge

- Current is the rate of charge flow:
  - 1 [ampere, A] = 1 [C/sec], 단위 시간당 이동한 전하량



음극선 실험

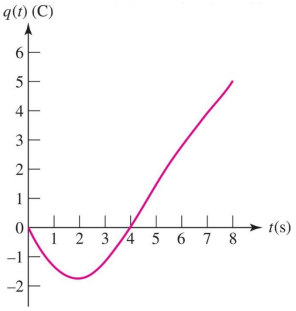
- 전자로 구성된 음극선의 발생을 실험
- 음극선이 자기장/전기장에 따라 휘어짐을 관측하여, 음극선이 전자의 흐름임을 증명



Current & Charge

- Current, $i(t)$, is the rate of flow of charge.
  - Current is a vector quantity: 크기와 방향
  - Same currents:

  - $i(t) = \frac{dq(t)}{dt}$, $q(t) = q(t_0) + \int_{t_0}^{t} i(\tau)d\tau$

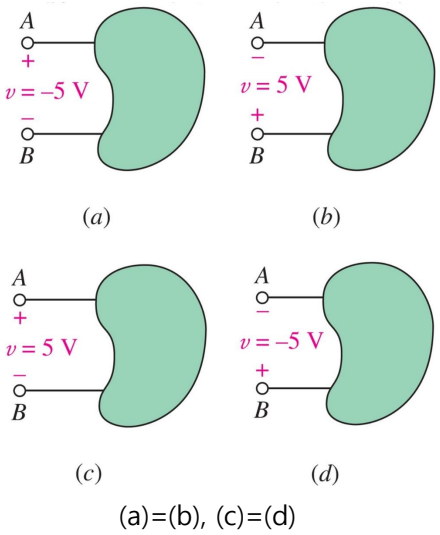


Voltage

- 전압(voltage) 혹은 전위차(potential difference)
  - 전기장 안에서 전하가 갖는 전위의 차이
  - 물이 높은 곳에서 낮은 곳으로 흐르는 것처럼, 전하는 전위가 높은 곳에서 낮은 곳으로 이동한다.
  - 물을 낮은 곳에서 높은 곳으로 이동시키려면 energy가 소모된다.
  - 단위 전하를 A에서 B로 이동시키는데 1 [J]의 energy가 요구된다면, A와 B 사이에는 1 [volt, V]의 전위차가 있다: $v(t) = \frac{dw}{dq}$ [V, J/C]

Voltage

- Voltage [V]: 표현 방법
  - 회로소자 양단에 1[V] 전압이 걸린다.
  - 회로소자 양단의 전위차가 1[V] 이다.
  - Voltage is a vector quantity: 크기와 방향 (극성)



(a)=(b), (c)=(d)

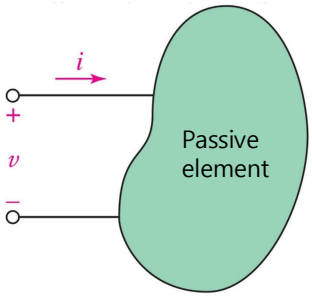
Power

- 전력 (power): 단위 시간당 회로소자에 전달되는 전기 energy의 양, $[W] = \left[\frac{J}{sec}\right]$
  - 어떤 소자를 통과하여, 1[C]의 전하를 1[sec] 동안 이동시키는데 1[J]의 energy가 소모된다면, 시간당 energy 전달률이 1[W]이다.
  - $P = VI$, $[W] = \left[\frac{J}{C} \cdot \frac{C}{s}\right]$
  - When power is positive, the element is absorbing (소모) energy and is called a passive element.
  - When power is negative, the element is supplying (공급) energy and is called an active element.

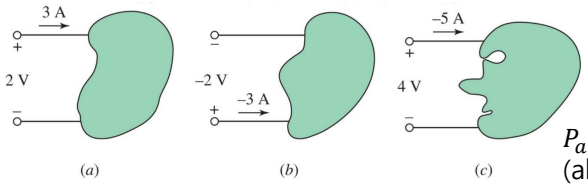
Passive sign convention

- Voltage polarity vs. current direction
  - 전류와 전압은 vector 양으로 크기와 방향을 갖는다.
  - 회로해석에서 전압의 극성에 따라, 전류의 기준방향을 설정해 주어야 한다: passive sign convention

Passive 소자에서, 전류는 positive 극성을 갖는 terminal에서 negative 극성을 갖는 terminal로 흐른다.



Power & Energy



$P_a = +6\ [W]$, $P_b = +6\ [W]$ (absorbing), $P_c = -6\ [W]$ (supplying)

- Energy in [J] or [watt-hours, Wh]
  - 1 [Wh] = 3600 [J]
- Battery capacity in [amp-hours, Ah]
  - Energy, w = (battery voltage, [V]) × (capacity, [Ah])
  - A 1.5 [V] battery with capacity of 2 [Ah]
    - Has total energy of 3 [Wh] = 10.8 [kJ]
    - Can supply a circuit drawing 200 mA for 10 h

Basic Circuit Elements

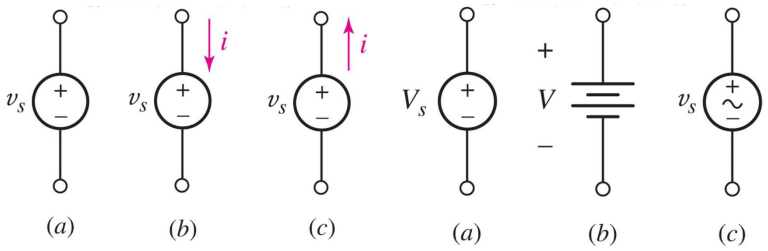
- Passive vs. active elements
  - A circuit element usually has two terminals (sometimes three or more).
  - Relative direction of current to voltage polarity (passive sign convention)
  - Active elements (source, 전원)
    - Current vs. voltage
    - Independent vs. dependent
  - Passive elements
    - Resistor

Thunder, 번개

번개는 구름과 대지 사이에서 일어나는 전기의 방전 현상이다. 뇌우가 내리는 동안 공기가 이동하면서 생기는 충돌로 인하여 구름 내에 전하가 생성되고 구름의 상층부에는 양전하, 하층부에는 음전하가 생성된다. 음전하의 양이 많아지면 전기장의 세기가 증가하여 지상의 양전하가 대전되어 있는 곳으로 떨어진다 (뇌 방전).
전하가 이동하는 통로에는 27,000℃ 정도의 열이 발생한다. 공기의 급격한 팽창으로 인하여 천둥이라는 충격파음이 발생한다. 결국, 전기 energy는 빛과 소리의 형태로 변환된다.

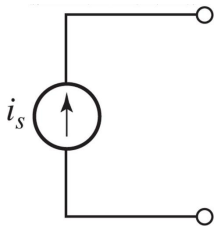
Voltage Sources

- Ideal voltage source
  - a circuit element that maintains a specified voltage v_s across its terminals.
  - Current is determined by other circuit elements.



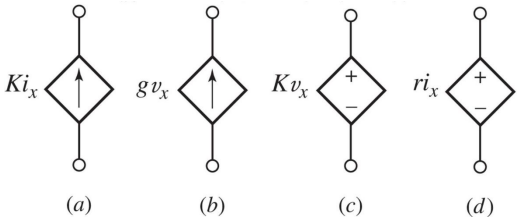
Current Sources

- Ideal current source
  - a circuit element that maintains the specified current flow i_s through its terminals.
  - The voltage is determined by other circuit elements.



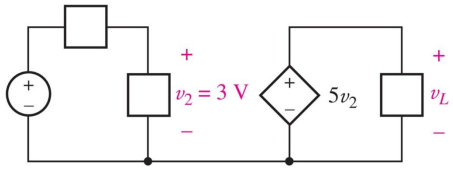
Dependent Sources

- Dependent current sources
  - (a) and (b) maintain a *current* specified by another circuit variable (control variable).
- Dependent voltage sources
  - (c) and (d) maintain a *voltage* specified by another circuit variable (control variable).

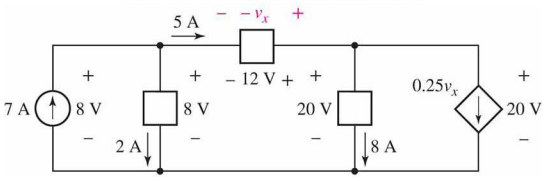


Dependent Sources

- Example 2.3

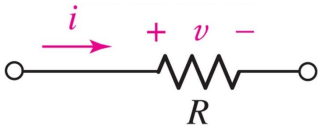


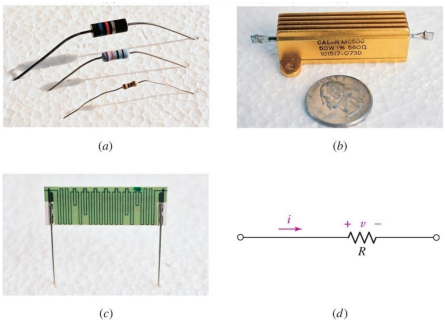
- Practice 2.10



Resistor, 저항

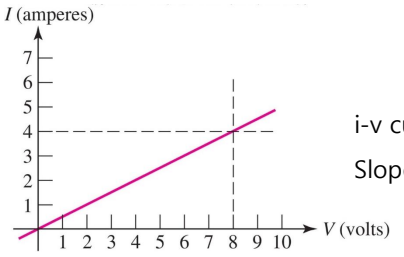
- Ohm's law
  - $v = Ri$, where R [Ω] is a resistance.
  - 도체의 저항, $R = \frac{\rho \ell}{A}$, ρ: resistivity, ℓ: length, A: area





Resistor

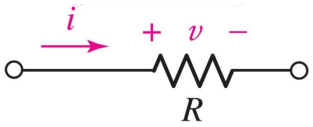
- Voltage-current relationship: $v = Ri$



i-v curve of a 2 [Ω] resistor:

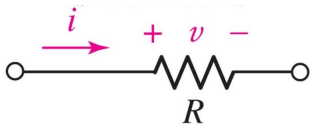
Slope := 4 [A] / 8 [V] or 0.5 [Ω^{-1}]

- Power: $p = vi = \frac{v^2}{R} = i^2 R\ [W] > 0$
  - Passive element (absorbing energy)



Register

- Example



Given $R = 560\ [\Omega]$ and $i = 42.4\ [mA]$,

(1) $v = Ri = 0.0424 \times 560 = 23.7\ [V]$

(2) $p = i^2R = 0.0424^2 \times 560 = 1.007\ [W]$

- Conductance
  - $G = \frac{1}{R}\ [S]$, (siemens)
  - $i = Gv$

Open & Short circuits

- An open circuit (개방회로) between A and B
  - $i = 0$
  - Voltage across an open circuit could be any value.
  - An open circuit is equivalent to $R = \infty\ [\Omega]$.

- A short circuit (단락회로) between A and B
  - $v = 0$
  - Current through a short circuit could be any value.
  - A short circuit is equivalent to $R = 0\ [\Omega]$.