Lecture 1.
Basic Concepts
of Electric Circuits

고윤호

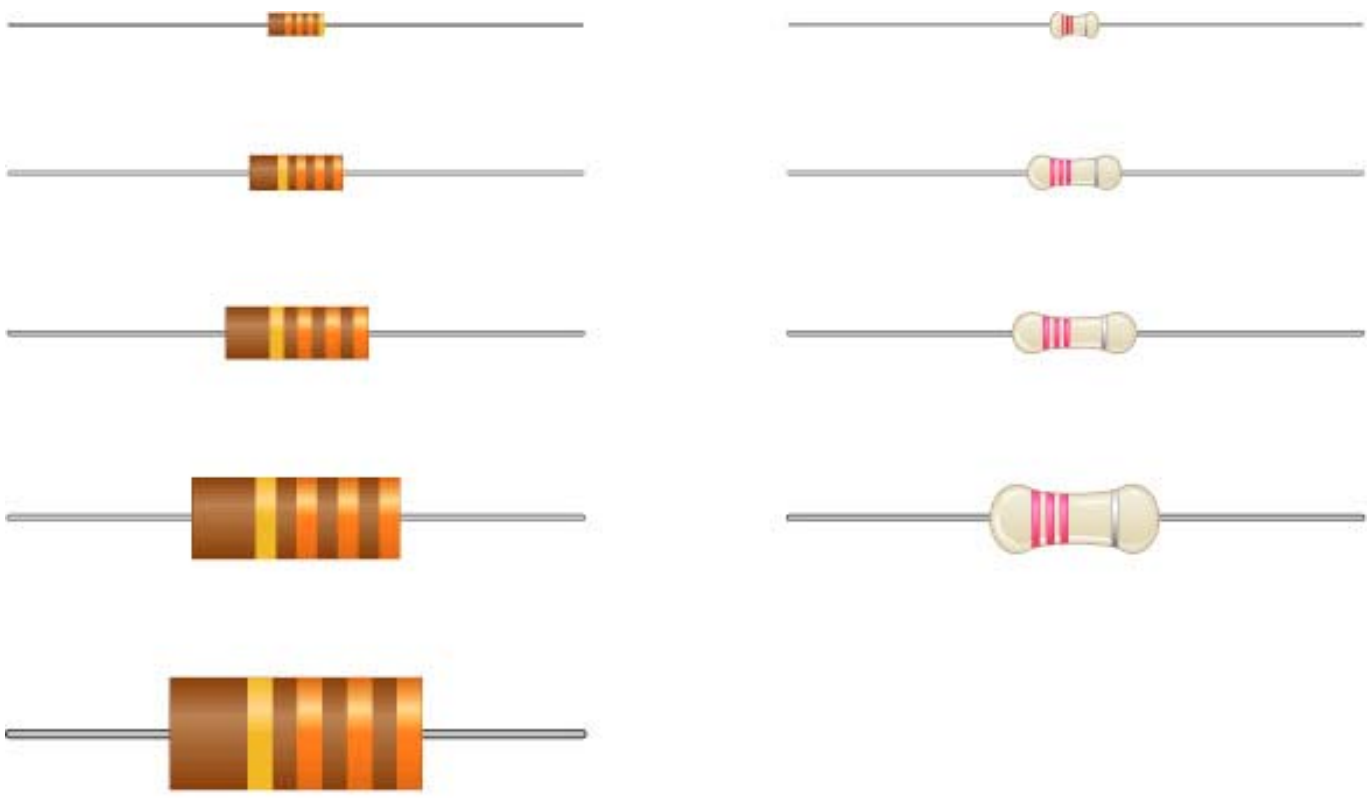
Index

1. Electrical Components and Measuring Instruments

This section will give an overview of the instruments and components you will use throughout this course.

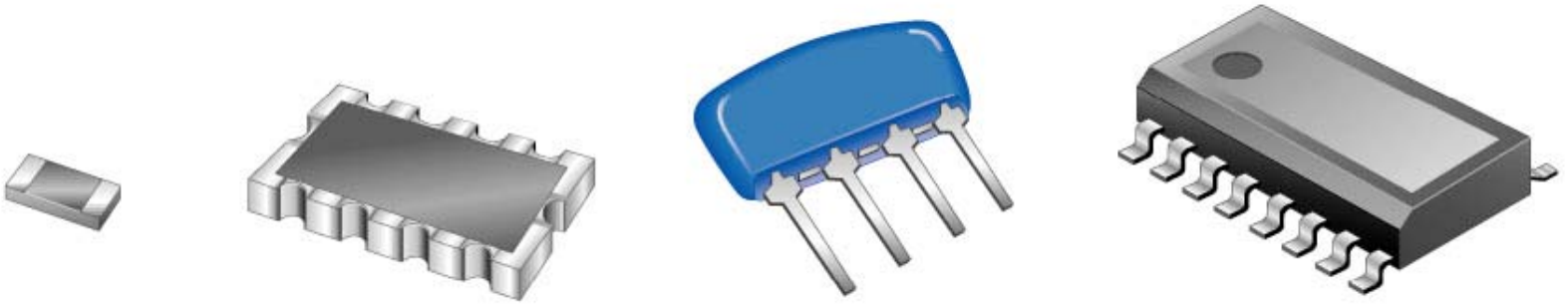
Resistors

- **Resistors limit electric current in a circuit.**



(a) Carbon-composition (b) Metal film

Two common types



(a) Metal film chip resistor (b) Chip resistor array (c) Resistor network (simm) (d) Resistor network (surface mount)

Chip resistor and resistor network

(a) Axial-lead wirewound (b) Adjustable wirewound (c) Radial-lead for PC board insertion (d) Surface mount

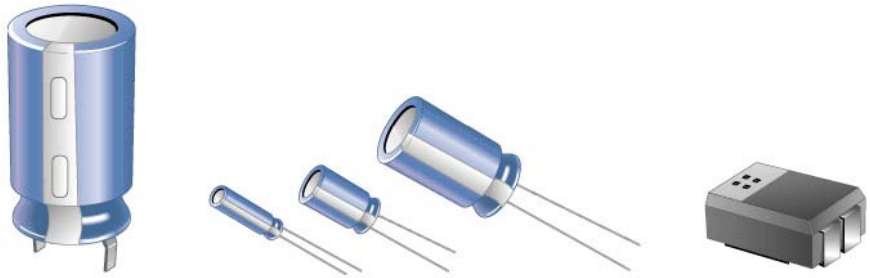
Power resistor

(a) Lead mounted (b) Surface mounted

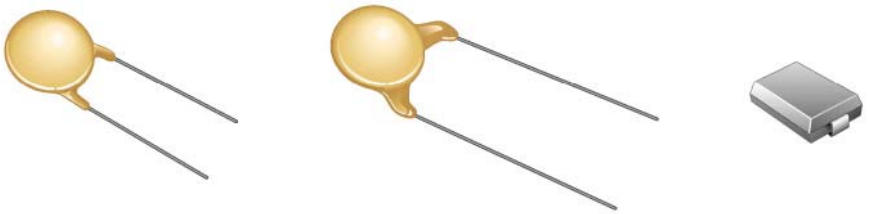
variable resistor

Capacitors

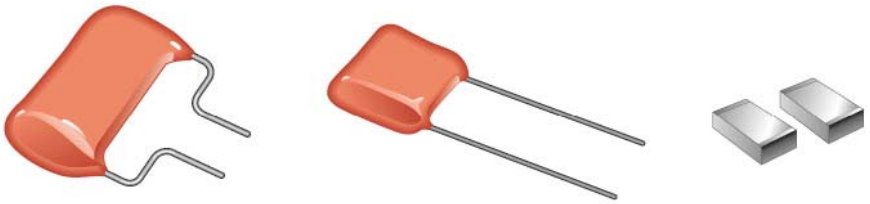
- **Capacitors store electrical charge.**



(a) Electrolytic, axial-lead, and surface mount



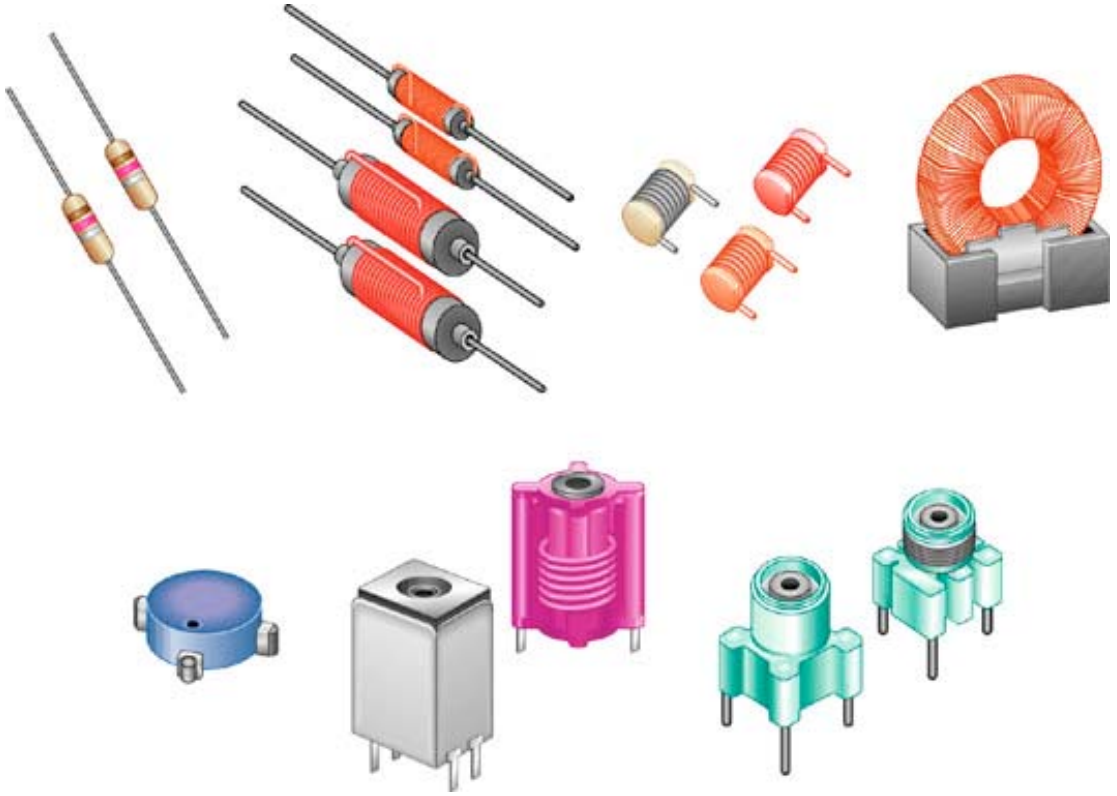
(b) Ceramic, axial-lead, and surface mount



(c) Film, axial-lead, and chip

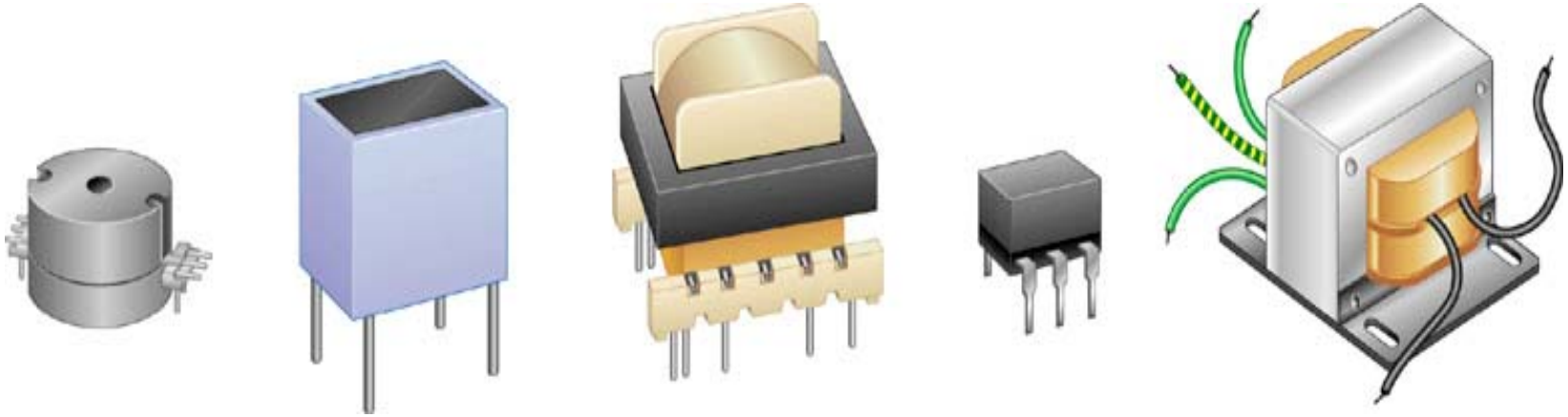
Inductors

- **Inductors, or coils, are used to store energy in an electromagnetic field.**



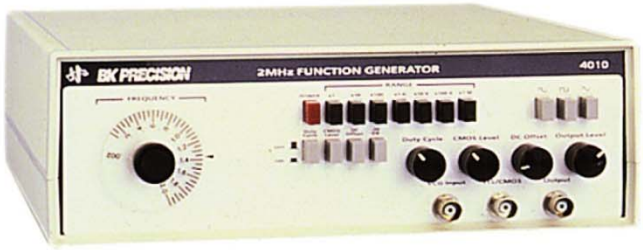
Transformers

- Transformers are used for ac coupling, or to increase/decrease ac voltages.

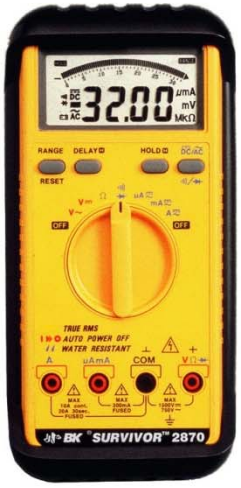


Electronic Instruments

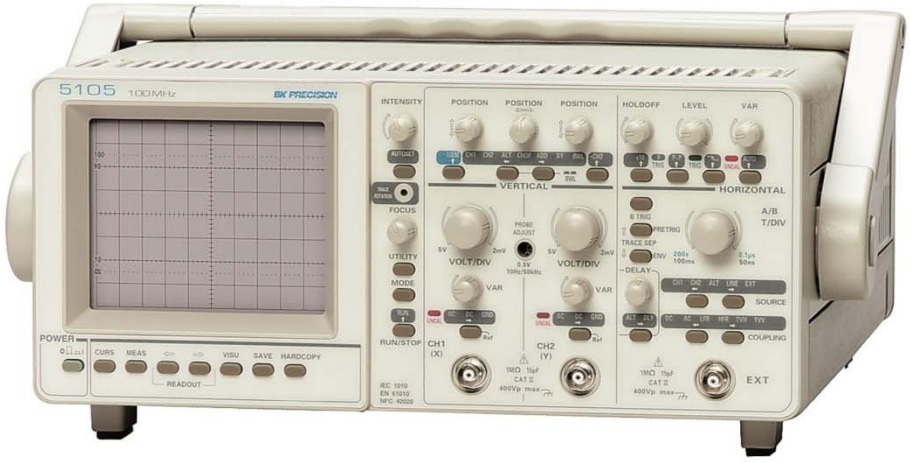
(a)



(b)



(c)



(d)

Electronic Instruments (cont.)

- **DC Power supply**
  - A DC power supply provides current and voltage to electronic circuits.
- **Function Generator**
  - A function generator provides electronic signals for circuits
- **Digital Multimeter**
  - A digital multimeter (DMM) measures voltage, current or resistance, depending upon the function selected.
  - Voltmeters, Ammeter, Ohmmeter
- **Oscilloscope**
  - The oscilloscope is used for observing and measuring voltage signals in a circuit

2. Scientific Notation

Scientific notation provides a convenient method to express large and small numbers

Scientific Notation

- Scientific notation is a method of expressing numbers.
- A quantity is expressed as a number between 1 and 10, and a power of ten.

Example:

5000 would be expressed as 5×10^3 in Scientific notation.

Powers of Ten

- The power of ten is expressed as an exponent(지수) of the base(밑수) 10.

$10^6 = 1{,}000{,}000$	$10^{-6} = 0.000001$
$10^5 = 100{,}000$	$10^{-5} = 0.00001$
$10^4 = 10{,}000$	$10^{-4} = 0.0001$
$10^3 = 1{,}000$	$10^{-3} = 0.001$
$10^2 = 100$	$10^{-2} = 0.01$
$10^1 = 10$	$10^{-1} = 0.1$
$10^0 = 1$	

- Exponent indicates the number of places that the decimal point is moved to the right (positive exponent) or left (negative exponent).

Engineering Notation

Engineering notation is similar to Scientific notation, except that engineering notation can have from 1 to 3 digits to the left of the decimal point, and the powers of 10 are multiples of 3.

Scientific notation vs Engineering notation

Consider the number: 23,000

In Scientific notation it would be expressed as:

$$2.3 \times 10^4$$

In Engineering notation it would be expressed as:

$$23 \times 10^3$$

Metric Prefixes

- Metric prefixes are symbols that represent the powers of ten used in Engineering notation.

METRIC PREFIX	SYMBOL	POWER OF TEN	VALUE
pico	p	10^{-12}	one-trillionth
nano	n	10^{-9}	one-billionth
micro	μ	10^{-6}	one-millionth
milli	m	10^{-3}	one-thousandth
kilo	k	10^{3}	one thousand
mega	M	10^{6}	one million
giga	G	10^{9}	one billion
tera	T	10^{12}	one trillion

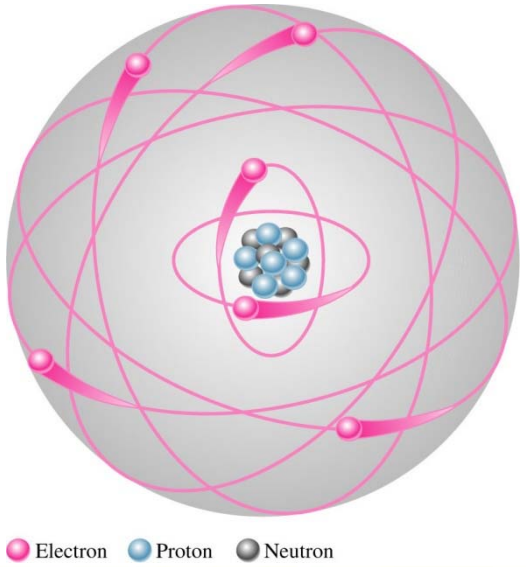
- Consider the quantity 0.025 amperes, it could be expressed as 25 x 10^{-3} A in Engineering notation, or using the metric prefix as 25 mA.

4. Atomic Structure

This section will give the structure of the atom, electron orbits and shells, valence electrons, ions, and types of materials used in electronics

Atomic Structure

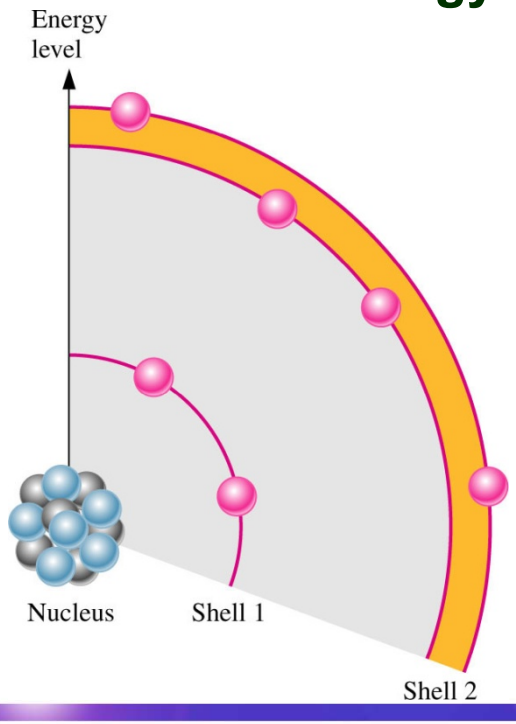
- **An atom is the smallest particle of an element that retains the characteristics of that element.**
- **An atom has a nucleus, consisting of positively charged particles called protons, and uncharged particles called neutrons.**
- **The basic particles of negative charge, called electrons, orbit the nucleus.**

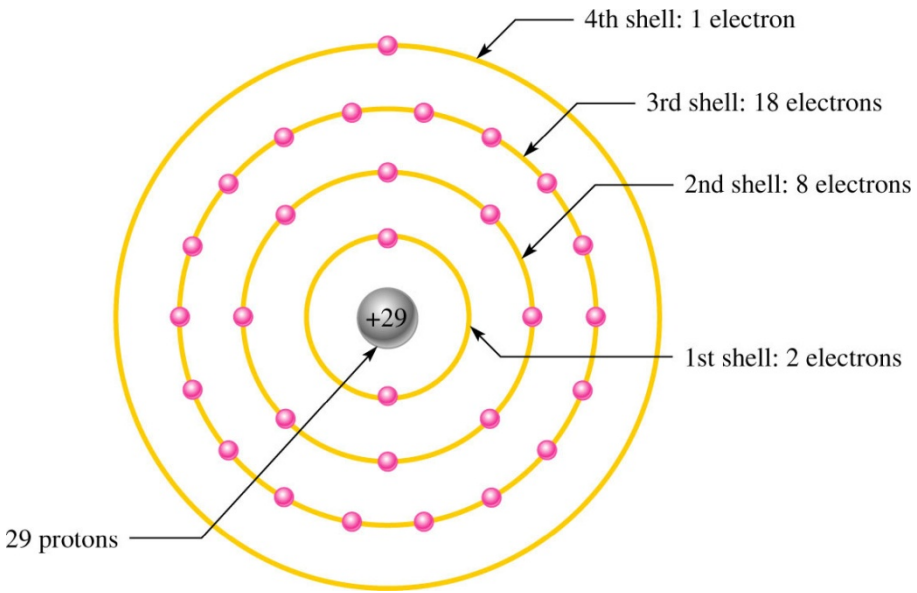


Bohr model

Electron shells and Orbits

- Electrons orbit the nucleus at discrete distances from the nucleus.
- Orbits are grouped onto energy bands known as shells.
- An atom has a fixed number of shells.
- Each shell has a fixed maximum number of electrons permissible at energy levels.





Valence Electrons

- **Electrons with the highest energy exist in the outermost shell, known as the** valence **shell, and its electrons are called** valence electrons**.**
- **Valence electrons are relatively loosely bound to the atom.**
- **If a valence electron acquires enough external energy to leave the atom, the process is known as** ionization**.**
- **The escaped electron is called a** free electron**.**

Categories of Materials

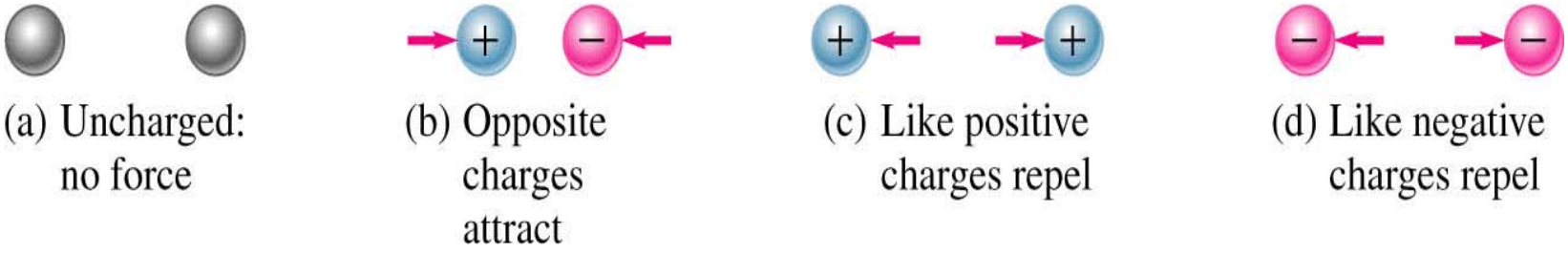
- **Conductors** readily permit current flow, due to a large number of free electrons in the material. Conductors are characterized by 1, 2, or 3 valence electrons in their atomic structure.
- **Semiconductors** have 4 valence electrons
- **Insulators** have few free electrons, and tend not to permit current to flow through them.

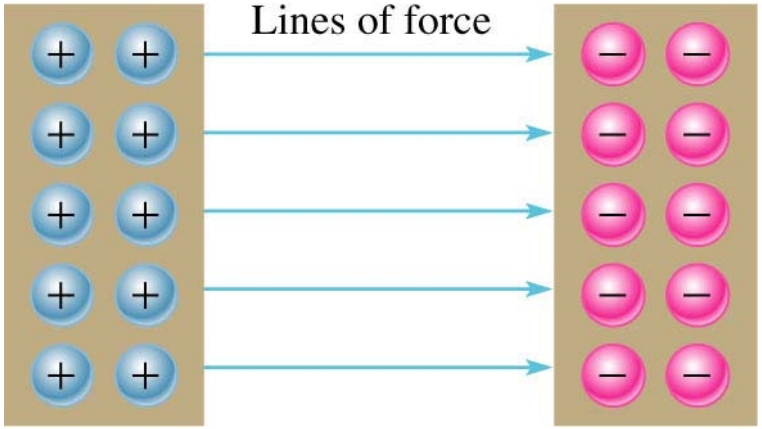
5. Electrical Charge, Voltage and Current

This section will give the concept of electrical charge, voltage and current

Electrical Charge

- The charge of an electron and that of a proton are equal in magnitude but opposite in polarity.
- The force acting between charges is called an electric field.





Coulomb

- **Electrical charge (*Q*) is measured in** coulombs **(C).**
- **By definition:**

  One coulomb is the total charge possessed by 6.25 x 10^{18} electrons.

$$Q = (\text{number of electrons})/(6.25 \times 10^{18})$$

  - **An electron has a charge of 1.6 x 10^{-19}**

Voltage

- **The unit of voltage is the** volt **(V).**
- **By definition: the difference in electric potential energy of a unit test charge transported between two points**

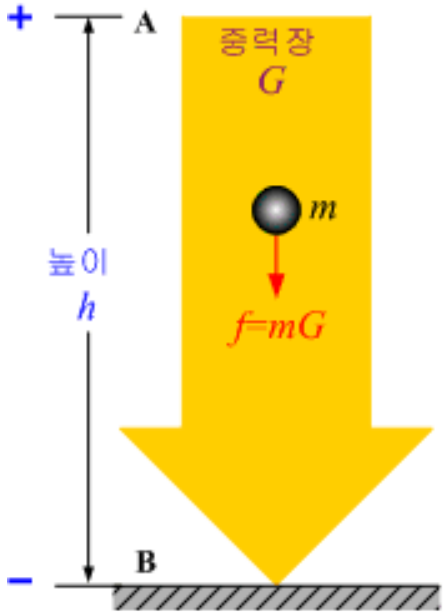
One volt is the potential difference (voltage) between two point when one joule of energy is used to move one coulomb of charge from one point to the other.

$$V = \frac{W}{Q}$$

V : *voltage* (V, *volt*)

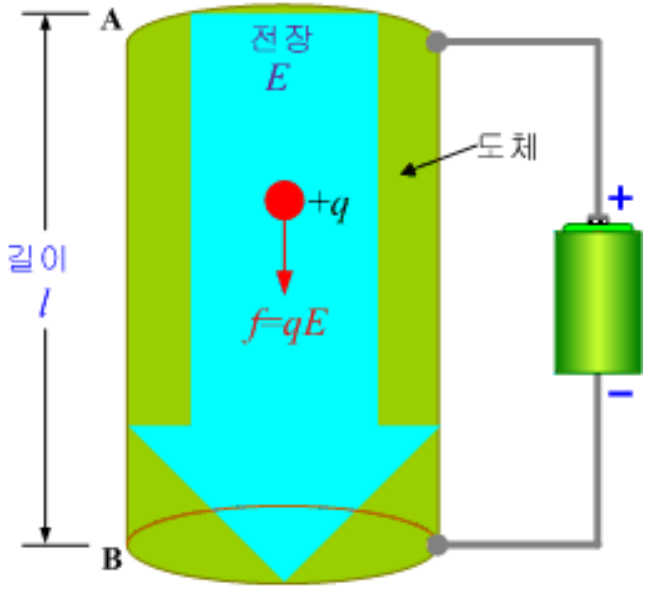
W : *energy* (J, *joules*)

Q : *charge* (C, *coulomb*)



단위 질량에 대한
A, B간의 위치에너지 차
$=Gh$

(a)

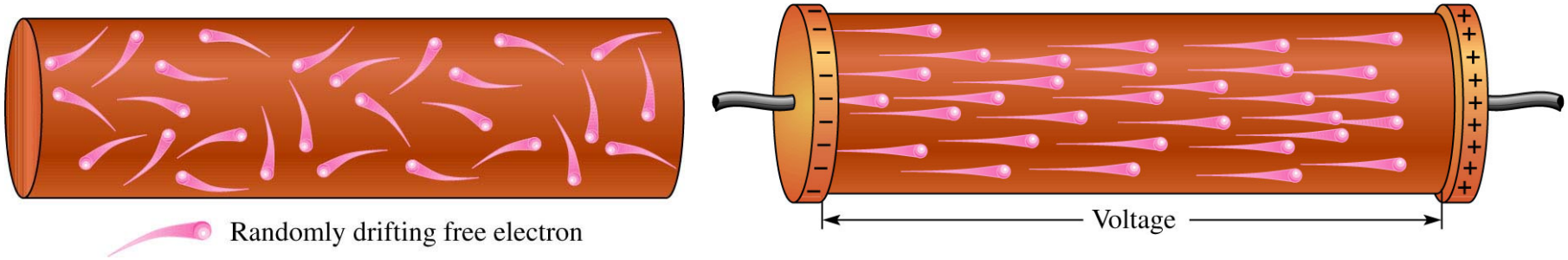


단위 전하에 대한
A, B간의 전기적 위치에너지 차
$=El$

(b)

Current

- **The movement of free electrons from negative to positive is electrical** current (*I*).



- **By definition:**

  electrical current is the rate of flow of charge

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

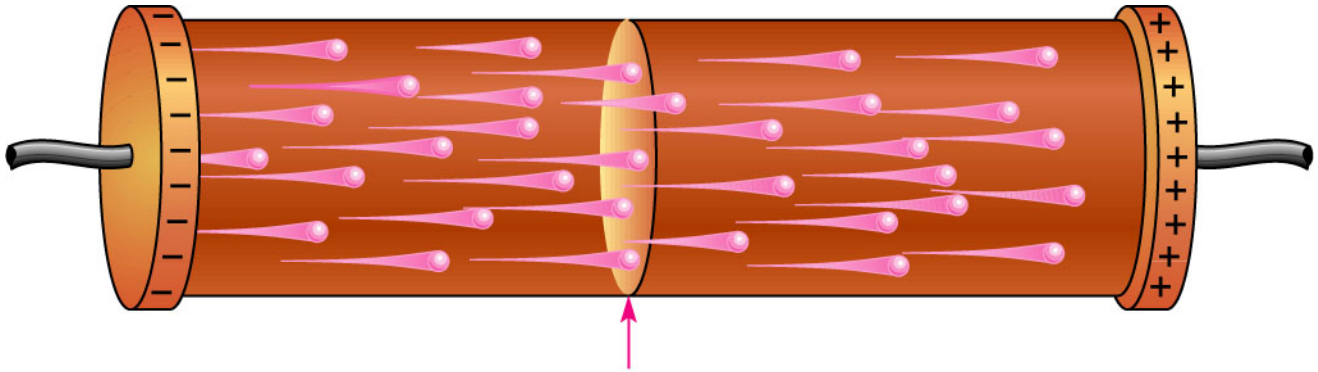
I : *current* (A, *ampere*)

t : *time* (t, *second*)

Q : *charge* (C, *coulomb*)

Ampere: The Unit of Current

One ampere is the amount of current that exists when a number of electrons having a total charge of one coulomb move through a given cross-sectional area in one second.



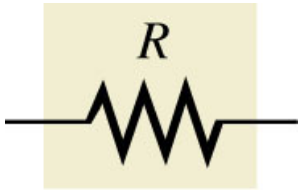
When a number of electrons having 1 coulomb of charge pass through this cross-sectional area in 1 second, there is 1 ampere of current.

6. Resistance

This section will give the concept of reistance

Resistance

- **The property of a material that restricts the flow of electrons is called** resistance**.**



Graphic symbol

- **Ohm: The unit of Resistance**
  - **One ohm of resistance exists if there is one ampere of current in a material when one volt is applied across the material.**
  - **The symbol of an ohm is omega (Ω).**
- **Conductance is the reciprocal of resistance.**

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

  - **The unit of conductance is** siemens **(S).**

Resistance

- Wire Resistance

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

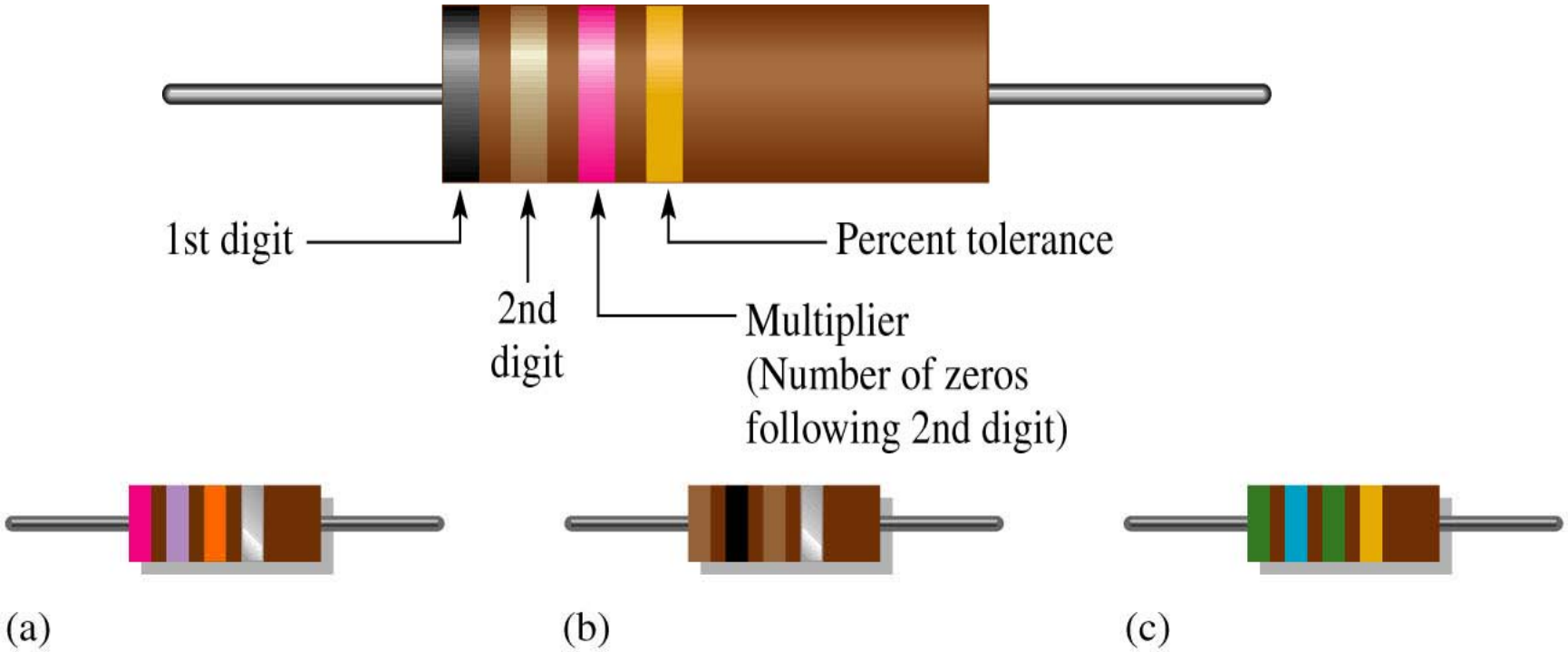
$\rho : resisitivity$

$l : length$

$A : cross - sectional\ area$

Color-code bands on a resistor

- 1st band is the first digit of the resistance value.
- 2nd band is the second digit of the resistance value.
- 3rd band is the multiplier (number of zeros).
- 4th band indicates the tolerance.



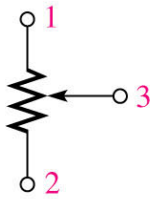
Resistor color code

	Digit	Color
Resistance value, first three bands: First band—1st digit Second band—2nd digit *Third band—multiplier (number of zeros following the 2nd digit)	0	Black
	1	Brown
	2	Red
	3	Orange
	4	Yellow
	5	Green
	6	Blue
	7	Violet
	8	Gray
	9	White
Fourth band—tolerance	±5%	Gold
	±10%	Silver

No band : 20%

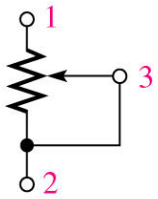
Variable Resistors

- **Variable resistors are designed so that their resistance values can be changed with manual or automatic adjustment.**
- **A** potentiometer **is a variable resistor used to divide voltage.**
- **A** rheostat **is a variable resistor used to control current.**

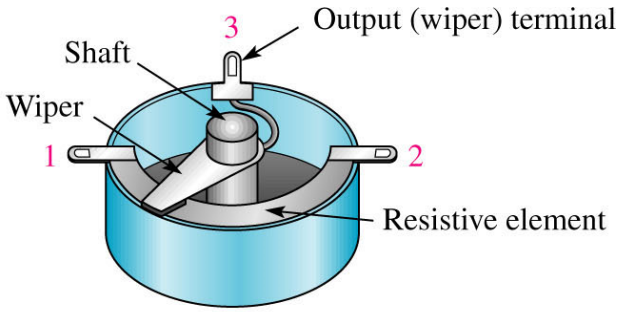


(a) Potentiometer

(b) Rheostat



(c) Potentiometer connected as a rheostat

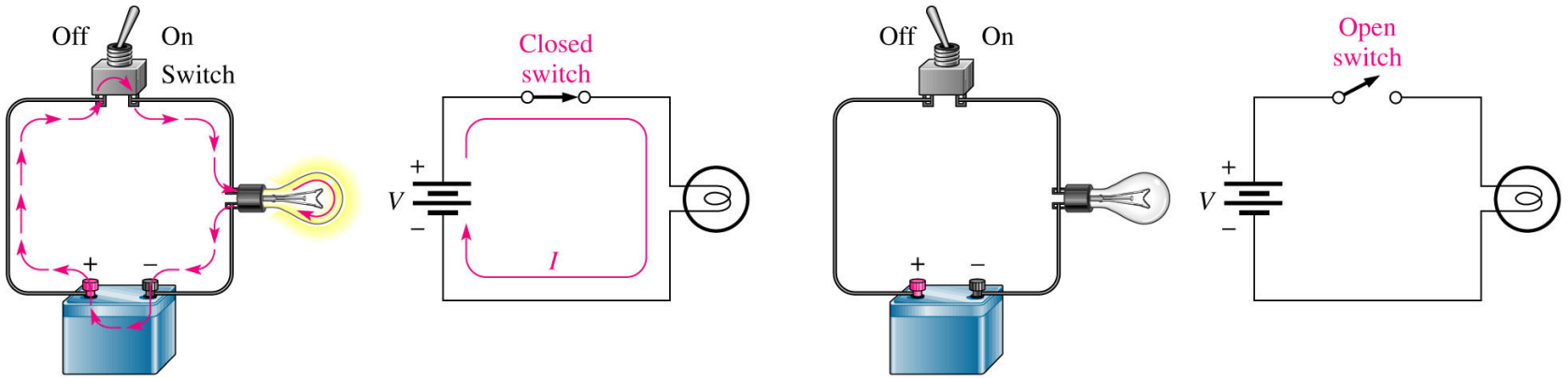


(d) Basic construction (simplified)

7. Basic electric circuit

This section will introduce a basic electric circuit

- **An electric** circuit **consists of a voltage source, a load, and a path for current between the source and the load.**
- **A** closed circuit **is one in which the current has a complete path.**
- **An** open circuit **is one in which the current path is broken, or incomplete.**



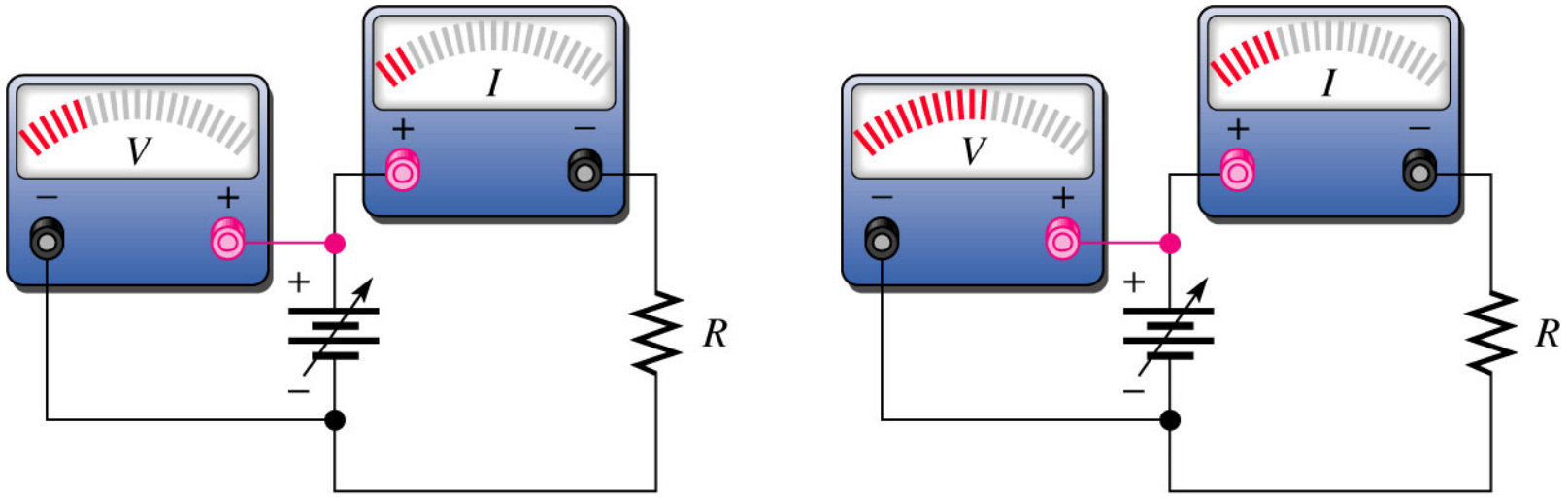
(a) There is current in a *closed* circuit because there is a complete current path (switch is ON or in the *closed* position). Current is almost always indicated by a red arrow in this text.

(b) There is no current in an *open* circuit because the path is broken (switch is OFF or in the *open* position).

8. Ohm's Law

Ohm's Law(오옴의 법칙)

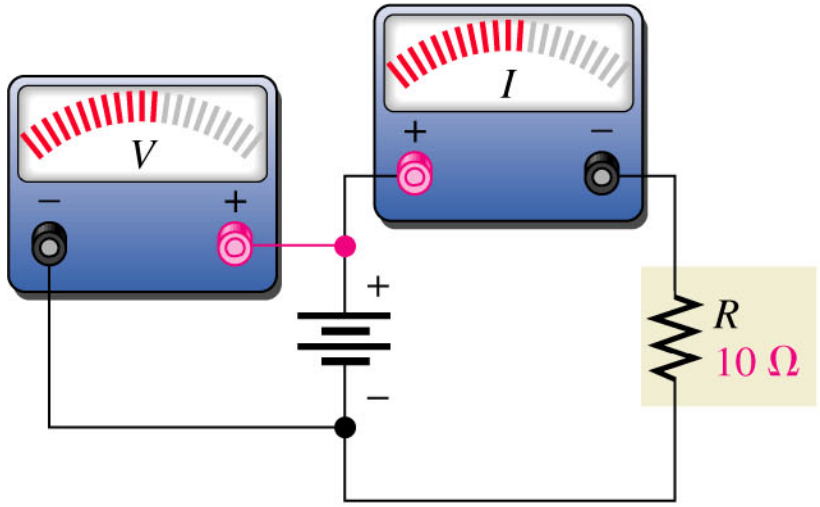
일정한 저항을 유지할 때 전압의 변화가 전류에 미치는 영향



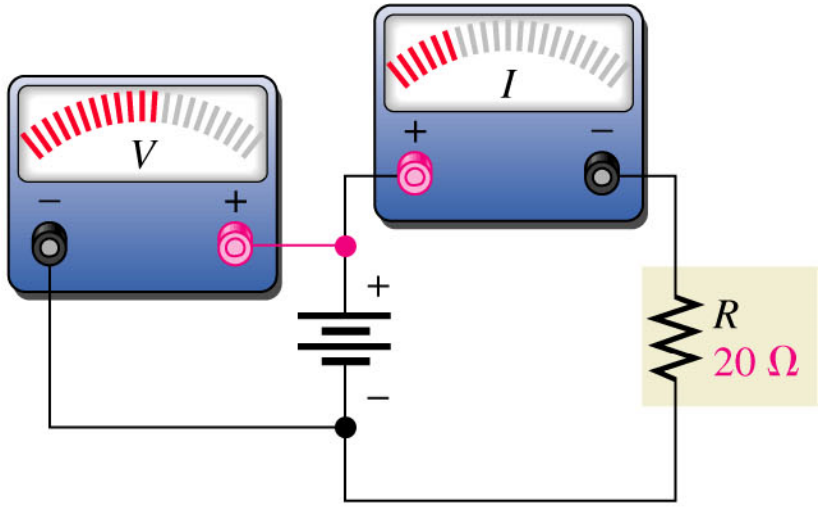
(a) Less V, less I (b) More V, more I

Ohm's Law(오옴의 법칙)

일정한 전압을 유지할 때 저항의 변화가 전류에 미치는 영향



(a) Less R, more I



(b) More R, less I

Ohm's Law(오옴의 법칙)

- 전류를 구하는 식

$$I = \frac{V}{R}$$

$$I(A), V(V), R(\Omega)$$

- 전압을 구하는 식

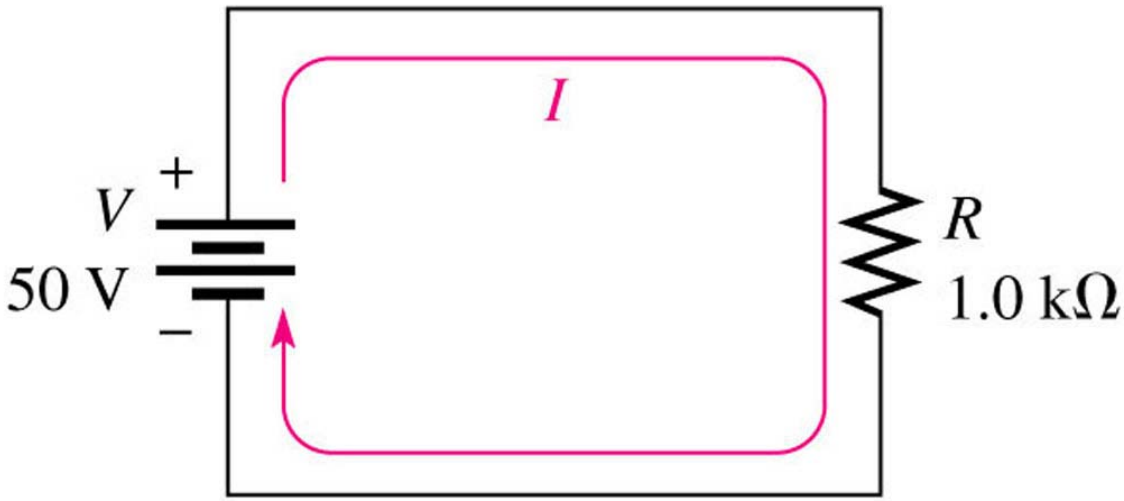
$$V = IR$$

- 저항을 구하는 식

$$R = \frac{V}{I}$$

전류 계산

예제



$$I = \frac{V}{R} = \frac{50V}{1.0k\Omega} = \frac{50V}{1\times10^{3}\,\Omega} = 50\times10^{-3}\,A = 50mA$$

9. Energy and Power

에너지(Energy)와 전력(Power)

- 에너지 (*W*)
  - 일을 하는 능력
- 전력 (*P*)
  - 에너지를 사용하는 속도
  - 단위 시간당 사용된 에너지

$$\text{전력} = \frac{\text{에너지}}{\text{시간}} \qquad P = \frac{W}{t}$$

- 에너지 단위는 주울 (J, joule)
- 시간 단위는 초 (s, second)
- 전력 단위는 와트 (W, watt)

예제 100J의 에너지를 5초간 사용했다면 전력은?

에너지(Energy)와 전력(Power)

- 전력의 단위 **(W, watt)**
  - 전자공학 : **mW, μW, *p*W**
  - 전기공학 : **kW, MW**
- 에너지의 킬로와트시간**(kWh)** 단위

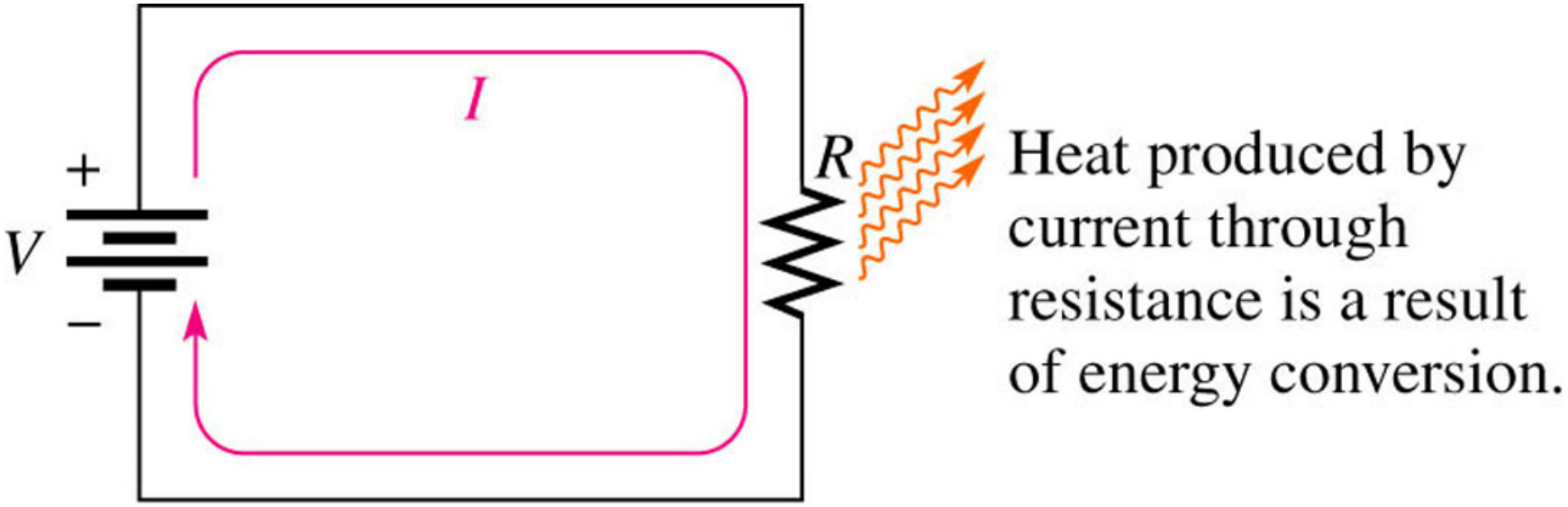
$$\text{에너지} = \text{전력} \times \text{시간} \qquad W = Pt$$

  - 전력의 단위가 **W**, 시간의 단위가 **s** 일 때, 에너지의 단위는 **J, Ws**
  - 전력의 단위가 **W**, 시간의 단위가 **h** 일 때, 에너지의 단위는 **Wh**
  - 전력의 단위가 **kW**, 시간의 단위가 **h**일 때, 에너지의 단위는 **kWh**

예제 2시간 동안 2500W의 전력을 소비한 경우 에너지는?

$$W = Pt = 2500W \times 7200s = 18 \times 10^6 J$$
$$W = Pt = 2500W \times 2h = 5000Wh$$
$$W = Pt = 2.5kW \times 2h = 5kWh$$

전기 회로의 전력



전기회로에서의 전력 → 저항에서 발생하는 열

전기 회로의 전력

- 와트의 법칙
  - 전기회로에서의 전력

$$P = IV$$

$$P = I^2 R$$

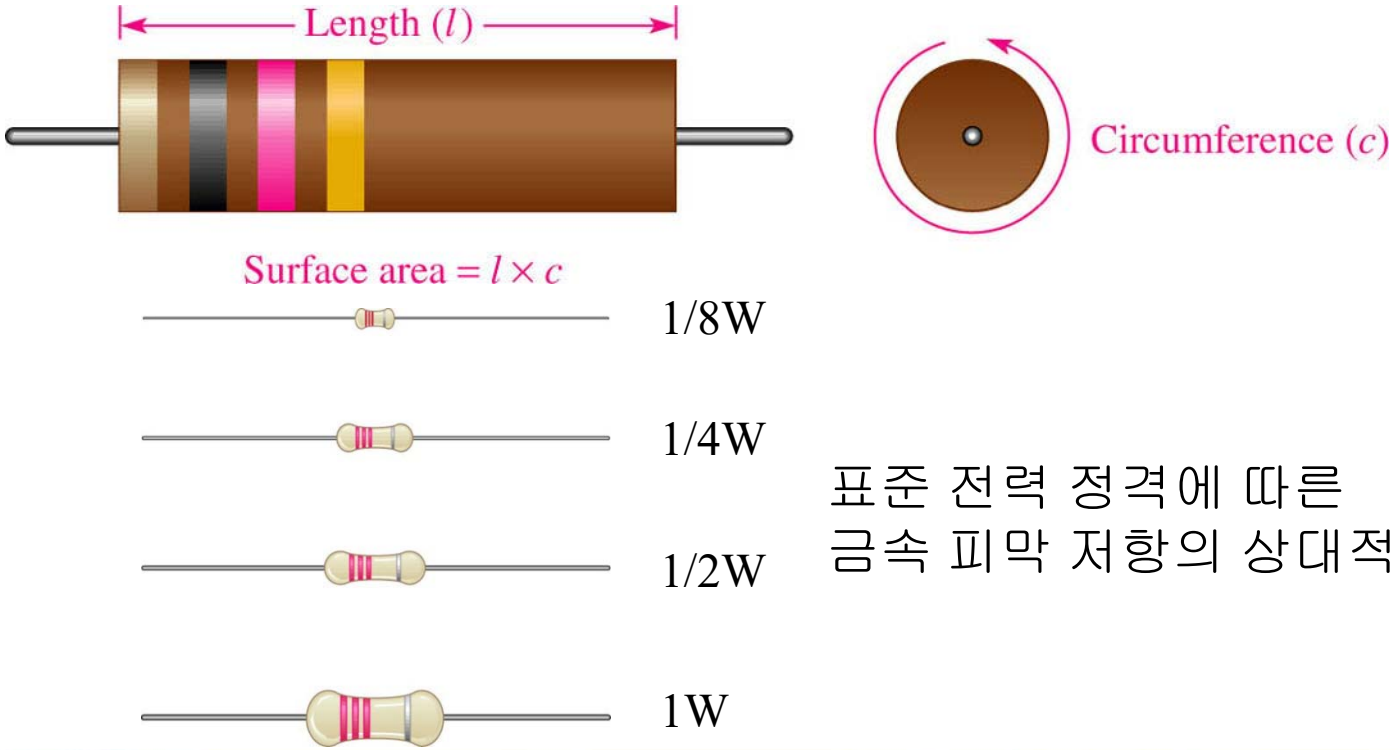
$$P = \frac{V^2}{R}$$

$$V = \frac{W}{Q} \quad I = \frac{Q}{t} \Rightarrow VI = \frac{W}{Q}\frac{Q}{t} = \frac{W}{t} = P$$

- 전류의 단위는 **A**
- 전압의 단위는 **V**
- 저항의 단위는 **Ω**

저항 전력의 정격

- 전력 정격, 정격 전력
  - 저항이 손상을 입지 않고 소비할 수 있는 최대 전력
    - 물리적 구성 성분, 크기에 관계
    - 저항의 표면적이 넓을수록 소비 가능한 전력도 커진다

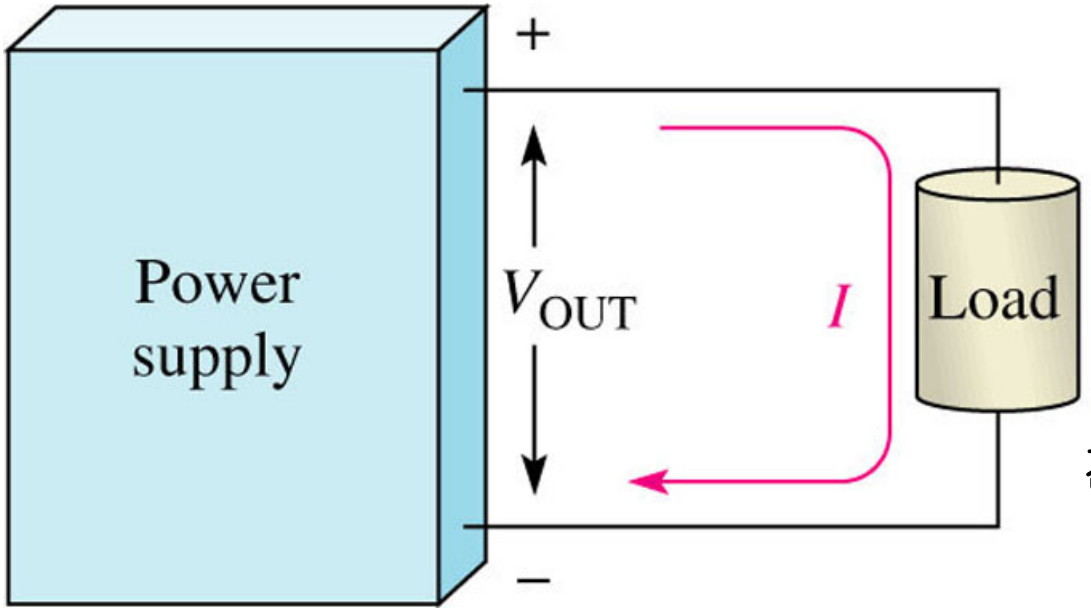


표준 전력 정격에 따른
금속 피막 저항의 상대적 크기

10. Power Supply

전원 공급기 (Power Supply)

- 전원 공급기
  - 부하(전원 공급기에 연결된 전기 소자)에 전력을 공급하는 장치



Power to load = IV_{OUT}

전원 공급기가 공급하는 전력
= 부하가 소비하는 전력

- ❖ 전지 **(battery)**
- ❖ 정전압 전자회로**(regulated electronic circuit, electronic power supply)**

전원 공급기 (Power Supply)

- 전지의 암페어-시간(Ah) 정격
  - 전지 : 제한된 화학 에너지 → 전기에너지
  - 전력 공급 시간 제한
  - 암페어-시간/Ampere-hour (Ah)의 단위로 측정

예제

70Ah로 표시된 전지로 2A의 전류를 몇 시간 공급할 수 있는가?