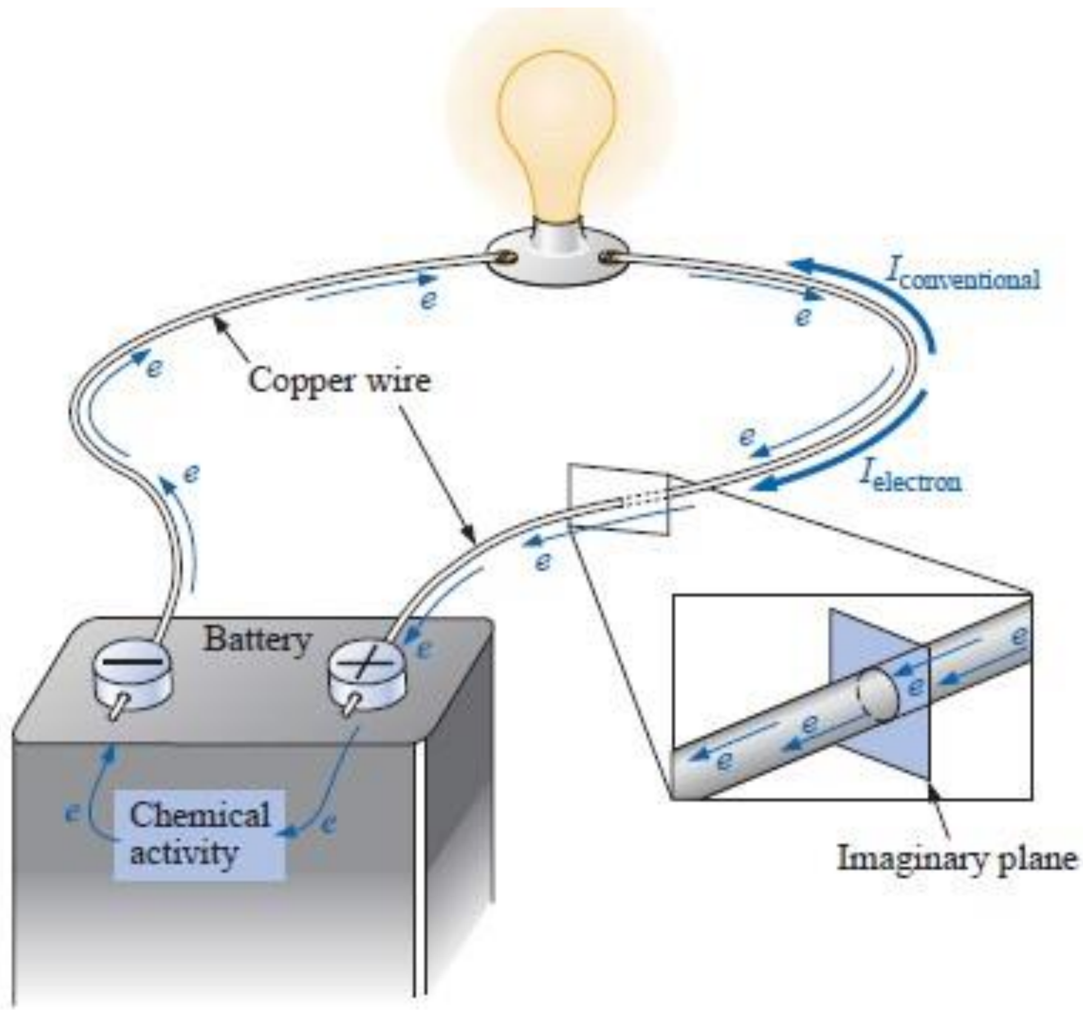
The Basic Electric Circuit



Basic Current Equation

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

$$\text{Charge/electron} = Q_e = \frac{1\ \text{C}}{6.242 \times 10^{18}} = 1.6 \times 10^{-19}\ \text{C}$$

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

$$\boxed{Q = It} \quad \text{(coulombs, C)}$$

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

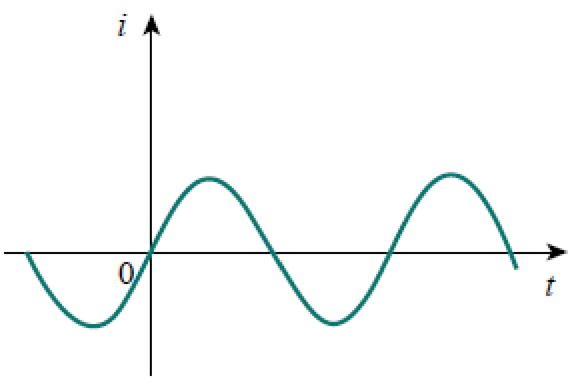
I = amperes (A)
Q = coulombs (C)
t = seconds (s)

$$\boxed{t = \frac{Q}{I}} \quad \text{(seconds, s)}$$

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

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

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



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

Types of Circuit Elements

Active Elements

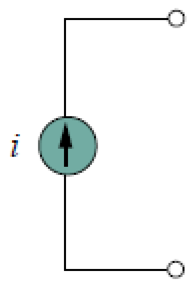
- Capable of generating energy
- Generators, batteries and operational amplifiers

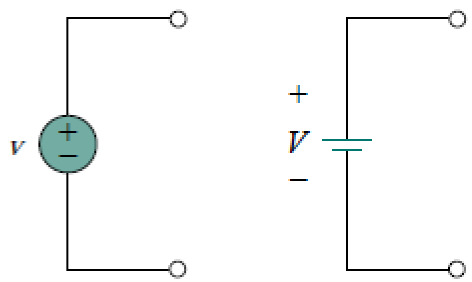
Passive Elements

- Not capable of generating energy
- Resistors, Inductors and capacitor

Types of Sources

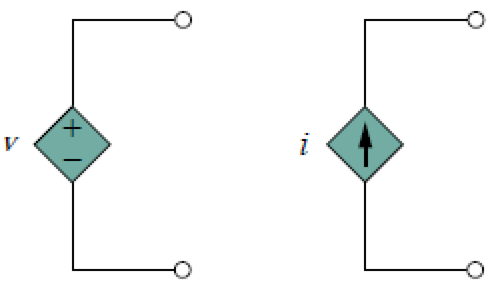
An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit variables.





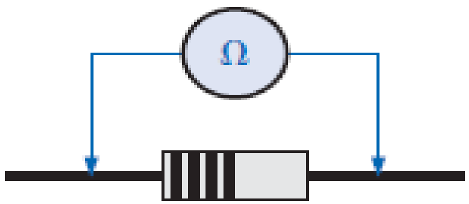
An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.

1. A voltage-controlled voltage source (VCVS).
2. A current-controlled voltage source (CCVS).
3. A voltage-controlled current source (VCCS).
4. A current-controlled current source (CCCS).

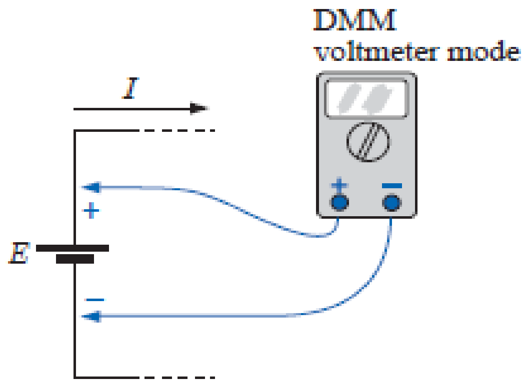


Measuring Instruments

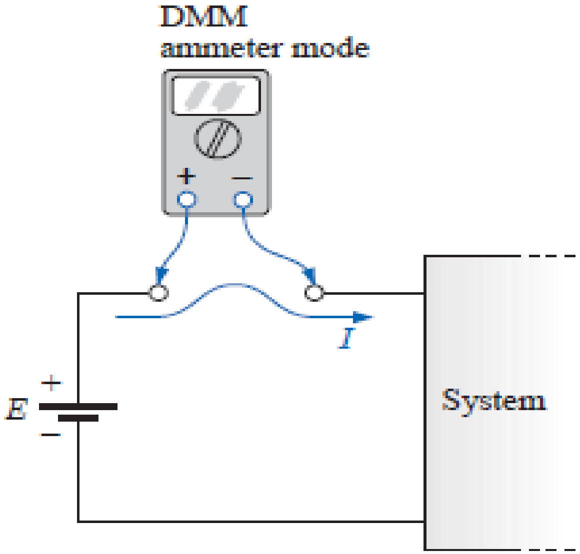
Ohmmeter



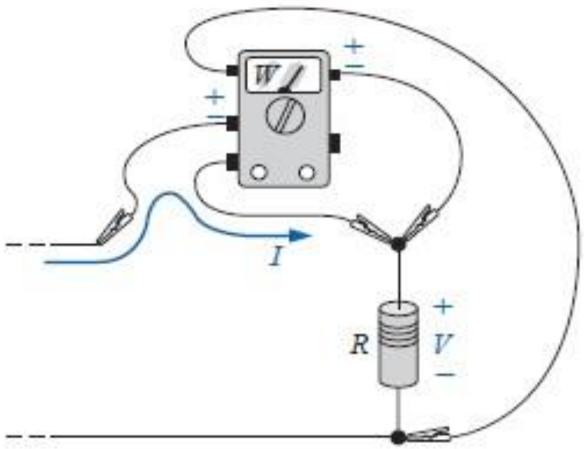
Voltmeter



Ammeter

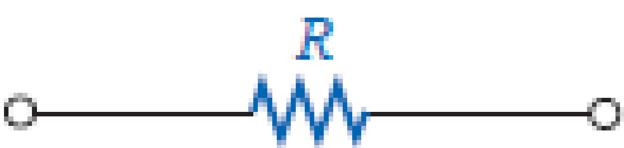


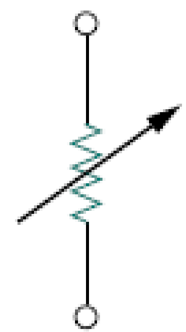
Wattmeter

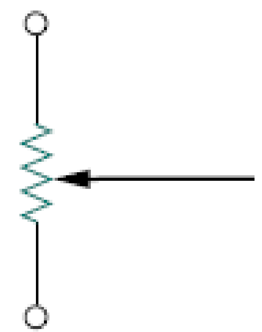


Circuit Element: Resistor

The resistance R of an element denotes its ability to resist the flow of electric current; it is measured in ohms (Ω).







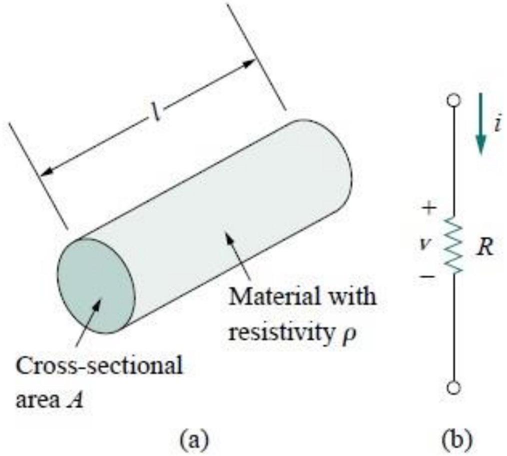


Figure 2.1 (a) Resistor, (b) Circuit symbol for resistance.

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

The resistance of any material with a uniform cross-sectional area is determined by the following four factors:

1. *Material*
2. *Length*
3. *Cross-sectional area*
4. *Temperature*

TABLE 3.1

Resistivity (ρ) of various materials.

Material	ρ @ 20°C
Silver	9.9
Copper	10.37
Gold	14.7
Aluminum	17.0
Tungsten	33.0
Nickel	47.0
Iron	74.0
Constantan	295.0
Nichrome	600.0
Calorite	720.0
Carbon	21,000.0

the higher the resistivity, the more the resistance.

the longer the length of a conductor, the more the resistance.

the smaller the area of a conductor, the more the resistance.

the higher the temperature of a conductor, the more the resistance.

Color Coding
and Resistor Values

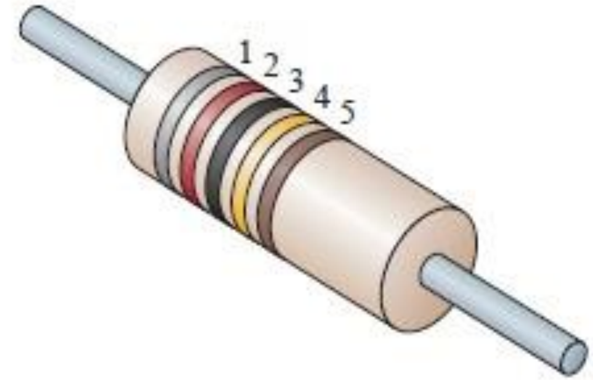
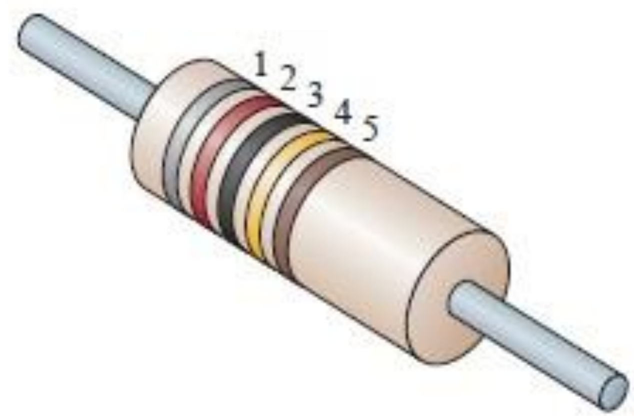


TABLE 3.7
Resistor color coding.

Bands 1–3*	Band 3	Band 4	Band 5
0 Black	0.1 Gold (multiplying factors)	5% Gold	1% Brown
1 Brown	0.01 Silver (multiplying factors)	10% Silver	0.1% Red
2 Red		20% No band	0.01% Orange
3 Orange			0.001% Yellow
4 Yellow			
5 Green			
6 Blue			
7 Violet			
8 Gray			
9 White			

*With the exception that black is not a valid color for the first band.

- The color bands are always read from the end that has the band closest to it.
- The first and second bands represent the first and second digits respectively.
- The third band determines the power-of-ten multiplier for the first two digits.
- The fourth band is the manufacturer's tolerance.
- The fifth band is the reliability factor.



EXAMPLE 3.13 Find the range in which a resistor having the following color bands must exist to satisfy the manufacturer's tolerance:

a.

1st band	2nd band	3rd band	4th band	5th band
Gray	Red	Black	Gold	Brown
8	2	0	$\pm 5\%$	1%

b.

1st band	2nd band	3rd band	4th band	5th band
Orange	White	Gold	Silver	No color
3	9	0.1	$\pm 10\%$	

Solutions:

a. **$82\ \Omega \pm 5\%$ (1% reliability)**

Since 5% of 82 = 4.10, the resistor should be within the range $82\ \Omega \pm 4.10\ \Omega$, or *between 77.90 and 86.10 Ω*.

b. **$3.9\ \Omega \pm 10\% = 3.9 \pm 0.39\ \Omega$**

The resistor should lie somewhere *between 3.51 and 4.29 Ω*.

Ohm's Law

German (Erlangen, Cologne)
(1789–1854)
Physicist and Mathematician
Professor of Physics, University of Cologne

Courtesy of the Smithsonian Institution Photo No. 51,145

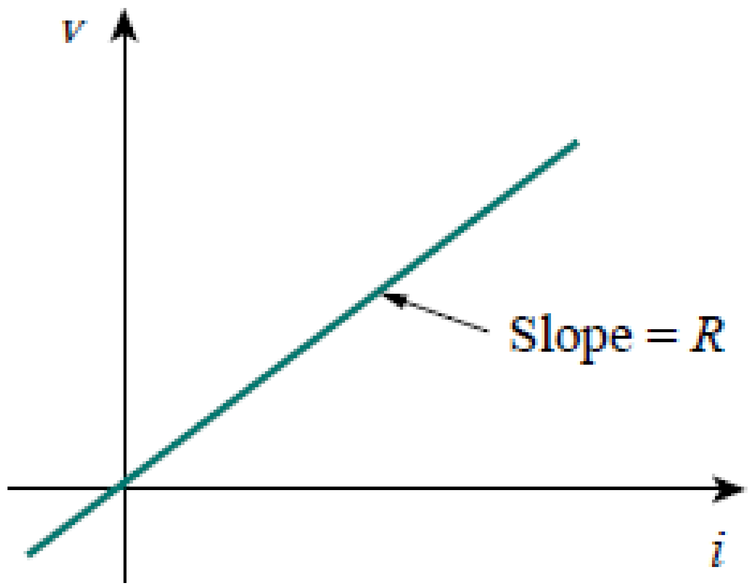
Ohm's law states that the voltage v across a resistor is directly proportional to the current i flowing through the resistor.

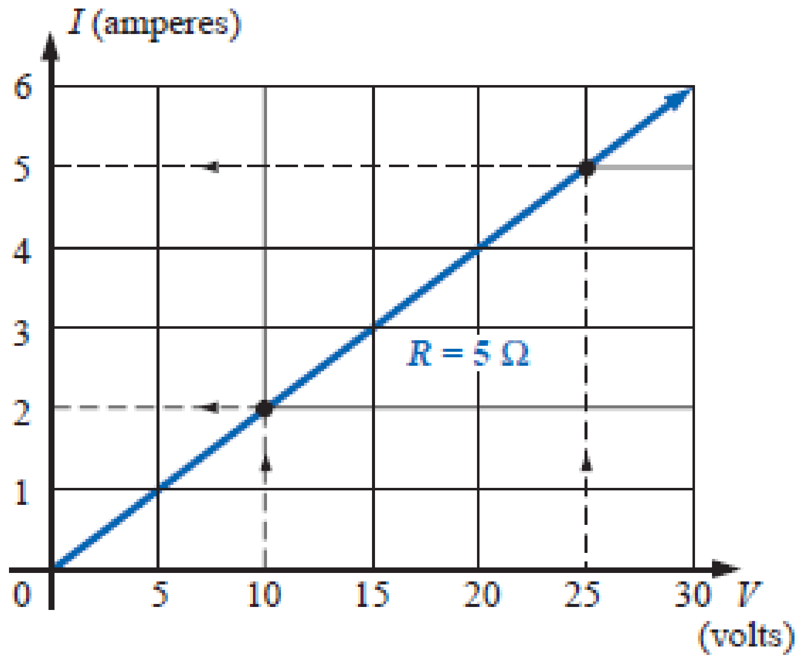
$$v \propto i \qquad v = iR$$

$$\text{Current} = \frac{\text{potential difference}}{\text{resistance}}$$

$$\boxed{\text{Effect} = \frac{\text{cause}}{\text{opposition}}}$$

$$\boxed{I = \frac{E}{R}} \qquad \text{(amperes, A)}$$


v
Slope = R
i


I (amperes)
6
5
4
3
2
1
0
5
10
15
20
25
30
V
(volts)
R = 5 Ω

Power, Energy & Efficiency

Power (P)

Rate of expending or absorbing energy per unit time. Measured in watts (w).

$$\boxed{P = \frac{W}{t}}$$

$$\boxed{1 \text{ watt (W)} = 1 \text{ joule/second (J/s)}}$$

- Another common unit of measurement is horsepower (hp).

$$\boxed{1 \text{ horsepower} \cong 746 \text{ watts}}$$

- $P = \frac{W}{t} = \frac{QV}{t} = V\frac{Q}{t}$ but, $I = \frac{Q}{t}$ so, $\boxed{P = VI}$ $\boxed{P = \frac{V^2}{R}}$ $\boxed{P = I^2R}$

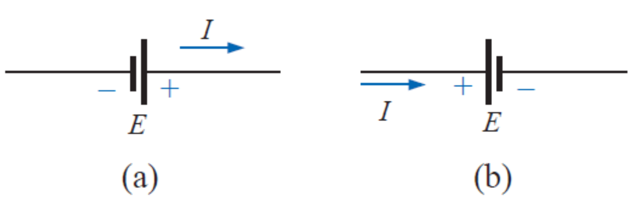


FIG. 4.13
Battery power: (a) supplied; (b) absorbed.

Power, Energy & Efficiency

Energy (E)

Energy is the capacity to do work. Measured in jouls (J).

$$W = Pt$$

$$1\ \text{Wh} = 3600\ \text{J}$$

* 1 kWh is the energy dissipated by a 100 W bulb in 10h.

Power, Energy & Efficiency

<u>Efficiency (η)</u>

The ratio between the o/p energy and the i/p energy. In other words, the percentage of useful energy in comparison to the total available energy.

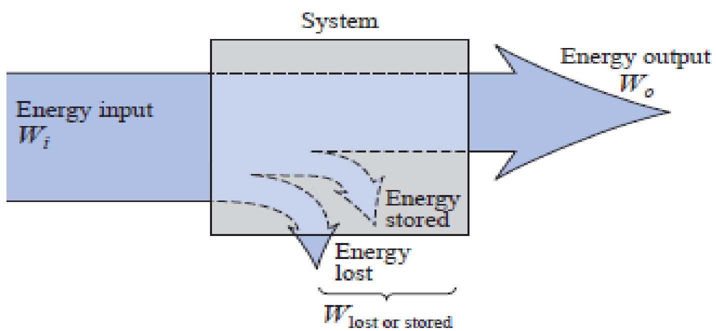


FIG. 4.18
Energy flow through a system.

$$\boxed{\eta = \frac{P_o}{P_i}}$$

$$\boxed{\eta\% = \frac{P_o}{P_i} \times 100\%}$$

* Maximum possible efficiency is 100%.