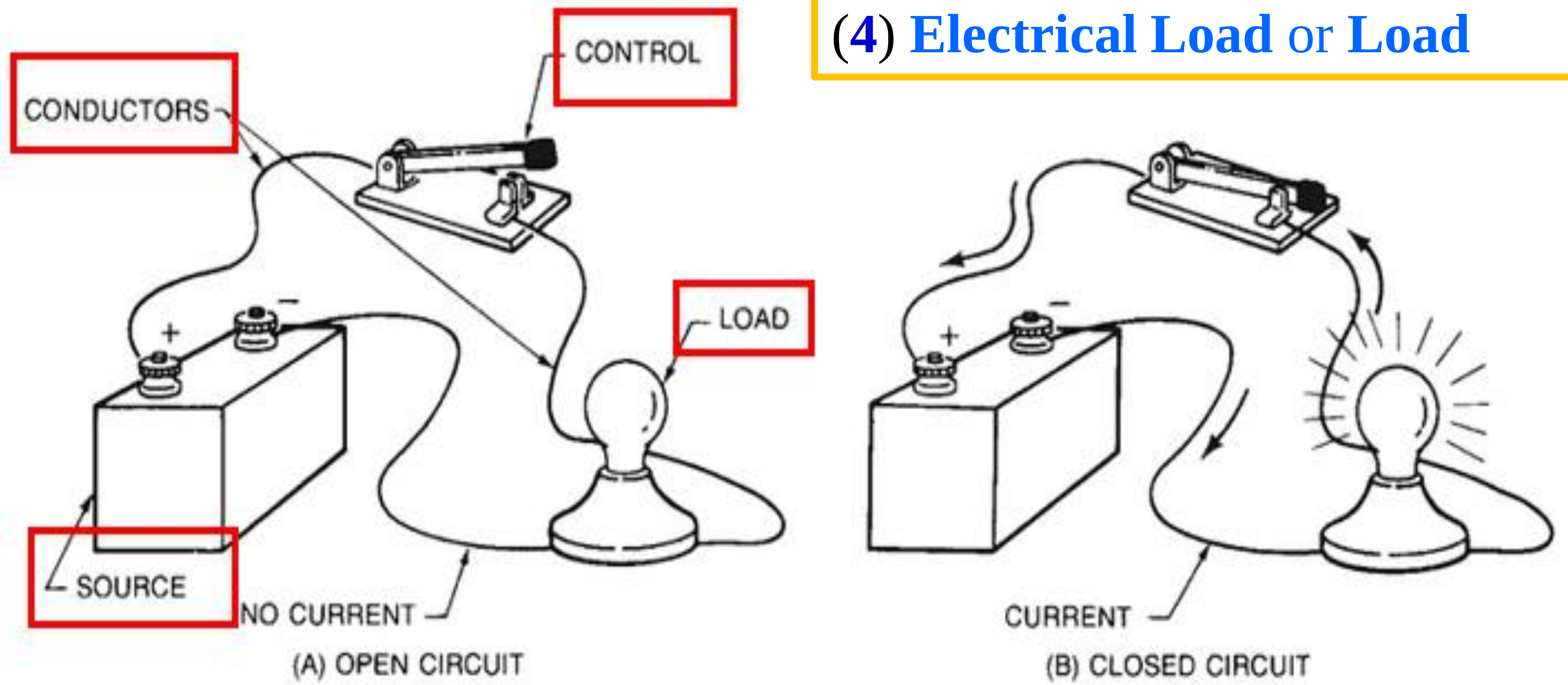
REVIEW ON THE LAST CLASS

Electrical System

An **electric circuit** or **network** is an interconnection of electrical elements.

The components or elements of an electrical system are:

(**1**) **Source**,
(**2**) **Conductors** or **Wires**,
(**3**) **Control Elements** or **Switches**, and
(**4**) **Electrical Load** or **Load**



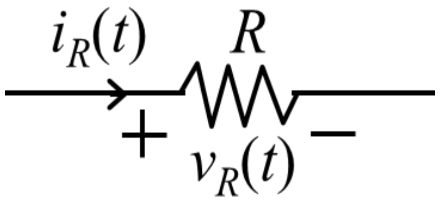
A closed path is required to flow of current.

Load Represent by Passive Elements

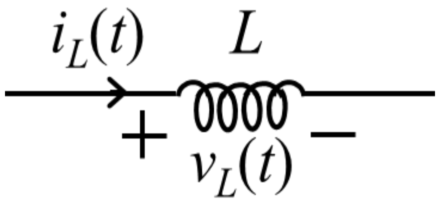
Loads can be represented by the combination of passive elements such as Resistor, Inductor, and Capacitor.

Passive Elements As a Load: Resistance (R), Inductance (L) and Capacitance (C)

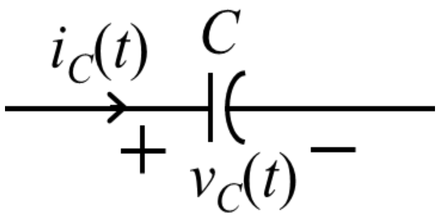
Combination of these elements: Series, Parallel and Series-Parallel



Resistance measured in **ohm** (Ω)

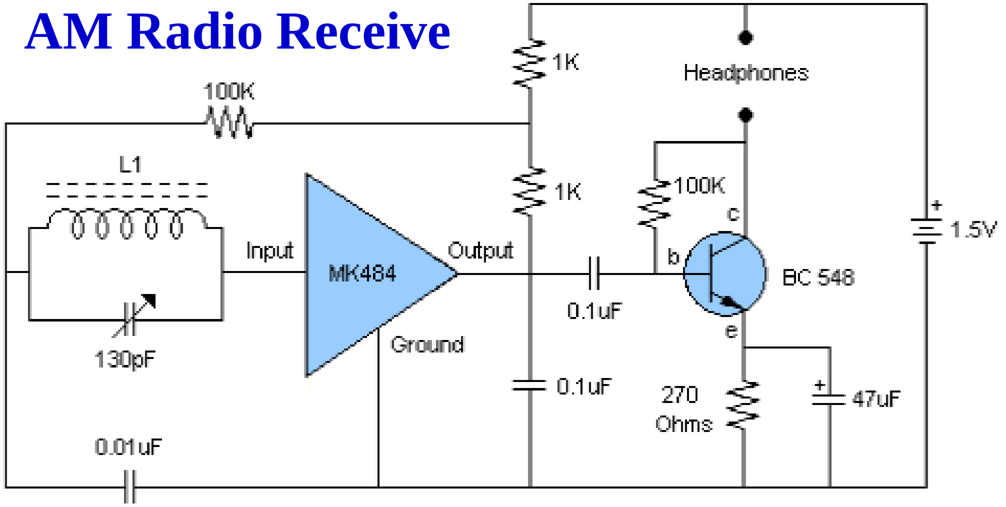


Inductance measured in **Henry** (H)



Capacitance measured in **Farad** (F)

AM Radio Receive



Test Your Knowledge

Problem 1.1.1: Perform the following conversions:

a. 21.56×10^{-7} H to μH	***b***. 478.5×10^{-4} F to μF
c. 1.045×10^{-4} H to mH	***d***. 25.68×10^{-5} F to μF

Practice Book Problem [SECTION 1.8 and SECTION 1.9] Problems: 24, 26 and 27

Chapter 2

Charge, Voltage and Current

Electric Charge

Electric Charge

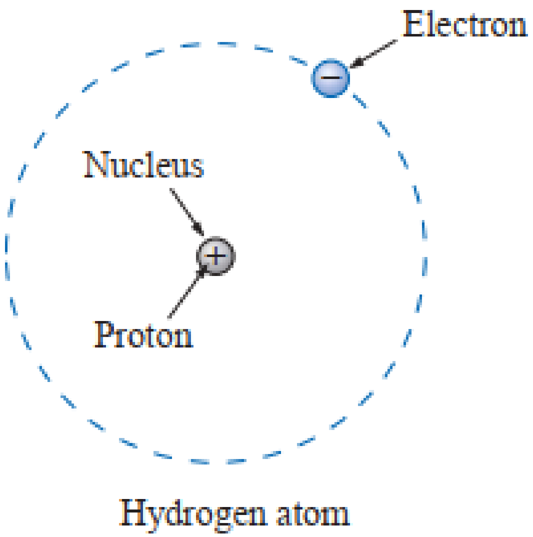
Atomic Charge:

- Two components of an electric charge [measured in **Coulombs** (**C**)] in an atom are:

  Proton [+] Charge [Charge of an electron: + 1.602×10^{-19} C]

  Electron [–] Charge [Charge of a proton: -1.602×10^{-19} C]

- Normally atoms charge is ***neutral*** (there are an equal number of number of protons and electrons in an atom).
- When electrons are ***removed***, **positive** charges are developed.
- When electrons are ***attached***, **negative** charges are developed.



Total deficiency or addition of excess electrons in an atom is called its charge and the element is said to be charged.

Important Characteristic of electric charge are:

- The charge is bipolar, meaning that electrical effects are described in terms of positive and negative charges.
- The electric charge exits in discrete quantities, which are ***integral multiple of the electronic charge***, 1.602×10^{-19} C [Charge is measured in **Coulombs** (**C**) and represent by Q or q]
- Electric effects are attributes to:

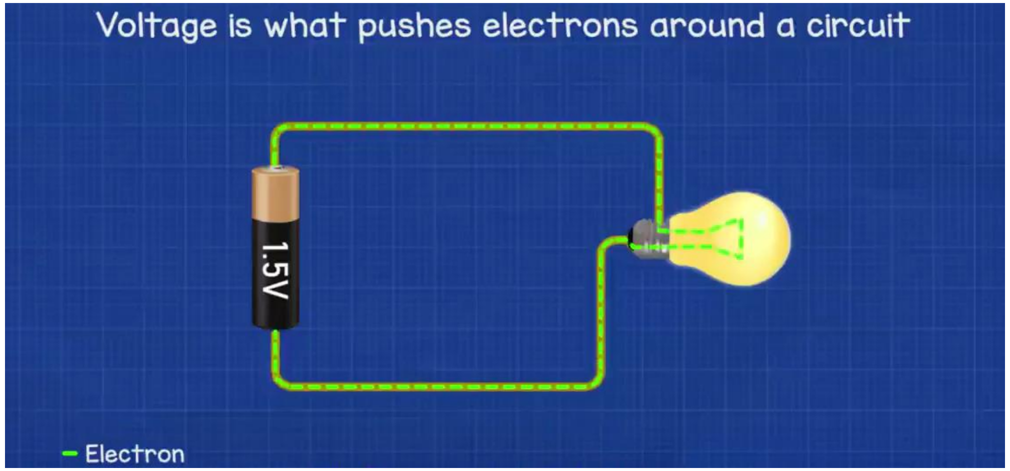
  (***i***) the **separation of charge** which is creates an **electric force** (electromotive force, voltage)

  (***ii***) the **charges in motion** which is creates an **electric** fluid (**current**).

$$\boxed{1\ \mathrm{C} = \frac{1}{1.602 \times 10^{-19}} = 6.24 \times 10^{18}\ \text{electrons}}$$

2.3 Voltage

2.3 Voltage



Electromotive Force (emf): An ***electrical effort*** (some work or energy transfer) is required to move the free electron in one particular direction, in a conductor is called electromotive force (emf). This emf is also known as ***voltage*** or ***potential difference***. EMF is ***created*** by chemical reaction (where positive charge and negative charge are separated) in battery or by changing magnetic field in a generator. It represents by "*E*". Some time also use "*V*".

Electric Potential: **The ability of a charged particle to do work** (when two similarly charged particles are brought near, they try to repel each other while dissimilar charges attracts each other) is called its ***electrical potential***. Electric potential is also known as ***voltage***. It also represents by "*V*".

Potential Difference: The difference between the electric potentials at any two points in a circuit is known as ***potential difference***. Potential difference is also called ***voltage*** or ***voltage drop*** between two points. It also represents by "*V*".

Unit: The unit of emf or electric potential or voltage or potential difference is **volt** [V].
A potential difference of 1 volt (V) exists between two points if 1 joule (J) of energy is exchanged in moving 1 coulomb (C) of charge between the two points.

The potential difference between two points is determined by:

$$\boxed{V = \frac{W}{Q}} \qquad \begin{aligned} V &= \text{volts (V)} \\ W &= \text{joules (J)} \\ Q &= \text{coulombs (C)} \end{aligned} \qquad \textbf{(2.2)}$$

$$\boxed{W = QV} \qquad \text{(joules, J)} \qquad \textbf{(2.3)}$$

$$\boxed{Q = \frac{W}{V}} \qquad \text{(coulombs, C)} \qquad \textbf{(2.4)}$$

$$1\ \text{V} = \frac{1\ \text{J}}{1\ \text{C}}$$

According to Eq. (2.2), **voltage** is the energy (work done) needed to move a unit charge from one point to another point.

EXAMPLE 2.1 Find the voltage between two points if 60 J of energy are required to move a charge of 20 C between the two points.

Solution: Eq. (2.2): $V = \frac{W}{Q} = \frac{60\ \text{J}}{20\ \text{C}} = \mathbf{3\ V}$

EXAMPLE 2.2 Determine the energy expended moving a charge of 50 μC between two points if the voltage between the points is 6 V.

Solution: Eq. (2.3):

$$W = QV = (50 \times 10^{-6}\ \text{C})(6\ \text{V}) = 300 \times 10^{-6}\ \text{J} = \mathbf{300\ \mu J}$$

Example 2.3.1: Find the charge that requires 120 J of energy to be moved through a potential difference of 20 V.

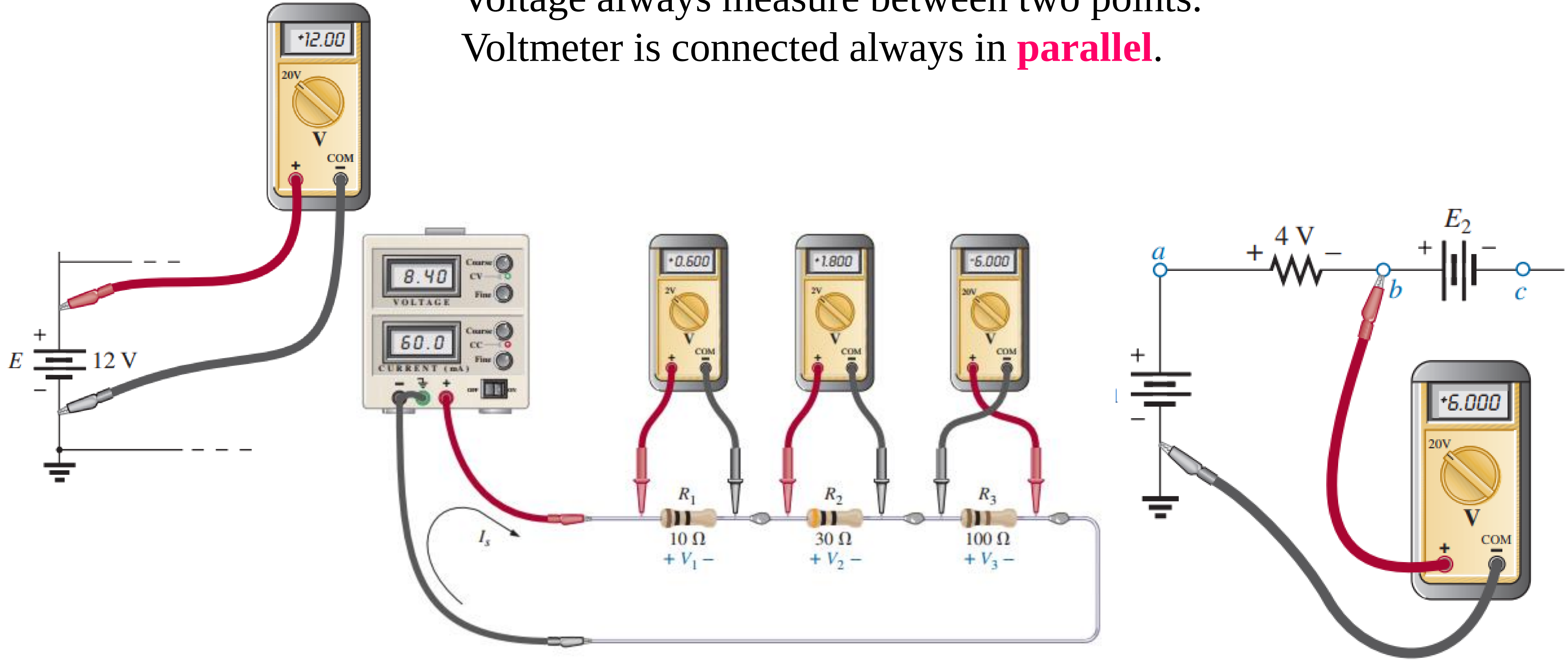
Solution: Given, $W = 120$ J, $V = 20$ V and $Q = ?$

$$Q = \frac{W}{V} = \frac{120\ \text{J}}{20\ \text{V}} = 6\ \text{V}$$

Practice Book Problem [SECTION 2.3 Voltage] Problems: 7 to 10

Voltmeter

Voltmeter measures the voltage.
Voltage always measure between two points.
Voltmeter is connected always in **parallel**.



2.4 Current

2.4 Current

The applied voltage (emf) is the starting mechanism —the current is a reaction to the applied voltage.

Definition: The rate of charge (Q) with respect to time (t) is known as the electric **current**.

Letter Symbol: It is represented by " I ". **Unit** is Ampere (A).

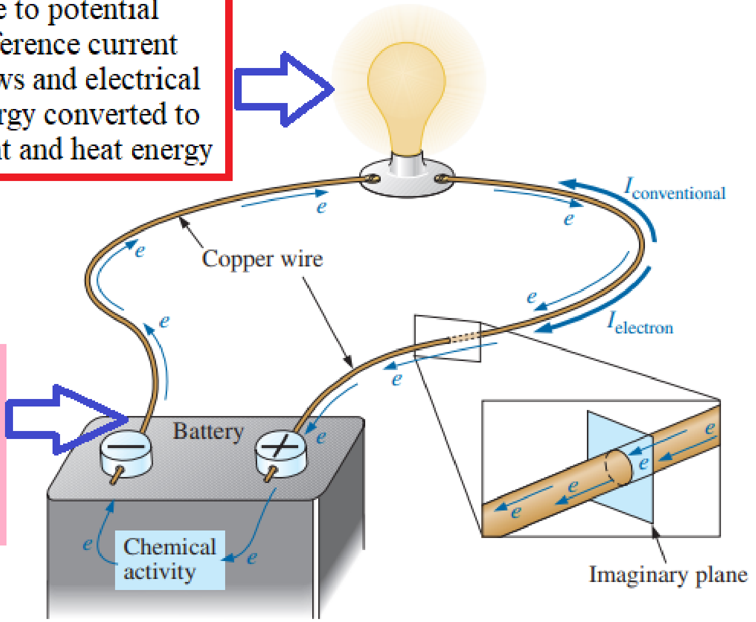
Relation Among Current, Charge and Time

$$\boxed{I = \frac{Q}{t}} \qquad \begin{aligned} I &= \text{amperes (A)} \\ Q &= \text{coulombs (C)} \\ t &= \text{time (s)} \end{aligned} \qquad (2.5)$$

1 Ampere: If 1 C [or 6.24 × 10^{18} electrons**] charge pass through a conductor in 1 second, the flow of charge, or current, is said to be 1 ampere (A).**

Due to potential difference current flows and electrical energy converted to light and heat energy

Force for converting chemical energy to electrical energy is electromotive force (emf)



$$\boxed{1 \text{ A} = \frac{1 \text{ C}}{1 \text{ s}}}$$

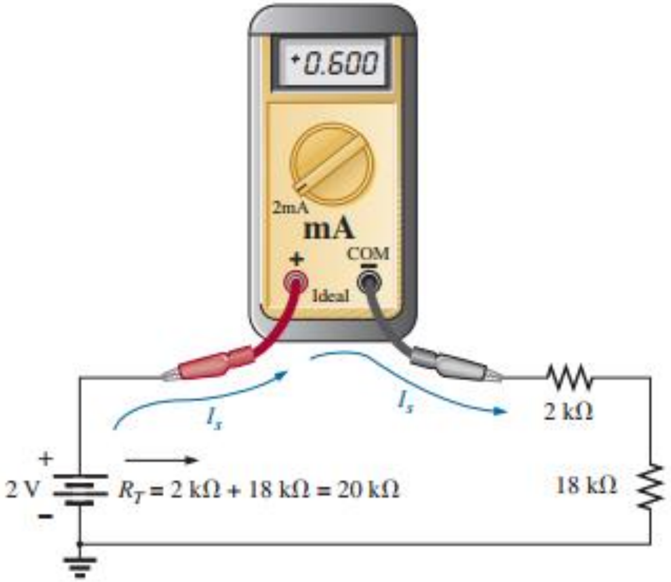
$$\boxed{t = \frac{Q}{I}} \quad \text{(s)} \quad (2.7)$$

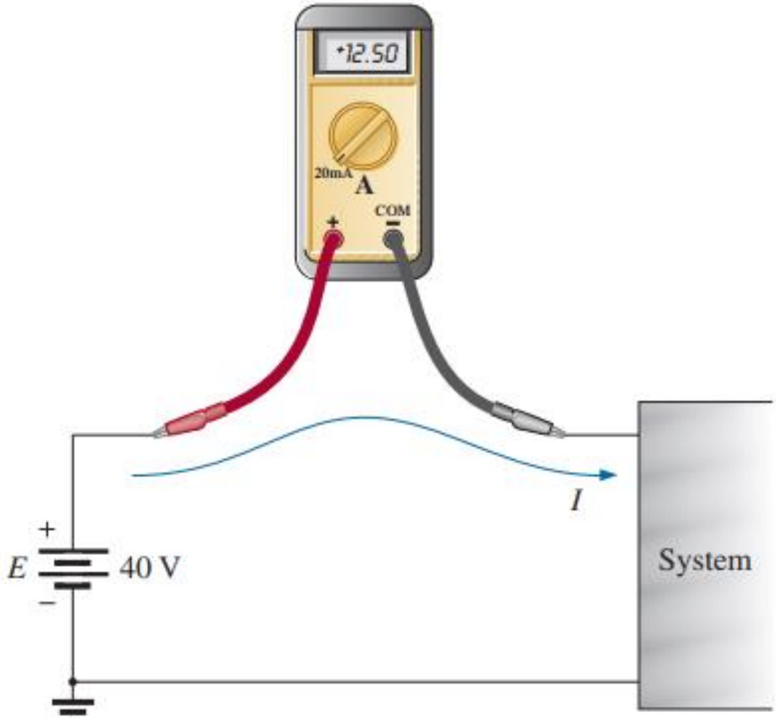
$$\boxed{Q = It} \quad \text{(C)} \quad (2.6)$$

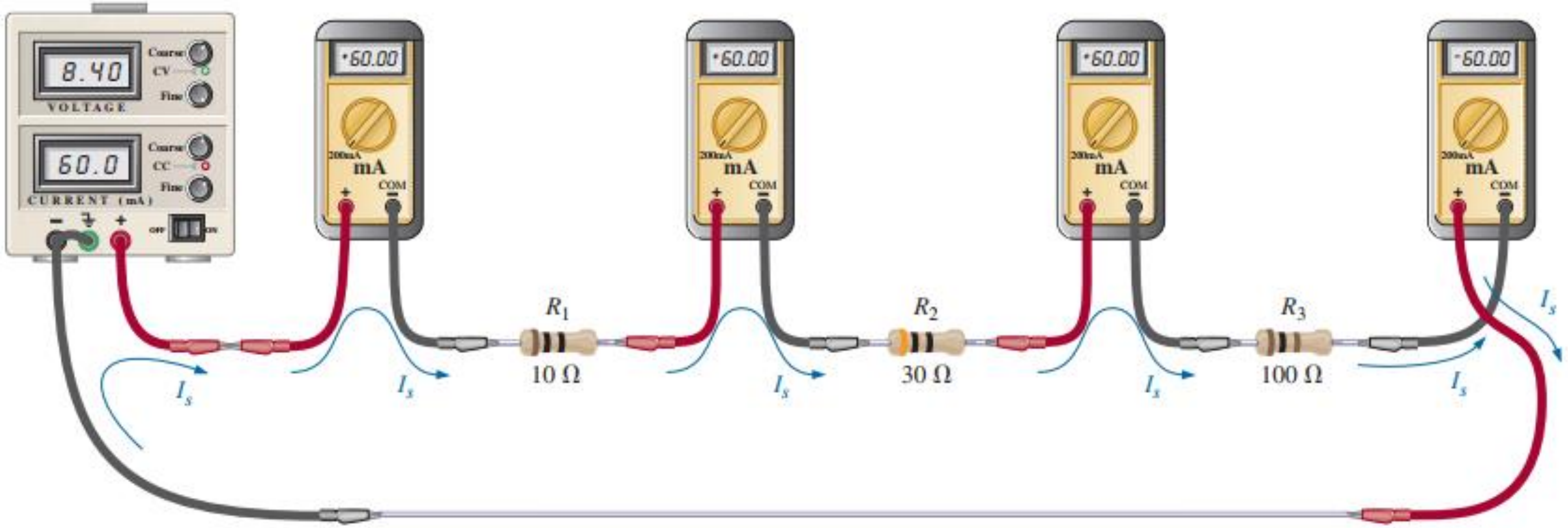
Ammeter

Ammeter measures the current in a circuit.

Ammeter is always connected in **series**.







EXAMPLE 2.3 The charge flowing through the imaginary surface in Fig. 2.9 is 0.16 C every 64 ms. Determine the current in amperes.

Solution: Eq. (2.5): $I = \dfrac{Q}{t} = \dfrac{0.16\text{ C}}{64 \times 10^{-3}\text{s}} = \dfrac{160 \times 10^{-3}\text{ C}}{64 \times 10^{-3}\text{ s}} = \mathbf{2.50\,A}$

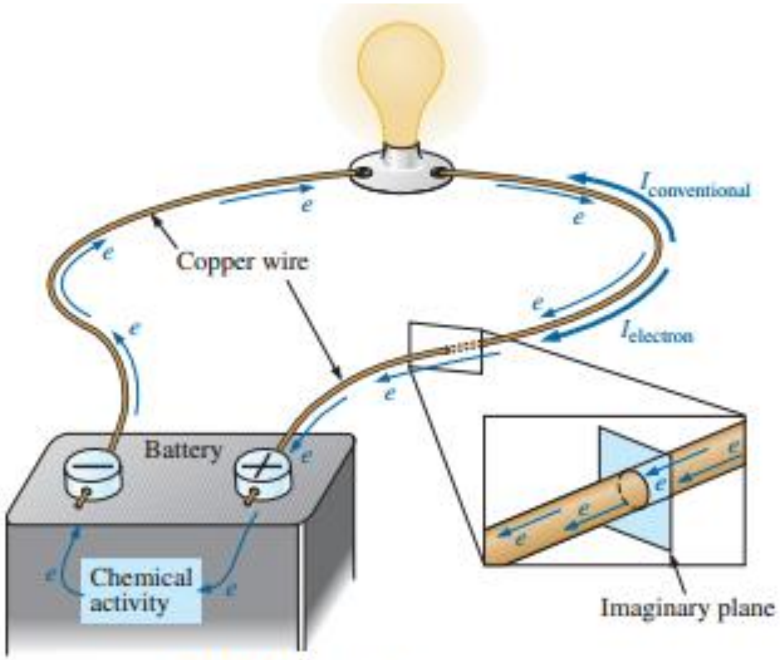


FIG. 2.9 *Basic electric circuit.*

EXAMPLE 2.4 Determine how long it will take 4×10^{16} electrons to pass through the imaginary surface in Fig. 2.9 if the current is 5 mA.

Solution: Determine the charge in coulombs:

$$4 \times 10^{16}\,\cancel{\text{electrons}}\left(\frac{1\text{ C}}{6.242 \times 10^{18}\,\cancel{\text{electrons}}}\right) = 0.641 \times 10^{-2}\text{ C}$$

$$= 6.41\text{ mC}$$

Eq. (2.7): $t = \dfrac{Q}{I} = \dfrac{6.41 \times 10^{-3}\text{C}}{5 \times 10^{-3}\text{ A}} = \mathbf{1.28\ s}$

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

Example 2.4.1: If a current 100 mA exists for 1.5 min, (*i*) how many coulomb of charge, and (*ii*) how many electrons have passed through the wire?

Solution: Given, $I = 100 \text{ mA} = 100 \times 10^{-3}$ A, $t = 1.5 \text{ min} = 1.5 \times 60 = 90$ s

(*i*) $Q = I \times t = (100 \times 10^{-3}) \times 90$

$= 9000 \times 10^{-3} \text{ C} = 9 \text{ C}$

(*ii*) We know that, $1 \text{ C} = 6.24 \times 10^{18}$ electrons

$9 \text{ C} = 9 \times (6.24 \times 10^{18})$

$= 56.16 \times 10^{18}$ electrons

Example 2.4.2: If a conductor with a current of 120 mA passing through it converts 20 J of electrical energy into heat in 20 s, what is the potential drop across the conductor?

Solution: Given, $I = 120 \text{ mA} = 120 \times 10^{-3}$ A,

$W = 20$ J, $t = 20$ s

We know that, $Q = It = (120 \times 10^{-3} \text{ A}) \times 20 \text{ s}$

$= 2.4 \text{ C}$

We know that, $V = \frac{W}{Q} = \frac{20 \text{ J}}{2.4 \text{ C}} = 8.33 \text{ V}$

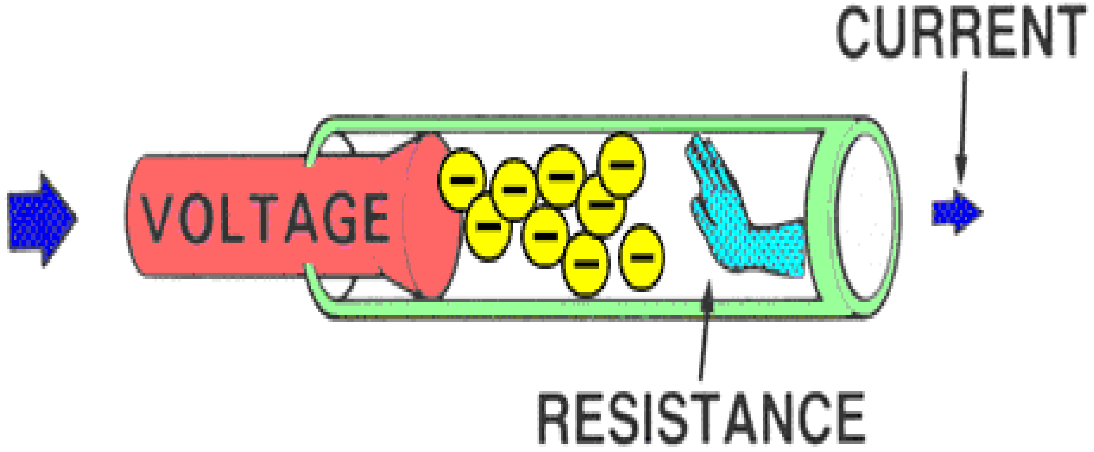
Practice Book Problem [SECTION 2.4 Current] Problems: 11 – 17 and 21 – 23

3.2 Resistance

Resistance

- The current in the electrical circuit not only depends on emf but also the circuit materials. Material in general have a property or ability to oppose/resist the flow of electric charge as well as current.
- This opposition, due to the collisions between electrons and between electrons and other atoms in the material, *which converts electrical energy into another form of energy such as heat.*

Definition: The property of materials in an electrical circuit tending to prevent/resist the flow of current and at the same time causes electrical energy to be converted to heat is called resistance.



Letter Symbol: It is represented by " *R* ".

Unit is ohm (Ω).

1 ohm: The resistance of a material in an electrical circuit, in which a current 1 Ampere generates the heat at the rate of one Joules per Second is said to be 1 ohm.

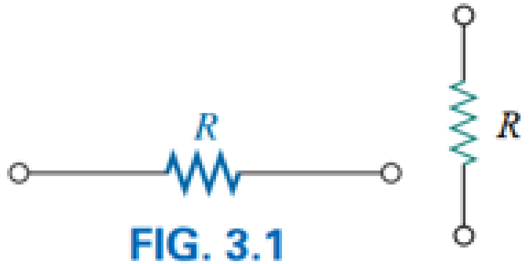


FIG. 3.1
Resistance symbol and notation.

3.2 Resistance: Circular Wires

Equation of Resistance:

$$R = \rho \frac{l}{A} \qquad \begin{aligned} \rho &= \Omega\text{-cm at } T = 20^\circ\text{C} \\ l &= \text{centimeters (cm)} \\ A &= \text{area in centimeters (cm}^2\text{)} \end{aligned} \qquad (3.1)$$

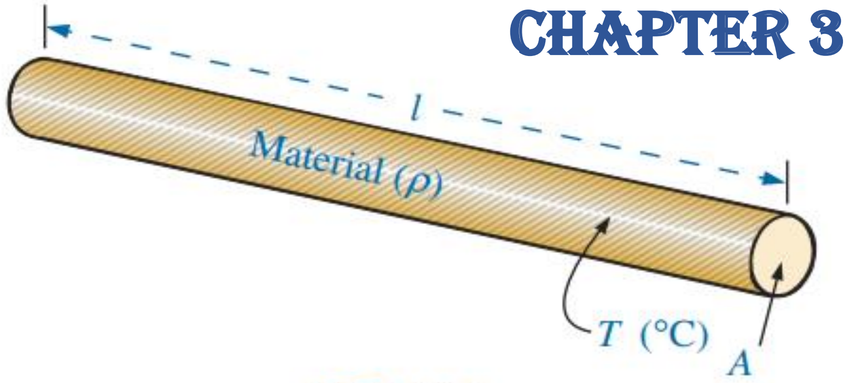


FIG. 3.2

Factors affecting the resistance of a conductor.

Resistivity: The resistance of a material having unit length (1 cm) and unit cross-sectional area (1 cm^2) is known as its ***resistivity*** or ***specific resistance***.

Factors Affecting the Resistance:

1. **Length (l)**: Resistance is directly proportional to length.
2. **Cross-sectional area (A)**: ***Resistance is inversely proportional to area***.
3. **Material (ρ called *rho*)**: The material is identified by a factor called the ***resistivity***, which is measured in Ω–cm or Ω–m. ***The higher the resistivity, the greater the resistance of a conductor***.
4. **Temperature of the material (T)**: Generally, ***the resistance increases as materials temperature increases***. The effect of small changes in temperature on the resistance is not considered.

TABLE 3.3 *Resistivity (ρ) of various materials.*

Material	Ω-cm
Silver	1.645×10^{-6}
Copper	$\mathbf{1.723 \times 10^{-6}}$
Gold	2.443×10^{-6}
Aluminum	2.825×10^{-6}
Tungsten	5.485×10^{-6}
Nickel	7.811×10^{-6}
Iron	12.299×10^{-6}
Tantalum	15.54×10^{-6}
Nichrome	99.72×10^{-6}
Tin oxide	250×10^{-6}
Carbon	3500×10^{-6}

EXAMPLE 3.7 Determine the resistance of 100 ft of #28 copper (From Table 3.3, $\rho = 1.723 \times 10^{-6}$ Ω–cm) telephone wire if the diameter is 0.0126 in.

Solution: l = 100 ft, $\rho = 1.723 \times 10^{-6}$ Ω–cm, d = 0.0126 in.

Since l is given in feet (ft) and d is given in inch (in), first convert these quantities in cm.

We know that 1 ft = 12 in and 1 in = 2.54 cm

$$l = 100\ \cancel{\text{ft}}\left(\frac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right)\left(\frac{2.54\ \text{cm}}{1\ \cancel{\text{in.}}}\right) = 3048\ \text{cm} \qquad d = 0.0126\ \text{in.}\left(\frac{2.54\ \text{cm}}{1\ \text{in.}}\right) = 0.032\ \text{cm}$$

We know that the area of a circle is: $A = \pi r^2 \qquad r = \dfrac{d}{2} \qquad A = \dfrac{\pi d^2}{4}$

$$\text{Therefore,}\quad A = \frac{\pi d^2}{4} = \frac{(3.1416)(0.032\ \text{cm})^2}{4} = 8.04 \times 10^{-4}\ \text{cm}^2$$

$$R = \rho\frac{l}{A} = \frac{(1.723 \times 10^{-6}\Omega\text{-cm})(3048\ \text{cm})}{8.04 \times 10^{-4}\ \text{cm}^2} \cong \mathbf{6.5\ \Omega}$$

Example 3.2.1: Determine the value of resistance of an aluminum conductor if the area is increased by a factor of 3. The original resistance was 12 Ω.

Solution: Let in original case: length = l_1 cm, Area = A_1 cm^2, and resistivity = ρ_1 Ω-cm and R_1 = 4 Ω

When the area is increased by a factor of 3: length $l_2 = l_1$ cm, Area $A_2 = 3A_1$ cm^2, and resistivity $\rho_2 = \rho_1$ Ω-cm and R_2 = ?

$$\frac{R_2}{R_1} = \left[\frac{\rho_2 l_2}{A_2} \div \frac{\rho_1 l_1}{A_1}\right] = \left[\frac{\rho_2 l_2}{A_2} \times \frac{A_1}{\rho_1 l_1}\right] = \left[\frac{\rho_1 l_1}{3A_1} \times \frac{A_1}{\rho_1 l_1}\right] = \frac{1}{3} \qquad R_2 = \frac{1}{3} R_1 = \frac{1}{3} \times 12 = 4\ \Omega$$

Example 3.2.2: Determine the value of resistance of a silver conductor if the length is doubled. The original resistance was 5 Ω.

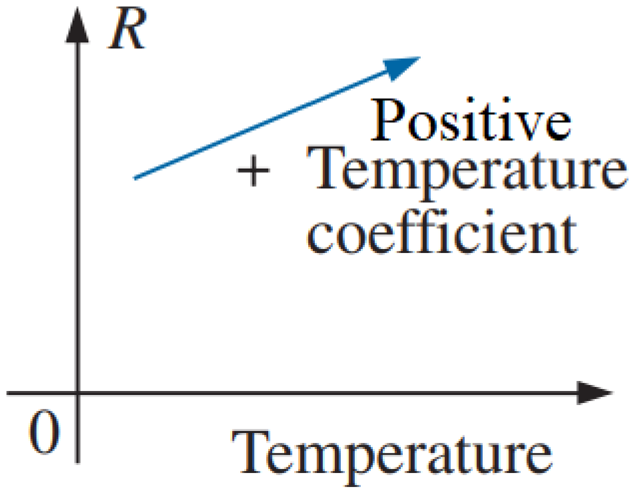
Solution: Let in original case: length = l_1 cm, Area = A_1 cm^2, and resistivity = ρ_1 Ω-cm and R_1 = 6 Ω

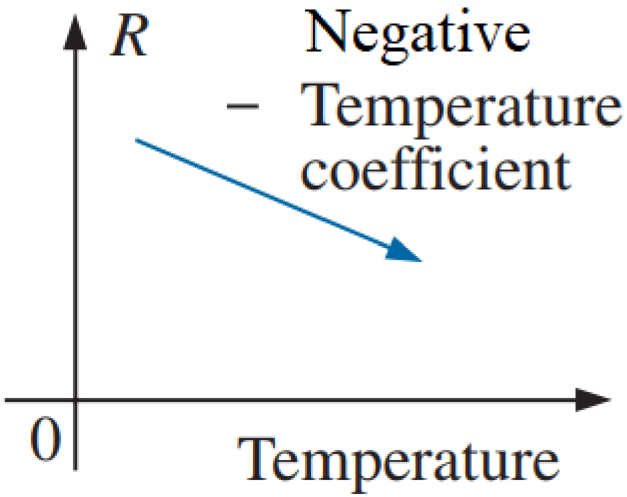
When the length is doubled : length $l_2 = 2l_1$ cm, Area $A_2 = A_1$ cm^2, and resistivity $\rho_2 = \rho_1$ Ω-cm and R_2 = ?

$$\frac{R_2}{R_1} = \left[\frac{\rho_2 l_2}{A_2} \div \frac{\rho_1 l_1}{A_1}\right] = \left[\frac{\rho_2 l_2}{A_2} \times \frac{A_1}{\rho_1 l_1}\right] = \left[\frac{\rho_1 2 l_1}{A_1} \times \frac{A_1}{\rho_1 l_1}\right] = 2 \qquad R_2 = 2R_1 = 2 \times 5 = 10\ \Omega$$

Practice Book Problem [SECTION 3.2 Resistance] Problems: 4, 7, 12 and 13

3.5 TEMPERATURE EFFECTS





Conductors

For good conductors, an increase in temperature results in an increase in the resistance level. Consequently, conductors have a **positive temperature coefficient**.

Semiconductors

For semiconductor materials, an increase in temperature results in a decrease in the resistance level. Consequently, semiconductors have **negative temperature coefficients**.

Insulators

Same as semiconductor materials, an increase in temperature results in a decrease in the resistance level of an insulator. Consequently, semiconductors have **negative temperature coefficients**.

Relation of Resistances in Different Two Temperature

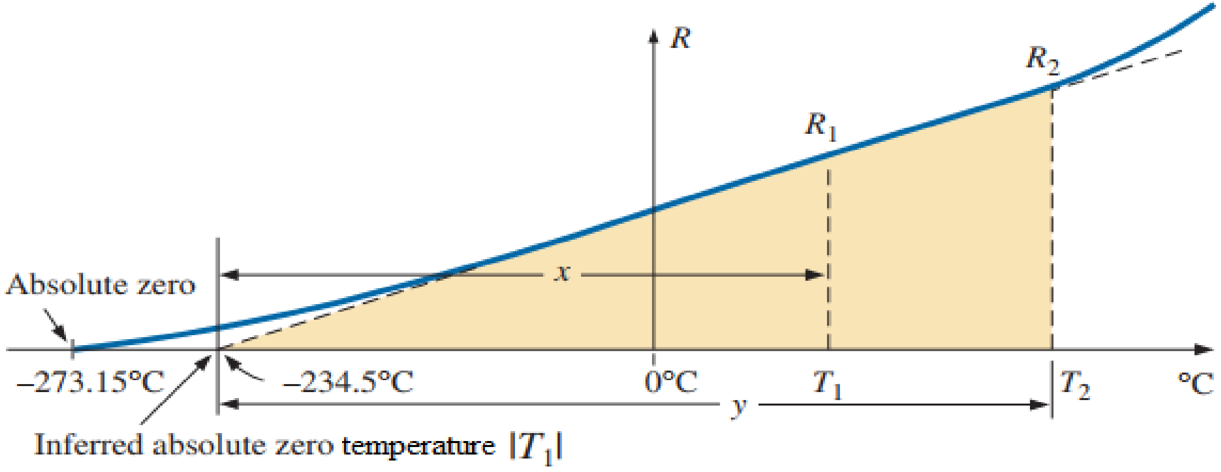


FIG. 3.13 *Effect of temperature on the resistance of copper.*

$$\alpha_{20} = \frac{1}{|T_1| + 20°\text{C}} \qquad \textbf{(3.9)}$$

$$R_1 = R_{20}[1 + \alpha_{20}(T_1 - 20°\text{C})] \qquad \textbf{(3.10)}$$

$$\frac{|T_1| + T_1}{R_1} = \frac{|T_1| + T_2}{R_2} \qquad \textbf{(3.8)}$$

$|T_1|$ is called the ***inferred absolute temperature*** of the material.

$$R_2 = R_1[1 + \alpha_1(T_2 - T_1)] \quad \text{where, } \alpha_1 = \frac{1}{|T_1| + T_1}$$

α_1 is called the ***temperature coefficient of resistance*** at a temperature of T_1.

TABLE 3.5

Inferred absolute temperatures (T_i).

Material	°C
Silver	−243
Copper	−234.5
Gold	−274
Aluminum	−236
Tungsten	−204
Nickel	−147
Iron	−162
Nichrome	−2,250
Constantan	−125,000

TABLE 3.6

Temperature coefficient of resistance for various conductors at 20°C.

Material	Temperature Coefficient (α_{20})
Silver	0.0038
Copper	0.00393
Gold	0.0034
Aluminum	0.00391
Tungsten	0.005
Nickel	0.006
Iron	0.0055
Constantan	0.000008
Nichrome	0.00044

EXAMPLE 3.9 If the resistance of a copper wire is 50 Ω at 20°C, what is its resistance at 100°C (boiling point of water)?

Solution: Given, $R_1 = 50\ \Omega$, $T_1 = 20°\text{C}$, $T_2 = 100°\text{C}$, From Table 3.5, $|T_1| = 234.5°\text{C}$, $R_2 = ?$

$$\boxed{\frac{|T_1| + T_1}{R_1} = \frac{|T_1| + T_2}{R_2} \qquad (3.8)}$$

$$\frac{234.5°\text{C} + 20°\text{C}}{50\ \Omega} = \frac{234.5°\text{C} + 100°\text{C}}{R_2}$$

$$R_2 = \frac{234.5°\text{C} + 100°\text{C}}{-234.5°\text{C} + 20°\text{C}} \times 50\ \Omega = 65.72\ \ \Omega$$

EXAMPLE 3.10 If the resistance of a copper wire at freezing (0°C) is 30Ω , what is its resistance at –40°C?

Solution: Given, $R_1 = 30\ \Omega$, $T_1 = 0°\text{C}$, $T_2 = -\ 40°\text{C}$, From Table 3.5, $|T_1| = 234.5°\text{C}$, $R_2 = ?$

$$\frac{234.5°\text{C} + 0°\text{C}}{30\ \Omega} = \frac{234.5°\text{C} + 40°\text{C}}{R_2}$$

$$R_2 = \frac{234.5°\text{C} - 40°\text{C}}{234.5°\text{C} + 0°\text{C}} \times 30\ \Omega = 24.88\ \ \Omega$$

Practice also EXAMPLE 3.11

Practice Book Problem [SECTION 3.5 Temperature Effects] Problems: 23 to 27 and 29

3.7 Types of Resistors

Fixed Resistors

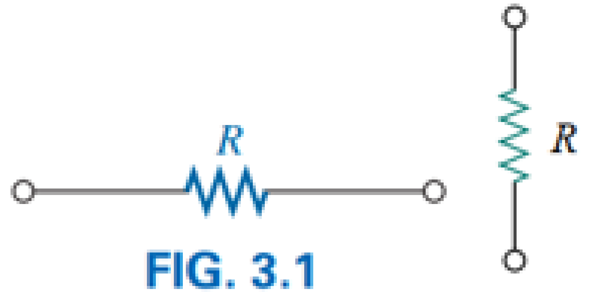
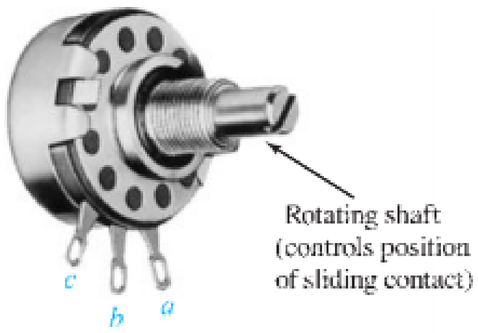


FIG. 3.1
Resistance symbol and notation.

Variable Resistors

Circuit Symbol

Variable resistor is usually referred to as a **rheostat** or **potentiometer.**



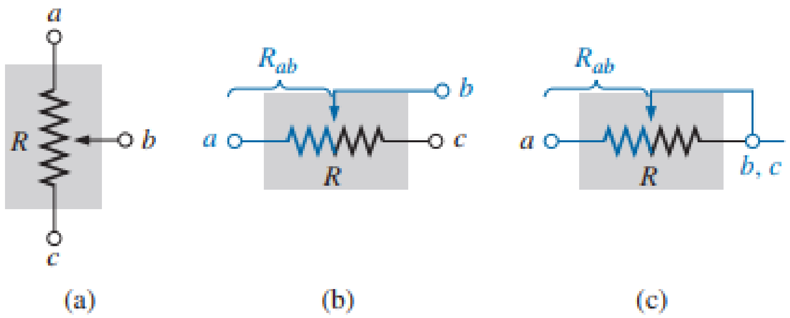


TABLE 3.7
Standard values of commercially available resistors.

Ohms (Ω)					Kilohms (kΩ)		Megohms (MΩ)	
0.10	1.0	10	100	1000	10	100	1.0	10.0
0.11	1.1	11	110	1100	11	110	1.1	11.0
0.12	**1.2**	**12**	**120**	**1200**	**12**	**120**	**1.2**	**12.0**
0.13	1.3	13	130	1300	13	130	1.3	13.0
0.15	1.5	15	150	1500	15	150	1.5	15.0
0.16	1.6	16	160	1600	16	160	1.6	16.0
0.18	**1.8**	**18**	**180**	**1800**	**18**	**180**	**1.8**	**18.0**
0.20	2.0	20	200	2000	20	200	2.0	20.0
0.22	2.2	22	220	2200	22	220	2.2	22.0
0.24	2.4	24	240	2400	24	240	2.4	
0.27	**2.7**	**27**	**270**	**2700**	**27**	**270**	**2.7**	
0.30	3.0	30	300	3000	30	300	3.0	
0.33	3.3	33	330	3300	33	330	3.3	
0.36	3.6	36	360	3600	36	360	3.6	
0.39	**3.9**	**39**	**390**	**3900**	**39**	**390**	**3.9**	
0.43	4.3	43	430	4300	43	430	4.3	
0.47	4.7	47	470	4700	47	470	4.7	
0.51	5.1	51	510	5100	51	510	5.1	
0.56	**5.6**	**56**	**560**	**5600**	**56**	**560**	**5.6**	
0.62	6.2	62	620	6200	62	620	6.2	
0.68	6.8	68	680	6800	68	680	6.8	
0.75	7.5	75	750	7500	75	750	7.5	
0.82	**8.2**	**82**	**820**	**8200**	**82**	**820**	**8.2**	
0.91	9.1	91	910	9100	91	910	9.1	

Ohmmeter

Ohmmeter measures the resistance in a circuit.

Ohm meter is connected in the two terminals of the resistance which ohm is needed to measure.

Ohmmeter is always connected in **parallel**.

In Figure (a) ohm meter is connected in between terminals *a* and *b*. So, it measured the total resistance (1 MΩ) in between terminals *a* and *b*.

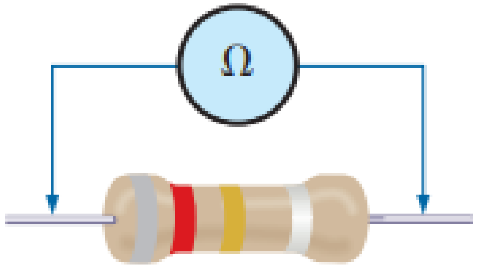
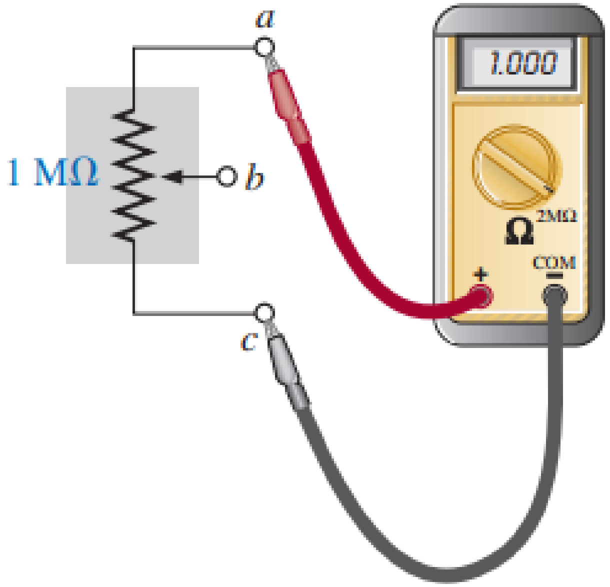
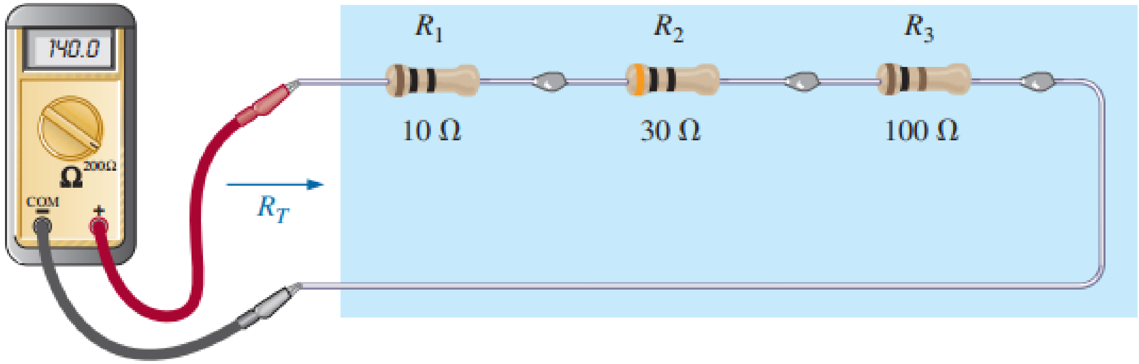


FIG. 3.32



(a)



3.9 Conductance

3.9 Conductance

Definition: The reciprocal of resistance is called conductance.

Conductance of a circuit indicates how well the material conducts electricity.

Letter Symbol: It is represented by " G ".

Unit is siemens (S).

$$\boxed{G = \frac{1}{R} = \frac{A}{\rho l} = \sigma \frac{A}{l} \qquad \text{(siemens, S)}}$$

Conductivity: ($\sigma = 1/\rho$): The reciprocal of resistivity is called conductivity.

EXAMPLE 3.9.1 Determine the conductance of 3048 cm length of copper telephone wire which resistivity is $\rho = 1.723 \times 10^{-6}$ Ω–cm and the area is 8.04×10^{-4} cm^2.

Solution: l = 3048 cm, $\rho = 1.723 \times 10^{-6}$ Ω–cm, $A = 8.04 \times 10^{-4}$ cm^2.

$$R = \rho \frac{l}{A} = \frac{(1.723 \times 10^{-6}\,\Omega - \text{cm})(3048\,\text{cm})}{8.04 \times 10^{-4}\ \text{cm}^2} = 6.5\ \Omega$$

$$G = \frac{1}{R} = \frac{1}{6.5\,\Omega} = \mathbf{0.1538\ S\ \ or\ \ 153.8\ mS}$$

EXAMPLE 3.15

a. Determine the conductance of a 1 Ω, 50 kΩ, and 10 MΩ resistor.
b. How does the conductance level change with increase in resistance?

Solution: Eq. (3.14):

a. $$1\Omega: G = \frac{1}{R} = \frac{1}{1\,\Omega} = \mathbf{1\ S}$$

$$50\text{ k}\Omega: G = \frac{1}{R} = \frac{1}{50\text{ k}\Omega} = \frac{1}{50 \times 10^3\,\Omega} = 0.02 \times 10^{-3}\text{ S} = \mathbf{0.02\ mS}$$

$$10\text{ M}\Omega: G = \frac{1}{R} = \frac{1}{10\text{ M}\Omega} = \frac{1}{10 \times 10^6\,\Omega} = 0.1 \times 10^{-6}\text{ S} = \mathbf{0.1\ \mu S}$$

Practice Book Problem [SECTION 3.9 Conductance] Problem: 29

Test Your Knowledge

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

Example 2.4.3: Charge is flowing through a conductor at the rate of 200 C/min. If 750 J of electrical energy are converted to heat in 45 s, what is the potential drop across the conductor?

Solution: Given, $I = Q/t = 200$ C/min $= (200/60)$ C/s, $W = 360$ J, $t = 45$ s

We know that, $Q = It = (200/60 \text{ C/s}) \times 25 \text{ s}$

$= 150$ C

We know that, $V = \dfrac{W}{Q} = \dfrac{750 \text{ J}}{150 \text{ C}} = 5 \text{ V}$

Example 2.4.4: The potential difference between two points in an electric circuit is 48 V. If 1.2 J of energy were dissipated in a period of 15 ms, what would the current be between the two points?

Solution: Given, $V = 24$ V, $W = 0.4$ J,
$t = 15$ ms $= 15 \times 10^{-3}$ s,

We know that, $V = \dfrac{W}{Q}$

$$\therefore Q = \frac{W}{V} = \frac{1.2 \text{ J}}{48 \text{ V}} = 0.025 \text{ C}$$

We know that, $I = \dfrac{Q}{t} = \dfrac{0.025 \text{ C}}{15 \times 10^{-3} \text{ s}} = 1.67 \text{ A}$

Thank You