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FUNDAMENTALS OF ELECTRICAL ENGINEERING.

LECTURE 1 NOTES

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BASIC ELECTRICAL QUANTITIES

- Units of Measurement

In any technical field it is important to understand the basic concepts and the impact they will have on certain parameters. Consider, for example, the following fundamental physics equation:

$$v = \frac{d}{t} \tag{1.1}$$

where v= velocity, d=distance, t=time.

Assume, for the moment, that the following data are obtained for a moving object: d= 4000ft, t = 1min. If v is desired in miles per hour. Often, without a second thought or consideration, the numerical values are simply substituted into the equation, with the result here that

As indicated above, the solution is totally incorrect. If the result is desired in miles per hour, the unit of measurement for distance must be miles, and that for time, hours.

✦Therefore there is the need to convert the distance and time to the proper unit of measurement. 1mi = 5280 ft, therefore 4000ft = 0.7576

$$1\,\mathrm{min} = \frac{1}{60}h = 0.0167h$$

Substituting into Eq. (1.1)

$$v = \frac{d}{t} = \frac{0.7576mi}{0.0167h} = 45.37mi/h$$

- Systems Of Units.

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The systems of units most commonly used are the English and metric, as outlines in Table 1.1.

English	Metric		
	MKS	**CGS**	**SI**
Length: Yard (yd) (0.914 m)	Meter (m) (39.37 in.) (100 cm)	Centimeter (cm) (2.54 cm = 1 in.)	**Meter (m)**
Mass: **Slug** (14.6 kg)	Kilogram (kg) (1000 g)	Gram (g)	**Kilogram (kg)**
Force: **Pound** (lb) (4.45 N)	Newton (N) (100,000 dynes)	Dyne	**Newton (N)**
Temperature: Fahrenheit (°F) $\left(=\frac{9}{5}°C + 32\right)$	Celsius or Centigrade (°C) $\left(=\frac{5}{9}(°F - 32)\right)$	Centigrade (°C)	**Kelvin (K)** K = 273.15 + °C
Energy: Foot-pound (ft-lb) (1.356 joules)	Newton-meter (N•m) or joule (J) (0.7376 ft-lb)	Dyne-centimeter or erg (1 joule = 10^7 ergs)	**Joule (J)**
Time: Second (s)	Second (s)	Second (s)	**Second (s)**

- Prefixes

To ease the difficulty of mathematical operations with numbers of such varying size, powers of ten are usually employed.

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Multiplication Factors	SI Prefix	SI Symbol
$1\ 000\ 000\ 000\ 000 = 10^{12}$	tera	T
$1\ 000\ 000\ 000 = 10^{9}$	giga	G
$1\ 000\ 000 = 10^{6}$	mega	M
$1\ 000 = 10^{3}$	kilo	k
$0.001 = 10^{-3}$	milli	m
$0.000\ 001 = 10^{-6}$	micro	μ
$0.000\ 000\ 001 = 10^{-9}$	nano	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico	p

1,000,000 ohms	1×10^{6} ohms	1 megaohms (MΩ)
100,000 meters	100×10^{3} meters	100 kilometers (km)
0.0001 second	0.1×10^{-3} second	0.1 millisecond (ms)
0.000001 farad	1×10^{-6} farad	1 microfarad (µF)

BASIC ELECTRICAL QUANTITIES

- Electrical Quantities.

- Current *I* (amperes) :Flow rate of electrical charge (1A = 1 C/s)
- ✦Consider a short length of copper wire cut with an imaginary perpendicular plane, producing the circular cross section shown in Figure. 1.1.
- ✦At room temperature with no external forces applied, there exists within the copper wire the random motion of free electrons created by the thermal energy that the electrons gain from the surrounding medium. When atoms lose their

free electrons, they acquire a net positive charge and are referred to as positive ions.

- ✦ The free electrons are able to move within these positive ions and leave the general area of the parent atom, while the positive ions only oscillate in a mean fixed position. For this reason, the free electron is the charge carrier in a copper wire or any other solid conductor of electricity.

BASIC ELECTRICAL QUANTITIES

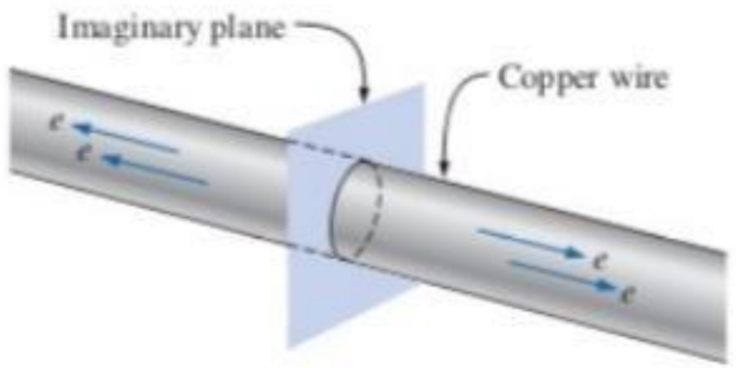


Figure 1.1: Random motion of electrons in a copper wire with no external "pressure" (voltage) applied

BASIC ELECTRICAL QUANTITIES

✦Let us connect copper wire between two battery terminals and a light bulb, as shown in Figure. 1.2, to create the simplest of electric circuits. The battery places a net positive charge at one terminal and a net negative charge on the other.

- To establish numerical values that permit immediate comparisons between levels, a coulomb (C) of charge is defined as the total charge associated with 6.242×10^{18} electrons. The current level in a conductor is measured with ammeter.

The current in amperes can now be calculated using the following equation:

BASIC ELECTRICAL QUANTITIES

$$I = \frac{Q}{t}, I = Amperes(A), Q = coulombs(C), t = seconds(s)$$

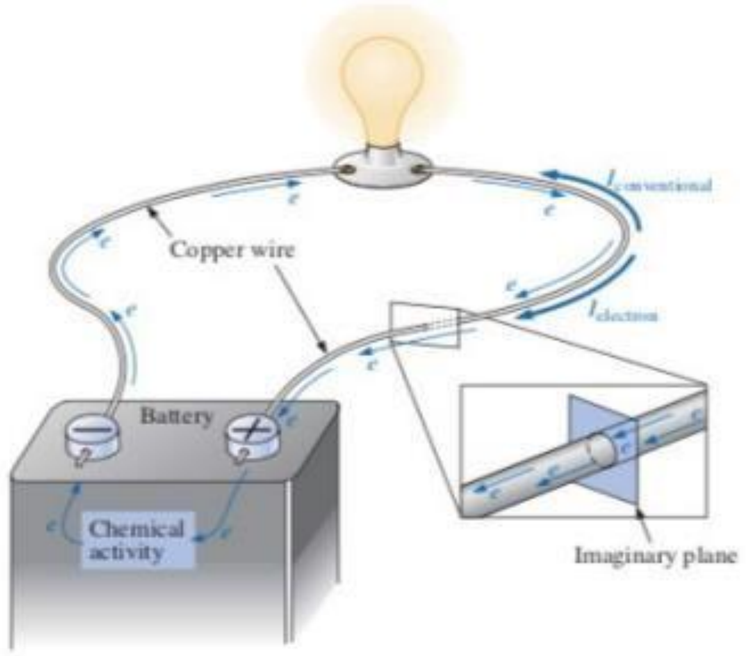


Figure 1.2: Basic electric circuit

- Voltage *V* (volts): Electrical potential difference - energy absorbed or released per coulomb of charge moving from point to another (1 V = 1 J/C).

- ✦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 unit of measurement is volt (honor Alessandro Volta). Voltage is therefore an indication of how much energy is involved in moving a charge between two points in an electrical system.

The potential difference between two points is determined by

$$v = \frac{W}{Q}, W = Energy, Q = Charge \qquad (1.3)$$

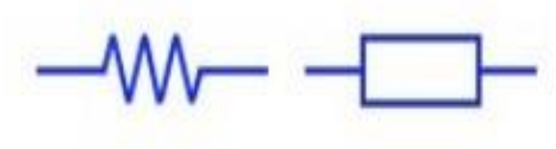
Terms commonly encountered include potential, potential difference, voltage, voltage difference (drop or rise), and electromotive force. Some are used interchangeably.

- **Potential**: The voltage at a point with respect to another point in the electrical system. Typically the reference point is ground, which is at zero potential.

- **Potential difference**: The algebraic difference in potential (or voltage) between two points of a network.
- **Voltage**: When isolated, like potential, the voltage at a point with respect to some reference such as ground (0 V).
- **Voltage difference**: The algebraic difference in voltage (or potential) between two points of the system. A voltage drop or rise is as the terminology would suggest.
- **Electromotive force (emf):** The force that establishes the flow of charge (or current) in a system due to the

application of a difference in potential. It is often associated primarily with sources of energy.

- Resistance R (ohms Ω): Degree to which an electrical component (resistor) opposes the flow of electric current.



Resistance symbol

- E.g

The charge flowing through the imaginary surface of Figure. 1.2 is 0.16 C every 64 ms.Determine the current in amperes.

$$I = \frac{Q}{t} = \frac{0.16C}{64 \times 10^{-3}s} = \frac{160 \times 10^{-3}}{64 \times 10^{-3}} = 2.5A$$

- E.g

Find the potential difference between two points in an electrical system if 60 J of energy are expended by a charge of

$$v = \frac{W}{Q} = \frac{60J}{20C} = 3V$$

20 C between these two points.

- Resistors

Resistors are passive elements that opposes the flow of current. The flow of charge through any material encounters an opposing force similar to mechanical friction.

- Resistors are made in many forms, but all belong in either of two groups: fixed or variable. The most common of the low-wattage, fixed-type resistors is the molded carbon composition resistor.

- ✦The relative sizes of all fixed and variable resistors change with the wattage (power) rating, increasing in size for increased wattage ratings in order to withstand the higher currents and dissipation losses.

BASIC ELECTRICAL QUANTITIES

- The unit of measurement of resistance is ohm(Ω). The circuit symbol for resistance appears in Fig. 1.3 with the graphic abbreviation for resistance (R).

Figure 1.3: Resistance

- Variable resistors have a terminal resistance that can be varied by turning a dial, knob, screw, or whatever seems appropriate for the application.

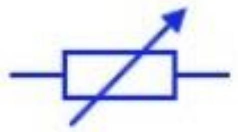


Figure 1.4: Variable Resistance

- Capacitors

A capacitor is a passive element designed to store energy in its electric field. A capacitor consists of two conducting plates separated by an insulator (or dielectric). In many practical applications, the plates may be aluminium foil while the dielectric may be air, ceramic, paper, or mica.

- ✦The amount of charge stored, represented by q, is directly proportional to the applied voltage v so that;

$$q = CV$$

where C, the constant of proportionality, is known as the capacitance of the capacitor.

BASIC ELECTRICAL QUANTITIES

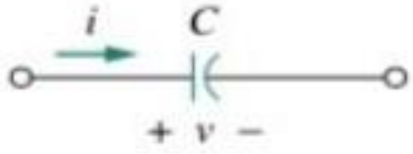
- Capacitance is the ratio of the charge on one plate of a capacitor to the voltage difference between the two plates, measured in farads (F).

The capacitance is given by

$$C = \frac{\varepsilon A}{d}$$

The energy stored in the capacitor is therefore;

$$W = \frac{1}{2}CV^2$$



Circuit symbol for capacitors

Inductors

An inductor is a passive element designed to store energy in its magnetic field. If current is allowed to pass through an inductor, it is found that the voltage across the inductor is directly proportional to the time rate of change of the current

$$v = L\frac{di}{dt}$$

where L is the constant of proportionality called the inductance of the inductor. The unit of inductance is the henry (H).

Inductance is the property whereby an inductor exhibits opposition to the change of current flowing through it.

✦The power delivered to the inductor is; $W = \frac{1}{2}Li^2$

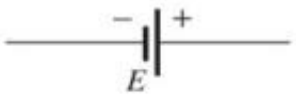
Circuit symbol for inductors

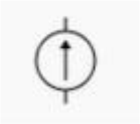
BASIC ELECTRICAL QUANTITIES

- Introduction to DC and AC Sources.

✦For direct current (dc), ideally the flow of charge (current) does not change in direction with time.

DC voltage sources can be divided into three broad categories: batteries (chemical action), dc generators (electromechanical), and power supplies (rectification). Ideally a dc voltage source will provide a fixed terminal voltage, even though the current demand from the electrical/electronic system may vary.



DC current source DC  voltage source.

Direct current encompasses the various electrical systems in which there is a unidirectional ("one direction") flow of charge. The waveform for DC voltage and current is shown in figure 1.11

Figure 1.11: Graph for DC voltage and Current

BASIC ELECTRICAL QUANTITIES

- ✦Alternating current (ac) is the flow of electric charge that periodically reverses direction. An ac is produced by an alternating emf, which is generated in a power plant, as described in Induced Electric Fields. If the ac source varies periodically, particularly sinusoidally, the circuit is known as an ac circuit. The symbols for AC voltage and current are shown in Figure 1.15 and 1.16 respectively.

Figure 1.15: AC voltage source

Figure 1.16: AC current source

✦Examples include the commercial and residential power that serves so many of our needs.

BASIC ELECTRICAL QUANTITIES

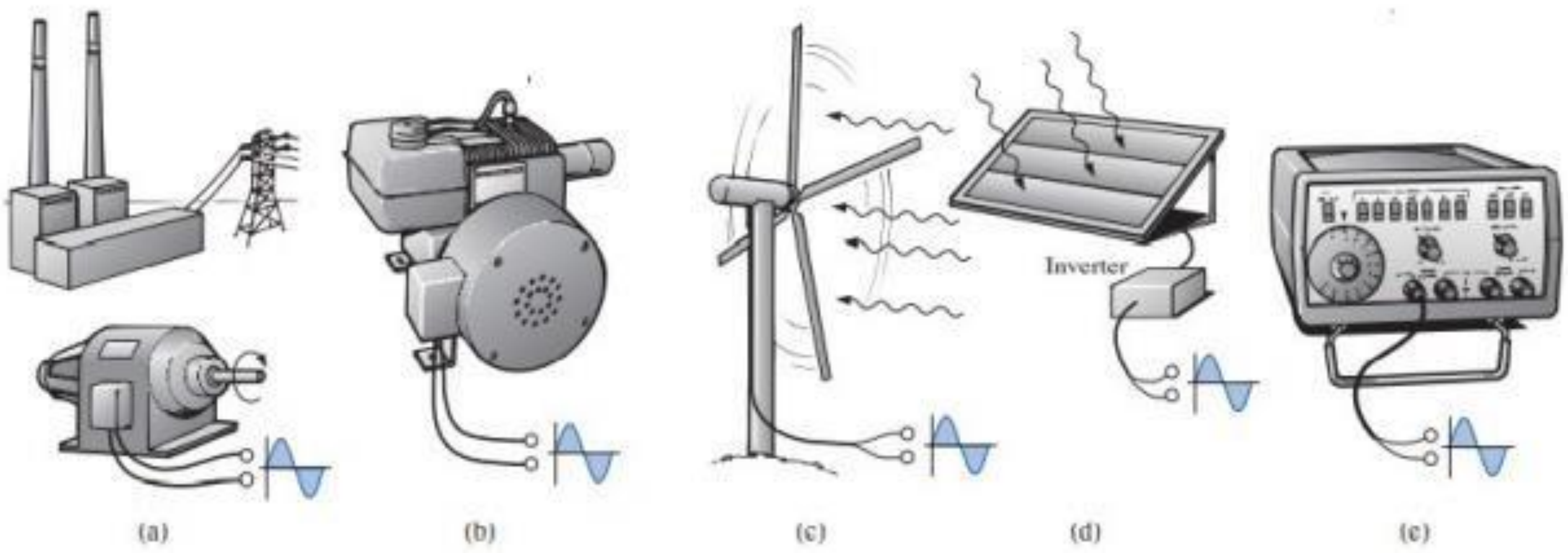


Figure 3.2: Various sources of ac power: (a) generating plant; (b) portable ac generator; (c) wind-power station; (d) solar panel; (e) function generator.

- For sinusoidal alternating current (ac), the flow of charge is continually changing in magnitude and direction with time. The waveform for AC voltage and current is shown in figure 1.12.

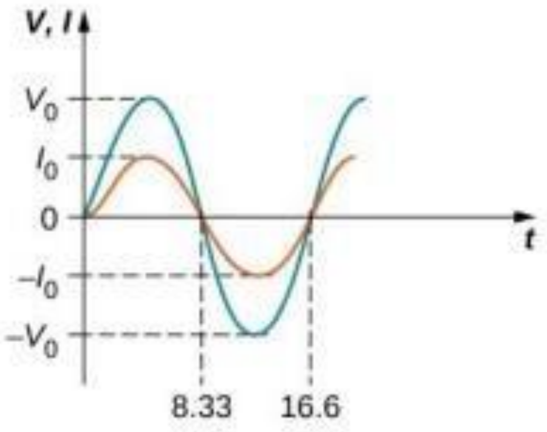


Figure 1.12: Waveform for AC (Voltage and current versus time for AC).

DC CIRCUIT THEORY

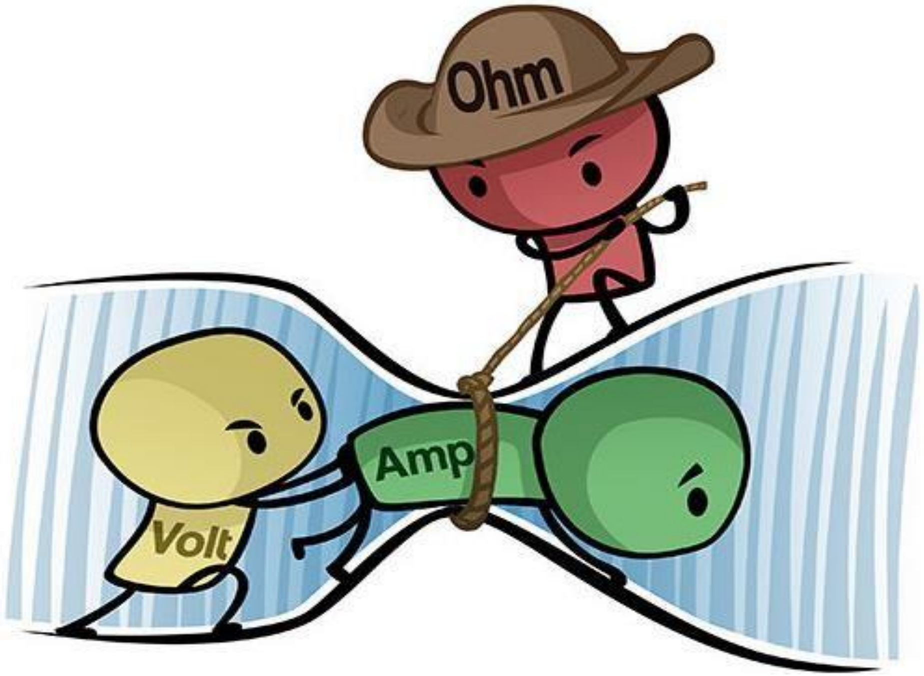
- Ohm's Law

The law states that the strength of a current is directly proportional to the voltage and inversely proportional to resistance offered provided the temperature of the conductor remain constant.

$$I \propto V \times \frac{1}{R}$$

If I, V and R be expressed in terms of units,

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



DC CIRCUIT THEORY

- Open and Short Circuits

- An open circuit is simply two isolated terminals not connected by an element of any kind as shown in Fig. 2.23(a).

The voltage across the open circuit, however, can be any value, as determined by the system it is connected to. Therefore, an open circuit can have a potential difference (voltage) across its terminals, but the current is always zero amperes.

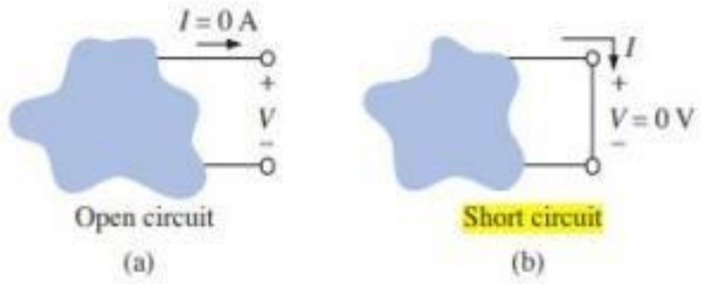


Figure 2.23: Two special network configurations.

DC CIRCUIT TRHEORY

- A short circuit is a very low resistance, direct connection between two terminals of a network, as shown in Fig. 2.23(b).

The current through the short circuit can be any value, as determined by the system it is connected to, but the voltage across the short circuit will always be zero volts because the resistance of the short circuit is assumed to be essentially zero ohms and $V = IR = I(0) = 0$ V.

- Power

Power is an indication of how much work (the conversion of energy from one form to another) can be done in a specified amount of time, that is, a rate of doing work.

The electrical unit of measurement for power is the watt (W), defined by 1 joule/second (J/s). In equation form, power is

$$P = \frac{W}{t}(watts, W, or J/s)$$

$$P = \frac{W}{t} = \frac{QV}{t} = V\frac{Q}{t}$$

determined by ;

$$P = VI = I^2R(watts)$$

- Energy

Energy is the capacity to do work, measured in Joules (J).

determined by $W = Pt$

Find the power delivered to the dc motor of Figure. 2.1.

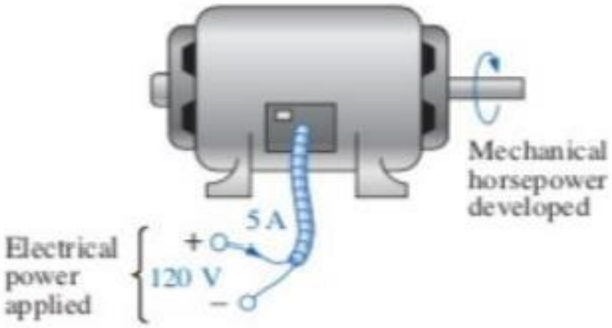


Figure 2.1: Example

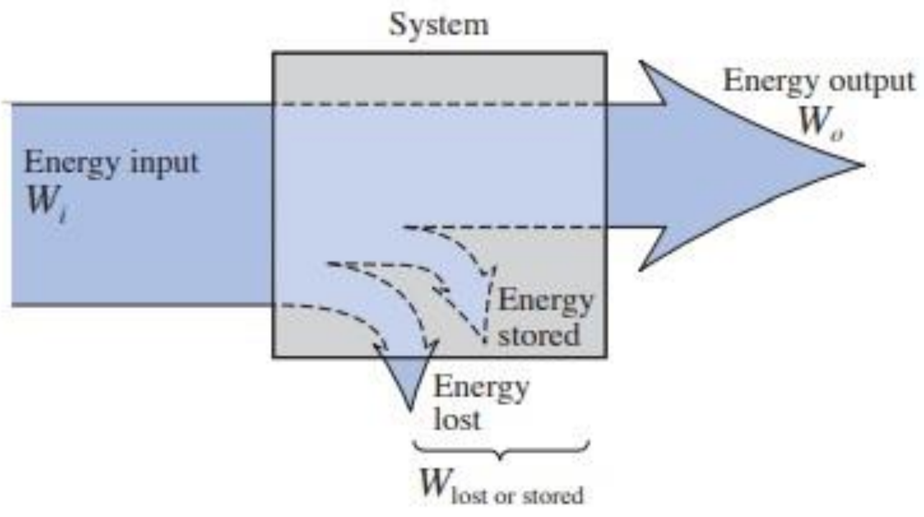
$$P = VI = (120 \times 5) = 600W = 0.6kW$$

The energy (W) lost or gained by any system is therefore

E.g

DC CIRCUIT THEORY

- Efficiency



The efficiency (η) of the system is then determined by the following equation:

$$\text{Efficiency} = \frac{\text{power output}}{\text{power input}}$$

And $$\boxed{\eta = \frac{P_o}{P_i}} \quad \text{(decimal number)}$$

where η (lowercase Greek letter eta) is a decimal number. Expressed as a percentage,

$$\boxed{\eta\% = \frac{P_o}{P_i} \times 100\%} \quad \text{(percent)}$$

In terms of the input and output energy, the efficiency in percent is given by

$$\boxed{\eta\% = \frac{W_o}{W_i} \times 100\%} \quad \text{(percent)}$$

The maximum possible efficiency is 100%, which occurs when Po = Pi, or when the power lost or stored in the system is zero.

- Feature Of Electrical Circuits.

- A branch represents a single element such as a voltage source or a resistor. The circuit in Fig. 2.2 has five branches, namely, the 10-V voltage source, the 2-A current source, and the three resistors.

- A node A node is usually indicated by a dot in a circuit. The circuit in Fig. 2.2 has three nodes a, b, and c is the point of connection between two or more branches.

- A loop is any closed path in a circuit. A loop is a closed path formed by starting at a node, passing through a set of nodes, and returning to the starting node without passing through any node more than once.

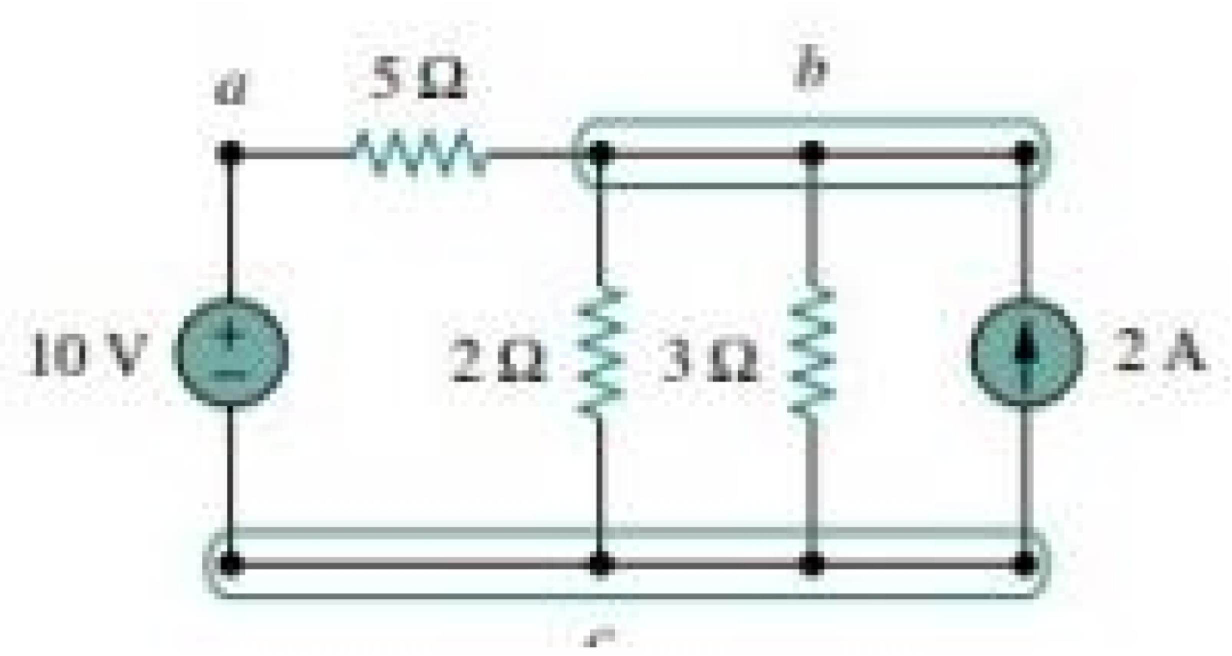
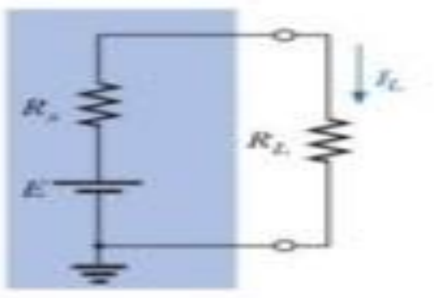


Figure 2.2:

- Source conversations

In reality, all sources; whether they are voltage or current, have some internal resistance in the relative positions shown.

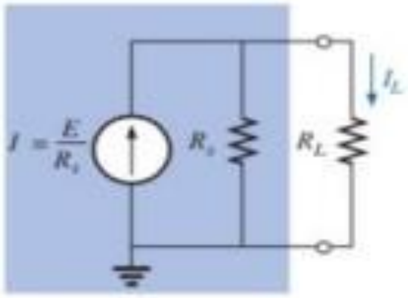


Practical voltage source.

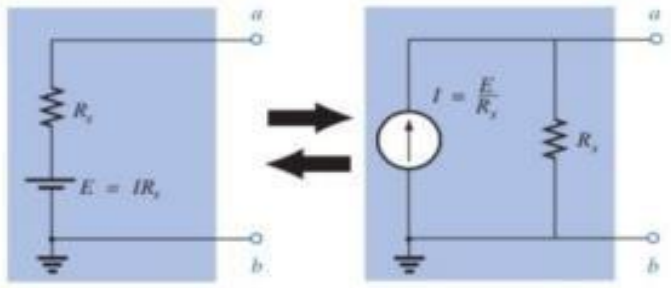
$$I_L = \frac{E}{R_S + R_L}$$

If we solve for the load current I_L, we obtain

$$I_L = \frac{(1)E}{R_S + R_L} = \frac{(R_S/R_S)E}{R_S + R_L} = \frac{R_S(E/R_S)}{R_S + R_L} = \frac{R_S I}{R_S + R_L}$$



Practical current source



Source conversion

The current of the current source or the voltage of the voltage source is determined using Ohm's law and the parameters of the other configuration.

- E.g

1. Convert the voltage source of Fig 1.16(a) to a current source, and calculate the current through the 4-Ω load for each source.
2. Replace the 4-Ω load with a 1-kΩ load, and calculate the current I_L for the voltage source.
3. Repeat the calculation of part (b) assuming that the voltage source is ideal (R_s = 0 Ω) because R_L is so much larger than R_s. Is this one of those situations where assuming that the source is ideal is an appropriate approximation?

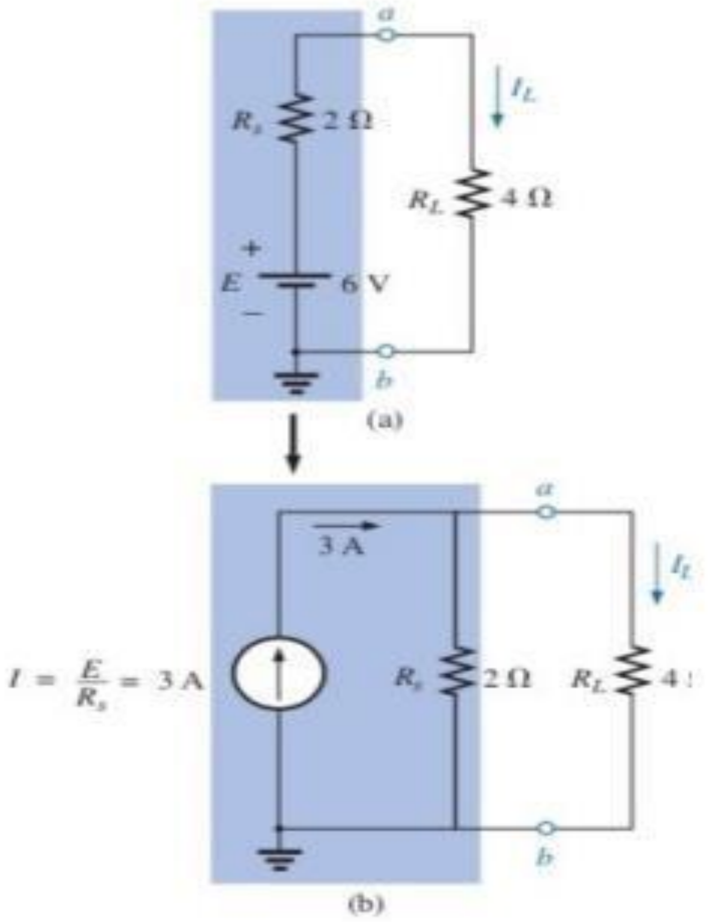


Figure 1.16: Example

Solution

a. See Fig 1.16

$$Fig.1.16(a): I_L = \frac{E}{R_S + R_L} = \frac{6V}{2\Omega + 4\Omega} = 1$$

$$Fig.1.16(b): I_L = \frac{R_S I}{R_S + R_L} = \frac{(2\Omega)(3A)}{2\Omega + 4\Omega} = 1A$$

b.

$$I_L = \frac{E}{R_S + R_L} = \frac{6V}{2\Omega + 1k} = 5.99mA$$

c.

$$I_L = \frac{E}{R_L} = \frac{6V}{1k} = 6mA \cong 5.99mA$$

$$Yes, R_L \gg R_S (voltagesource)$$