LESSON 1: BASIC CONCEPTS

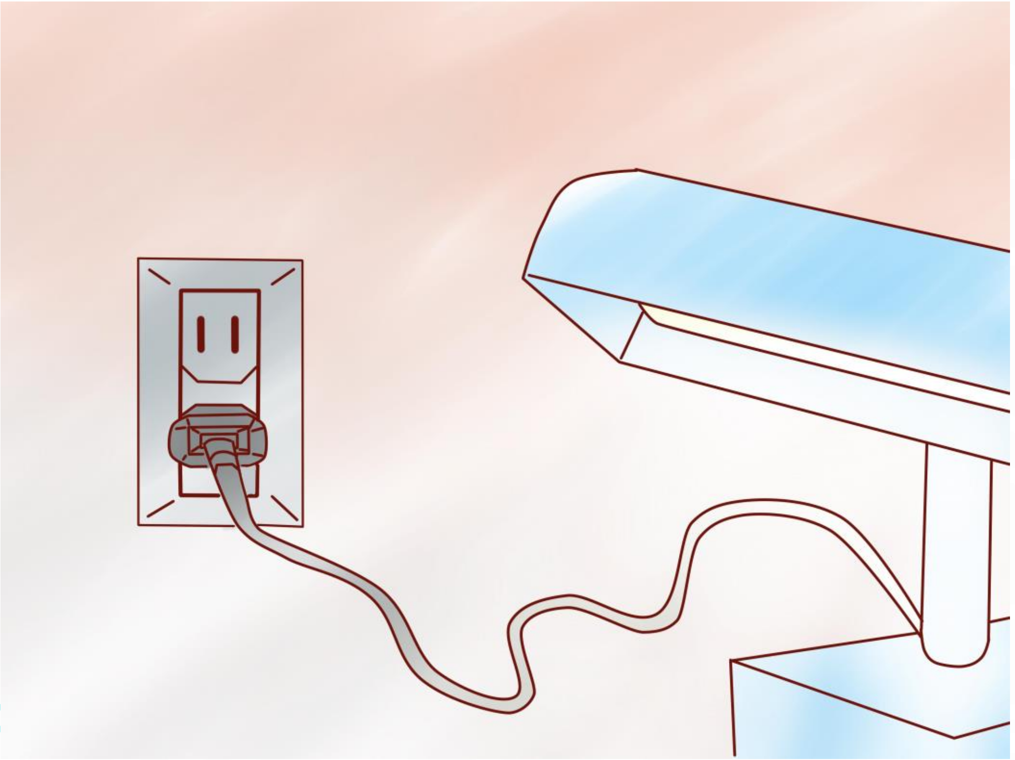
COURSE CODE: EEE 201

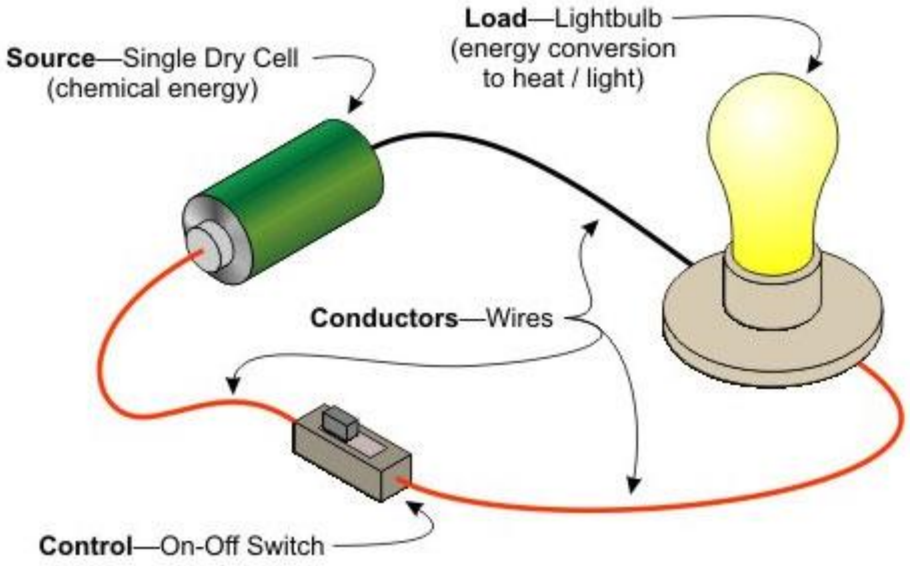
COURSE TITLE: ELECTRICAL ENGINEERING

ELECTRICAL ENGINEERING

- Electrical engineering is an engineering discipline concerned with the study, design and application of equipment, devices and systems which use electricity, electronics, and electromagnetism.
- Electrical engineering is now divided into a wide range of fields, including computer engineering, systems engineering, power engineering, telecommunications, radio-frequency engineering, signal processing, instrumentation, and electronics.
- Many branches of electrical engineering, such as power, electric machines, control, electronics, communications, and instrumentation, are based on electric circuit theory.

CURRENT, VOLTAGE & RESISTANCE





CURRENT : FLOW OF ELECTRONS

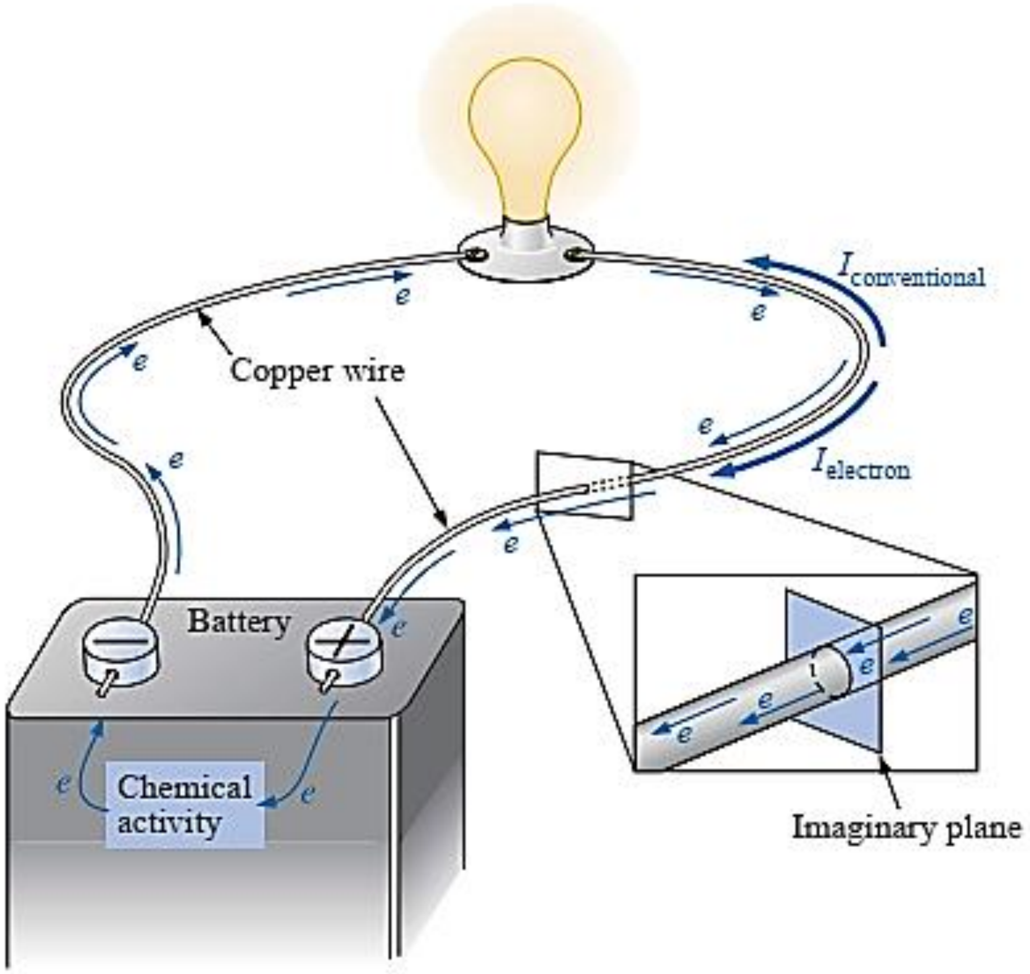
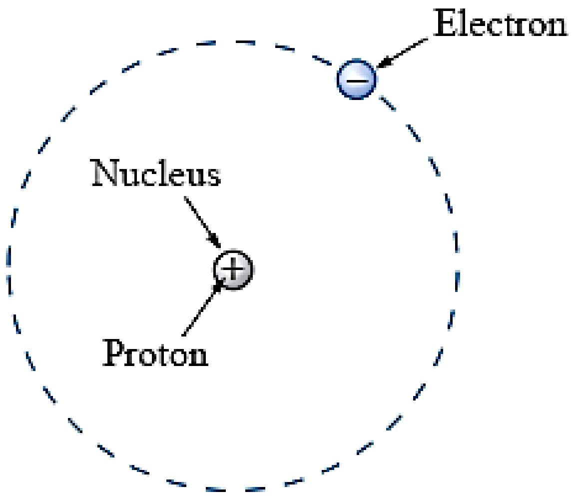
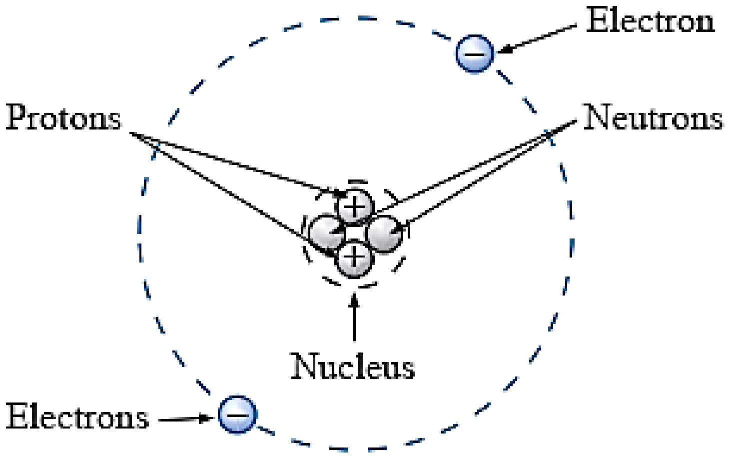


FIG. 2.7
Basic electric circuit.

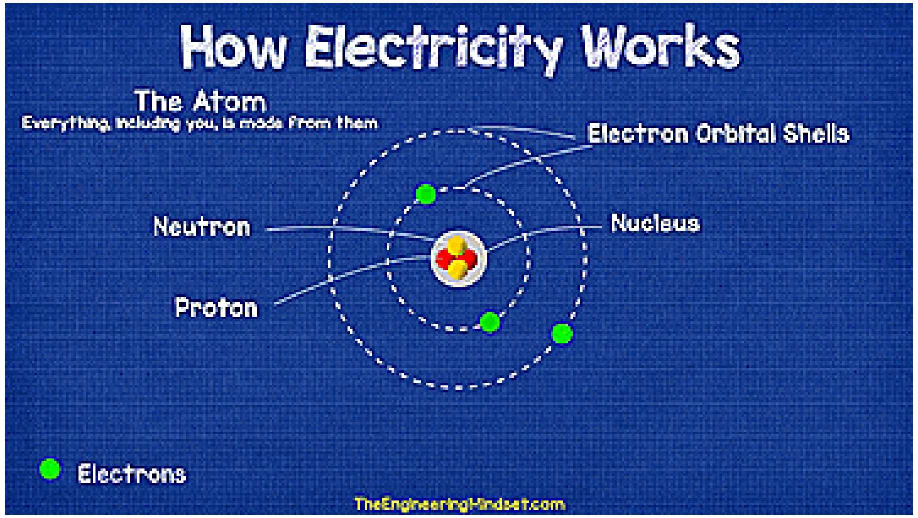
CURRENT : FLOW OF ELECTRONS



(a) Hydrogen atom



(b) Helium atom



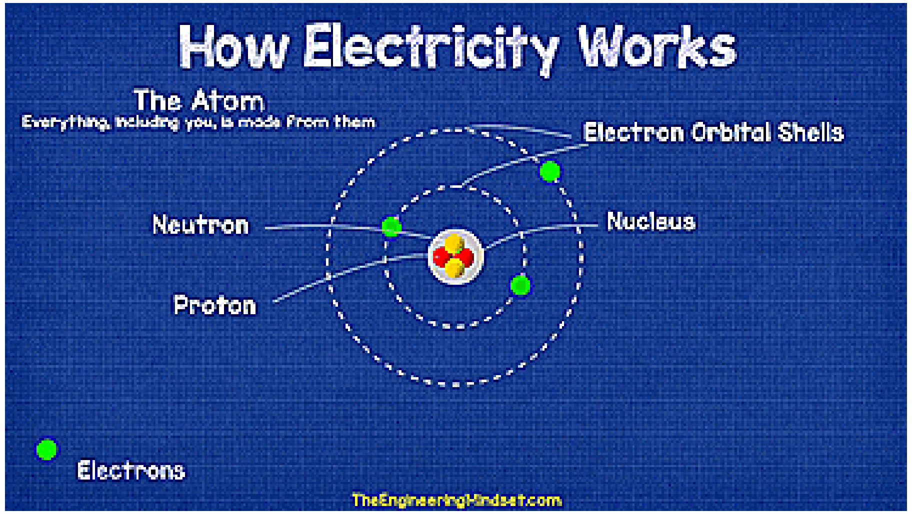


Fig. 01: Loosely bond electron.

CURRENT : FLOW OF ELECTRONS

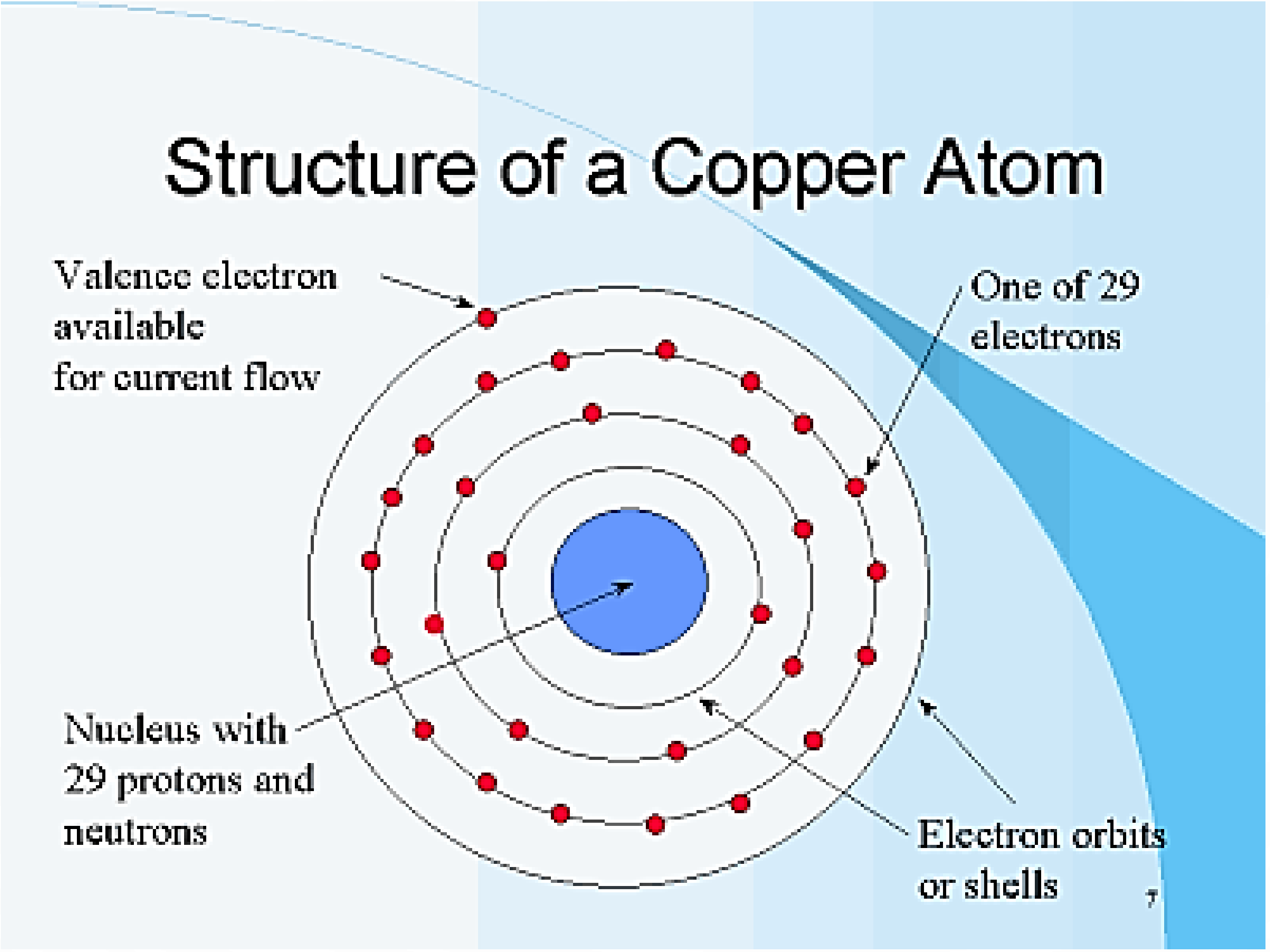


Fig. 02: Structure of a copper atom.

CURRENT : FLOW OF ELECTRONS

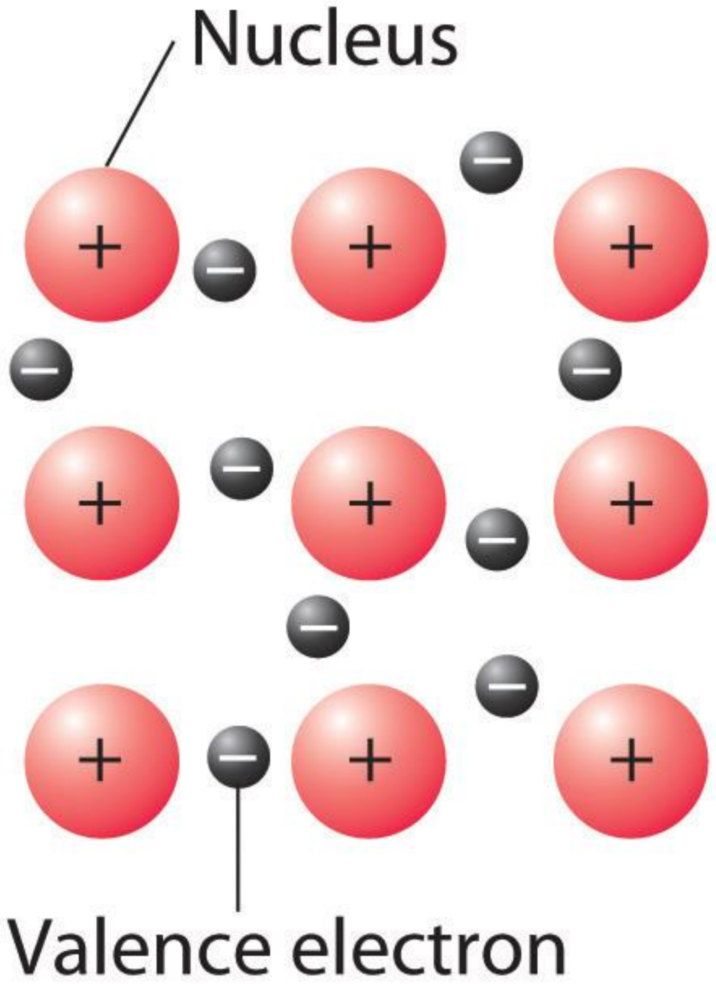


Fig. 03: Free electrons in a copper conductor. In copper, no. of free electrons = $10^{23}/cm^3$ at room temperature.

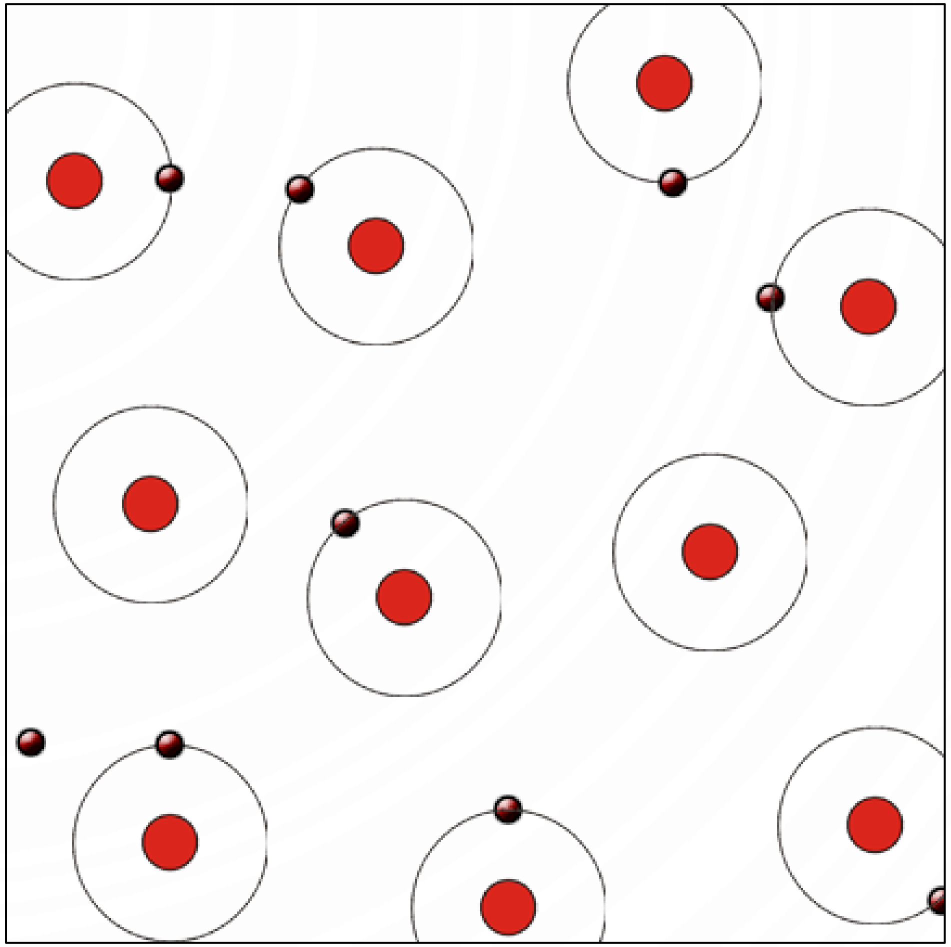
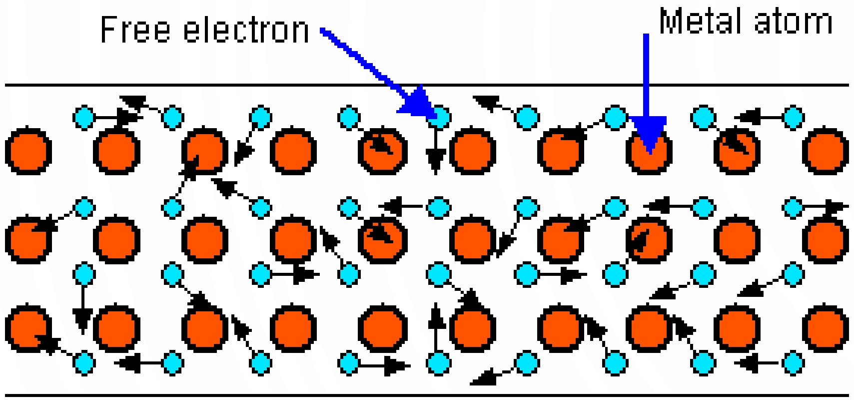


Fig. 04: *Random motion of free electrons in an atomic structure.*

CURRENT : FLOW OF ELECTRONS



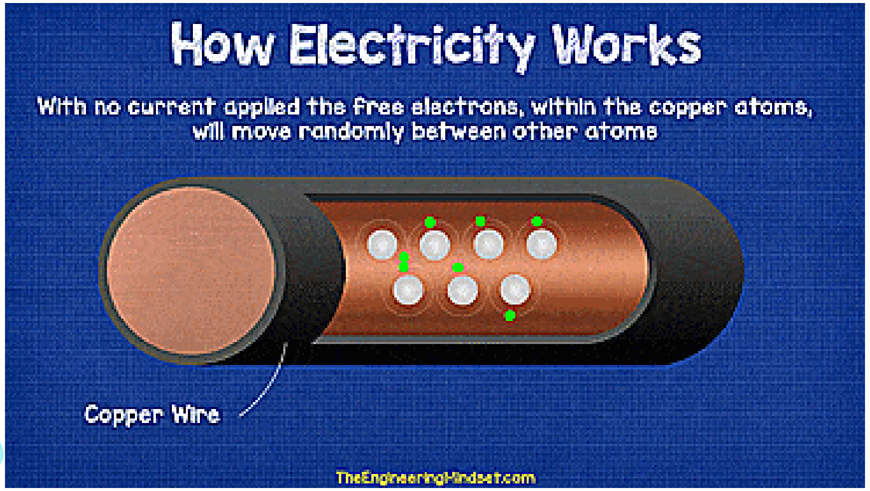
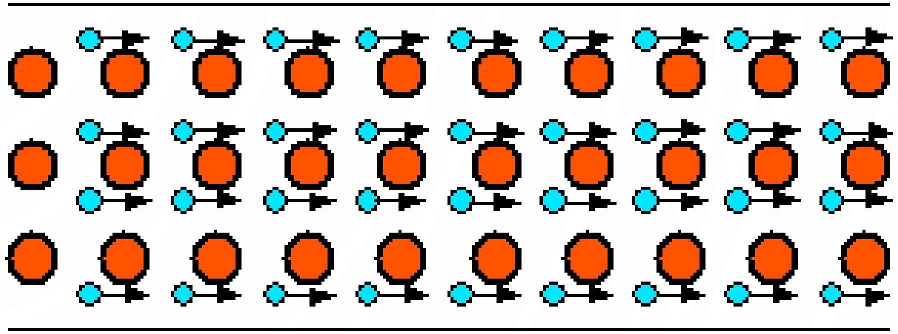


Fig. 05:Random motion of free electrons.



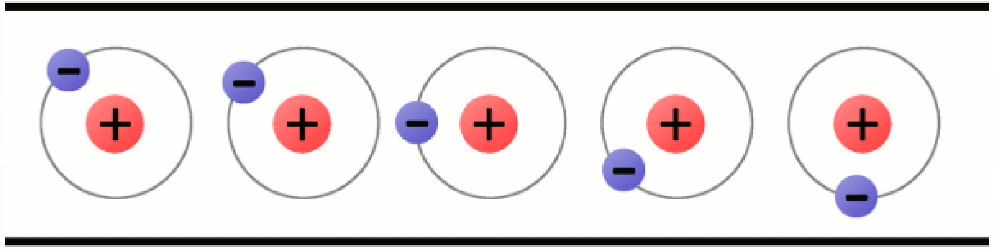


Fig. 06: Uniform motion of electrons to a certain direction by applying external force.

Unit of current is Ampere (A)

CURRENT : FLOW OF ELECTRONS

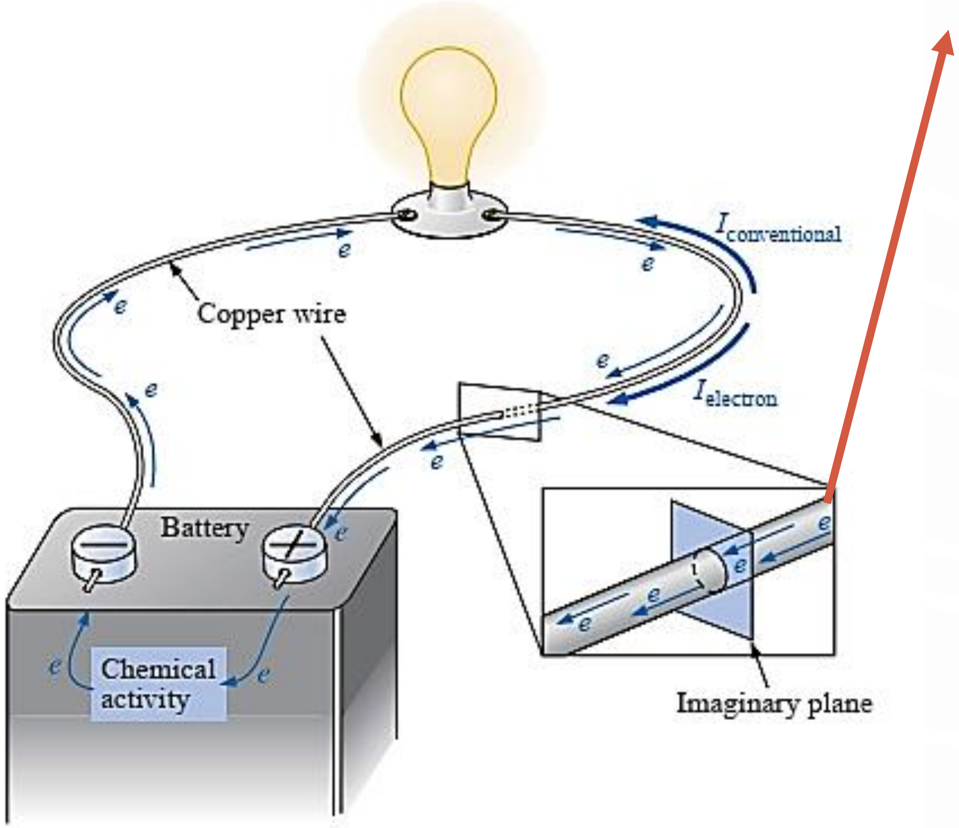


FIG. 2.7
Basic electric circuit.

- This movement of charge is called an electric **current.**
- The more electrons per second that pass through the circuit, the greater is the current.
- Thus, current is the *rate of flow* (or *rate of movement*) of charge.

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

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

➢ 1 ampere is the current in a circuit when 1 coulomb of charge passes a given point in 1 second.
➢ 1 coulomb charge=6.242×10^{18} electrons

CURRENT : FLOW OF ELECTRONS

If the current does not change with time, but remains constant, we call it a *direct current* (dc).

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

By convention the symbol I is used to represent such a constant current.

A time-varying current is represented by the symbol i. A common form of time-varying current is the sinusoidal current or *alternating current* (ac).

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

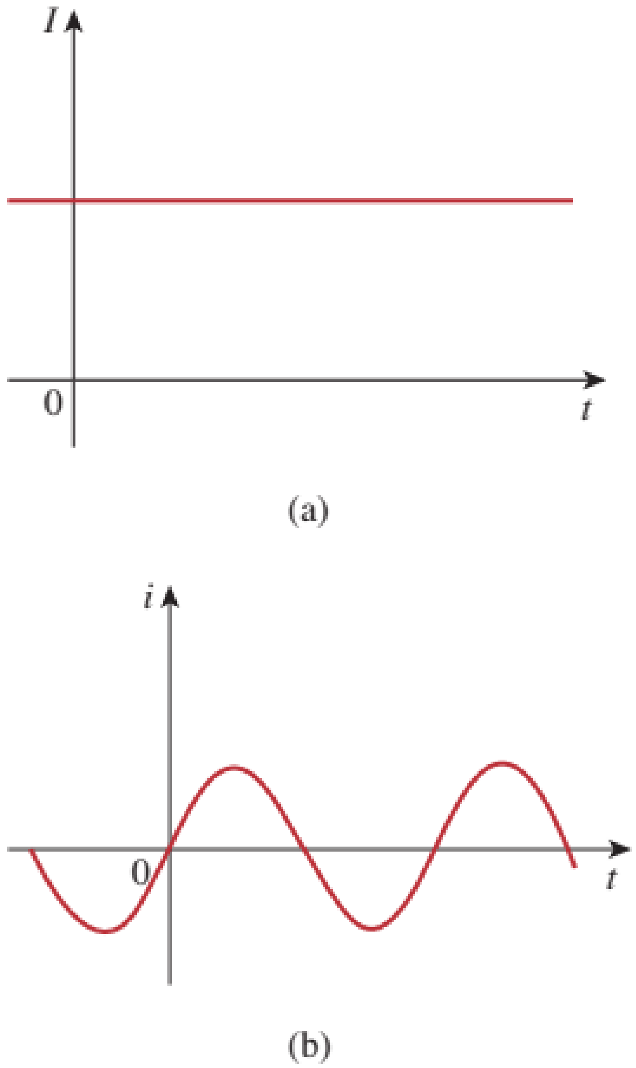
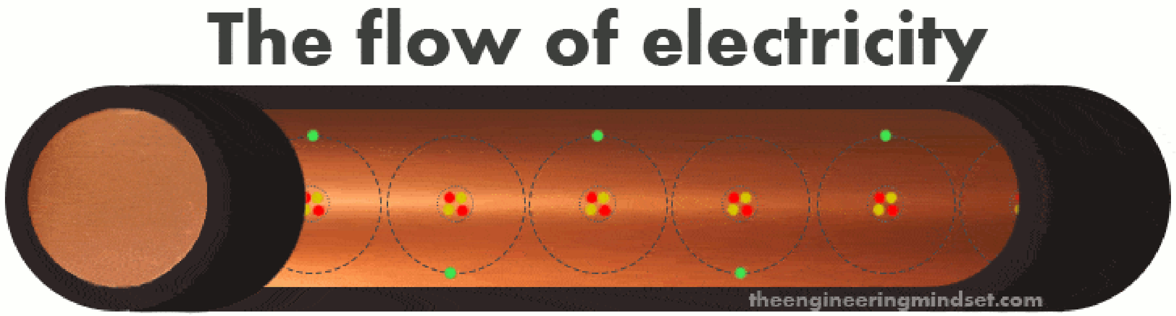


Figure 1.4
Two common types of current: (a) direct current (dc), (b) alternating current (ac).

VOLTAGE : PUSHING FORCE OF ELECTRONS



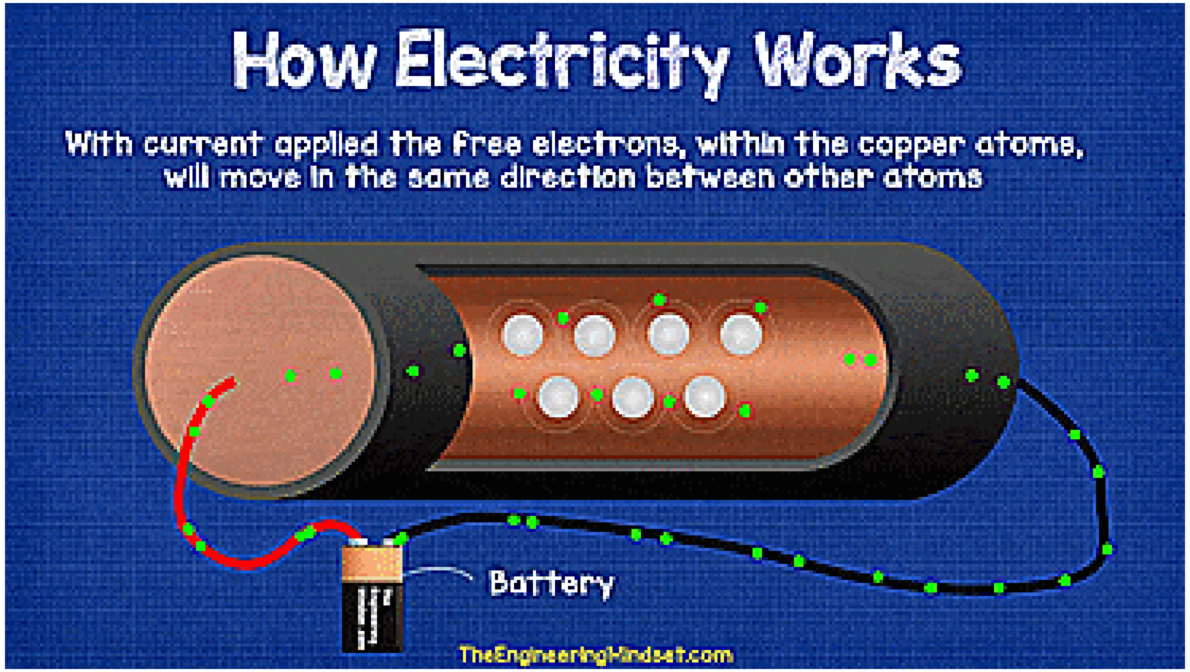


Fig. 07: Uniform motion to a certain direction by applying chemical energy of a battery.

- To move the electron in a conductor in a particular direction requires some work or energy transfer.
- This work is performed by an external electromotive force (emf), typically represented by the battery. This emf is also known as *voltage* or *potential difference*.

- ➢ More voltage you have the more electrons can flow.
- ➢ Units: Volts (V)
- ➢ Voltage Source: Battery

VOLTAGE : PUSHING FORCE OF ELECTRONS

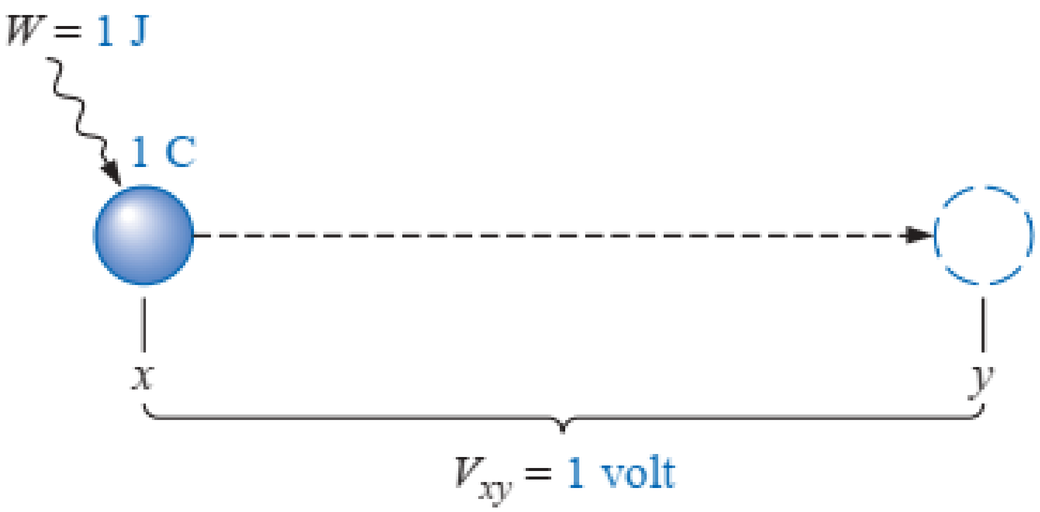


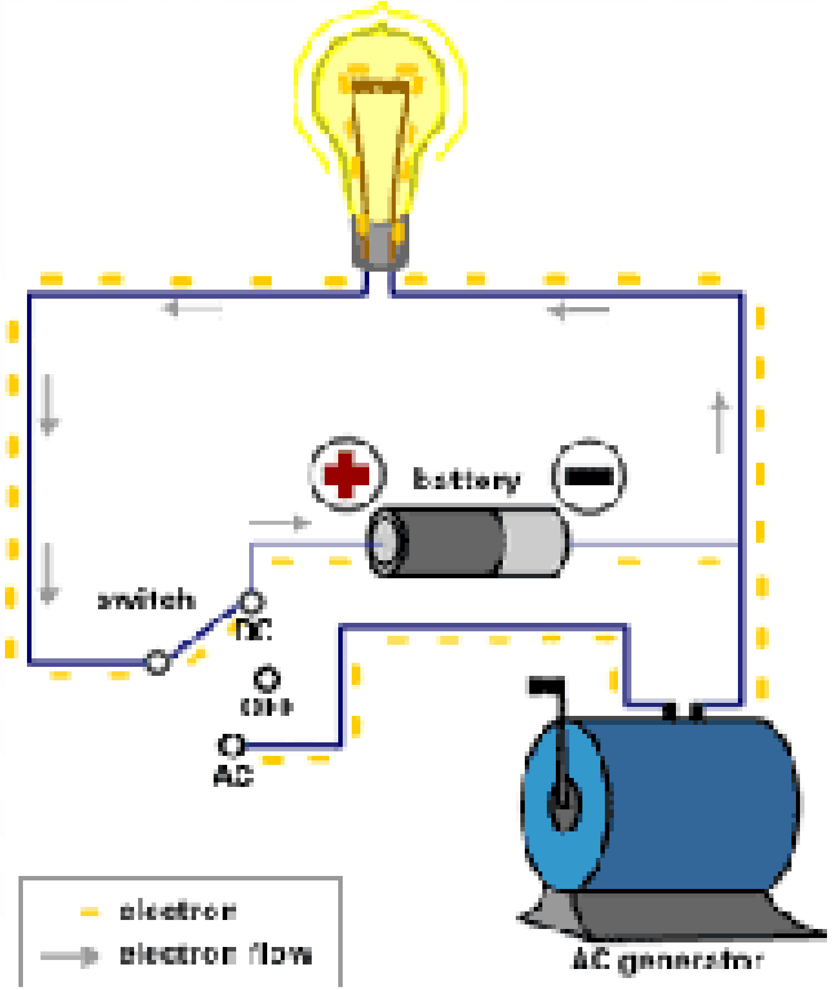
FIG. 2.10
Defining the unit of measurement for voltage.

- If one joule of energy (1 J) is required to move the one coulomb (1 C) of charge of Fig. 2.10 from position x to position y, the potential difference or voltage between the two points is one volt (1 V).
- If the energy required to move the 1 C of charge increases to 12 J due to additional opposing forces, then the potential difference will increase to 12 V.

In general, the potential difference between two points is determined by

$$\boxed{V = \frac{W}{Q}} \quad \text{(volts)} \qquad \textbf{(2.6)}$$

VOLTAGE SOURCE: DC & AC



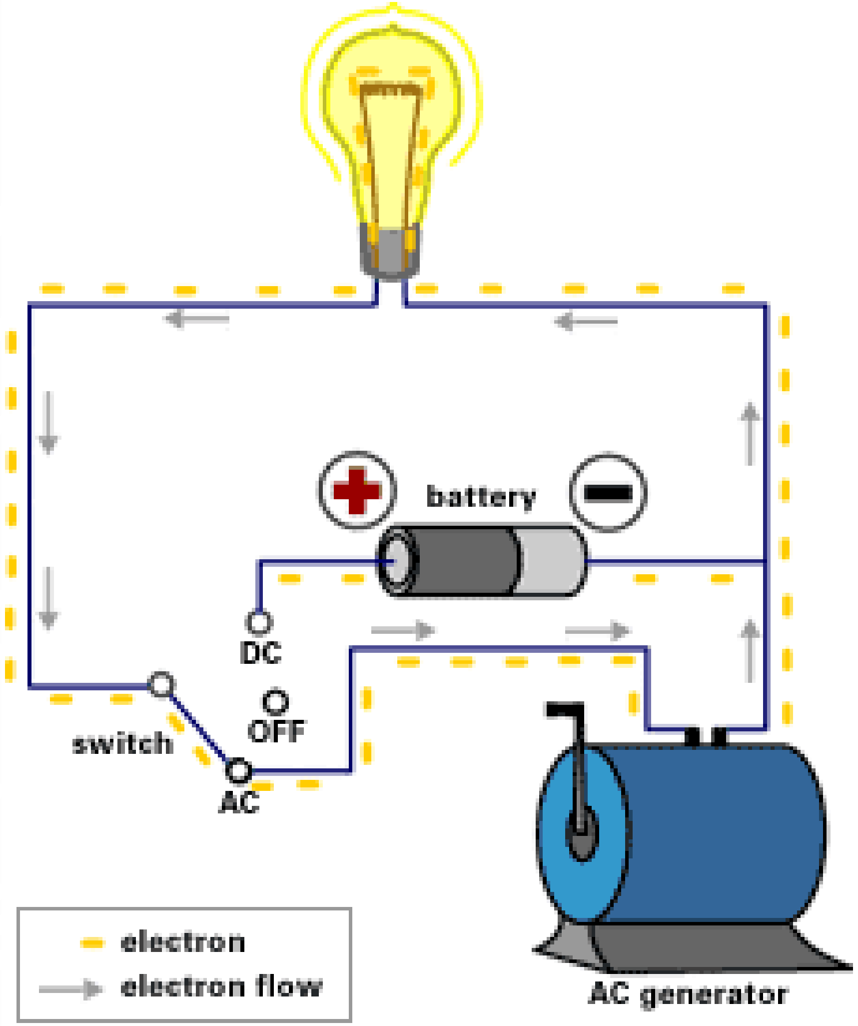


Fig. 08: Direct Current (DC) voltage Source (Battery).

Fig. 09: Alternating Current (AC) voltage Source (AC generator).

CONDUCTORS & INSULATORS

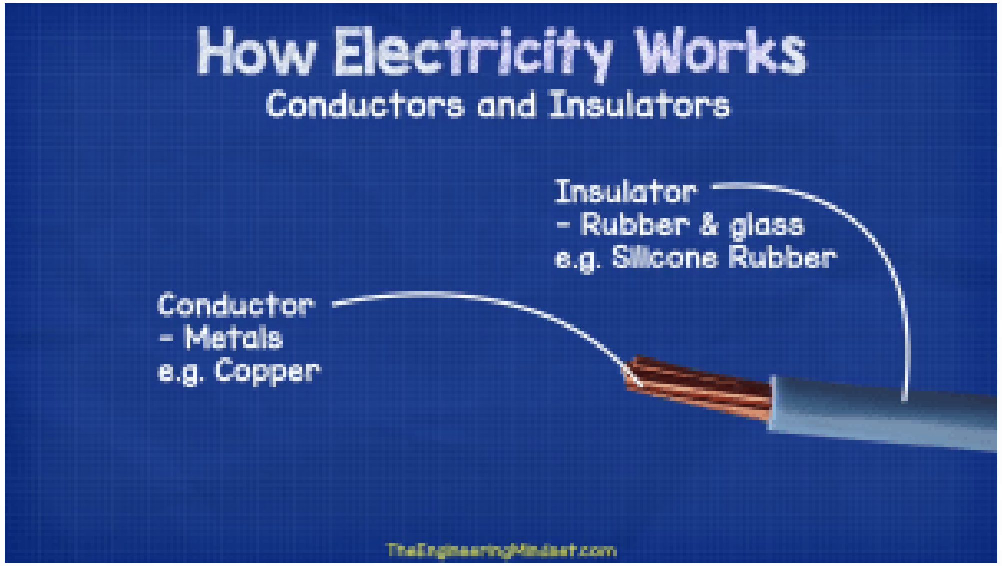


TABLE 2.1

Relative conductivity of various materials.

Metal	Relative Conductivity (%)
Silver	105
Copper	100
Gold	70.5
Aluminum	61
Tungsten	31.2
Nickel	22.1
Iron	14
Constantan	3.52
Nichrome	1.73
Calorite	1.44

Conductors

- ***Materials that permit a generous flow of electron with very little external force (voltage) applied.***
- ***Typically have only one electron in the valence r***

CONDUCTORS & INSULATORS

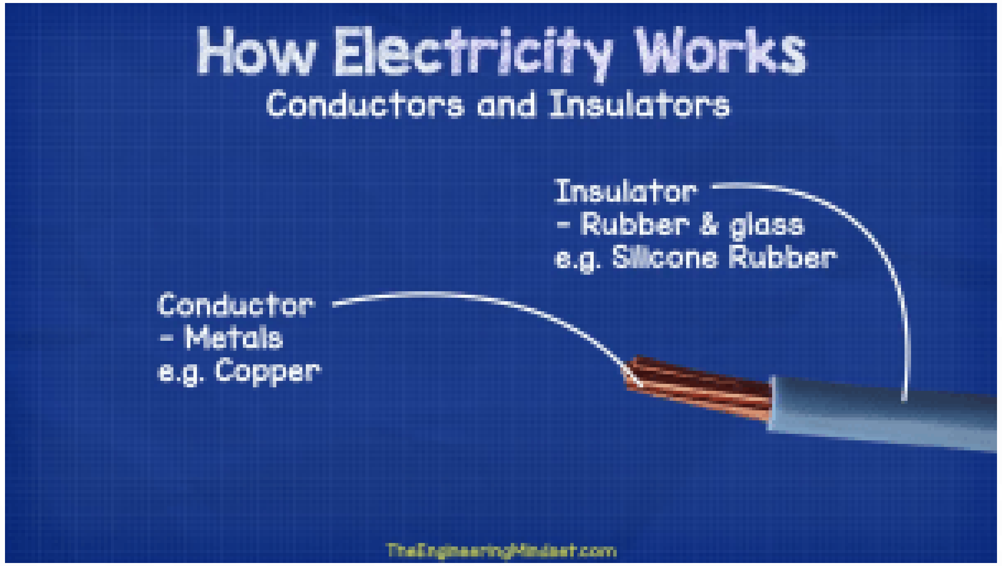


TABLE 2.2

Breakdown strength of some common insulators.

Material	Average Breakdown Strength (kV/cm)
Air	30
Porcelain	70
Oils	140
Bakelite	150
Rubber	270
Paper (paraffin-coated)	500
Teflon	600
Glass	900
Mica	2000

Insulators

- ***Materials that have very few free electrons.***
- ***require a large applied potential (voltage) to establish a measurable current level.***

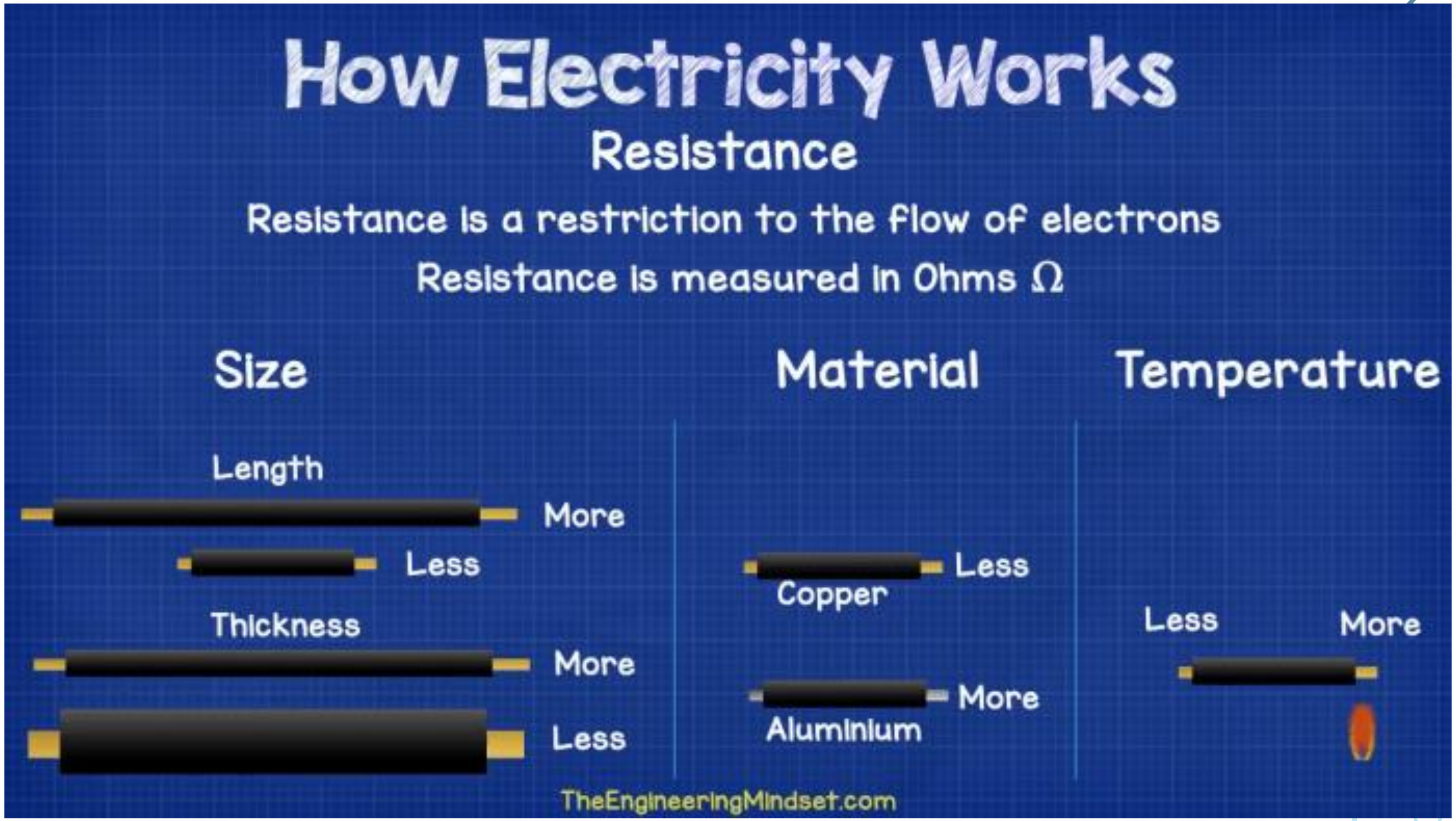
SEMICONDUCTORS

- Specific group of elements that exhibit characteristics between those of insulators and conductors.
- Typically have four electrons in the outermost valence ring.
- Semiconductor materials: silicon (Si) is the most extensively employed material, germanium (Ge) and gallium arsenide (GaAs) are also used in many important devices.

RESISTANCE & RESISTOR

- *Resistance is determined by the following four factors*
    1. *Material*
    2. *Length*
    3. *Cross-sectional area*
    4. *Temperature*

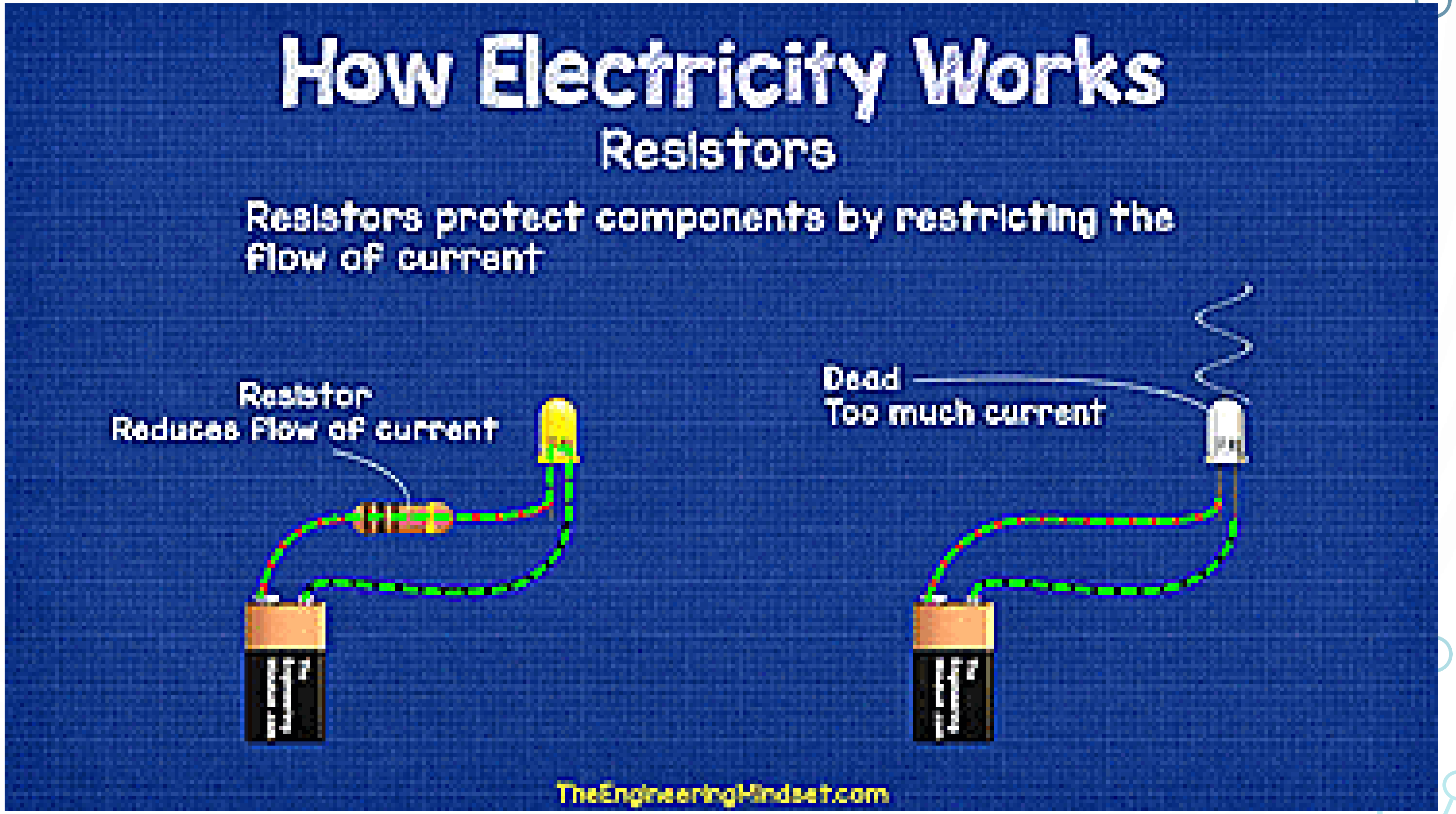
$$R = \frac{\rho \ell}{A} \quad [\text{ohms}, \Omega]$$



RESISTANCE & RESISTOR

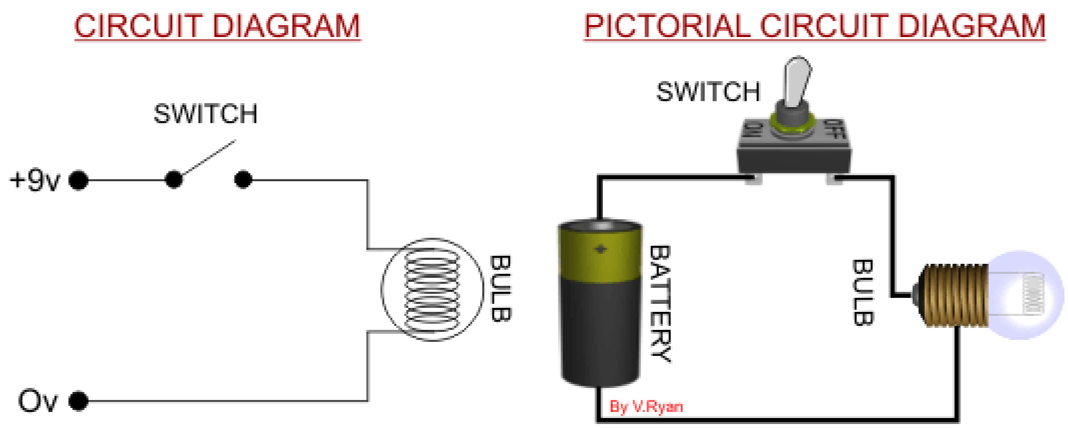
Resistors:

- Restrict the flow of electrons.
- Used to generate light and heat such as in an incandescent light bulb.



ELECTRIC CIRCUIT: INTERCONNECTION OF ELECTRICAL COMPONENTS.

Electrical engineering: Interested in communicating or transferring energy from one point to another. To do this requires an interconnection of electrical devices. Such interconnection is referred to as an electric circuit, and each component of the circuit is known as an element.



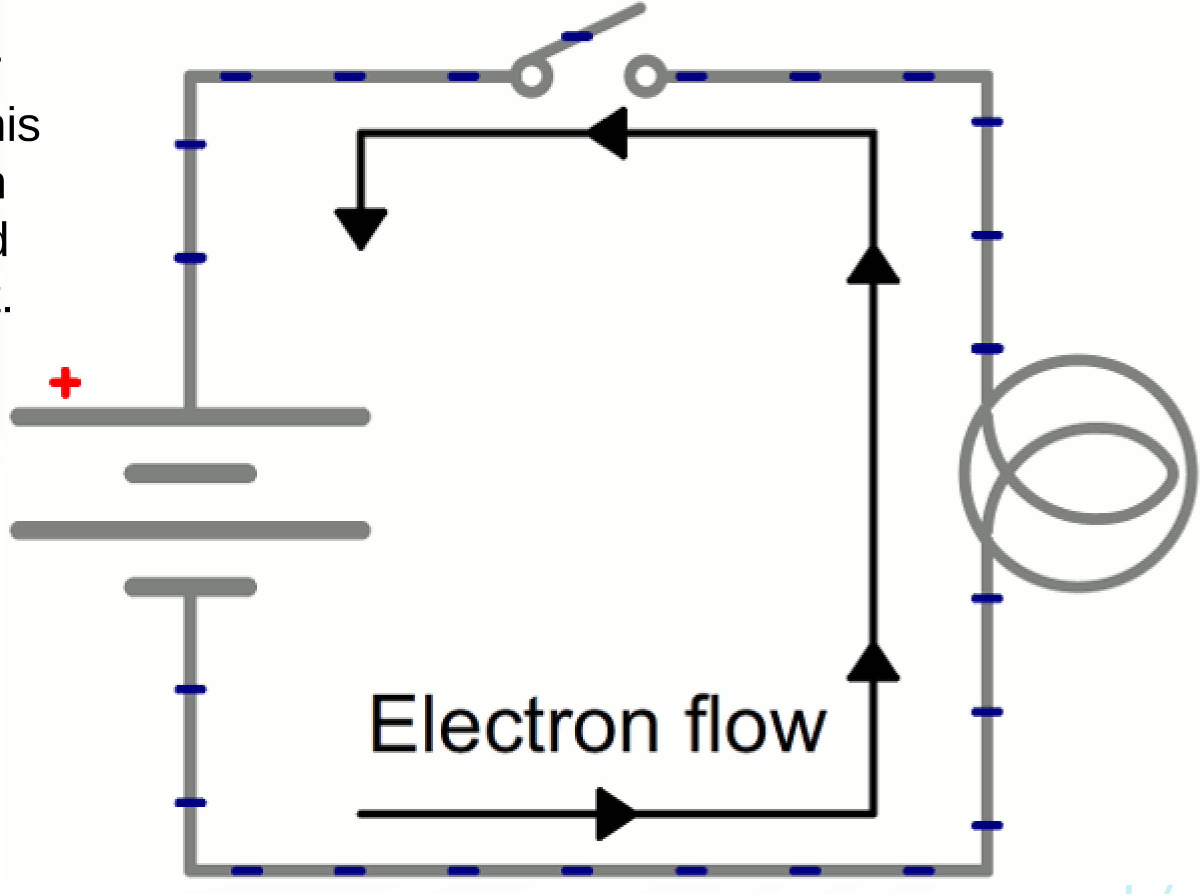


Fig 10: Circuit Diagram.

ELECTRIC CIRCUIT:
INTERCONNECTION OF ELECTRICAL COMPONENTS.

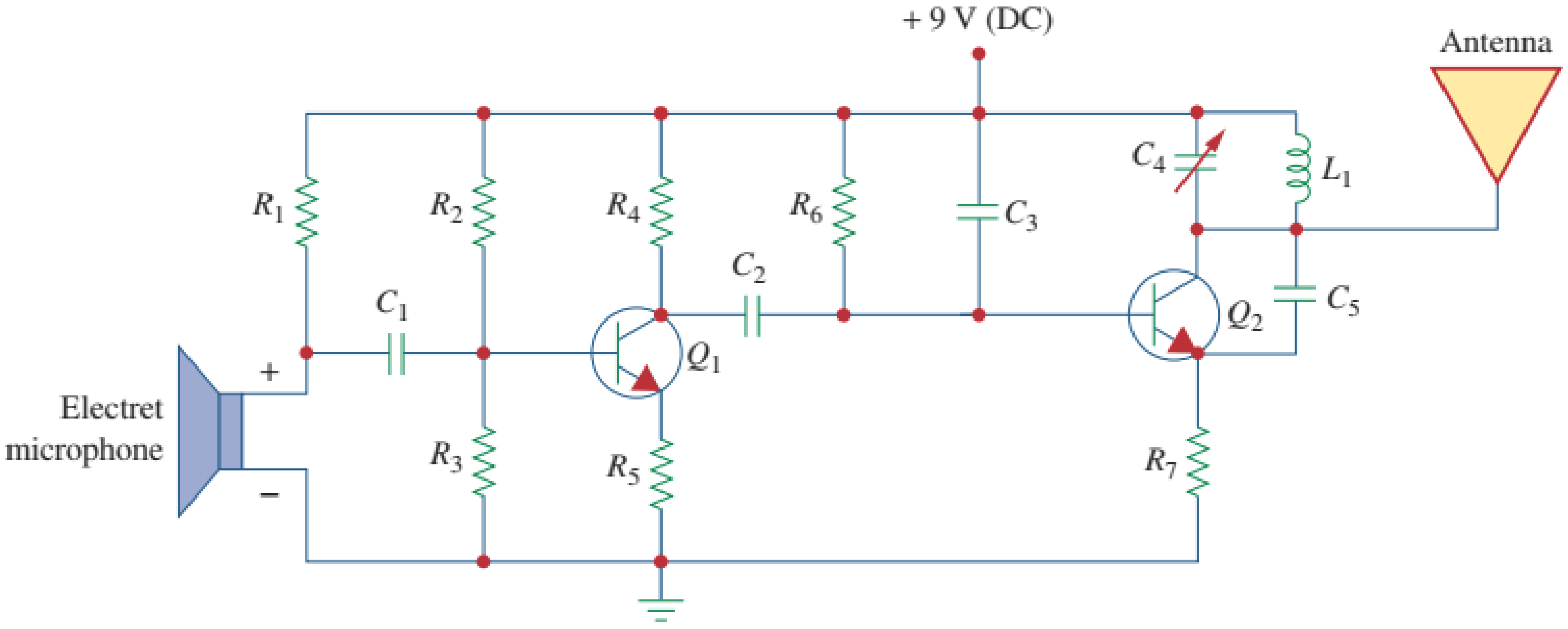
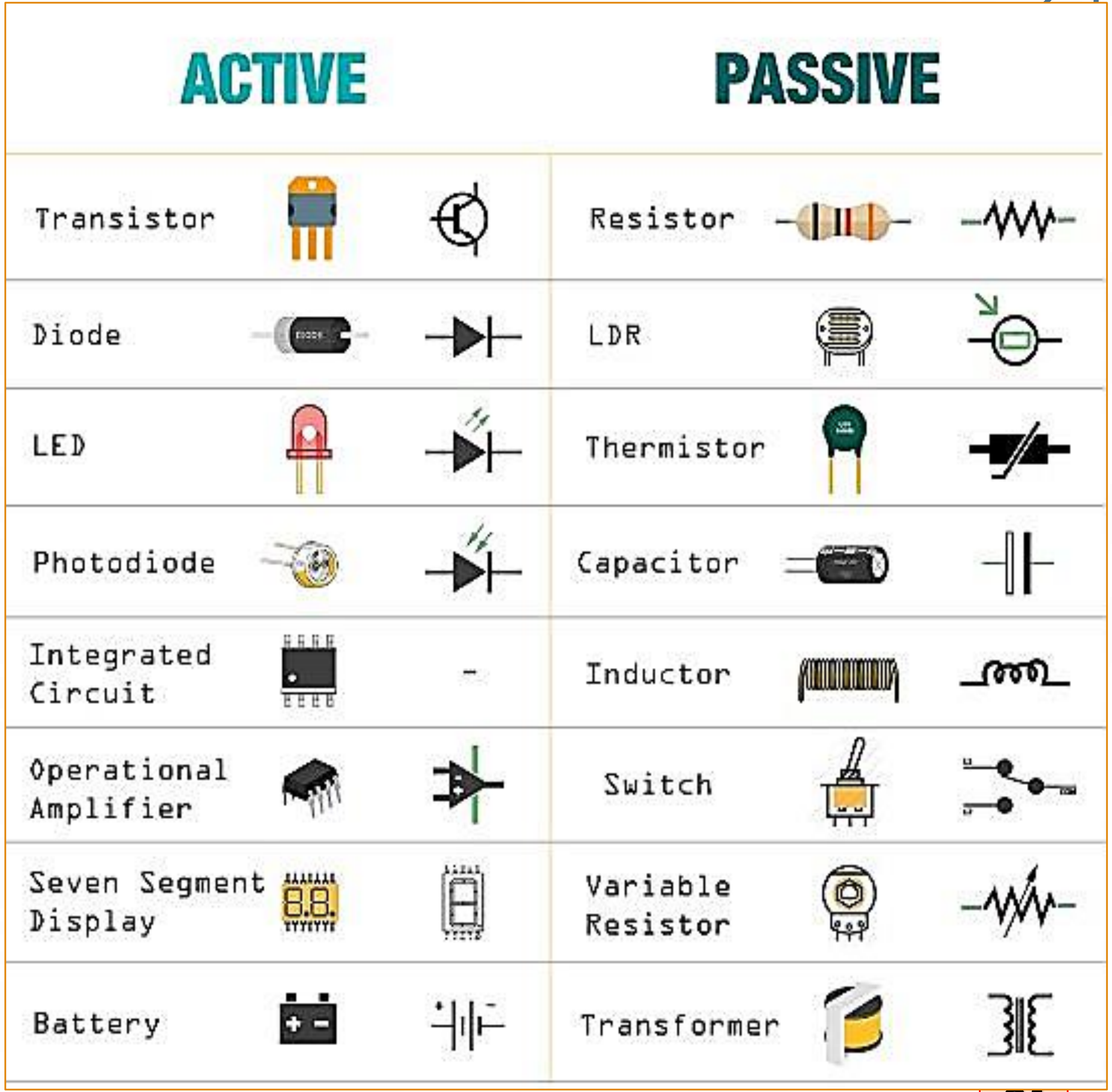


Figure 1.2
Electric circuit of a radio transmitter.

CIRCUIT ELEMENTS

- Active Elements: Generate, Supply and control energy.
- Passive Elements: Respond to the flow of electrical energy and can dissipates or store energy.



CIRCUIT ELEMENTS

- Active Elements: Generate, Supply and control energy.

The most important active elements are voltage or current sources that generally deliver power to the circuit connected to them. There are two kinds of sources: independent and dependent sources.

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

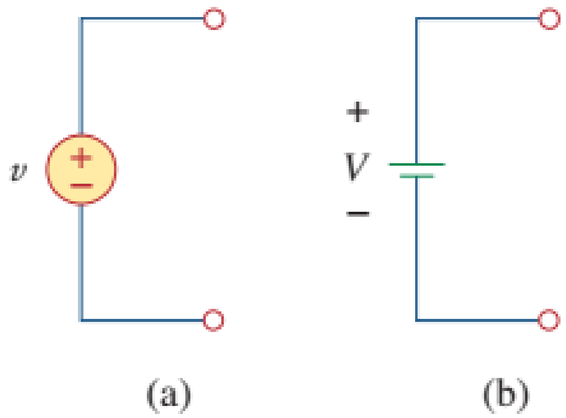


Figure 1.11
Symbols for independent voltage sources: (a) used for constant or time-varying voltage, (b) used for constant voltage (dc).

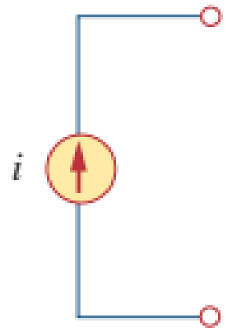


Figure 1.12
Symbol for independent current source.

THEORY: DC POWER SUPPLY

Figure 11: DC power supply module.

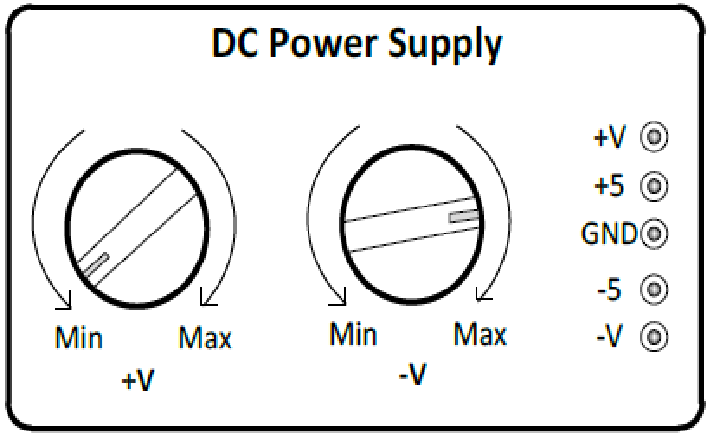


Figure 12: Trainer board dc source.

CIRCUIT ELEMENTS

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).

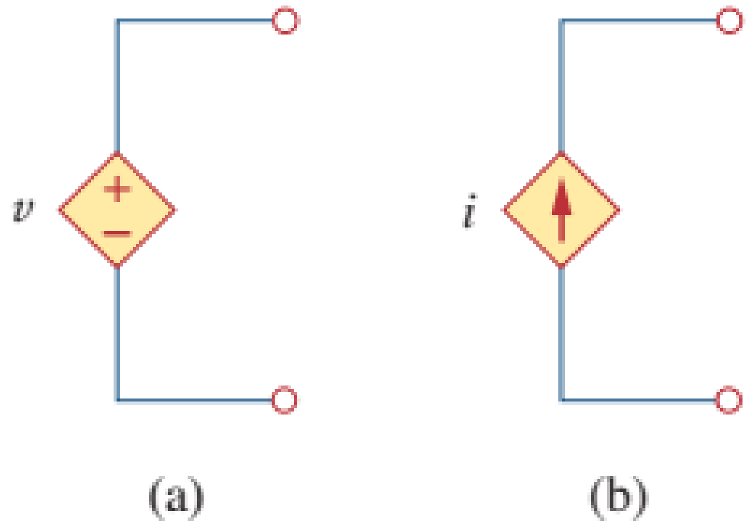


Figure 1.13
Symbols for: (a) dependent voltage source, (b) dependent current source.

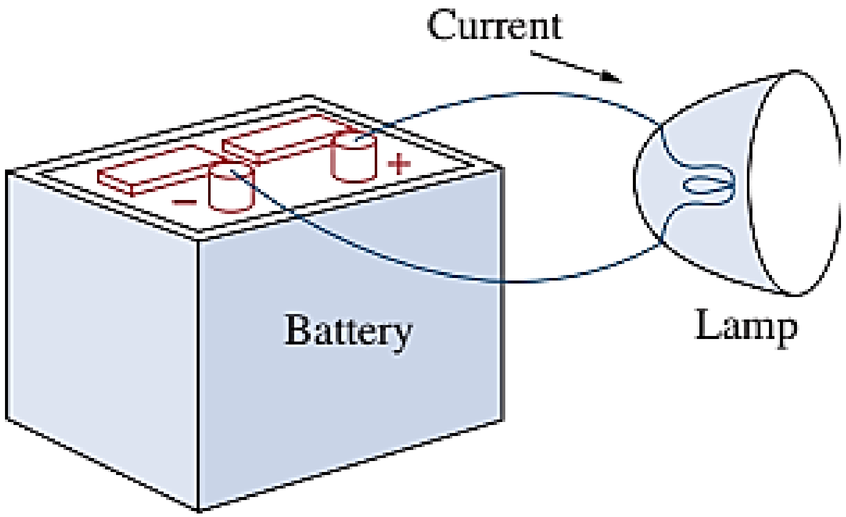
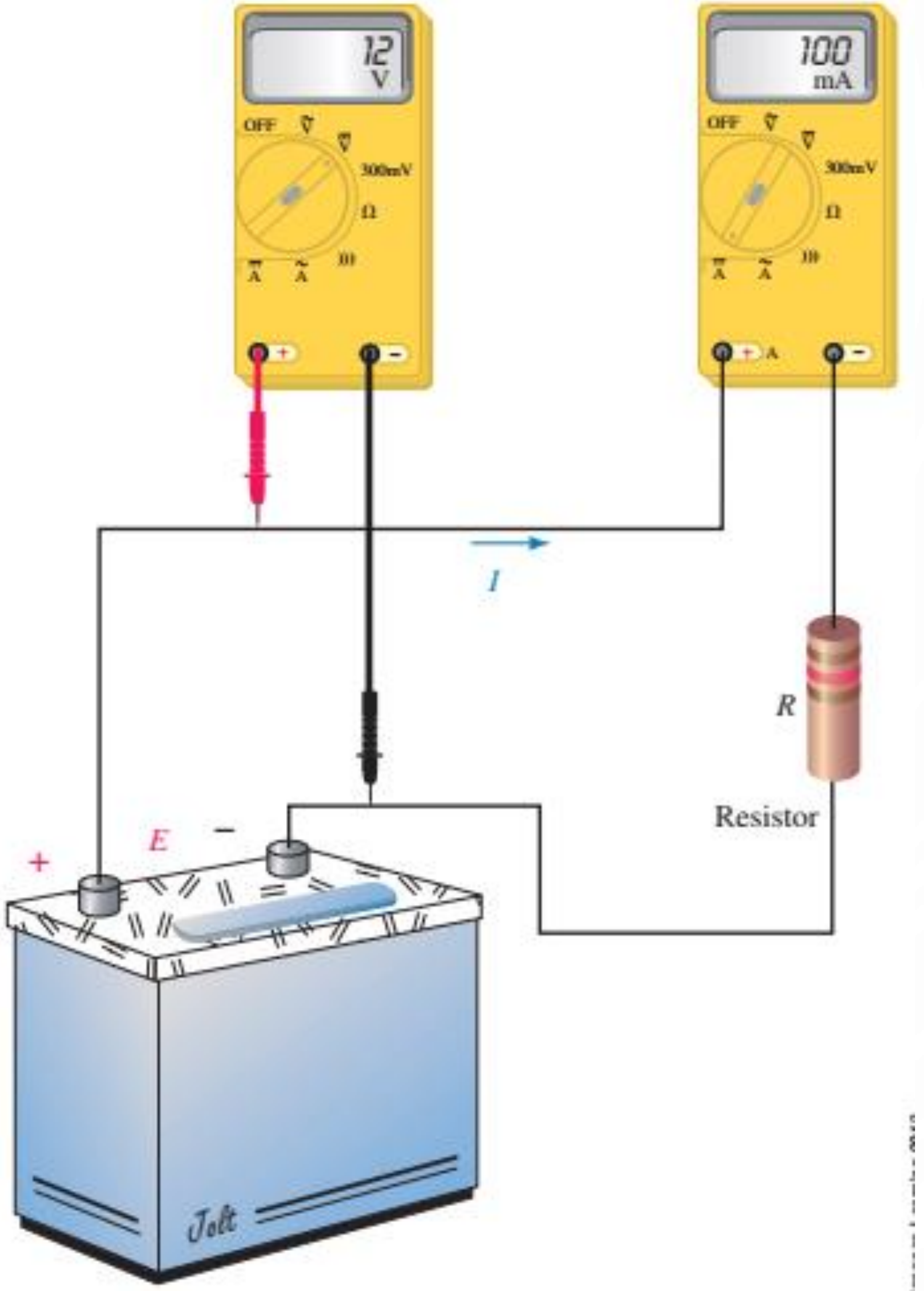
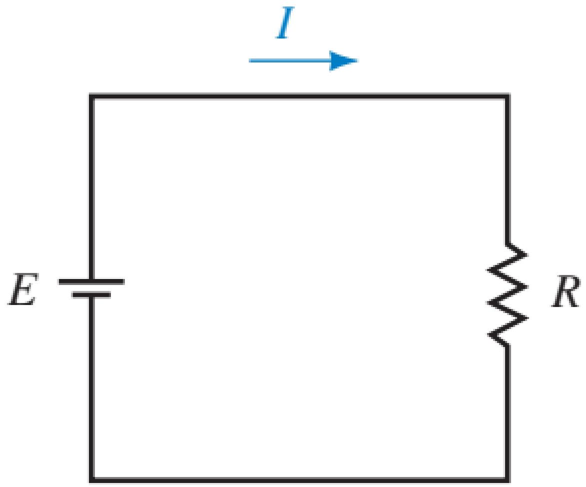


Figure 1.1
A simple electric circuit.





OHM'S LAW

"Current in a resistive circuit is directly proportional to its applied voltage and inversely proportional to its resistance."

$$I = \frac{E}{R} \quad \text{[amps, A]}$$

where

E is the applied voltage in volts,

R is the resistance in ohms,

I is the current in amperes.

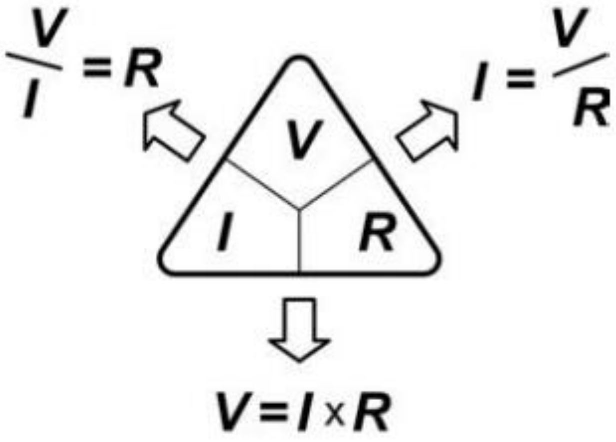


Figure 1.5 Triangle showing the relationship between V, I and R

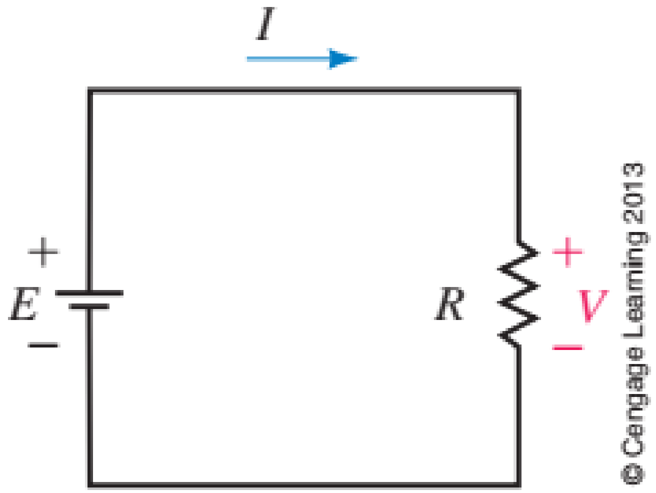
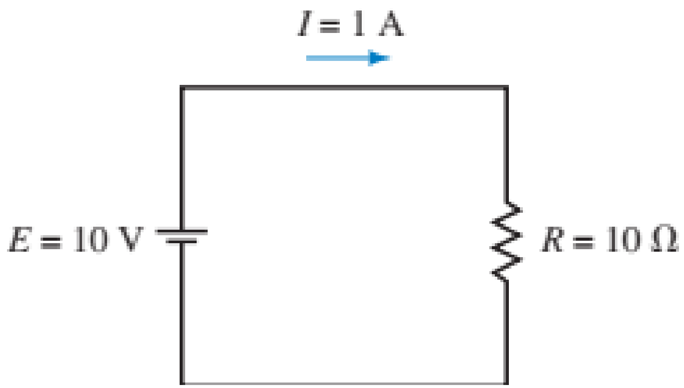


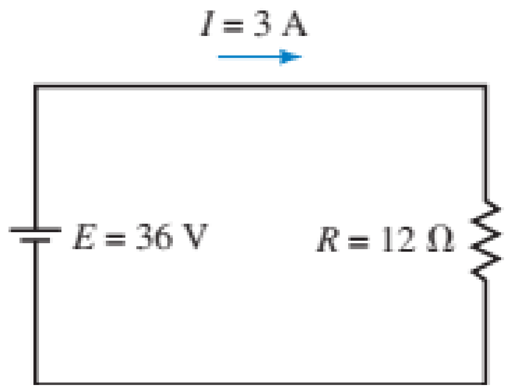
FIGURE 4–9 Symbols used to represent voltages. E is used for source voltages while V is used for voltage across circuit components such as resistors.

OHM'S LAW

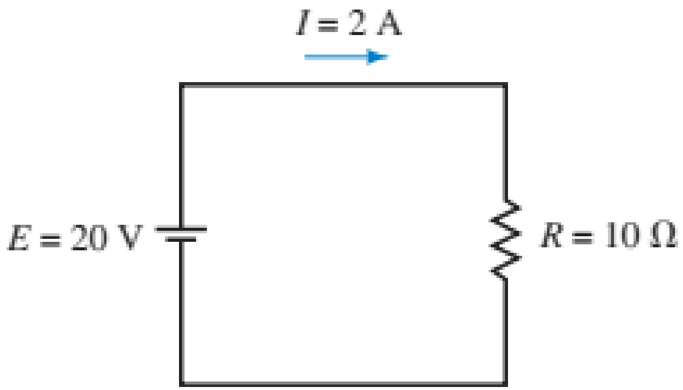
$$I = \frac{E}{R} \quad \text{[amps, A]}$$



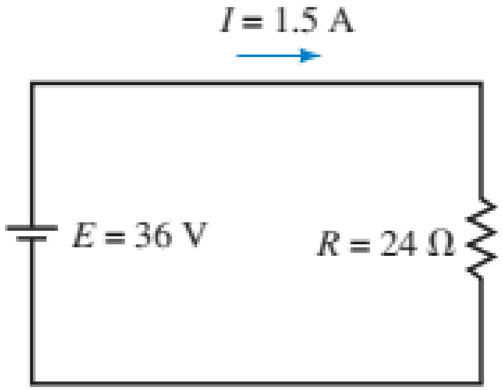
(a) $I = \frac{10\ \text{V}}{10\ \Omega} = 1\ \text{A}$



(a) $I = \frac{36\ \text{V}}{12\ \Omega} = 3\ \text{A}$



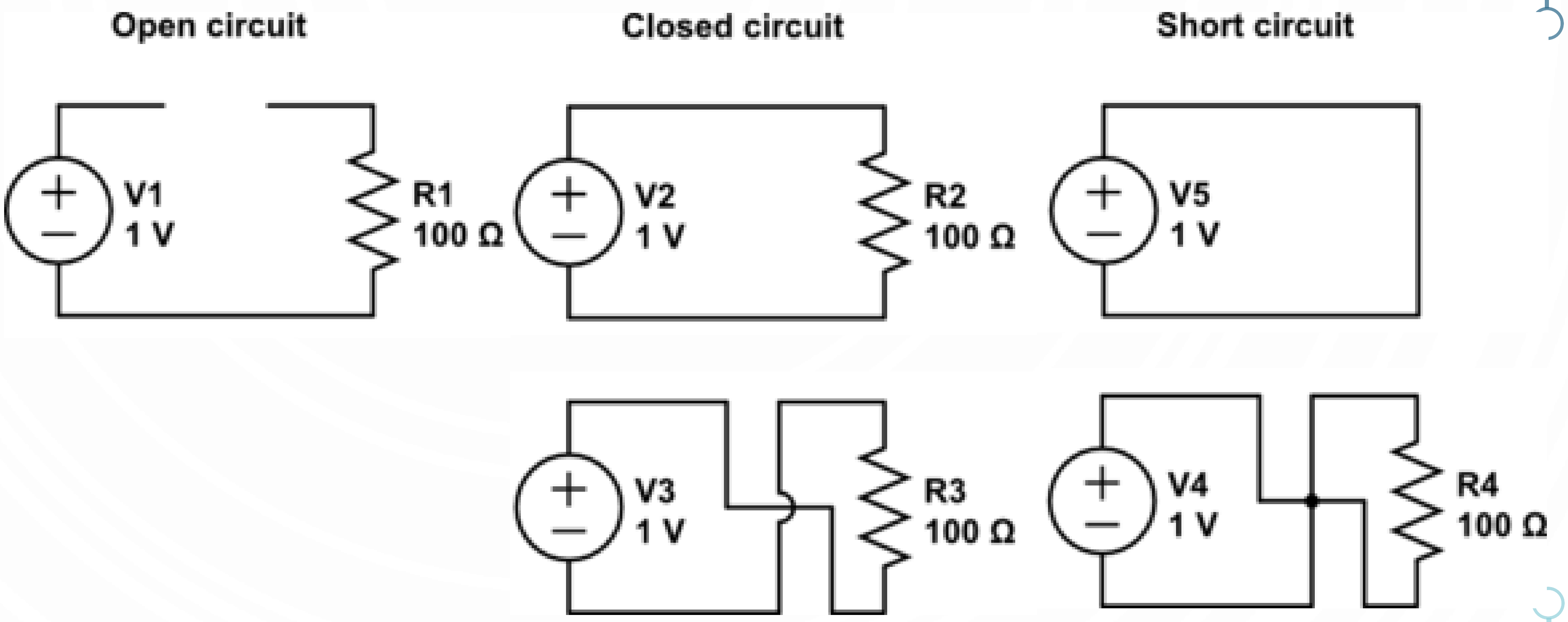
(b) $I = \frac{20\ \text{V}}{10\ \Omega} = 2\ \text{A}$



(b) $I = \frac{36\ \text{V}}{24\ \Omega} = 1.5\ \text{A}$

OHM'S LAW

$$I = \frac{E}{R} \quad \text{[amps, A]}$$



❖ Considering that a current of 100-200 mA through your heart will almost certainly kill you, how much voltage across your hands would be lethal?

POWER

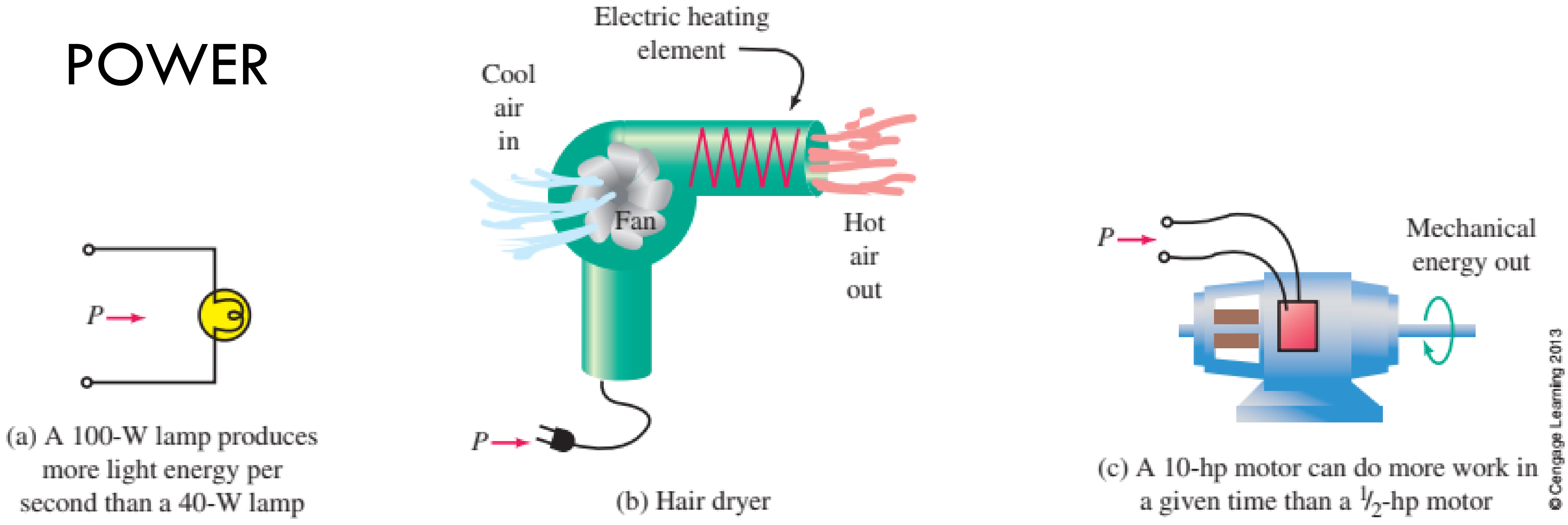


FIGURE 4–15 Energy conversion. Power *P* is a measure of the rate of energy conversion.

Figure 4–15 illustrates the idea.

- In (a), the greater the power rating of the light, the more light energy it can produce per second.
- In (b), the greater the power rating of the heater, the more heat energy it can produce per second.
- In (c), the larger the power rating of the motor, the more mechanical work it can do per second.

POWER

As you can see, power is related to energy, which is the capacity to do work. Formally, **power** is defined as the rate of doing work or, equivalently, as the rate of transfer of energy. The symbol for power is P. By definition,

$$P = \frac{W}{t} \quad \text{[watts, W]} \qquad \textbf{(4–7)}$$

where W is the work (or energy) in joules and t is the corresponding time interval of t seconds (see Notes).

The SI unit of power is the watt. From Equation 4–7, we see that P also has units of joules per second. If you substitute $W = 1$ J and $t = 1$ s, you get $P = 1$ J/1 s $= 1$ W. From this, you can see that *one watt equals one joule per second*. Occasionally, you also need power in horsepower. To convert, recall that 1 hp $= 746$ watts.

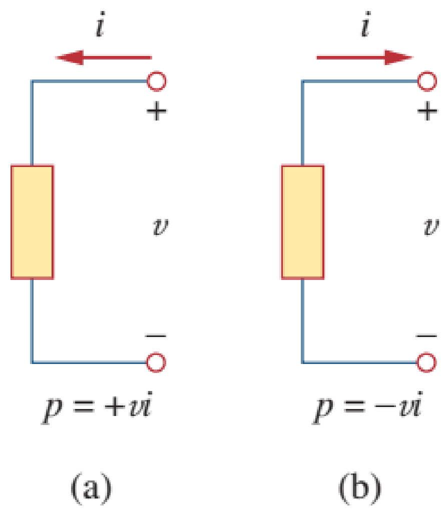


Figure 1.8
Reference polarities for power using the passive sign convention: (a) absorbing power, (b) supplying power.

$$P = VI \quad \text{[watts, W]}$$

for a source

$$P = EI \quad \text{[watts, W]}$$

$$P = I^2R \quad \text{[watts, W]}$$

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

$$I = V/R$$

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

$$+\text{Power absorbed} = -\text{Power supplied}$$

POWER: EXAMPLE (B-1)

Example 1.7 Calculate the power supplied or absorbed by each element in Fig. 1.15.

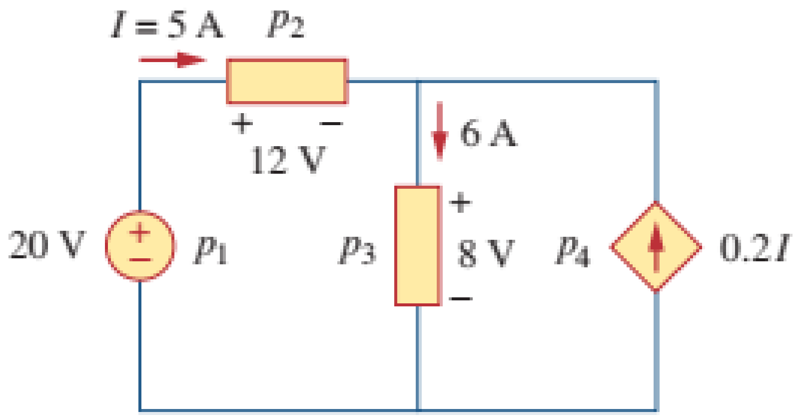


Figure 1.15
For Example 1.7.

$p_1 = 20(-5) = -100$ W Supplied power

$p_2 = 12(5) = 60$ W Absorbed power

$p_3 = 8(6) = 48$ W Absorbed power

$p_4 = 8(-0.2I) = 8(-0.2 \times 5) = -8$ W Supplied power

$$p_1 + p_2 + p_3 + p_4 = -100 + 60 + 48 - 8 = 0$$

ENERGY

For power, which is the rate of doing work, to produce an energy conversion of any form, it must be *used over a period of time*. For example, a motor may have the horsepower to run a heavy load, but unless the motor is *used* over a period of time, there will be no energy conversion. In addition, the longer the motor is used to drive the load, the greater will be the energy expended.

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

$$\boxed{W = Pt} \qquad \text{(wattseconds, Ws, or joules)} \qquad \textbf{(4.21)}$$

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

The electric power utility companies measure energy in watt-hours (Wh), where

$$1 \text{ Wh} = 3{,}600 \text{ J}$$

ENERGY: EXAMPLE (B-2)

EXAMPLE 4.19 What is the total cost of using all of the following at 9¢ per kilowatthour?

A 1200-W toaster for 30 min
Six 50-W bulbs for 4 h
A 400-W washing machine for 45 min
A 4800-W electric clothes dryer for 20 min

TABLE 4.1

Typical wattage ratings of some common household items.

Appliance	Wattage Rating	Appliance	Wattage Rating
Air conditioner	860	Lap-top computer:	
Blow dryer	1,300	Sleep	< 1 W (Typically 0.3 W to 0.5 W)
Cassette player/recorder	5	Normal	10–20 W
Cellular phone:		High	25–35 W
Standby	≅ 35 mW	Microwave oven	1,200
Talk	≅ 4.3 W	Pager	1–2 mW
Clock	2	Phonograph	75
Clothes dryer (electric)	4,800	Projector	1,200
Coffee maker	900	Radio	70
Dishwasher	1,200	Range (self-cleaning)	12,200
Fan:		Refrigerator (automatic defrost)	1,800
Portable	90	Shaver	15
Window	200	Stereo equipment	110
Heater	1,322	Sun lamp	280
Heating equipment:		Toaster	1,200
Furnace fan	320	Trash compactor	400
Oil-burner motor	230	TV (color)	200
Iron, dry or steam	1,100	Videocassette recorder	110
		Washing machine	500
		Water heater	4,500

Courtesy of General Electric Co.

Assignment 1: List all the appliances (load) of your home with wattage rating in the table below and calculate the total kWh energy consumption and the cost for the month of December 2020.

Sl.	Appliance	No. of Appliance	Wattage Rating (W)	Hours used/day (h)	kWh consumed/day

Homework

1.28 A 60-W incandescent lamp is connected to a 120-V source and is left burning continuously in an otherwise dark staircase. Determine:

(a) the current through the lamp.

(b) the cost of operating the light for one non-leap year if electricity costs 9.5 cents per kWh.

1.29 An electric stove with four burners and an oven is used in preparing a meal as follows.

Burner 1: 20 minutes	Burner 2: 40 minutes
Burner 3: 15 minutes	Burner 4: 45 minutes
Oven: 30 minutes	

If each burner is rated at 1.2 kW and the oven at 1.8 kW, and electricity costs 12 cents per kWh, calculate the cost of electricity used in preparing the meal.

1.36 A battery may be rated in ampere-hours (Ah). A lead-acid battery is rated at 160 Ah.

(a) What is the maximum current it can supply for 40 h?

(b) How many days will it last if it is discharged at 1 mA?

1.37 A 12-V battery requires a total charge of 40 ampere-hours during recharging. How many joules are supplied to the battery?

1.38 How much energy does a 10-hp motor deliver in 30 minutes? Assume that 1 horsepower = 746 W.

1.39 A 600-W TV receiver is turned on for 4 h with nobody watching it. If electricity costs 10 cents/kWh, how much money is wasted?

END LESSON 1……………………..
NEXT TOPIC: LAWS OF CIRCUIT ANALYSIS (LESSON 2)
TEXT: B-1