BASIC ELECTRICITY AND ELECTRONICS

kiot

Mceng 2262

Chapter 1

Basic Electrical Theory

In this chapter we will discuss about

- Atom and Its Forces,
- Electrical Terminology,
- Units of Electrical Measurement,
- Methods of Producing Voltage,
- Electrical Symbols,
- Conductors,
- Insulators and Semiconductors

objectives

- After completing this chapter ,the students should be able to :
  - Define matter,element,and molecule.
  - List the parts of the atom.
  - Define the valance shell of an atom.
  - Identify the units for measuring current
  - Draw the symbol used to represent current flow in the circuit
  - Describe the difference between conductors and insulators and semi conductor

cont'd

- Define the difference of potential electromotive force and voltage
- Draw the symbol used to represent voltage.
- Identify the unit used to measure voltage.
- Define resistance.
- Identify the characteristics of resistance in a circuit.
- Identify the units of measuring resistance.
- Draw the symbol used to represent resistance in a circuit.

The structure of matter

- In the understanding of fundamentals of electricity, the knowledge of the structure of matter plays an important role.
- The Matter: which occupies space(may be solid,liquid,or gaseous)
- It has weight .

Cont'd

- All forms of matters are composed of molecules

Fundamental particles of matter	Symbol	Nature of charge possessed	Mass in kg.
Neutron	n	0	1.675×10^{-27}
Proton	p+	+	1.675×10^{-27}
Electron	e^-	–	9.107×10^{-31}

Table 1.1

Cont'd

- Elements
  - Basic building block of nature.
  - Cannot be reduced to a simpler substance by chemical means.

The Atom

- Elements are the basic building blocks of all matter. The atom is the smallest particle to which an element can be reduced while still keeping the properties of that element.
- An atom consists of a positively charged nucleus surrounded by negatively charged electrons, so that the atom as a whole is electrically neutral. The nucleus is composed of two kinds of subatomic particles, protons and neutrons,
- The proton carries a single unit positive charge equal in magnitude to the electron charge.

- The neutron is slightly heavier than the proton and is electrically neutral, as the name implies. These two particles exist in various combinations, depending upon the element involved.
- The electron is the fundamental negative charge (-) of electricity and revolves around the nucleus, or center, of the atom in concentric orbits, or shells.

Structure of an Atom

- All of the protons and neutrons bound together in to a compact nucleus.
- Parts of an atom

-nucleus

- ✓ located at the center of an atom

-proton

- ✓ Positively charged particles in side the nucleus

-neutrons

- ✓ Uncharged particle in side nucleus

-Electrons

- ✓ Negatively charged particles that orbit the nucleus

Cont'd

- In the normal atom the number of protons and electrons are equal. This type of atom is termed as electrically neutral .
- The electrons are arranged in different orbits.
- The nucleus exerts the force of attraction on the revolving electron and hold them together
- All these different orbits are called shells and posses s a certain energy
- These are called energy shell or quanta

Cont'd

Key point:

- The electron or the electrons revolving in the farthest orbit are loosely held to the nucleus.
- Such a shell is called the valance shell. And such electron are called valance electron
- In some atoms such valance electrons are loosely bound to the nucleus at room temperature when additional energy is imparted to the valance electrons cause them to escape from the shell and exists as free electrons.
- Such free electrons are basically responsible for the flow of electric current through metals.

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Note :

- More the number of free electrons ,better is the metal for the conduction of current.
- For example, copper has 8.5×10^{28} free electrons per cubic meter and hence it is good conductor of electricity

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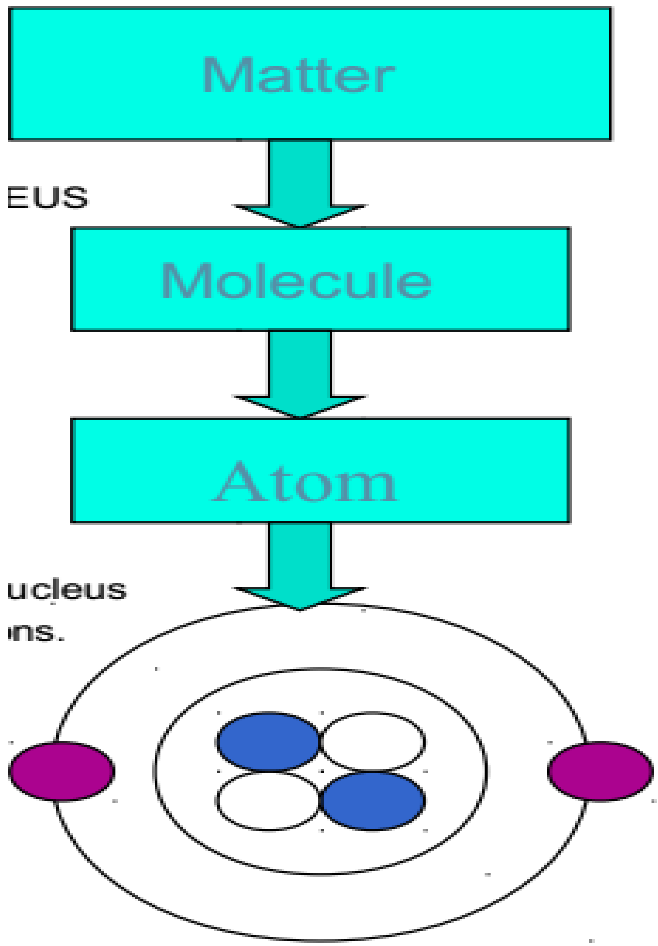
- This is the process tha how electricity is processed in a given circuit.



Atoms and its force

#Electro static force:

- In an atom , the electron and the nucleus attract each other. This attraction is called *electrostatic force*, the force that holds the electron in orbit**.**

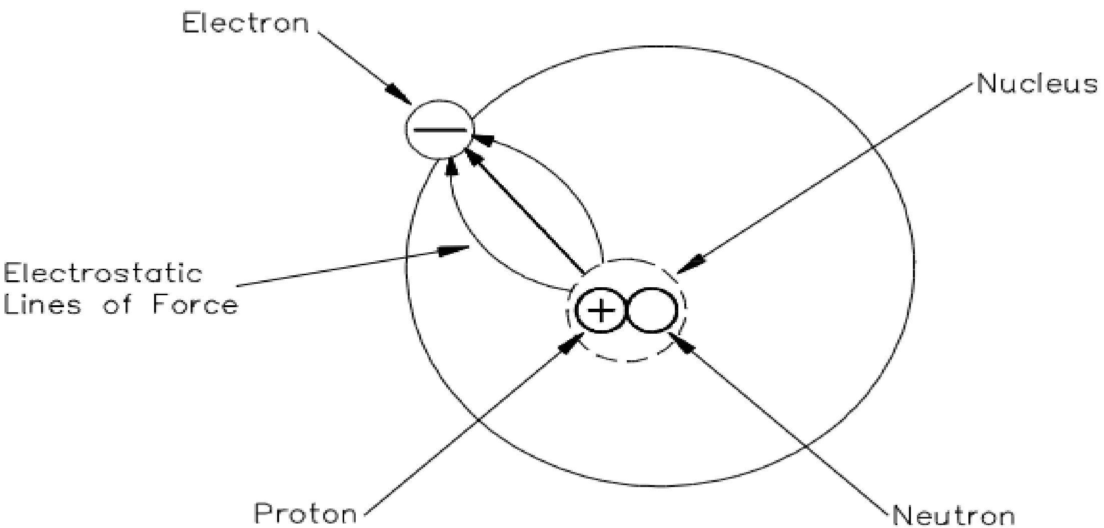


figure : electrostatic force

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- Without this electrostatic force, the electron, which is traveling at high speed, could not stay in its orbit. Bodies that attract each other in this way are called charged bodies.

The First Law of Electrostatics

- The negative charge of the electron is equal, but opposite to, the positive charge of the proton. These charges are referred to as electrostatic charges.

Cont'd

- In nature, unlike charges (like electrons and protons) attract each other, and like charges repel each other. These facts are known as the *First Law of Electrostatics* and are sometimes referred to as the law of electrical charges.
- This law should be remembered because it is one of the vital concepts in electricity.
- Some atoms can lose electrons and others can gain electrons; thus, it is possible to transfer electrons from one object to another.

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- These objects, which can contain billions of atoms, will then follow the same law of electrostatics as the electron and proton.
- The electrons that can move around within an object are said to be free electrons.
- The greater the number of these free electrons an object contains, the greater its negative electric charge.
- Thus, the electric charge can be used as a measure of electrons.

What is electricity?

- We will discuss here the basic introduction of electricity.
- Each substance in this universe is made of plenty of atoms and each atom has the same number of negative electrons and positive protons.
- As a result, we can say that each neutral substance has the same number of electrons and protons in it.
- The protons are immovable and strongly attached to the nucleus of the atoms. Electrons are also bounded to atoms and orbiting around the nucleus in different distinct levels.
- But some of the electrons can move freely or can come out from their orbit due to external influences.
- These free and as well as loosely bonded electrons cause electricity.

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- Electricity is defined as "the flow of electrons through simple materials and devices" or "that force which moves electrons." Scientists think electricity is produced by very tiny particles called electrons and protons.
- These particles are too small to be seen, but exist as subatomic particles in the atom.

Methods of producing voltage

- To produce voltage we can use one of the following methods .These are
- *Electrochemistry*
- *Static (friction)*
- *Induction (magnetism)*
- *Piezoelectric (pressure)*
- *Thermal (heat)*
- *Light*
- *Thermionic emission*

1, Electro chemistry

- Chemicals can be combined with certain metals to cause a chemical reaction that will transfer electrons to produce electrical energy. This process works on the *electrochemistry* principle.
- One example of this principle is the voltaic chemical cell Chemicals can be combined with certain metals to cause a chemical reaction that will transfer electrons to produce electrical energy. This process works on the *electrochemistry* principle. One example of this principle is the voltaic chemical cell, shown in Figure .

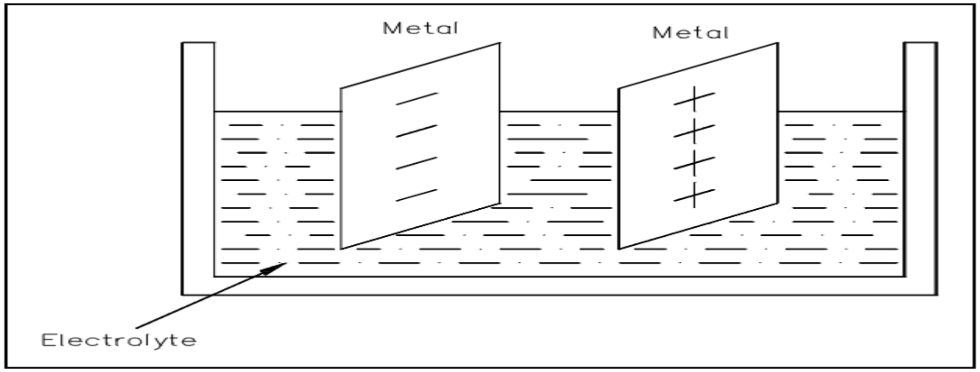

Figure : voltaic chemical cell

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- A chemical reaction produces and maintains opposite charges on two dissimilar metals that serve as the positive and negative terminals. The metals are in contact with an electrolyte solution.
- Connecting together more than one of these cells will produce a battery.
- A chemical reaction produces and maintains opposite charges on two dissimilar metals that serve as the positive and negative terminals.
- The metals are in contact with an electrolyte solution. Connecting together more than one of these cells will produce battery.
- A battery can maintain a potential difference between its positive and negative terminals by chemical action

2. Static electricity

- Atoms with the proper number of electrons in orbit around them are in a neutral state, or have a "zero charge."
- A body of matter consisting of these atoms will neither attract nor repel other matter that is in its vicinity. If electrons are removed from the atoms in this body of matter, as happens due to friction when one rubs a glass rod with a silk cloth, it will become electrically positive as shown in Figure 12.

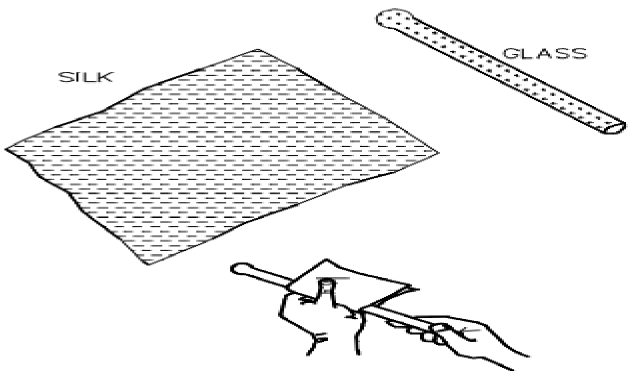

figure : static electricity

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- If this body of matter (e.g., glass rod) comes near, but not in contact with, another body having a normal charge, an electric force is exerted between them because of their unequal charges.
- The existence of this force is referred to as *static electricity* or *electrostatic force*.
- Example :
- Have you ever walked across a carpet and received a shock when you touched a metal door knob? Your shoe soles built up a charge by rubbing on the carpet, and this charge was transferred to your body. Your body became positively charged and, when you touched the zero-charged door knob, electrons were transferred to your body until both you and the door knob had equal charges.

3.Magnetic induction

- A generator is a machine that converts mechanical energy into electrical energy by using the principle of *magnetic induction*.
- Magnetic induction is used to produce a voltage by rotating coils of wire through a stationary magnetic field, as shown in Figure, or by rotating a magnetic field through stationary coils of wire.

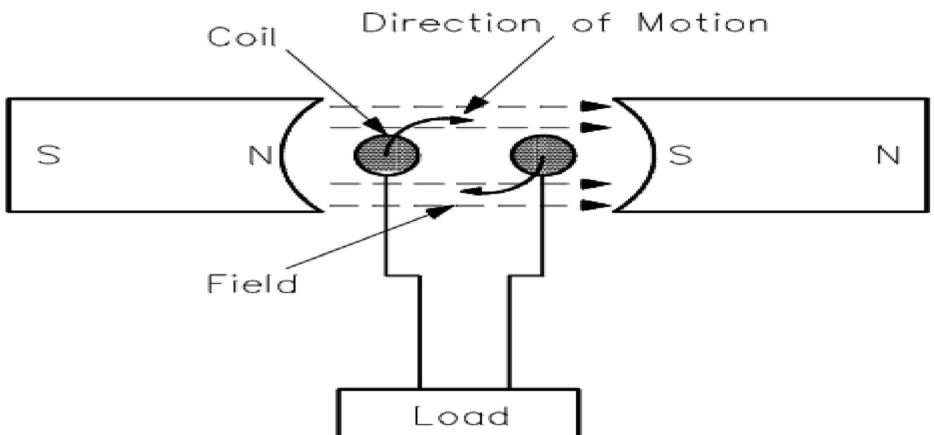

Figure : generator – electric magnetic induction

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- This is one of the most useful and widely employed applications of producing vast quantities of electric power. Magnetic induction will be studied in more detail in the next two chapters "Magnetism," and "Magnetic Circuits."

4. Piezo electric effect

- By applying pressure to certain crystals (such as quartz or Rochelle salts) or certain ceramics (like barium titanate), electrons can be driven out of orbit in the direction of the force.
- Electrons leave one side of the material and accumulate on the other side, building up positive and negative charges on opposite sides, as shown in Figure.

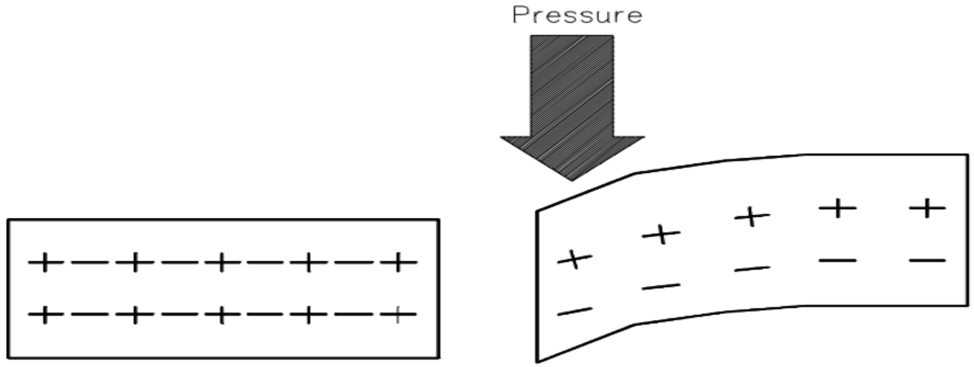

Figure : pressure applied to a certain crystals produces an electric charge

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- When the pressure is released, the electrons return to their orbits. Some materials will react to bending pressure, while others will respond to twisting pressure.
- This generation of voltage is known as the *piezoelectric effect*.
- If external wires are connected while pressure and voltage are present, electrons will flow and current will be produced.
- If the pressure is held constant, the current will flow until the potential difference is equalized.

Cont'd

- When the force is removed, the material is decompressed and immediately causes an electric force in the opposite direction.
- The power capacity of these materials is extremely small. However, these materials are very useful because of their extreme sensitivity to changes of mechanical force.

Conductors, Insulators, and Semiconductors

- The atomic structure of matter affects how easily charges, i.e., electrons, move through a substance and hence how it is used electrically.
- Electrically, materials are classified as conductors, insulators, or semiconductors.

Conductors

Materials through which charges move easily are termed **conductors.**

- The most familiar examples are metals. Good metal conductors have large numbers of free electrons that are able to move about easily.
- In particular, silver, copper, gold, and aluminum are excellent conductors. Of these, copper is the most widely used. Not only is it an excellent conductor, it is inexpensive and easily formed into wire, making it suitable for a broad spectrum of applications ranging from common house wiring to sophisticated electronic equipment.
- Aluminum, although it is only about 60% as good a conductor as copper, is also used, mainly in applications where light weight is important, such as in overhead power transmission lines. Silver and gold are too expensive for general use.

Cont'd

- However, gold, because it oxidizes less than other materials, is used in specialized applications; for example, some critical electrical connectors use it because it makes a more reliable connection than other materials.

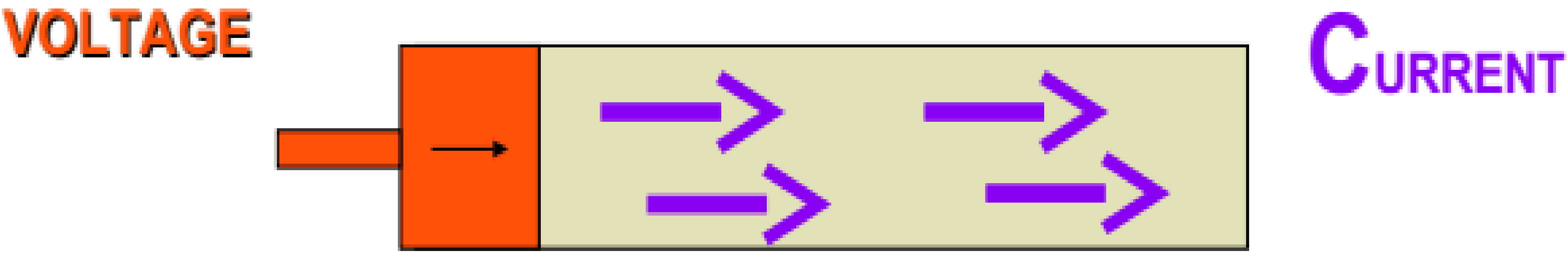
Insulators

- Materials that do not conduct (e.g., glass, porcelain, plastic, rubber, and so on) are termed **insulators.**
- The covering on electric lamp cords, for example, is an insulator. It is used to prevent the wires from touching and to protect us from electric shock.
- Insulators do not conduct because they have full or nearly full valence shells and thus their electrons are tightly bound.
- However, when high enough voltage is applied, the force is so great that electrons are literally torn from their parent atoms, causing the insulation to break down and conduction to occur.
- In air, you see this as an arc or flashover. In solids, charred insulation usually results.

semiconductors

- Silicon and germanium (plus a few other materials) have half-filled valence shells and are thus neither good conductors nor good insulators.
- They have unique electrical properties that make them important to the electronics industry.
- The most important material is silicon.
- It is used to make transistors, diodes, integrated circuits, and other electronic devices. Semiconductors have made possible personal computers, VCRs, portable CD players, calculators, and a host of other electronic products.

Fundamentals of electrical circuits



VOLTAGE = ELECTRICAL PRESSURE

- Voltage provides the electrical pressure or force that enables the current or electrons to flow.
- Voltage is the difference in electrical pressure between two points in a circuit .
- Voltage is measured in units called volts . The symbol for Voltage is E and the symbol for volt is V

The concept of charge

- In all atoms, there exists number of which are very loosely bound to its nucleus, such electrons are free to wonder about, through the space under the influence of specific forces.
- When such electrons are removed from, it become positively charged(i.e. losing negatively charged particles).
- When electrons are added to the atom it becomes negatively charged.

 # note : Thus total deficiency or addition of excess electrons in an atom is called its charge and the element is said to be charged.

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- The following table shows the different particles and charge possessed by them.

Particle	Charge possessed in Coulomb	Nature
Neutron	0	Neutral
Proton	1.602×10^{-19}	Positive
Electron	1.602×10^{-19}	Negative

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

Electric Charge (Q)

- Characteristic of subatomic particles that determines their electromagnetic interactions
- The unit of the measurement of the charge is **coulomb**
- **The charge on one electron is** -$1.602 \cdot 10^{-19}$, so one coulomb is defined as the charge possessed by the total number of

$(1/\ 1.602\times10^{-19})$ electrons i.e. 6.24×10^{18} number of electrons

- An electron has a -$1.602 \cdot 10^{-19}$ Coulomb charge
- N.B : if an element has a positive charge of one coulomb , then that element has a deficiency of -$6.24 \cdot 10^{18}$ number of electrons.

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Thu

$$1 \text{ coulomb} = \text{charge on } 6.24\times10^{18} \text{ electrons}$$

 # note:

- Thus, addition or removal of electrons causes the change in the nature of the charge possessed by the element.
- The rate of flow of charged particles is called current

The concept of electromotive force and current

- The movement of free electrons are responsible for the flow of electric current.

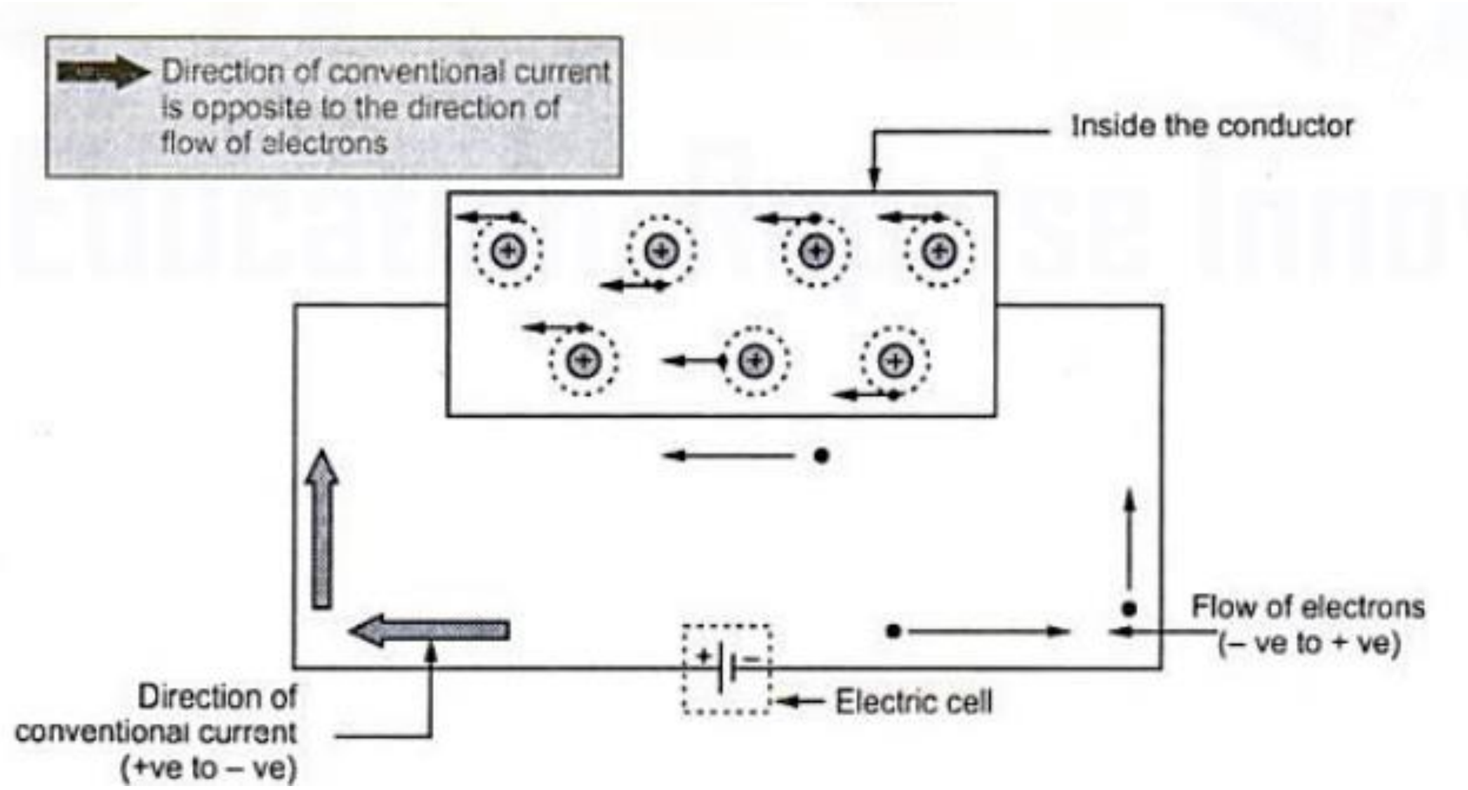

Figure : The flow of current

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- When the small effort , externally applied to such a conductor makes all such free electrons to drift along the metal in a definite particular direction.
- The applied electrical effect may be cells, batteries connected across the two ends of the conductor.

 # Note : 1 An electrical effect required to drift the free electrons in one particular direction, in a conductor is called Electro motive force.

 # Note : 2 The electric effect i.e. e.m.f. is maintained across the positive and negative electrodes of the cell, due to the chemical action in side the solution contained in the ell

Cont'd

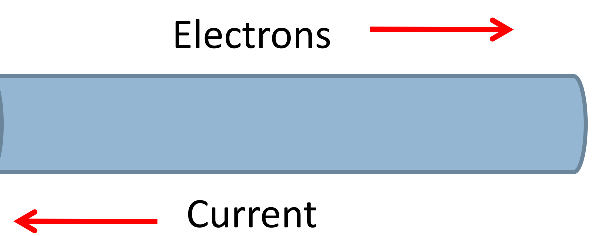
- This movement of electrons is called an **Electric current**.
- The movement of electrons is always from negative to positive while the movement of current is always assumed as from positive to negative . This is called **conventional current**.
- # Note : The direction of conventional current is form positive to negative terminal while the direction of flow of electrons is always from negative to positive terminal, through the external circuit across which the e.m.f. is applied.

Current (I)

- Current = (Number of electrons that pass in one second) · (charge/electron)
  - -1 ampere = (6.242·10^{18} e/sec) ·(-1.602 10^{-19}Coulomb/e)
  - Notice that an ampere = Coulomb/second

1 Ampere current = Flow of 6.24 × 10^{8} electrons per second

- The negative sign indicates that the current inside is actually flowing in the opposite direction of the electron flow



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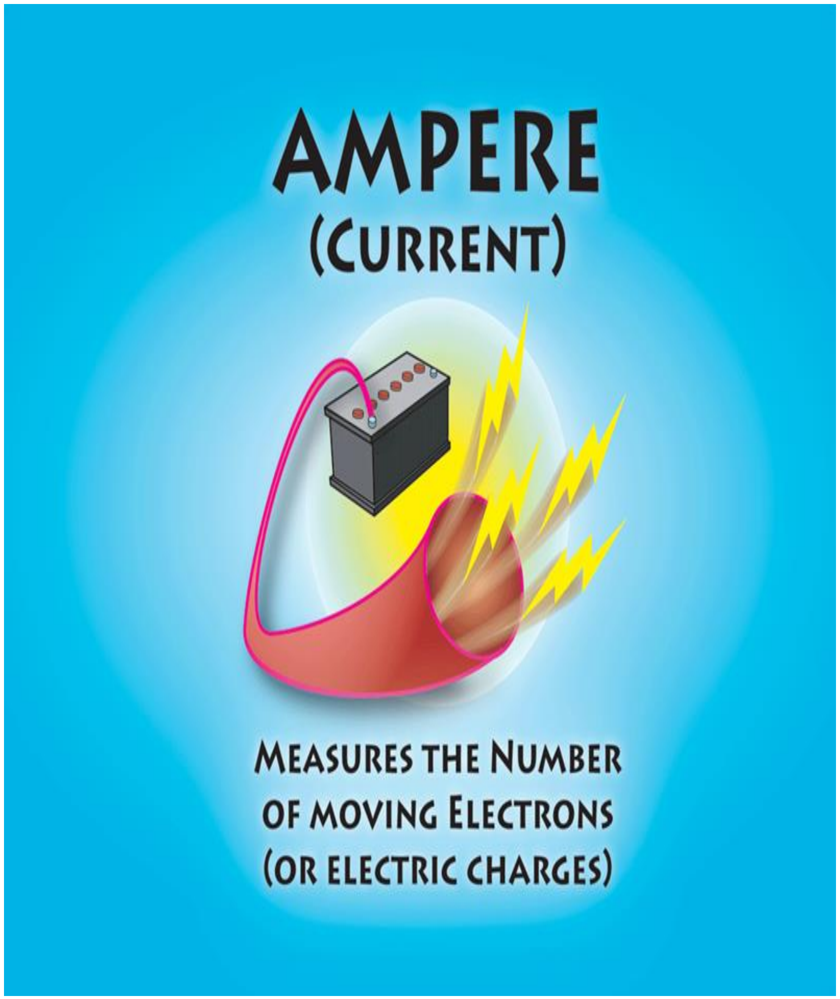


$$I = \frac{Q}{t} \text{ amperes}$$

Where

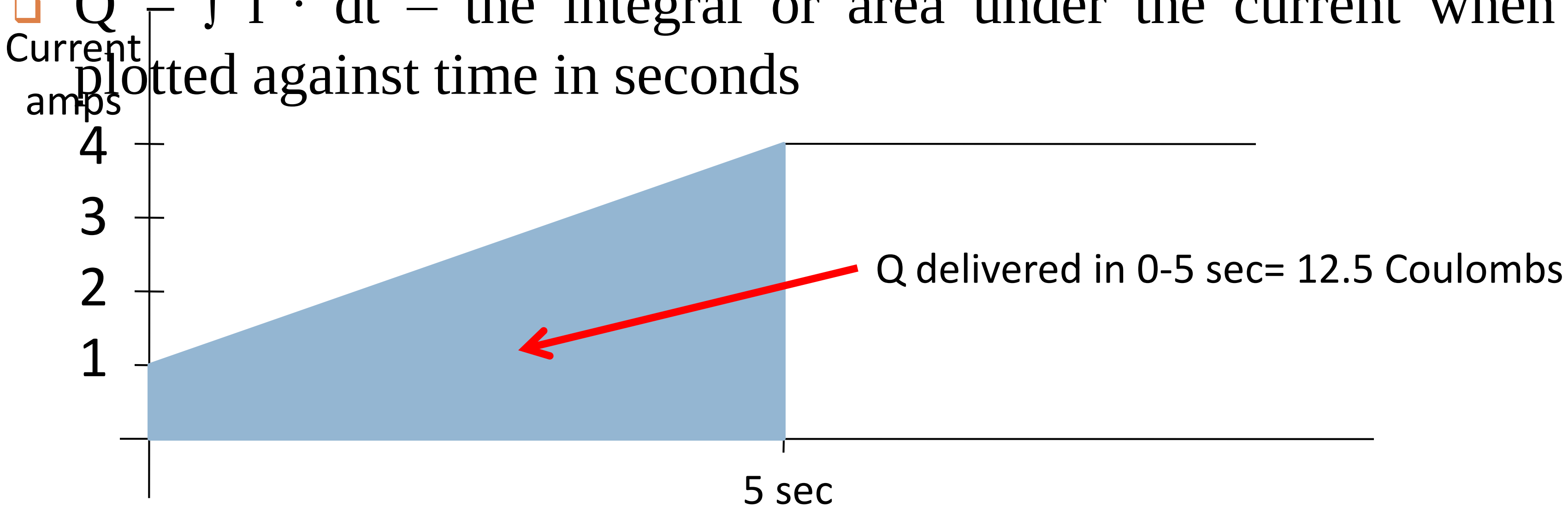
I = Average current flowing

Q = Total charge transferred

t = Time required for transfer of charge.

Current

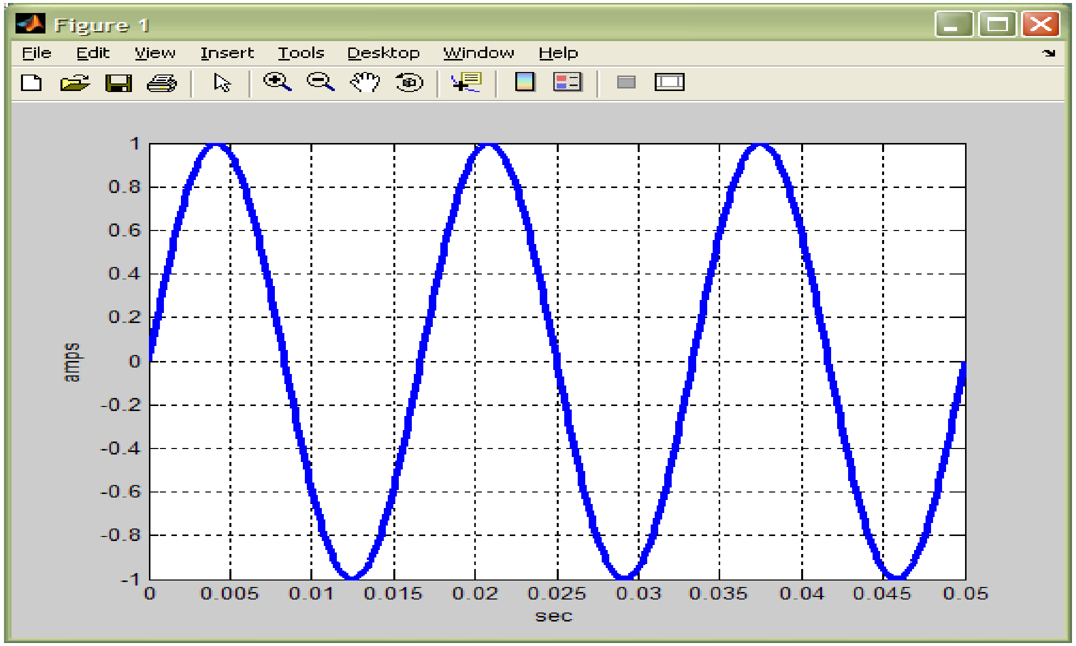
- So current can be defined as the rate of flow of charge in an electric circuit or in any medium in which charges are subjected to an external electric field.
- i = dq/dt – the derivitive or slope of the charge when plotted against time in seconds
- Q = ∫ i · dt – the integral or area under the current when plotted against time in seconds



AC and DC Current

•DC Current has a constant value

•AC Current has a value that changes sinusoidally



➢Notice that AC current changes in value and direction

➢No net charge is transferred

Why Does Current Flow?

- A voltage source provides the energy (or work) required to produce a current
  - Volts = joules/Coulomb = dW/dQ
- A source takes charged particles (usually electrons) and raises their potential so they flow out of one terminal into and through a transducer (light bulb or motor) on their way back to the source's other terminal

Voltage

- Voltage is a measure of the potential energy that causes a current to flow through a transducer in a circuit
- Voltage is always measured as a difference with respect to an arbitrary common point called ground
- Voltage is also known as electromotive force or EMF
- # The ability of a charged particle to the work(i.e. when charged particles are brought near, they try to repel each other while dissimilar charges attract each other) is called its ***electric potential.***
- The unit of electric potential is ***volt***

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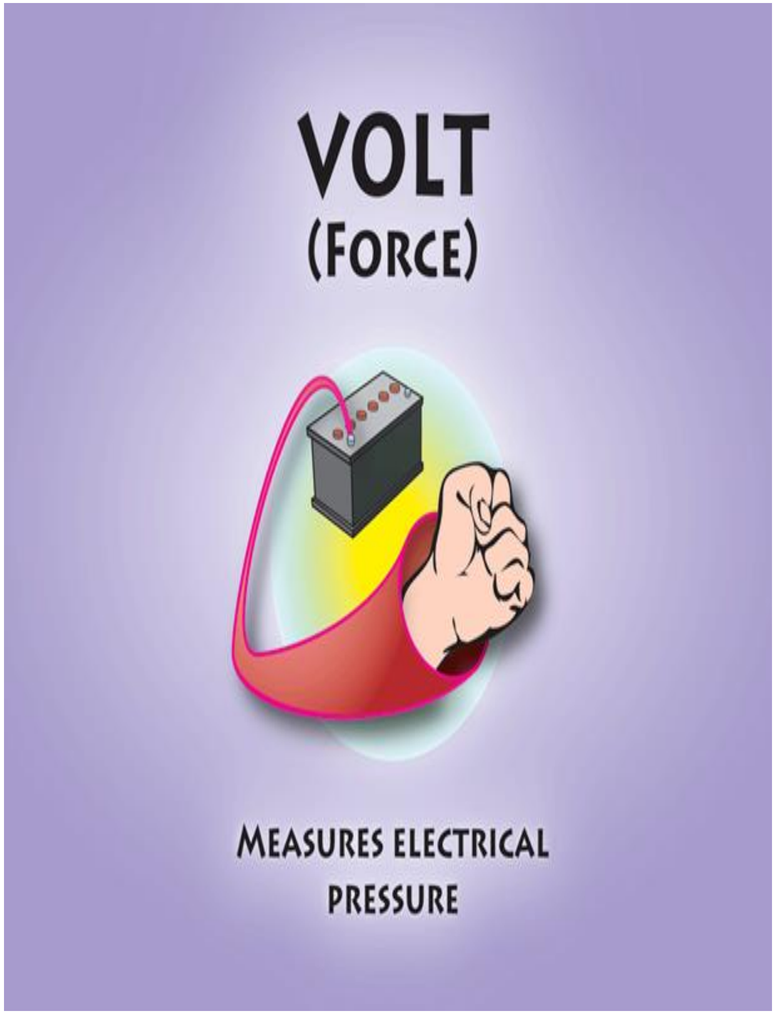
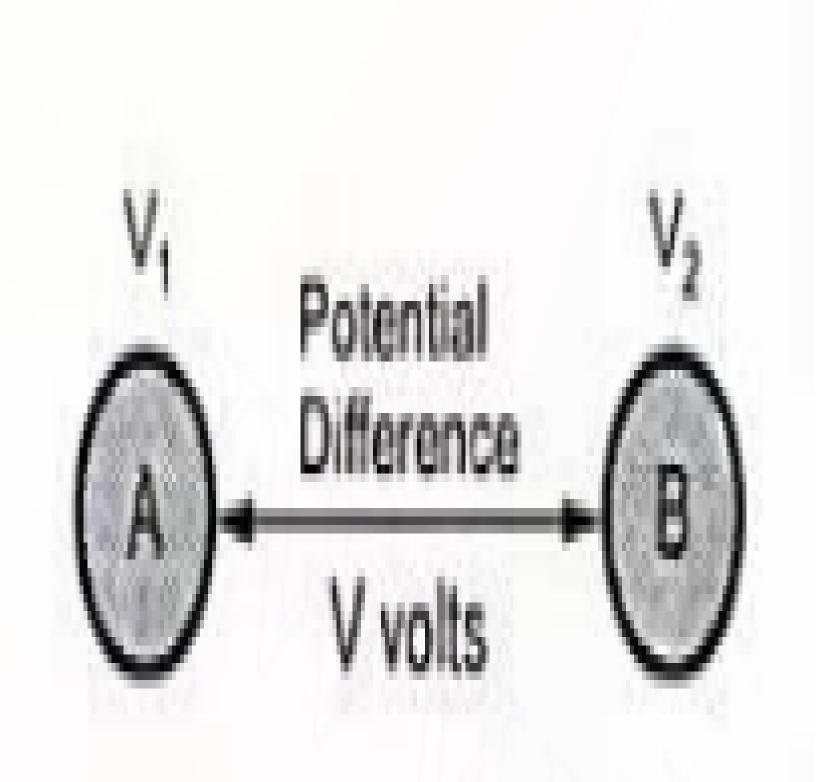

VOLT
(FORCE)
MEASURES ELECTRICAL
PRESSURE


V1
V2
Potential
Difference
A
B
V volts

Cont'd

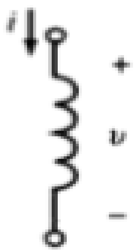
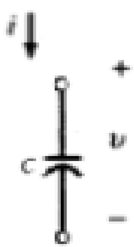
- The electric potential at a point due to a charge is one volt if one joule of work is done in bringing a unit positive charge i.e. positive charge of one coulomb from infinity to that point.

mathematically expressed as :

$$\text{Electrical Potential} = \frac{\text{Work done}}{\text{Charge}} = \frac{W}{Q}$$

- The difference between the electric potentials at any two given points in a circuit is known as potential difference(p.d.) . This is also called voltage between the two points and measured in VOLTS.
- The symbol for voltage is 'V'.

Voltage-Current Relations

Circuit element	Units	Voltage	Current	Power
 **Resistance**	ohms (Ω)	$v = Ri$ (Ohms's law)	$i = \frac{v}{R}$	$p = vi = i^2 R$
 **Inductance**	henries (H)	$v = L\frac{di}{dt}$	$i = \frac{1}{L}\int v\,dt + k_1$	$p = vi = Li\frac{di}{dt}$
 **Capacitance**	farads (F)	$v = \frac{1}{C}\int i\,dt + k_2$	$i = C\frac{dv}{dt}$	$p = vi = Cv\frac{dv}{dt}$

Resistance, Inductance and Capacitance

- All electrical devices that consume energy must have a resistor (also called a resistance) in their circuit model.
- Inductors and capacitors may store energy but over time return that energy to the source or to another circuit element.
- The circuit element that stores energy in a magnetic field is an inductor (also called an inductance).
- With time-variable current, the energy is generally stored during some parts of the cycle and then returned to the source during others.
- When the inductance is removed from the source, the magnetic field will collapse; in other words, no energy is stored without a connected source.
- Coils found in electric motors, transformers, and similar devices can be expected to have inductances in their circuit models.
- Energy stored in the magnetic field of an inductance is wL=1/2Li2.

Cont'd

- The circuit element that stores energy in an electric field is a capacitor (also called capacitance). When the voltage is variable over a cycle, energy will be stored during one part of the cycle and returned in the next.
- While an inductance cannot retain energy after removal of the source because the magnetic field collapses, the capacitor retains the charge and the electric field can remain after the source is removed. This charged condition can remain until a discharge path is provided, at which time the energy is
- released. The charge, q=Cv, on a capacitor results in an electric field in the dielectric which is the mechanism of the energy storage.
- The energy stored in the electric field of capacitance is WC=1/2Cv2.

Resistance

- Resistance :
  - Opposes flow of current.
  - Unit is ohms.
  - Measured by ohm meter connected across it.
  - Depends upon type of material, area & length.
  - Produces heat when current flows through it.
  - Fixed and variable resistor (potentiometer).

Cont'd

- RESISTANCE (OHMS).
  Resistance is a restriction to current flow.
  Increasing resistance will reduce flow of current.
  Electrical resistance is measured in units called ohms, they are abbreviated by the letter R, and the symbol is Ω (omega)

Cont'd

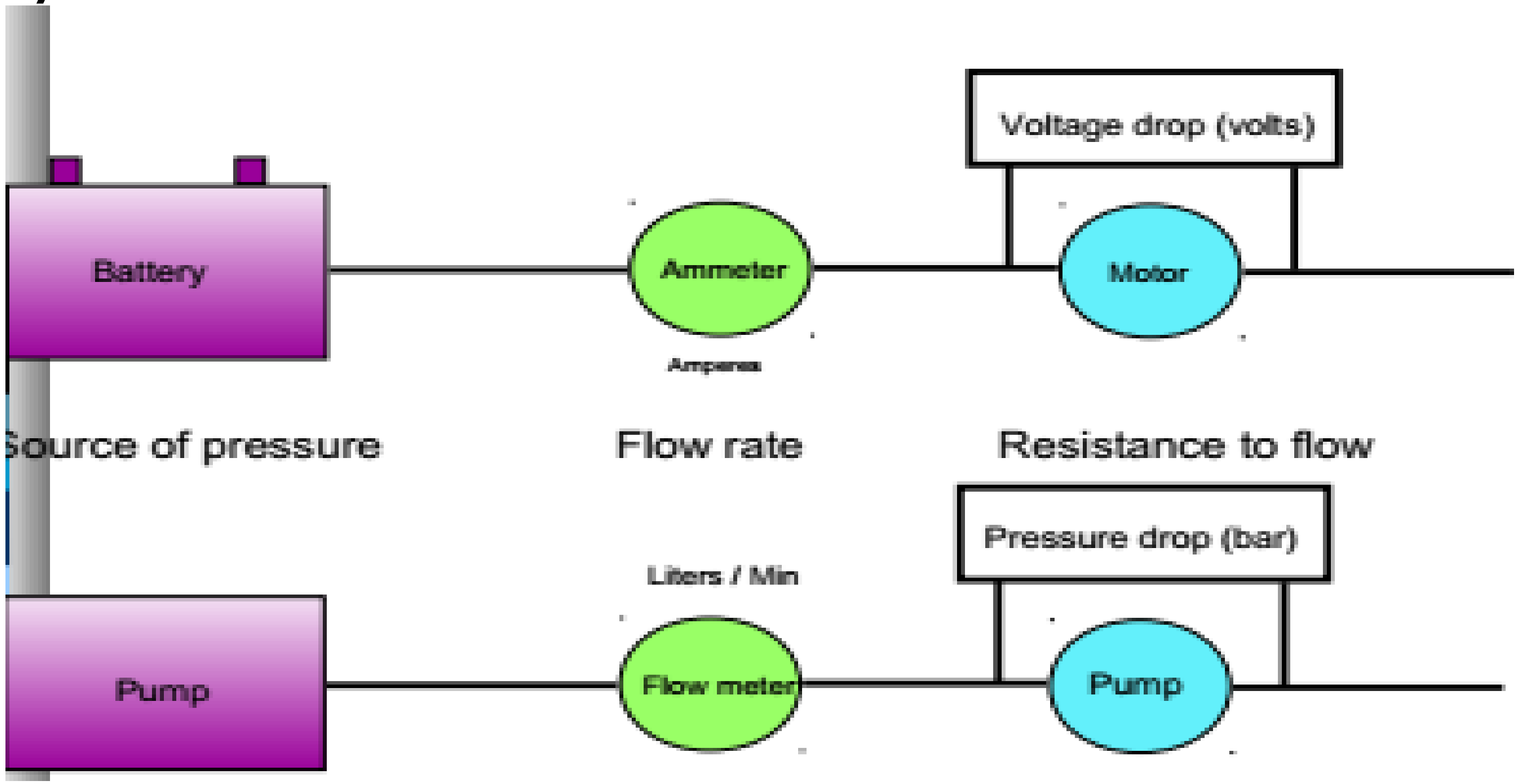
- Inductor -
  - Coil of wire.
  - Opposes change in current.
  - Used to create magnetic field for rotation.
  - Unit is henry.
  - Open and short inductor.

Cont'd

- Capacitor -
  - Two metal plates separated by a DI-electric (Max volts/mm which a
  medium can withstand without breakdown).
  - Gets charged when voltage is applied.
  - Unit of capacitance is farad.
  - Capacitor in series $1/C=1/C1+1/C2$ & in parallel $C= C1+C2$.
  - $C = Q / V$
  - Practical unitsMicro and Pico farad.

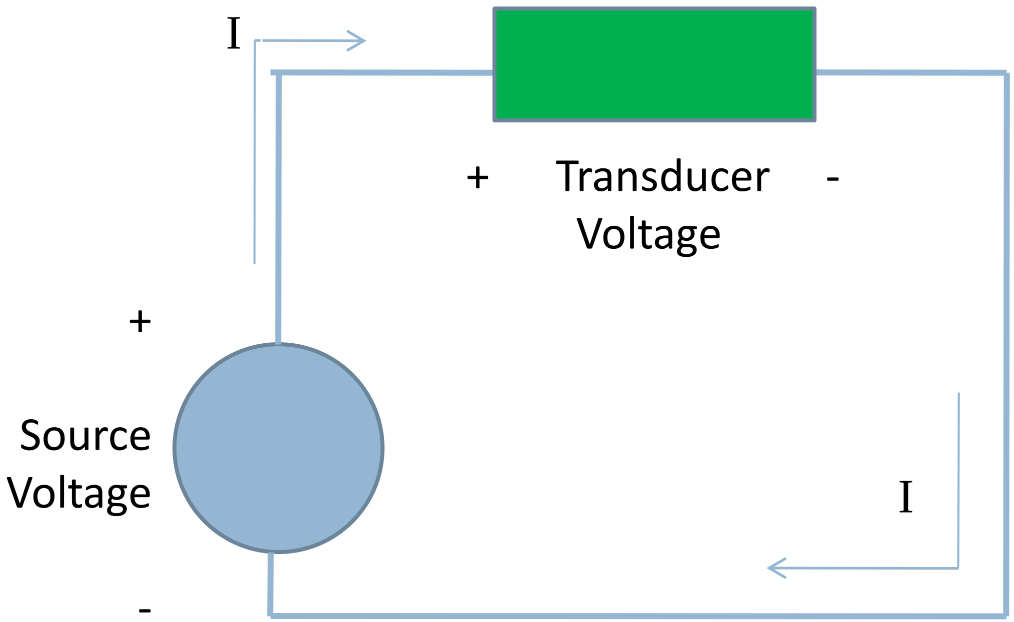
The electrical circuit

- An electrical circuit can be compared to a simple hydraulic circuit.



A Circuit

- Current flows from the higher voltage terminal of the source into the higher voltage terminal of the transducer before returning to the source



- The source expends energy & the transducer converts it into something useful

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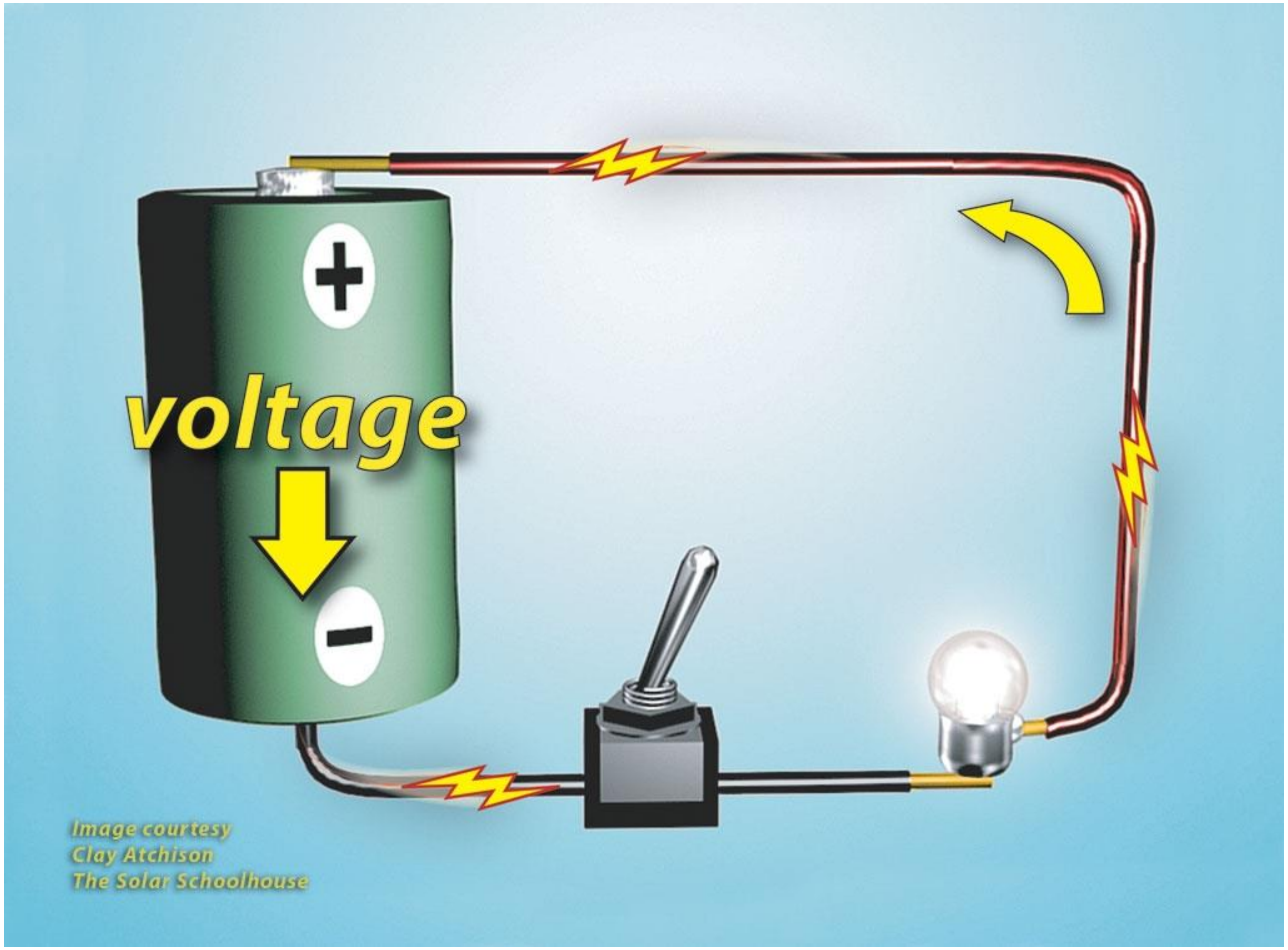

voltage
Image courtesy
Clay Atchison
The Solar Schoolhouse

Circuit Element

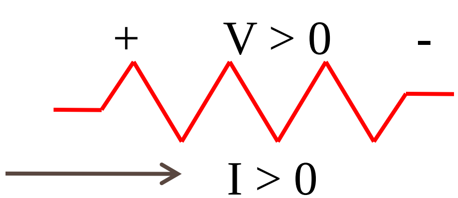
- An element is the basic building block of a circuit. An electric circuit is simply an interconnection of the elements. Circuit analysis is the process of determining voltages across (or the currents through) the elements of the circuit.
- There are two types of elements found in electric circuits:

passive elements and

Active elements.

Passive Devices

- A passive transducer device functions only when energized by a source in a circuit
  - Passive devices can be modeled by a resistance
- Passive devices always draw current so that the highest voltage is present on the terminal where the current enters the passive device



- **Notice that the voltage is measured across the device**
- **Current is measured through the device**

Active Devices

- Sources expend energy and are considered active devices
- Their current normally flows out of their highest voltage terminal
- Sometimes, when there are multiple sources in a circuit, one overpowers another, forcing the other to behave in a passive manner

Power

- Power is an indication of how much work (the conversion of energy from one form to another) can be accomplished in a specified amount of time, that is. a rate of doing work.
- For instance, a large motor has more power than a small motor because it can convert more electrical energy into mechanical energy in the same period of time.
- Since converted energy is measured in joules (J) and time in seconds (s). power is measured in joules second (J s).
- The electrical unit of measurement for power is the watt (\V). defined by $1 \text{ watt (W)} = 1 \text{ joule/second (J/s)}$

In equation form, power is determined by ----→ $P = \frac{W}{t}$

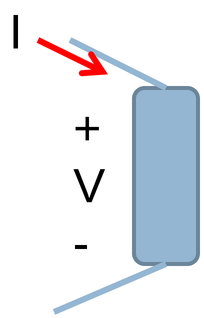
Power

- The rate at which energy is transferred from an active source or used by a passive device
- P in watts = dW/dt = joules/second
- P= V·I = dW/dQ · dQ/dt = volts · amps = watts
- W = ∫ P · dt – so the energy (work in joules) is equal to the area under the power in watts plotted against time in seconds.
- Power is measured in watts and also non si units by using horse power

1 horsepower ≅ 746 watts

Conservation of Power

- Power is conserved in a circuit - $\sum P = 0$
- We associate a positive number for power as power absorbed or used by a passive device
- A negative power is associated with an active device delivering power



If I=1 amp
V=5 volts
Then passive
P=+5 watts
(absorbed)

If I= -1 amp
V=5 volts
Then active
P= -5 watts
(delivered)

If I= -1 amp
V= -5 volts
Then passive
P=+5 watts
(absorbed)

Example

- A battery is 11 volts and as it is charged, it increases to 12 volts, by a current that starts at 2 amps and slowly drops to 0 amps in 10 hours (36000 seconds)
- The power is found by multiplying the current and voltage together at each instant in time
- In this case, the battery (a source) is acting like a passive device (absorbing energy)

Energy

- In order 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 watt second. however, is too small a quantity for most practical purposes, so the watr hour (Wh) and kilowatt hour (kWh) were defined, as follows:

$$\text{Energy (Wh)} = \text{power (W)} \times \text{time (h)}$$

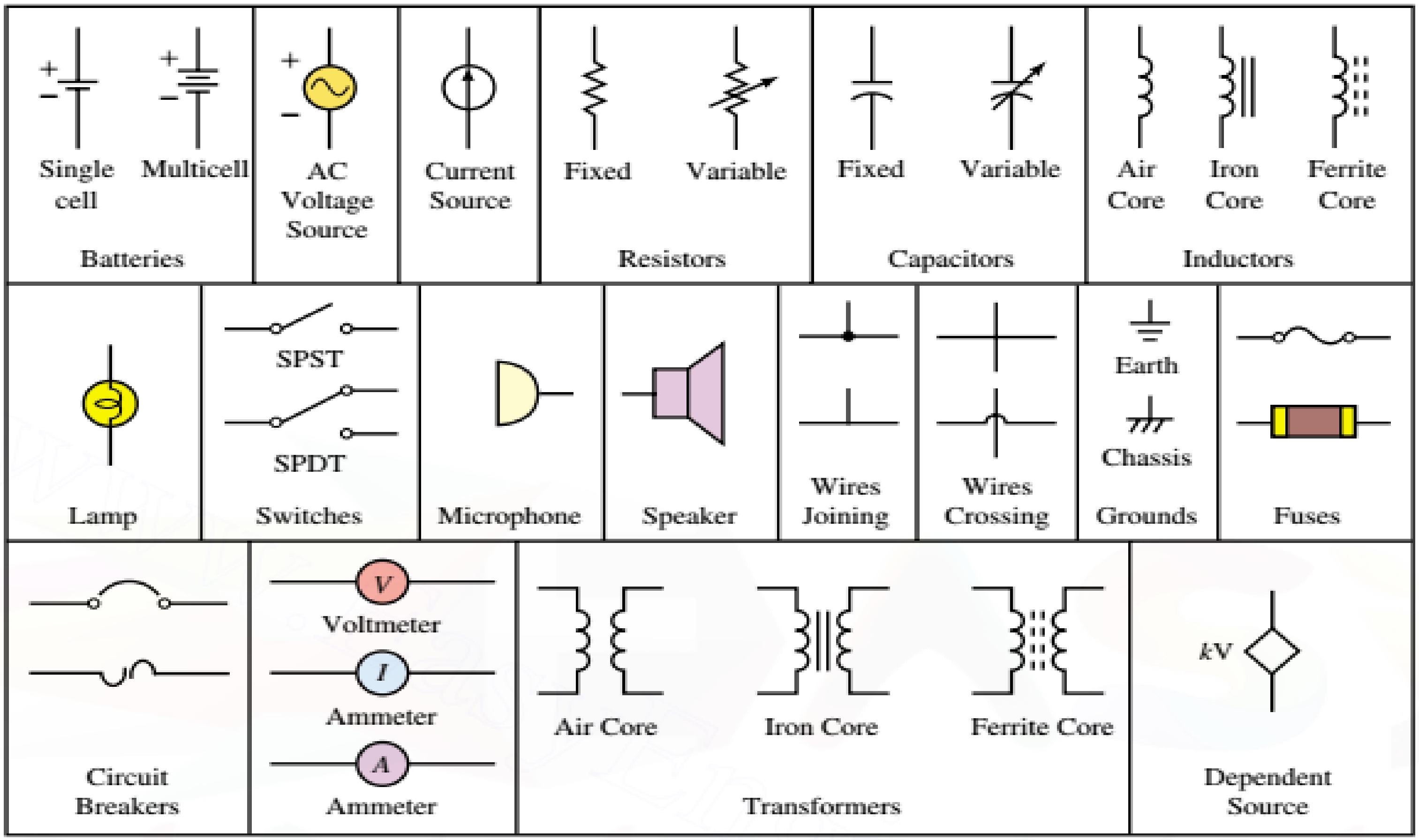
$$\text{Energy (kWh)} = \frac{\text{power (W)} \times \text{time (h)}}{1000}$$

Energy

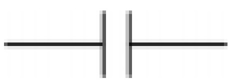
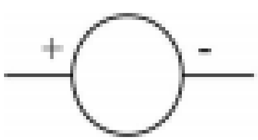
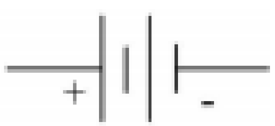
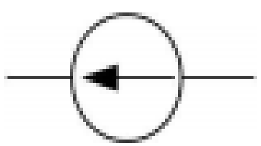
- The energy is the area under the power curve
  - Area of triangle = .5 · base · height
  - W=area= .5 · 36000 sec. · 22 watts = 396000 J.
  - W=area= .5 · 10 hr. · .022 Kw. = 110 Kw.·hr
- So 1 Kw.·hr = 3600 J.
- Since 1 Kw.·hr costs about $0.10, the battery costs $11.00 to charge

Electrical terms and symbols

TABLE 1–7 Schematic Circuit Symbols



Cont'd

Circuit Element	Symbol	Schematic
Resistor	R	 or 
Inductor	L	
Capacitor	C	
DC Voltage Source	V_s	 or 
DC Current Source	I_s	

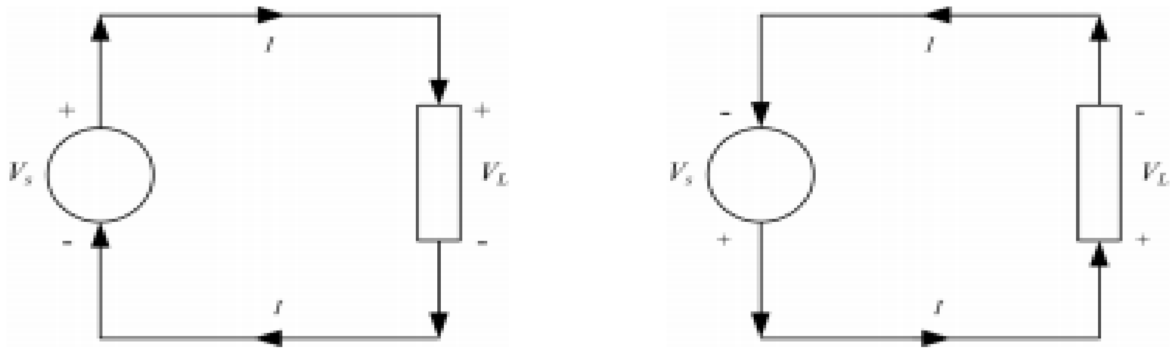
Circuit load

- A load generally refers to a component or a piece of equipment connected to the out put of an electric circuit .
- A load is represented by any one or the combination of the following.

Quantity	Symbol	Unit
Voltage	V	Volts (V)
Current	I	Ampere (A)
Charge	Q	Coulomb (C)
Power	P	Watts (W)
Energy	W	Joules (J)
Time	t	seconds (s)

Sign convention

- In a given circuit, the current direction depends on the polarity of the source voltage. Current always flow from positive(high potential) side to the negative (low potential) side of the source as shown in the following diagram.



(a) (b)

- Vs is the source voltage
- Vl is the voltage a cross the load and I is the loop current flowing in the clockwise direction.

Cont'd

- # Note :
- ***In Source*** : current leaves from the positive terminal
- ***In load*** : current enters from the positive termial

CHAPTER TWO

2.BASIC DC THEORY

Introduction