

Chapter One

Basic Concepts and Units

1.1 Modern Electron Theory:

It's states that all matter (solid, liquid, gaseous) consists of very small particles called molecules; which are made up rather small particles known as atoms.

An atom is the smallest part of chemical element that retains the chemical characteristics of that element.

The atoms consists of the following parts

- 1) Electrons: they have positive charge
- 2) Protons: they have negative charge
- 3) Neutron: they have no any charge (neutral)

Protons and Neutrons are exists in a central core called nucleus, while the electrons spin around the nucleus in one or more elliptical orbits

Mass of proton =1836 times of electron.

1.2 Electric Charge:

Electric charge is a characteristic property of many subatomic particles.

In physics, a **neutral particle** is a particle with no electric charge(no. of electrons=no of protons).

When some of electrons removed from neutral body, then it will charged positively.

While some of electrons are supplied to a neutral body, it will charged negatively.

Coulomb is the unit of charge

1Coulomb=charge on 6.28×10^{16}

$$\text{Charge of electron} = \frac{1}{6.28 \times 10^{16}} = 1.6 * 10^{-19} C$$

example(1): How much charge is represented by 4,600 electrons?

Solution:

Each electron has $-1.602 \times 10^{-19} C$. Hence 4,600 electrons will have

$-1.602 \times 10^{-19} C/\text{electron} \times 4,600 \text{ electrons} = -7.369 \times 10^{-16} C$

1.3 Electric Current:

Electric current is a flow of electric charge through a conductive medium.

In some type material which called conductors, electrons can move freely and randomly from one atom to another

A flow of positive charges gives the same *electric* current, and has the same effect in a circuit, as an equal flow of negative charges in the opposite direction. Since current can be the flow of either positive or negative charges, or both, a convention for the direction of current which is independent of the type of charge carriers is needed. **The direction of conventional current is defined arbitrarily to be the direction of the flow of positive charges.**

In metals, which make up the wires and other conductors in most electrical circuits, the positive charges are immobile, and the charge carriers are electrons. Because the electron carries negative charge, the *electron* motion in a metal conductor is in the direction opposite to that of conventional (or *electric*) current.

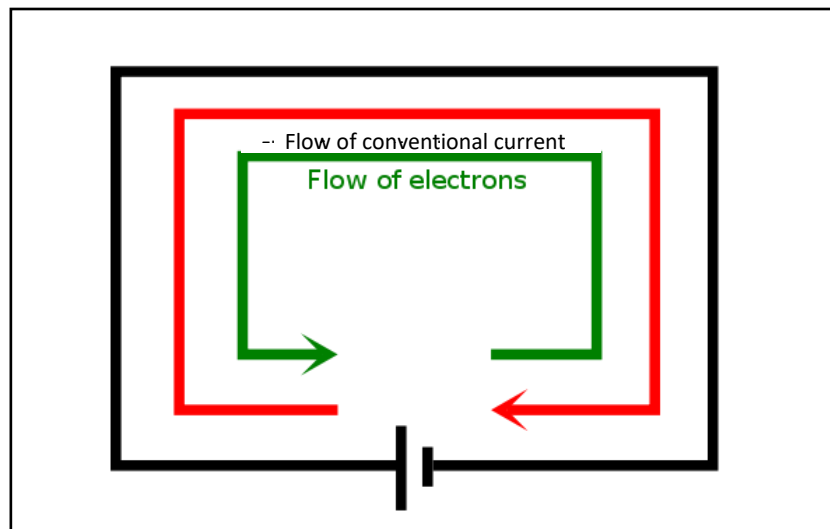


Fig.1 The direction of flow of conventional current

The strength of electric current I is the rate of change of electric charge in time

$$I = \frac{dQ}{dt}$$

Where:

I : current in Ampere (A)

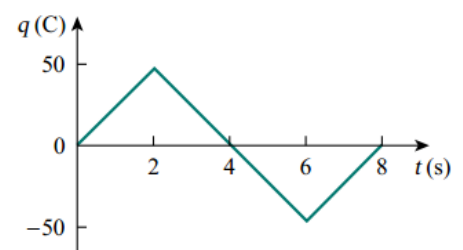
Q : charge in Coulomb (C)

t : time in seconds (sec)

example(2): flow of charge that passes throw a given reference point is shown below sketch the current wave form

1) for $0 \leq t < 2$ sec

$$I = \frac{\Delta Q}{\Delta t} = \frac{Q_2 - Q_1}{t_2 - t_1}$$



$$= \frac{50-0}{2-0} = 25 \text{ A}$$

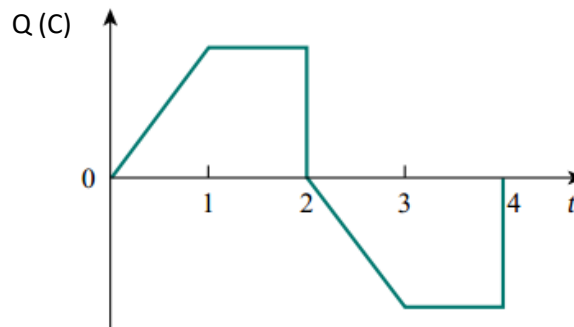
2) for $2 \leq t < 6$ sec

$$I = \frac{\Delta Q}{\Delta t} = \frac{Q_2 - Q_1}{t_2 - t_1}$$
$$= \frac{-50-50}{6-2} = -25 \text{ A}$$

3) for $6 \leq t < 8$ sec

$$I = \frac{\Delta Q}{\Delta t} = \frac{Q_2 - Q_1}{t_2 - t_1}$$
$$= \frac{0-50}{8-6} = -25 \text{ A}$$

H.W: flow of charge that passes through a given reference point is shown below sketch the current wave form



The Conditions of Continuous Current Flow are:

- 1) a closed circuit around which the electron may travel along
- 2) there must be a source which causes the current.

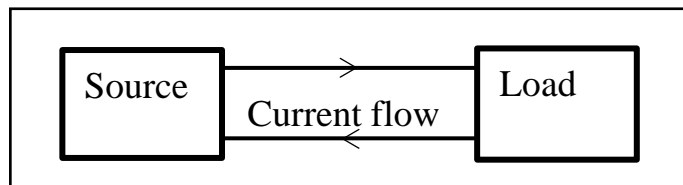


Fig.2 Simple circuit

The three essential parts of any electrical circuit are: a **power source** (like a battery or generator), a **load** (like a light lamp or motor) and **transmission system** (wires) to join them together. See Fig. 3.

A fourth part, that is always a very important thing to have in most circuits, is a **control device** such as a switch, circuit breaker or fuse.

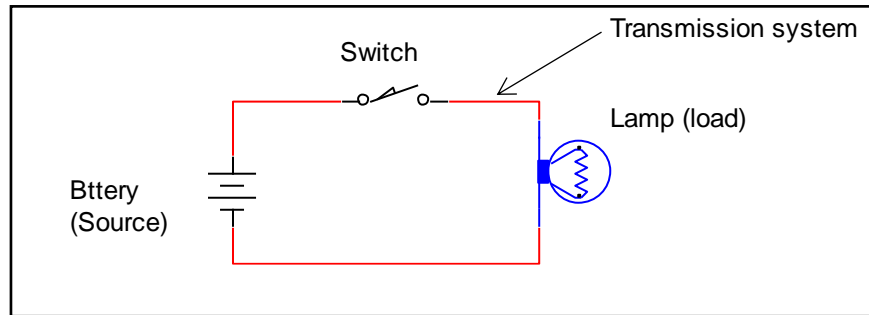


Fig.4 An example of basic circuit.

1.4 Electric Potential, Electric Potential Difference, and Electromotive Force:

Electric Potential: Is the work required by an electric field to move electric charges. Its unit is the volt. Also called *voltage*

$$\text{Electric Potential} = \frac{\text{work}}{\text{charge}} \quad \frac{\text{Joules}}{\text{Coulomb}} (\text{Volt})$$

Electric Potential Difference: It's the difference in the potential between two charged bodies. Or the work that has to be done in transferring unit positive charge from one point to the other.

Electromotive Force (emf): The energy per unit charge that is converted reversibly from chemical, mechanical, or other forms of energy into electrical energy in a battery or dynamo.

1.5 Electrical Power:

Electric power, like [mechanical power](#), is the rate of doing [work](#), measured in [watts](#), and represented by the letter P .

If there is a q coulombs of charge moves as a result of potential difference V , the work (w) done will be

$$w = Vq \quad (\text{Joules})$$

And the power (p) will be:

$$p = \frac{dw}{dt} = v \frac{dq}{dt} = vi \quad (\text{watt})$$

1.6 The Principle of Ohm's law:

Ohm's law states that the [current](#) (I) through a conductor between two points is directly [proportional](#) to the [potential difference](#) (V) across the two points. Introducing the constant of proportionality,

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

Where R is the resistance of the conductor measured in ohm (Ω).

The interchangeability of the equation may be represented by a triangle, where V ([voltage](#)) is placed on the top section, the I ([current](#)) is placed to the left section, and the R ([resistance](#)) is placed to the right. The line that divides the left and right sections indicates multiplication, and the divider between the top and bottom sections indicates division (hence the division bar).

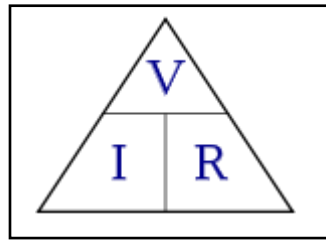


Fig.5 Ohm's triangle

if we plot voltage on the x-axis of a graph and current on the y-axis of the graph, we will get a straight-line. The gradient of the straight-line graph is related to the resistance of the conductor.

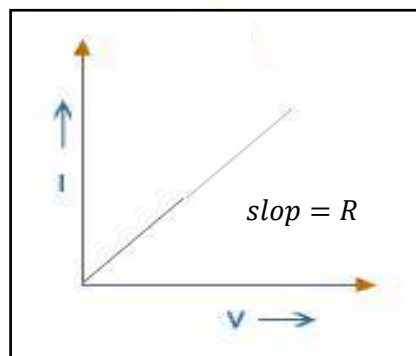


Fig.6 Graphical representation of Ohm's law

1.7 The SI Units:

In 1960 the Conference Generale des Poids et Mesures (CGPM), which is the international authority on the metric system, accepted a universal, practical system of units and gave it the name Le Systeme International d'Unites with the abbreviation SI. Since then, this most modern and simplest form of the metric system was introduced throughout the world.

The International System of Units consists of a set of units together with a set of prefixes. The units are divided into two classes—base units and derived units. There are seven base units, each representing, by convention, different kinds of physical quantities. see Table 1.

Table 1. the SI base units

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K

Since, in practice, one often needs to describe quantities that occur in large multiples or small fractions of a unit, standard prefixes are used to denote powers of 10 of SI (and derived) units. These prefixes are listed in Table 2.

Table 2. Standard prefixes.

Prefix	Symbol	Power
Pico	P	10^{-12}
nano	N	10^{-9}
micro	μ	10^{-6}
milli	M	10^{-3}
centi	C	10^{-2}
kilo	K	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}

The derived units are:

1. Area (A) m^2
2. Volume (V) m^3
3. Velocity (v) m/s

4. Acceleration (a) m/s^2
5. Angular velocity (ω) rad/sec
6. Work or energy (w) Joule
 $w = F.l \text{ (N.m) or (kg.m}^2\text{/s}^2\text{)}$
7. Force F (Newton) or $(\text{kg.m}^2/\text{s})$
8. Torque $T \text{ (N.m)}$
9. Power $P \text{ (watt) or (J/s)}$
10. Potential $v \text{ (Volt) or (J/C)}$
11. Charge $Q \text{ (C) or (A.s)}$
12. Resistance (R) (Ω) or (V/A)
13. Kilowatthour (kwh) = is a unit of energy which is used commercially
 $1 \text{ kwh} = 1000 \text{ w.h}$
 $= 1000 * 60 \text{ w.min}$
 $= 1000 * 60 * 60 \text{ w.s}$
 $= 3.6 * 10^6 \text{ J} = 3.6 \text{ MJ}$
14. Efficiency (η) (unitless)
$$\eta = \frac{\text{output power}}{\text{input power}} \times 100\%$$
15. Horse power hp = 746w

Chapter Two

Analysis of Direct Current Circuits

2.1 Introduction:

An electric circuit is a closed path or combination of paths through which current can flow. Fig 2.1 shows a simple direct current circuit. The direct current (DC) starts from the positive terminal of the battery and comes back to the starting point via the load.

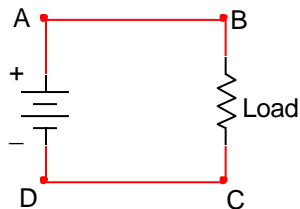


Fig 2.1 simple dc circuit

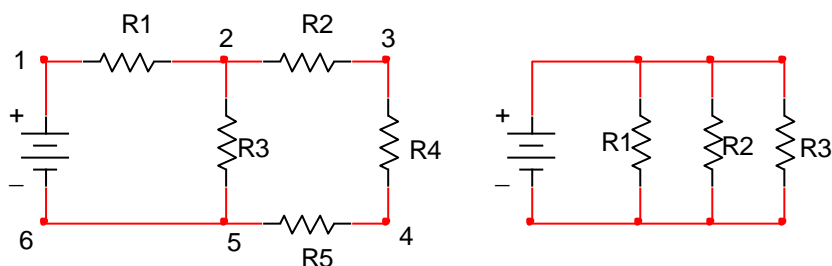
Electric Network: A combination of various electric elements, connected in any manner is called an electric network.

Node: is a junction in a circuit where two or more circuit elements are connected together.

Loop. It is a close path in a circuit in which no element or node is encountered more than once.

Mesh. It is a loop that contains no other loop within it.

For example, the circuit of Fig. 2.2 (a) has six nodes, three loops and two meshes whereas the circuit of Fig. 2.2 (b) has four branches, two nodes, six loops and three meshes.



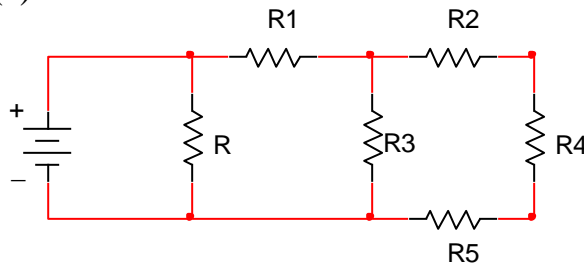
(a)

(b)

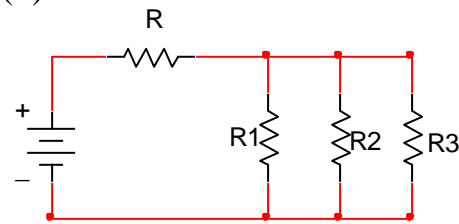
Fig 2.2

Example 2.1 find the numbers of nodes, meshes, loops in the following networks

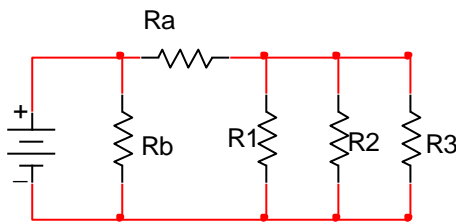
(a)



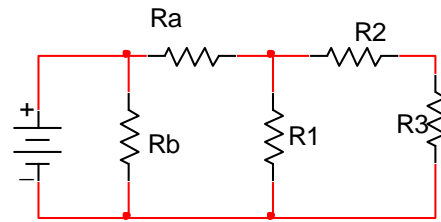
(b)



(b)



(d)



* There are two general approaches to network analysis :

(i) Direct Method

Here, the network is left in its original form while determining its different voltages and currents. Such methods are usually restricted to fairly simple circuits and include Kirchhoff's laws, Loop analysis, Nodal analysis, superposition theorem, etc.

(ii) Network Reduction Method

Here, the original network is converted into a much simpler equivalent circuit for rapid calculation of different quantities. This method can be applied to simple as well as complicated networks. Examples of this method are : Delta/Star and Star/Delta conversions, Thevenin's theorem and Norton's Theorem etc.

2.2 Kirchhoff's Laws *

These laws are more comprehensive than Ohm's law and are

used for solving electrical networks which may not be readily solved

by the latter. Kirchhoff's laws, two in number, are particularly useful

(a) in determining the equivalent resistance of a complicated network of conductors and (b) for calculating the currents flowing in the

various conductors. The two-laws are :

1) Kirchhoff's Point Law or Current Law (KCL)

It states as follows :

in any electrical network, the algebraic sum of the currents meeting at a point (or junction or node) is zero.

Put in another way, it simply means that the total current leaving a junction is equal to the total current entering that junction. It is obviously true because there is no accumulation of charge at the junction of the network.

Consider the case of a few conductors meeting at a point A as in Fig. 2.2 (a). Some conductors have currents leading to point A, whereas some have currents leading away from point A. Assuming the incoming currents to be positive and the outgoing currents negative, we have

$$I_1 + (-I_2) + (-I_3) + (+I_4) + (-I_5) = 0$$

- or $I_1 + I_4 - I_2 - I_3 - I_5 = 0$ or $I_1 + I_4 = I_2 + I_3 + I_5$
- or incoming currents = outgoing currents

Similarly, in Fig. 2.2 (b) for node A

$$+I + (-I_1) + (-I_2) + (-I_3) + (-I_4) = 0 \text{ or } I = I_1 + I_2 + I_3 + I_4$$

We can express the above conclusion thus : $\Sigma I = 0$...at a junction

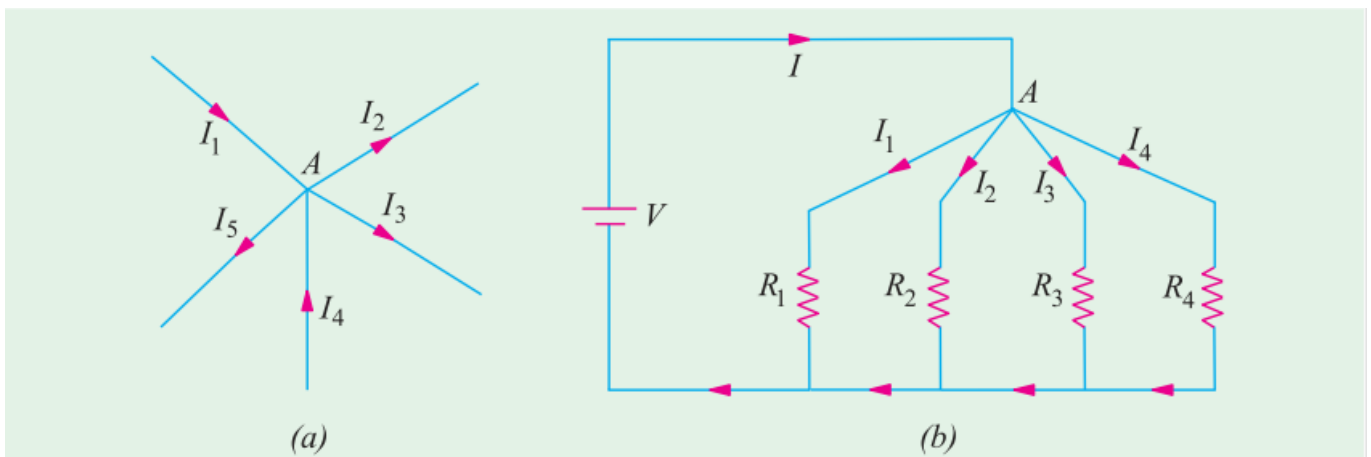


Fig 2.2

2) Kirchhoff's Mesh Law or Voltage Law (KVL)

It states as follows :

The algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the e.m.fs. in that path is zero.

- In other words, $\Sigma I_R + \Sigma \text{e.m.f} = 0$...round a mesh
- It should be noted that algebraic sum is the sum which takes into account the polarities of the voltage drops.

2.2.1 Determination of Voltage Sign

In applying Kirchhoff's laws to specific problems, particular attention should be paid to the algebraic signs of voltage drops and e.m.fs., otherwise results will come out to be wrong. Following sign conventions is suggested :

(a) Sign of Battery E.M.F.

If we go from the -ve terminal of a battery to its +ve terminal (Fig. 2.3), and hence this voltage should be given a + ve sign, and vice versa.

- It should be noted that algebraic sum is the sum which takes into account the polarities of the voltage drops.

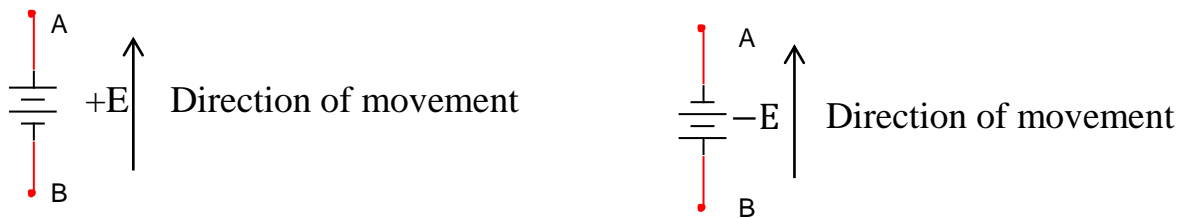


Fig 2.3

(b) Sign of IR Drop

Now, take the case of a resistor (Fig 2.4). If we go through a resistor in the same direction as the current, then there is a fall in potential because current flows from a higher to a lower potential. Hence, this voltage fall should be taken –ve. However, if we go in a direction opposite to that of the current, then there is a rise in voltage. Hence, this voltage rise should be given a positive sign. It is clear that the sign of voltage drop across a resistor depends on the direction of current through that resistor but is independent of the polarity of any other source of e.m.f. in the circuit under consideration.

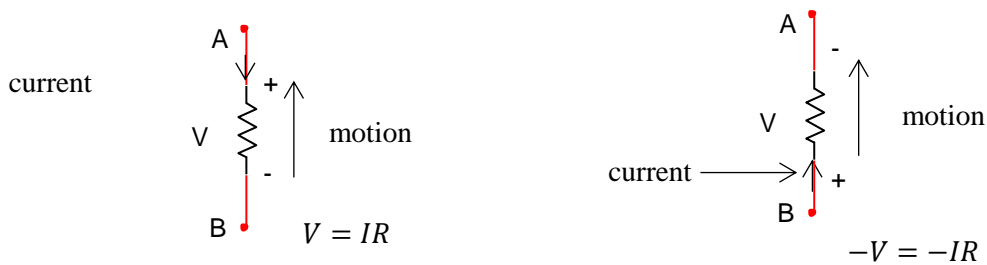


Fig 2.4

Consider the closed path ABCDA in Fig. 2.5. As we travel around the mesh in the clockwise direction, different voltage drops will have the following signs :

$I_1 R_1$ is – ve

$I_2 R_2$ is – ve

$I_3 R_3$ is + ve

$I_4 R_4$ is – ve

E_2 is – ve

E_1 is + ve

Using Kirchhoff's voltage law, we get

$$- I_1 R_1 - I_2 R_2 - I_3 R_3 - I_4 R_4 - E_2 + E_1 = 0$$

$$\text{or } I_1 R_1 + I_2 R_2 - I_3 R_3 + I_4 R_4 = E_1 - E_2$$

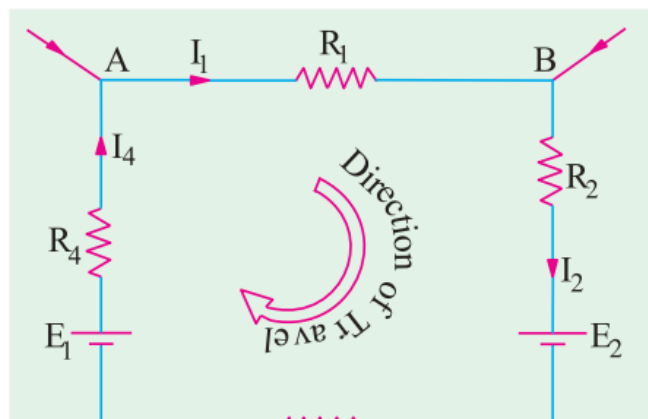


Fig 2.5

Example 2.1 What is the voltage V_s across the open switch in the circuit of Fig. 2.6 ?

Solution. We will apply KVL to find V_s . Starting from point A in the clockwise direction and using the sign convention given in Art. 2.3, we have

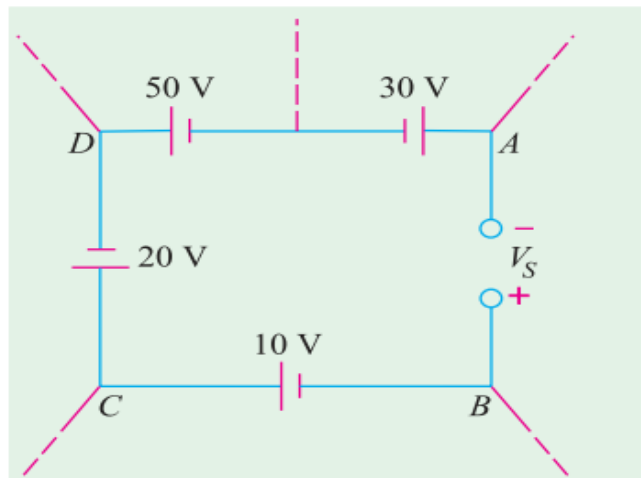


Fig 2.6

$$+V_s + 10 - 20 - 50 + 30 = 0$$
$$\therefore V_s = 30 \text{ V}$$

Example 2.2 Find the unknown voltage V_1 in the circuit of Fig. 2.7.

Solution. Initially, one may not be clear regarding the solution of this question. One may think of Kirchhoff's laws or mesh analysis etc. But a little thought will show that the question can be solved by the simple application of Kirchhoff's voltage law. Taking the outer closed loop ABCDEFA and applying KVL to it, we get

$$-16 \times 3 - 4 \times 2 + 40 - V_1 = 0 ;$$

$$V_1 = -16 \text{ V}$$

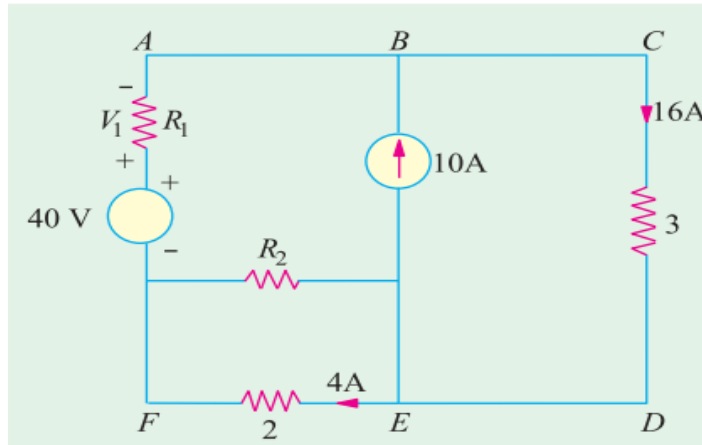


Fig 2.7

2.3 type of DC circuits:

DC circuit can be classified as:

- 1) series circuits
- 2) parallel circuits
- 3) series-parallel circuits

2.3.1 Series Circuits

$$V_1 + V_2 + V_3 + \dots + V_n = E$$

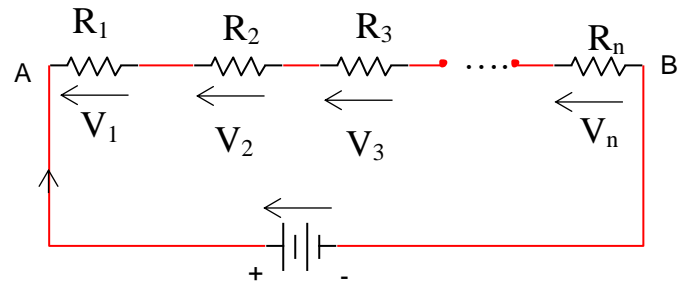
$$I_1 R_1 + I_2 R_2 + I_3 R_3 + \dots + I_n R_n = E$$

$$I_1 = I_2 = \dots = I$$

$$E = I(R_1 + R_2 + \dots + R_n) = I R_{eq}$$

$$R_{eq} = (R_1 + R_2 + \dots + R_n)$$

- Special case of series circuits (voltage divider)

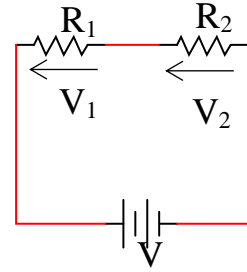


$$I = \frac{V}{R_1 + R_2}$$

$$V_1 = IR_1 = \frac{V}{R_1 + R_2} R_1$$

Or

$$V_1 = V \frac{R_1}{R_1 + R_2}$$



Similarly

$$V_2 = V \frac{R_2}{R_1 + R_2}$$

In general for n resistances in series

$$V_x = V \frac{R_x}{R_T}$$

The equivalent resistance actually the resistance “seen” by the battery as it “looks” into the series combination of elements as shown in Fig. 2.8.

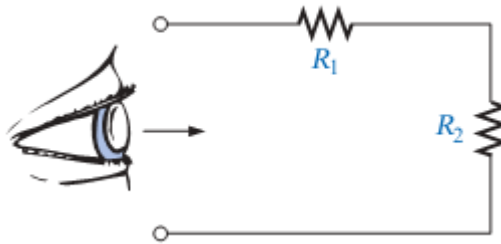


Fig 2.8

* Two elements are in series if

1. They have only one terminal in common (i.e., one terminal of the 1st element is connected to only one terminal of the other).
2. The common point between the two elements is not connected to another current-carrying element. Look to Fig 2.9

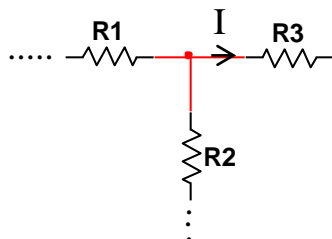
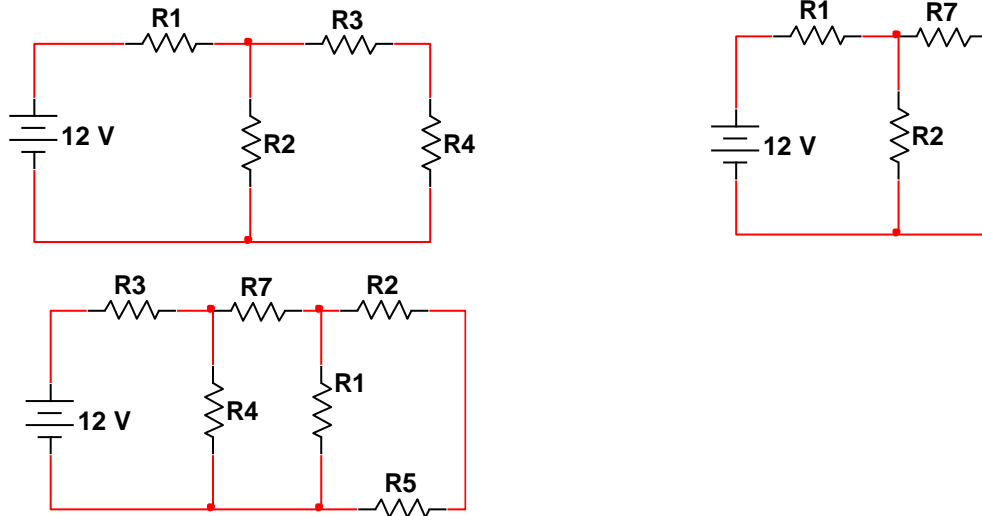


Fig 2.9

Example 2.3: In which one of the following circuits R_1 and R_2 are in series?



- Example 2.4: a. Find the total resistance for the series circuit of Fig. 2.10
 b. Calculate the source current I_s .
 c. Determine the voltages V_1 , V_2 , and V_3 .
 d. Calculate the power dissipated by R_1 , R_2 , and R_3 .
 e. Determine the power delivered by the source, and compare it to the sum of the power levels of part (d).

Solutions:

a. $R_T = R_1 + R_2 + R_3 = 2 + 1 + 5 = 8\Omega$

b. $I_s = \frac{E}{R_T} = 2.5 \text{ A}$

c. $V_1 = IR_1 = (2.5)(2) = 5 \text{ V}$

$V_2 = IR_2 = (2.5)(1) = 2.5 \text{ V}$

$V_3 = IR_3 = (2.5)(5) = 12.5 \text{ V}$

d. $P_1 = V_1 I_1 = (5)(2.5) = 12.5 \text{ W}$

$P_2 = I_2^2 R_2 = (2.5)^2 (1) = 6.25 \text{ W}$

$P_3 = \frac{V_3^2}{R_3} = \frac{(12.5)^2}{5} = 31.25 \text{ W}$

e. $P_{del} = EI = (20)(2.5) = 50 \text{ W}$

$P_{del} = P_1 + P_2 + P_3 = 31.25 + 12.5 + 6.25 = 50 \text{ W}$

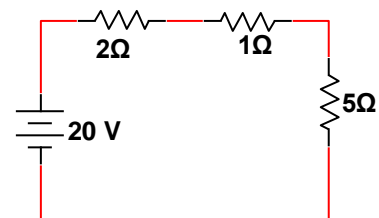


Fig 2.10

Example 2.5: Find the total resistance and current I for each circuit of Fig.2.11

