Unit: 3 Circuit Fundamental

AC/DC Fundamentals: Sources of DC voltage: Lead-Acid and Ni-Cd Battery: Construction, Chemical action, Current rating. Other DC sources (only names), Solar cell

A.C. Fundamentals: Types of AC, Important terms of AC: Cycle, Time period, Frequency, Amplitude, Peak to peak value, Phase, Phase Difference.

Electric circuit, Active and Passive elements, Bilateral and unilateral element, Linear and non linear element, Lumped and distributed element. Basic voltage and current relations for R, L and C

Energy sources: - AC and DC sources, constant voltage and constant current source, and their inter conversions, Reference direction for voltage and current. Basic laws and rules: - Ohm's law, Kirchhoff's laws, voltage and current divider rules, power in series and parallel circuits. Mesh-analysis method and Nodal analysis method (only for dc resistive circuit)

The source which supplies energy in the form of a voltage is called voltage source. Voltage sources are classified into two categories depending upon whether a source supplies dc or ac to the load. Some dc sources are batteries, dc generators & regulated power supplies.

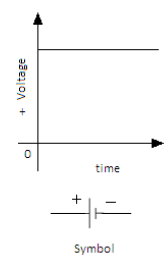


Fig (a)

The direct current is a current in which the flow of electric charges is unidirectional i.e. in one direction only. Fig shows the symbol of a dc voltage source & waveform of dc voltage.

As seen, the waveform is a straight horizontal line. In actual practice, we can have a dc voltage which varies w.r.t. time. But so long as it does not reverses its polarity we define it as dc voltage.

1) **Batteries:** A battery consists of two or more number of similar cells. A cell is a fundamental source of energy. It consists of a combination of materials, which produce direct current electric energy from its internal chemical reactions. The cells can be divided into two classes namely primary cells & secondary cells. Primary cells are those, which cannot be recharged after they are discharged; whereas the secondary cells are those which can be recharged.

	Primary cells	Use
1	Carbon zinc cells	Used as commercial dry cells
2	Manganese alkaline	Radio, TV set, tape recorder & cordless home appliances
3	Mercury	Used in cameras, hearing aids, electronic watches & test instruments
4	Silver oxide cells	
	Secondary cells	Use
1	Lead acid	Automobile batteries

2) **Solar cell:** A solar cell is a device which if exposed to sunlight, produces a voltage across its terminals. A basic solar cell consists of two layers of different semiconductors joined together to form a junction. When one layer is exposed to light, many electrons acquire enough energy to break away from their parent atoms & cross the junction. This process forms negative ions on one side of the junction & positive ions on the other. Thus, a potential diff is developed. Fig shows the basic construction of the solar cell

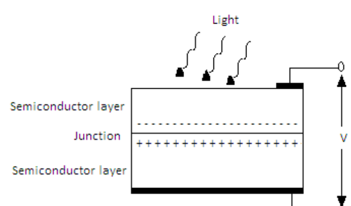


Fig Solar Cell

3) **Lead-acid wet cell:** When high values of load current are necessary these lead acid cells are used. One cell has output of 2.1 V, but these are often used in series combination of 3 for 6V battery or 6 for 12 V battery.

Construction: Inside a lead acid battery, the positive & negative electrode consists of a group of plates welded to a connecting strap. The plates are immersed in the electrolyte, consisting of 8 parts of water &3 parts of concentrated sulfuric acid. Each plate is grid or framework made of a lead-antimony alloy. This construction enables the active material, which is lead oxide, to be pasted into the grid. In manufacture of the cell, a forming charge produces the positive & negative electrodes. In the forming process, the active material in the positive plate is changed to lead peroxide ($Pb0_2$). The negative electrode is spongy lead (Pb).

Chemical reaction: Sulfuric acid is a combination of hydrogen & sulfate ions. When the cell discharges, lead peroxide from the positive electrode combines with hydrogen ions to form water & with sulfate ions to form lead sulfate. The lead sulfate is also produced by combining lead on the negative plate with sulfate ions. Therefore the net result of discharge is to produce more water, which dilutes the electrolyte & to form lead sulfate on the plates.

On charge, the external dc source reverses the current in the battery. The reversal direction of ions flowing in the electrolyte results in a reversal of the chemical reactions. Now the lead sulfate on the positive plate reacts with the water & sulfate ions to produce lead peroxide & sulfuric acid. This action reforms the positive plate & makes the electrolyte stronger by adding sulfuric acid. At the same time charging enables the lead sulfate on the negative plate to react with hydrogen ions; this also forms sulfuric acid while reforming lead on the negative electrode.

The chemical equation for the lead acid cell is

$$Pb + PbO_2 + 2H_2SO_4 \rightleftharpoons 2\,PbSO_4 + 2H_2O$$

On discharge, the Pb & PbO_2 combine with the SO_4 ions at the left side of the equation to form the lead sulfate ($PbSO_4$) & water (H_2O) at the right side of the equation.

On charge, the Pb ions from the lead sulfate on the right side of the equation reform the lead & lead peroxide electrodes. Also the S04 ions combine with H_2 ions from the water to produce more sulfuric acid at the left side of the equation.

Current rating: Lead acid batteries are rated in terms of how much discharge current they can supply for a specified period of time. The output voltage must be maintained above a minimum level (1.5 to 1.8 V per cell). A common rating is ampere hours (Ah) based on a specific discharge time, which is often 8h, typical values for automobile batteries are 100 to 300 Ah.

Ex. 200 Ah battery can supply a load current of 200/8 = 25 A, based on 8h discharge.

Note that Ah unit specifies coulombs of charge. E.g. 200 Ah corresponds to 200 A* 3600s= 7,20,000 AS.

To put this much charge back into the battery would require 20H with a charging current of 10A.

Nickel cadmium (Nicd) cell: These sells are popular because of their ability to deliver high current & to be cycled many times (1000) for recharging. Also, the cell can be stored for a long time, even when discharged, without any damage. Nominal output voltage is 1.25V per cell. Applications include portable power tools, alarm systems & portable radio, TV equipments.

Chemical action: The chemical equation for the Nicd cell can be written as follows

$$2Ni\,(OH)_3 + Cd \rightleftharpoons 2\,Ni(OH)_2 + Cd\,(OH)_2$$

The electrolyte is potassium hydroxide (KOH), but it does not appear in the chemical equation. The reason is that the function of this electrolyte is just to act as a conductor for the transfer of hydroxyl (OH) ions.

Maximum charging current is equal to the 10 h discharge rate.

The alternating current (ac) is a current in which the flow of electric charge periodically reverses in direction. Fig shows the symbol of ac voltage source& waveform of an alternating voltage. In the waveform, the amount of ac voltage is plotted against time. It may be noted that in the ac voltage waveform, the magnitude of voltage varies during the positive & negative cycles.

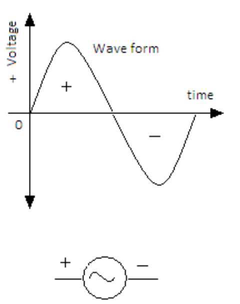
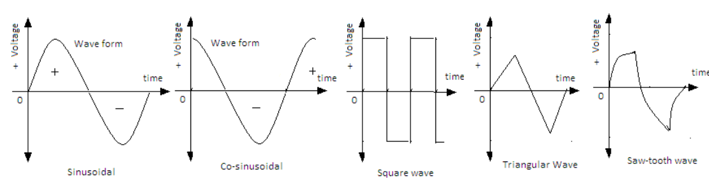


Fig (b) Ac Voltage symbol & wave form

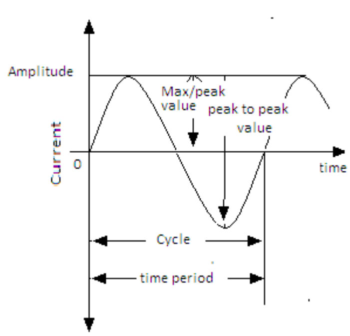


Types of ac voltage or current:

i) *Sinusoidal:* The alternating current (or voltage) whose value varies in a manner, which is similar to a sine or cosine function is known as sinusoidal alternating current (or voltage). The waveforms of a sinusoidal alternating current are as shown in fig.

ii) *Non-sinusoidal:* The waveforms such as square, triangular, saw-tooth are called non sinusoidal waveforms as shown in fig.

Important terms of AC: *Cycle*: One complete set of positive & negative values of an alternating current as shown in gig is called a cycle.



Time period: The time taken by an alternating current to complete one cycle (as shown in fig) is called its time period & is designated by the letter T. Mathematically time period is the reciprocal of number of cycles. E.g. if an ac mains 50 cycles in one second, then its time period is 1/50 = 0.02 sec.

Frequency: The number of cycles of per second, made by an alternating current is called frequency (f).Mathematically, f = number of cycles/ time in seconds

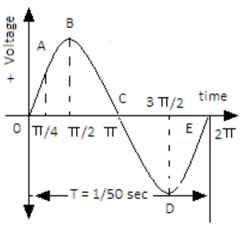
It is also defined as the reciprocal of the period (T) of the alternating current i.e. f= 1/T Hz or T=1/f Sec.

$1KHz = 10^3 Hz$, $1MHz = 10^6$ Hz, $1GHz = 10^9$ Hz.

Amplitude: (or peak value): The maximum value of positive or negative half cycle of an alternating current is called its amplitude or peak value as shown in fig. It is designated by the symbol Im, Imax, Ip or Ipeak.

Peak to peak value: The sum of positive or negative peak values is called a peak to peak value (Ipp). The peak to peak value of a sinusoidal alternating current is equal to 2 times the peak value.

Phase: The fraction of a cycle or time period which has elapsed since an alternating current (or voltage) last passed a given reference point, is called its phase. The phase may be expressed in any one of the following three different ways

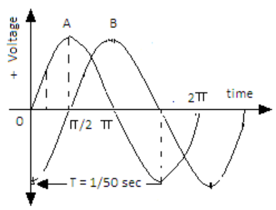


i) Angle expressed in radians or degrees
ii) Fraction of a time period
iii) Time measured in seconds

Consider a sinusoidal alternating current waveform as shown in fig (a). the phase at point A may be expressed as follows

i) Angle expressed in radians or degrees is $\pi/4$ or 45^0
ii) Fraction of a time period = $1/8^{th}$ of a cycle
iii) Time measured in seconds = T/8 =1/50 * 8= 1/400 sec.

Phase difference: The difference in phases between two alternating current (or voltages), of the same frequency, is called phase difference. It is designated by letter φ & may be expressed in any one of the following three ways.



i) Angle expressed in radians or degrees
ii) Fraction of a time period
iii) Time measured in seconds

Consider two alternating currents as shown in fig. Te phase difference between these two waveforms may be expressed as follows.

i) Angle expressed in radians or degrees = $\pi/2$ or 90^0
ii) Fraction of a time period = ¼ of a cycle
iii) Time measured in seconds = T/4 = 1/50*4 = 1/200 second.

A leading current is that which reaches its maximum or zero value earlier as compared to the other. Similarly, a legging current is that which reaches its maximum or zero value later than the other i.e. in fig the phase difference between currents A & B may now be expressed as A leading B by 90^0. Similarly, the phase difference may also be expressed as B lagging A by 90^0.

Electric circuit: This has three imp characteristics

i. There must be a source of energy, without its application current cannot flow.
ii. There must be a complete path for the current flow from one point of the source to other through the electric circuit.
iii. The current path has some definite value of resistance; the main purpose of resistance is to control the flow of current.

Active Element: An energy source (voltage or current) is said to be an active element. Ex of voltage source is battery, dc source. Ex of current source is an amplifier, transistor, diode, UJT, FET etc.

Passive Element: Elements which does not introduce gain or does not have directional function i.e. these elements by themselves are not capable of amplifying or processing an electrical signal.

Bilateral Element: An element which transmit equally well in either direction is bilateral element ex. resistor, inductor, capacitor.

Unilateral Element: An element which transmit unequally well in the two directions are unilateral element & also they have diff laws relating to voltage & current for diff directions of current ex. Vacuum tubes, crystals, rectifiers.

Linear Element: A linear element is one which is governed by a linear diff equation for all values of applied stimulus. For these elements the response is directly proportional to the excitation ex R,L,C

Non linear Element: The element in which the response is not directly proportional to the excitation is called non-linear element ex. Transistor, diode

Lumped & distributed Elements: Physically separate elements such as resistor, capacitor are referred to as lumped elements. On the other hand, network elements which are not separable for analytical purposes are called distributed elements ex transmission line, antenna.

Electric power: The electric power may be defined as the rate of producing or using electrical energy. It is the rate of doing work. P = Work/time = joules/sec = Watt

One watt of power is equal to the work done in one second by a voltage of one volt in moving one coulomb charge. 1 Watt = 1 volt * 1 coulomb/ 1 sec = 1 volt * 1 amp . Thus power is also defined as the product of voltage & current. $P = I * V = I * I * R = I^2 R$.

Basic voltage & current relations for R, L, C: *Resistor:* Ohm's low states that the electric current through a metallic conductor is directly proportional to the P.D. across its terminals, as long as the physical conditions of the conductor remains unchanged. i. e. I α V or V= I * R , where R is the resistance.

Inductor: When a current in the inductor changes with time an emf is induced in the circuit & is directly proportional to the rate of change of current i.e. $V \alpha dI/dt$, $V = L * dI/dt$.

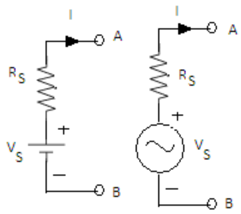
Capacitor: If the charge on either plate is Q & the P.D. between the plates is V then the ratio of the charge to the P.D. is called the capacitance of the capacitor.

$C=Q/V$. $V = Q/C = dV/dt= 1/C * dQ/dt = 1/C * I$

$\therefore V = 1/C \int i\, dt$

Energy sources: - *AC and DC sources:* Every electronic circuit requires some source of energy for its operation. The energy may be supplied either in the form of a voltage or current. The source, which supplies the energy in the form of a voltage, is called voltage source. And the source which supplies the current in the form of current is called current source. All voltage & current sources may be broadly classified into two categories, depending upon whether a source supplies dc or ac to the load. Ex of dc sources batteries, regulated dc power supplies. Ex of ac sources alternators, oscillators or signal generators.

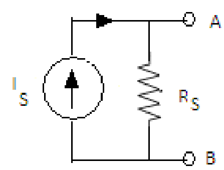
A practical voltage source consists of an ideal voltage source (has zero internal resistance) in series with a resistance (internal resistance of the source). Fig (a) & (b) shows the circuit symbols & reference direction for current of the practical dc & ac sources.



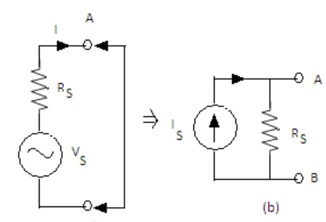
(a) (b)

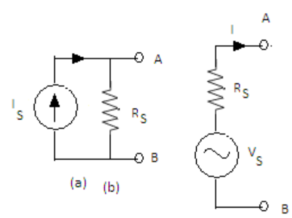
Ideal or perfect voltage source: A voltage source, which produces a terminal voltage (or load voltage) & does not depend upon the value of load resistance is called an ideal or perfect voltage source.

Ideal current source: A source, which supplies a constant current to a load, even if its resistance varies, is known as constant current source. A practical current source consists of an ideal current source in parallel with the internal resistance. The arrow inside the circle indicates the direction in which the current flows in the circuit when a load is connected across it.



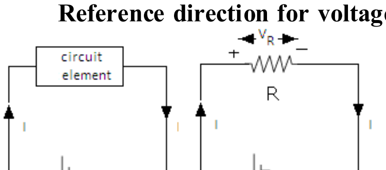
Conversion of voltage source into current source: let us consider a practical voltage source Vs with its internal resistance Rs as shown in fig (a). To convert this voltage source into its equivalent current source, let us short circuit the terminals A & B then find out the current through this short circuit. The short circuit current = Vs/Rs. The current source has same internal resistance. Then equivalent current source Is in parallel with a source resistance as shown in fig.





Conversion of current source into voltage source: Consider a practical current source (Is) with its internal resistance Rs as shown in fig(a). To convert this current source into its equivalent voltage source, find out the open terminal voltage Vs = Is * Rs. As the internal resistance of the voltage source is same as that of current source, the voltage source can be drawn by putting Vs in series with Rs as shown in fig (b).

Reference direction for voltage and current: The conventional direction of a current flow is that it flows from positive terminal of supply through circuit elements & finally returns to the negative terminal as shown in fig.



a) Current direction b) Voltage direction

When a current flows through a resistance it develops a voltage drop equal to I * R across it. The end through which the current enters the resistance is taken as positive & the other end is taken as negative.

Voltage notation: Consider a simple circuit consisting of three resistances & a voltage source as shown in fig. The voltage drop across each resistance is shown in + & - signs. A,B,C,D represents nodes. Let VAB, VBC & VCD be the voltage drop across resistances R1, R2 & R3 respectively. In this notation the second subscript letter stands for the reference point. The polarity of designated voltage is assigned by a positive sign e.g. the voltage VAB is designated as 12 V, because node A is positive w.r.t. node B. the polarity of a designated voltage is assigned a negative sign, if the first node is negative w.r.t. second node e.g. Voltage VBA is designated as -12 V, because node B is negative w.r.t. A.

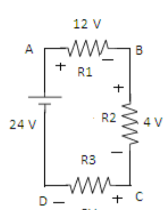


Fig: Voltage notation

Ohm's law: The physical condition of a conductor remaining the same, the steady current (I) between the points in the conductor is directly proportional to the potential difference (voltage) between these points.

i.e. I α V, I = V/R or V= I * R where R is the resistance of the conductor.

Ex1: A certain soldering iron has a resistance of 600 Ω, when operated from a 230 V power line. How much current does it take from the power line?

Given: R 600 Ω, V = 230 V I = V/R = 230/600 = 0.38A.

Ex 2: In a moving coil loud speaker, the coil has a resistance of 8 Ω. The max current it can carry safely is 2.5A. find the max safe voltage, which can be applied to the speaker coil.

Solution: Given R=8 Ω, I =2.5 A

The safe voltage that can be applied to the speaker coil is V= I * R = 2.5 * 8 = 20 V

Ex 3: A certain relay coil has a resistance of 1.5 K Ω. The coil requires a current of 16mA in order to energize (i.e. to close its contacts). How much voltage must be applied to the relay coil to energize it?

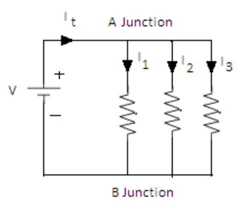
Solution: Given R = 1500 Ω, I = 16mA = 16 * 10^{-3}A.

The voltage that must be applied to the relay coil to energize it is V=I*R= 16 * 10^{-3} *1500= 24V

Ex 4: Typically, a seven segment readout device of a digital clock requires a current of 20mA/segment for adequate visibility. If the readout device is driven by a source of 5V, how much resistance should be inserted into the circuit for each segment? Assume that a segment has no resistance of its own.

Solution: Given current/ segment = 20mA= 20 * 10^{-3} A, V = 5V

The resistance that should be inserted into the circuit of each segment R=V/I=5/20*10^{-3} = 250 Ω.



Kirchhoff's current law: In any network the algebraic sum of currents meeting at a point or junctions is zero or the algebraic sum of the currents into any point of the circuit must equal to the algebraic sum of the currents leaving that point.

Kirchhoff's voltage law: The algebraic sum of the voltages around any closed path (or loop) is zero or the algebraic sum of the products of currents & resistances in a closed path along with the emf's is zero.

Fig shows a circuit with one dc voltage source & three resistive branches.

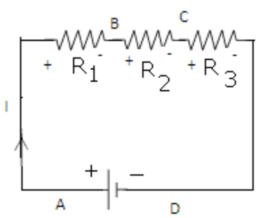


Fig Illustration of KVL

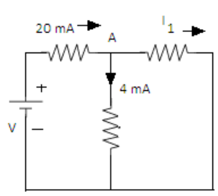
Now let us adopt a sign convention that the current entering the junction is positive & that leaving the junction is negative

We see that the current entering the junction A is I_T & current leaving the junction A = - (I_1 + I_2 + I_3)

According to KCL I_T - (I_1 + I_2 + I_3)= 0 or IT = I_1 + I_2 + I_3 i.e. I in = I out

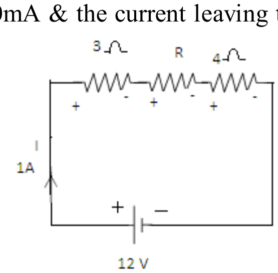
Following procedure is adopted for applying the KVL to any circuit.

1) First of all, select any point in the circuit as a starting point (say A) as shown in fig. Now let us move along the circuit in a clockwise direction & return to the starting point.
2) Go on adding algebraically, the values of each voltage source & voltage drop across resistance. Care should always be taken to write down the first sign & the magnitude of the voltage source or voltage drop across resistance.
3) After returning back to the starting point, equate the sum of all the voltages in the circuit to zero.



Ex1: From the circuit shown find the value of current I_1

Solution : Given current entering the junction A = 20mA & the current leaving the junction = I_1+4, □ I_1=16mA.



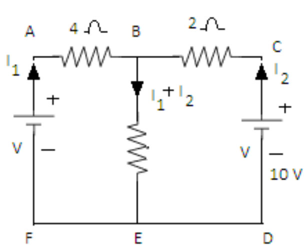
Ex2: In a circuit shown, find the value of the unknown resistance R, by applying KVL.

Solution: Given: I=1A. Applying KVL (1*3)+ (R*1)+ (1*4) =0 R=5Ω

Ex3: Using Kirchhoff's laws, calculate the branch currents in the network shown in fig

Solution: As shown in fig, we have taken I1 & I2 as originating from the positive terminals of the batteries. However, it is not always essential to do so because a stronger battery can drive current tnto one with lower emf i.e. it can charge it. We will consider two closed loops.

1) Loop ABEFA: starting from point A & going clockwise round the loop, we have



4I1 + 8(I1+I2)-12 =0

12 I1+ 8 I2=12; 3I1+2I2=3

2) Loop BCDEB: Starting from point B & going clockwise round the loop, we get

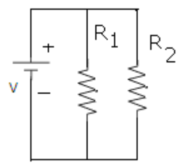
2I2-10+8(I1+I2)=0; 2I2-10 +8I1+8I2=0 8I1+10I2=10 4I1+5I2=5

3I1+2I2=3 *5 15I1+10I2=15

4I1+5I2=5 *2 -8I1-10I2=-10

7I1=5; I1= 5/7 A Therefore I2 = 3/7A

Since these have come out to be positive, it means that their assumed

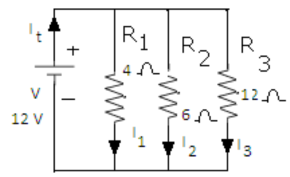


directions are the actual directions. Therefore current through branch BE I1+I2=8/7=1*1/7 A

Resistances in series Rt= R1+R2+R3

Resistances in parallel 1/Req = 1/R1+1/R2

Consider a simple two branched parallel circuit consisting of two resistances R1 & R2 as shown in fig.



1/Req= 1/R1+1/R2 therefore Req=R1*R2/(R1+R2)

Ex: Find the equivalent resistance of a two branched circuit, if R1=R2=10KΩ

Req= R1*R2/(R1+R2)= 10 * 10/(10 +10) K= 5KΩ

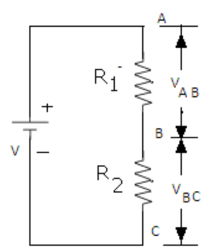
Ex: A circuit consists of three resistances connected in parallel as shown. Determine equivalent resistance & branch currents in the circuit.

Solution: Given V=12V , R1 = 4Ω, R2=6Ω, R3=12Ω

1/Req = 1/R1+1/R2 =1/R3 = ¼ + 1/6 + 1/12 = 6/12 = ½ Therefore Req=2Ω

I1= V/R1= 12/4 = 3A, I2 = V/R2= 12/6 = 2A, I3 = V/R3= 12/12 = 1A

Voltage division rule: The voltage drop across any resistance in a series circuit is equal to the value of that resistance to the total resistance multiplied by the source voltage.



Vab = R1/Rt V = R1/(R1+R2) V

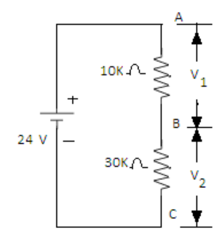
Vbc= R2/Rt V = R2/(R1+R2) V

Ex : Find out the voltage V1 & V2 for the circuit as shown in fig.

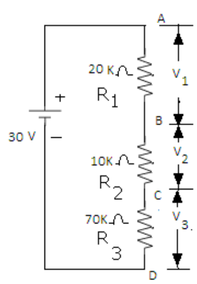
Given : V=24 V, R1 = 10 K Ω, R2= 30 KΩ, V2=?

V1= (10/(10 + 30)) 24 = 6V

V2= (30/(10 + 30)) 24 = 18V



Ex: Fig shows a voltage divider circuit with resistance R1, R2, R3 connected across a 30 V battery. Determine a) the voltage drop across R1, R2, R3& b) the voltage at each node.



Solution: Given : V= 30 V R1 = 20 KΩ, R2=10 KΩ, R3=70 KΩ

Rt= R1+ R2+ R3= 100KΩ

Voltage drop across R1is V1= R1/Rt= 20/100 * 30 = 6V

Voltage drop across R2is V2= R2/Rt= 10/100 * 30 = 3V

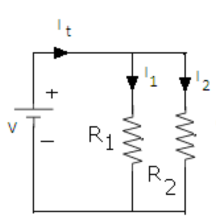
Voltage drop across R3is V3= R3/Rt= 70/100 * 30 = 21V

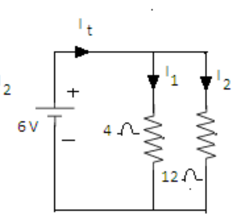
Voltage at node C = Vc =V3+Vd = 21 + 0 = 21 V

Voltage at node B= VB =V2+VC = 3 + 21 = 24 V

Voltage at node A = VA =V1+VB = 6 + 24 =30 V

Current division rule: The total current divider itself among the parallel branches in a manner proportional to their resistance values.





It = I1 + I2

I1 = R2/(R1 + R2) * It & I2 = R1/(R1 + R2) * It

Ex: two resistances of 4 Ω & 12 Ω are connected in parallel across a 6 V battery. Determine the amount of current through each resistance.

Solution: Given R1 = 4 Ω & R2 =12 Ω & V = 6V

Req= R1*R2/(R1+R2) = 4*12/(4+12) =3 Ω

Total current It = V/req= 6/3= 2A

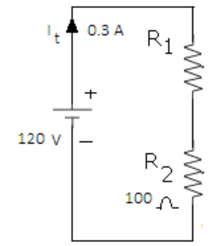
Current through R1is I1= (R2/(R1+R2)) * It= 12/(4+12) *2=1.5A

Current through R2is I2= (R1/(R1+R2)) * It= 4/(4+12) *2=0.5A

Power in series circuits: The power needed to produce current in each series resistance is used up in the form of heat. Therefore, the total power used is the sum of the individual values of power dissipated in each component of the circuit. Mathematically Pt= P1 + P2 + P3 + ……

Where P1, P2, P3 ….. are individual values of power dissipated in each component of the circuit. The total dissipated in the circuit is always equal to the power generated by the source.

Ex: Two resistances R1 & R2 are connected in series. How much resistance R1 must be needed in series with a 100 Ω R2 to limit the current to 0.3 A with a 120 V applied? How much power is dissipated in each resistance?



Given: R2 = 100 Ω, I=0.3A, Vt=120V

Let Rt be the total resistance I = Vt/Rt 0.3 = 120/ Rt

Rt= 400 Ω, therefore R1 = 300 Ω

Now $P1 = I^2 R1 = (0.3)^2\ 300 = 0.09 * 300 = 27$ w

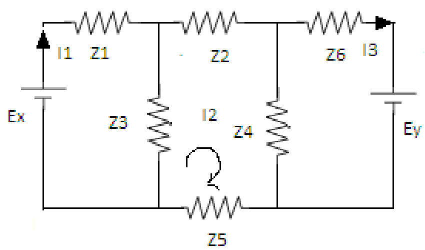
$P2 = I^2 R2 = (0.3)^2\ 100 = 0.09 * 100 = 9$ w

Total power in a parallel circuit: The total power in a parallel circuit, is the sum of the individual values of power dissipated in the circuit. It is also equal to the total power generated by the source. Mathematically, total power

Pt = P1 + P2+ P3+ ….. Where P1,P2, P3 are the individual values of power dissipated in the branches. (It may be noted that total power formula is the same for a series & a parallel circuit. It is due to the fact that series or parallel connection can change the distribution of voltage & current. But power is the rate at which energy is supplied by the source to the circuit & cannot change with a circuit arrangement.)

Kirchhoff's laws provide two methods for the solutions of networks. The potential law leads to the method of network solution known as mesh or loop analysis. The current law leads to node or junction analysis.

Mesh analysis method: Consider the circuit in fig. Applying potential law to the three meshes or loops, we write the three relations.



I1Z1+ (I1-I2)* Z3-Ex = 0 ……. (i)

-(I1-I2) *Z3 + I2 (Z2 + Z5) – (I3-I2) Z4 =0 …..(ii)

(I3-I2) Z4 + I3 Z6 + Ey =0 ………..(iii)

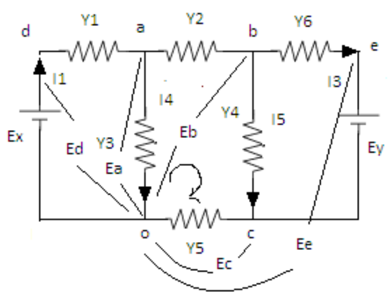
A solution for the three currents can then be obtained. To find the potentials between junctions we form additional two currents given by

I4 = I1-I2 …..(iv)

I5 = I2- I3 ….. (v)

By using these two relations potentials between any pair of junctions in the network may be obtained, the solution is complete.

Nodal analysis method: In many circuits voltages between junctions or nodes are the primary objective of the solution. This can be obtained by node or junction analysis. This method starts with the assumed branch currents & uses admittance instead of impedances.



Some convenient junction between elements is chosen as a reference junction or node & is indicated as o as reference junction it is possible to write five nodal equations.

Two of the node voltage equations may be written directly as

Ed = Ex …..(i) Ee = Ey+Ec ……(ii)

Writing a current summation at junction a gives I1-I2 – I4 = 0

Which in terms of potentials & admittance is:

(Ex-Ea) Y1 – (Ea- Eb) Y2 – Ea Y3 = 0 ……(iii)

At junction b , I2-I3-I5 = 0

(Ea-Eb) Y2-(Eb-Ec-Ey) Y6 – (Eb-Ey) Y4= 0 …..(iv)

At junction c , I3-I2+I5=0

(Eb-Ex-Ey)Y6 + (Eb-Ec) Y4- EcY5=0…..(v)

Equations iii), iv), v) give all potentials information at once.