SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
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SCHOOL OF COMPUTING

ELECTRICAL AND ELECTRONICS ENGINEERING (SEEA1103)

UNIT – I
DC CIRCUITS

Electrical /Quantities – Definitions, Symbols and / Units

- **Charge:**

A body is said to be changed positively, if it has deficit of electrons. It is said to be charged negatively if it has excess of electrons. The charge is measured in Coulombs and denoted by Q (or) q.

1 Coulomb = Charge pm 6.28×10^{18} electrons.

Electrical /Quantities – Definitions, Symbols and / Units

- **Electric Potential:**

When a body is charged, either electrons are supplied on it (or) removed on from it. In both cases the work is done. The ability of the charged body to do work is called electric Potential. The charged body has the capacity to do (or) by moving the other charges by either attraction Repulsion.

The greater the capacity of a charged body to do work, the greater is its electric potential And, the work done, to charge a body to 1 coulomb is the measure of electric Potential.

Electric Potential, $V = \frac{Workdone}{Charge} = \frac{W}{Q}$

W = Work done per unit charge.

Q = Charge measured in coulombs.

Unit of electric potential is **joules / Coulomb (or) volt**. If W1= 1 joule; Q= 1 coulomb, then V=1/1 = 1 Volt.

A body is said to have and electric potential of 1 volt, if one joule of work is done to / charge a body to one coulomb. Hence greater the joules / coulomb on charged body, greater is electric Potential.

Electrical /Quantities – Definitions, Symbols and / Units

- **Potential Difference**:

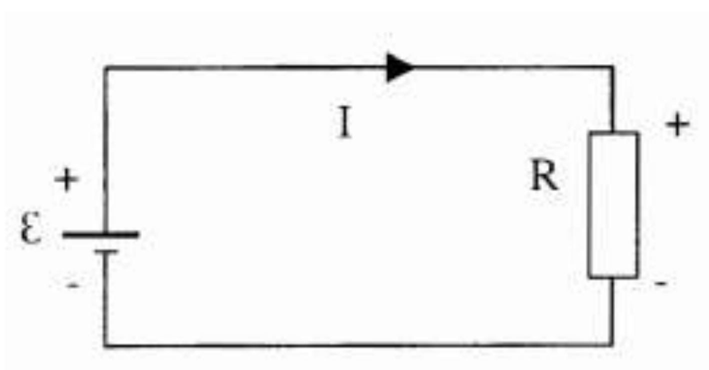
The in the potentials of two charged bodies is called potential difference.
difference

Electric Current:

Flow of free electrons through a conductor is called electric current. Its unit is ampere (or) Coulomb / sec.

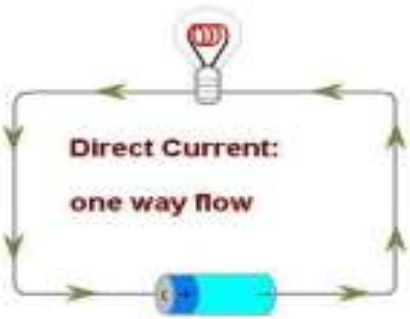
$$Current(i) = \frac{Charge(q)}{Time(t)} = \frac{q}{t} couombs/second$$

In differential Form, $i = \frac{dq}{dt} coulombs/second$

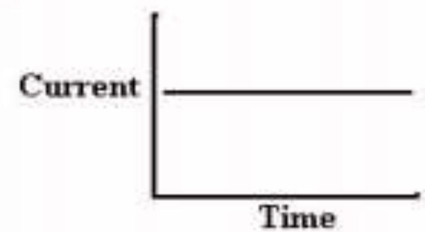


Electrical /Quantities – Definitions, Symbols and / Units

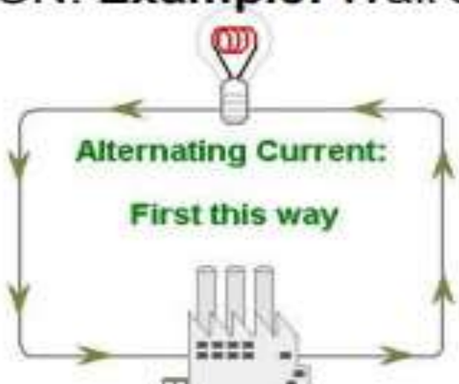
There are 2 types of Current

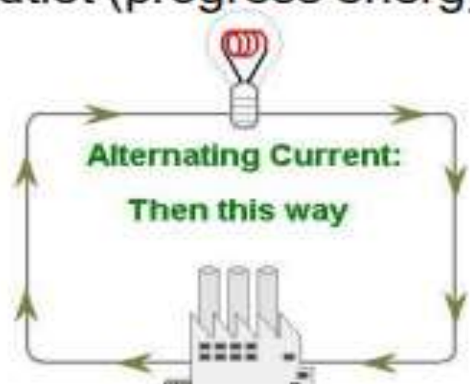


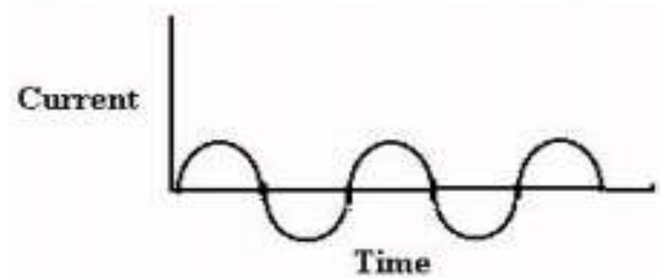
DC = Direct Current - current flows in one direction
Example: Battery



AC = Alternating Current- current reverses direction many times per second. This suggests that AC devices turn OFF and ON. **Example:** Wall outlet (progress energy)





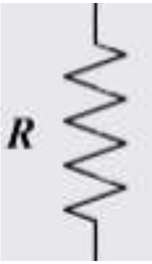


Electrical /Quantities – Definitions, Symbols and / Units

- **Resistance:**

Resistance is defined as the property of the substance due to which restricts the flow of electrons through the conductor. Resistance may, also be defined as the physical Property of the substance due to which it opposes (or) Restricts the flow of electricity (ie electrons) through it. Its unit is ohms.

A wire is said to have a resistance of 1 ohm if a p.d. /of 1V across the ends causes current of 1 Amp to flow through it (or) a wire is said to have a resistance of 1 ohm if it releases 1 joule, when a current of 1A flows through it.



Electrical /Quantities – Definitions, Symbols and / Units

- **conductors**

Certain substances offer very little opposition to the flow of electric current, they are called as conductors for examples, metals, acids etc. Amongst Pure metals, Sliver, Copper and aluminium are very good conductors.

- **Insulators**

Certain substances offer very high opposition to the flow of electric current, they are called as insulators. For eg, Bakelite, mica, glass, rubber, P.V.C, dry wood etc. The substance, whose properties lies between those of Conductors and insulators are called semi-conductors, for eg, Silicon, Germanium etc.

Electrical /Quantities – Definitions, Symbols and / Units

- **Laws of Resistance:**

The electrical resistance (R) of a metallic conductor depends upon the various Factors as given below,

i. It is directly proportional to length l, ie, R αl

ii. It is l inversely proportional to the Cross Sectional area of the Conductor, ie,$R \propto \frac{1}{A}$

iii. It depends upon the nature of the matter of the Conductor.

iv. It depends upon the temperature of the conductor.

Therefore by assuming the temperature to remain constant, we get,

$$R \propto \frac{1}{A}$$

$$R = \rho \frac{1}{A}$$

ρ (‘Rho’) is a constant of proportionality called **resistivity** (or) Specific resistance of the material of the conductor. The value of *r* depend upon the nature of the material of the conductor.

Electrical /Quantities – Definitions, Symbols and / Units

- **Specific Resistance (or) Resistivity:**

Resistance of a wire is given by $R = \rho \frac{1}{A}$

Resistivity is the property (or) nature of the material due to which it opposes the Flow of Current through it. The unit of resistivity is ohm-metre.

$\rho = \frac{RA}{l}$ =(Ω m^2)/m= Ωm=ohm-metre

- **Conductance (or) Specific Conductance:**

Conductance is the inducement to the flow of current. Hence, Conductance is the reciprocal of resistance. It is denoted by symbol G.

$$G = \sigma \frac{A}{l} \text{(or)} \sigma = G \frac{l}{A}$$

G is measured in mho

$$\sigma = \frac{mho*m}{m^2} = mho/metre$$

The S.I unit of Conductivity is mho/metre.

Electrical /Quantities – Definitions, Symbols and / Units

- **Electric Power:**

The rate at which the work is done in an electric Circuit is called electric power.

$$\text{Electric Power} = \frac{\text{Work done in electric circuit}}{\text{Time}}$$

When voltage is applied to a circuit, it causes current to flow through it. The work done moving the electrons in a unit time is called electric power. The unit of electric Power is Joules/sec or Watt.[$P = VI = I^2R = V^2 / R$]

Electrical Energy:

The total work done in an electric circuit is called electrical energy. ie, Electrical Energy = electric power * time. Electrical Energy is measured in

Kilowatt hour (kwh)

Problem

The resistance of a conductor $1mm^2$ in Cross section and 20m long is 0.346Ω. Determine the Specific resistance of the conducting material.

- **Given Data**

Area of Cross-Section A = $1mm^2$

Length, l = 20m

Resistance, R = 0.346Ω

Formula used: Specific resistance of the Conducting Material, $R = \rho \frac{1}{A}, \rho = \frac{RA}{l}$

- **Solution:** Area of Cross-section, $A = 1mm^2 = 1 * 10^{-6}\ m^2$

$$\rho = \frac{1*10^{-6}*0.346}{20} = 1.73*10^{-8}\ \Omega m$$

- Specific Resistance of the conducting Material, ρ **=** $1.738*10^{-8}$Wm.

Problem

A Coil consists of 2000turns of Copper wire having a Cross-sectional area of 1mm^{2}. The mean length per turn is 80cm and resistivity of copper is 0.02μΩm at normal working temperature. Calculate the resistance of the Coil.

Given data:

No of turns = 2000

Length /turn = 80cm = 0.8m

Resistivity = ρ = 0.02μΩm = 0.02*10-6 P = 2*10-8Ωm.

Cross-Sectional area of the wire, A = 1mm2 = 1*10-6m

Solution:

Mean length of the wire, l = 2000*0.8 = 1600m.

We know that $R = \rho \frac{1}{A}$

Substituting the Values,

$$R = \frac{2*10^{-8}*1600}{1*10^{-6}} = 32\Omega$$

Resistance of the Coil =32Ω.

Ohm’s law and its limitations:

The relationship between the potential difference (V), the current (I) and Resistance(R) in a d.c. Circuit was first discovered by the scientist George Simon ohm, is called ohm’s law.

Statement:

The ratio of potential difference between any two points of a conductor to the current following between them is constant, provided the physical condition (eg. Temperature, etc.) do not change. ie, $\frac{V}{I} = \text{Constant}$

(or)

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

- Where, R is the resistance between the two points of the conductor. It can also be stated as, provided Resistance is kept constant, current is directly proportional to the potential difference across the ends of the conductor.

  Power $P = V * I = I^2 R - \frac{V^2}{R}$
- **Limitations**:

(i) Ohm’s law does not applied to all non-metallic conductors. For eg. For Silicon carbide.

(ii) It also does not apply to non-linear devices such as zener diode, voltage Regulators.

(iii)Ohm’s law is true for metal conductor at constant temperature. If the temperature changes the law is not applicable.

Problems based on ohm's law

1.An electric heater draws 8A from 250V Supply. What is the power rating? Also find the resistance of the heater Element.

Given data:

Current, $I = 8A$

Voltage, $V = 250V$

Solution:

Power rating, $P = VI = 8*250 = 2000 Watt$

Resistance $(R) = \frac{V}{I} = \frac{250}{8} = 31.25\Omega$

Problems based on ohm's law

2. What will be the current drawn by a lamp rated at 250V, 40Watt, connected to a 230V Supply.

Given Data:

Rated Power = 40W

Rated Voltage = 250V

Supply Voltage = 230V

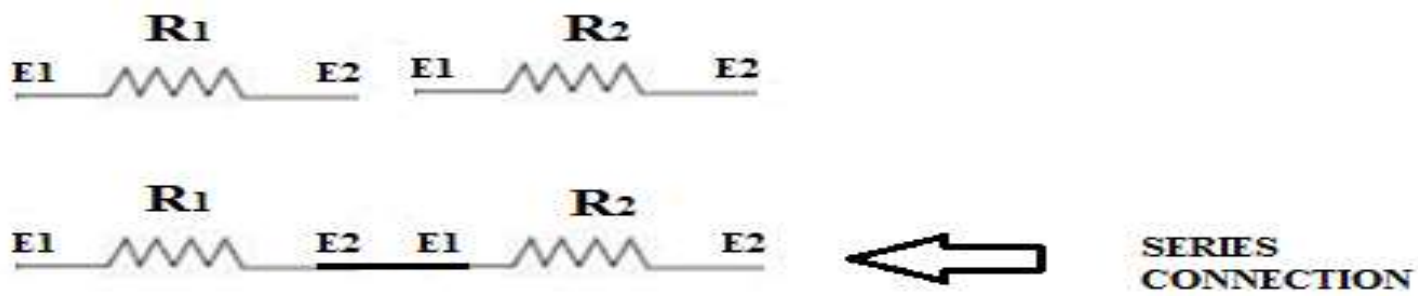
Solution:

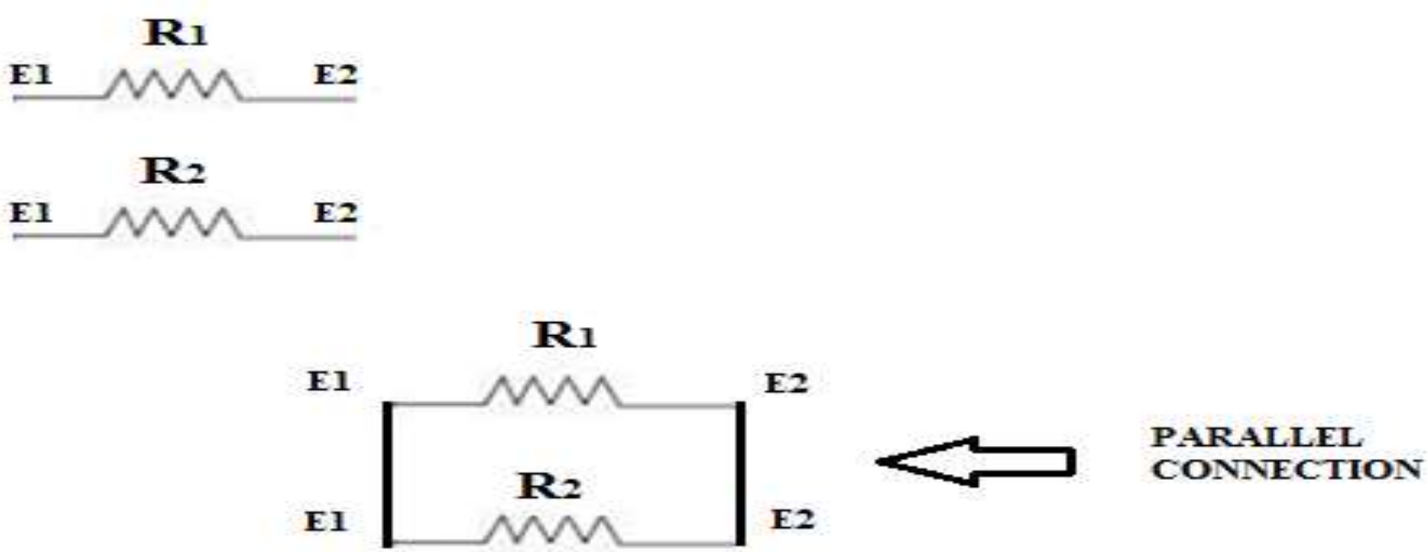
Resistance,

$$R = \frac{V^2}{P} = \frac{250^2}{40} = 1562.5\Omega$$

$$Current, I = \frac{V}{P} = \frac{230}{1562.5} = 0.1472A$$

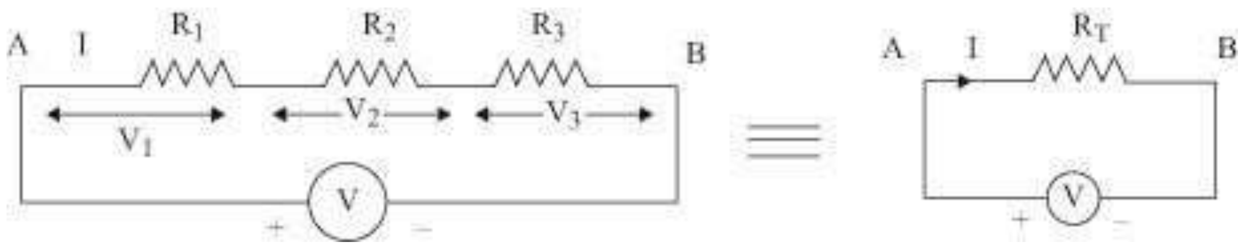
Combination of Resistors
SERIES AND PARALLEL CONNECTION





Resistances in series (or) series combination

The circuit in which resistances are connected end to end so that there is one path for the current flow is called **series circuit**. The voltage source is connected across the free ends A and B.



In the above circuit, there is only one closed path, so only one current flow through all the elements. In other words if the Current is same through all the resistors the combination is called series combination

To find equivalent Resistance: Let, V = Applied voltage

I = Source current = Current through each Element V1, V2, V3 are the voltage across R1, R2 and R3 respectively.

By ohms low, $V1 = IR1$, $V2 = IR2$ *and* $V3 = IR3$

But

$V = V1 + V2 + V3 = IR1 + IR2 + IR3 = I(R_1 + R_2 + R_3)$

$V = I(R_1 + R2 + R_3)$

$V = IR_T$

The ratio of (V/I) is the total resistance between points A and B and is called the total (or) equivalent resistance of the three resistances.

$R_T = R1 + R2 + R3$

Therefore Equivalent resistance (RT) is the sum of all individual resistances.

Concepts of series circuit

- The current is same through all elements.
- The voltage is distributed. The voltage across the resistor is directly proportional to the current and resistance.
- The equivalent Resistance (RT) is greater than the greatest individual resistance of that combination.
- Voltage drops are additive.
- Power are additive.
- The applied voltage equals the sum of different voltage drops.

Voltage Division Technique

To find V1, V2, V3 in terms of V and R1, R2, R3:

Equivalent Resistance, *RT*= *R*1 +*R*2 + *R*3

$$\text{By ohm's low, } I = \frac{V}{RT} = \frac{V}{R_1 + R_2 + R_3}$$

$$V_1 = IR_1 = \frac{V}{R_T} R_1 = \frac{VR_1}{R_1 + R_2 + R_3}$$

$$V_2 = IR_2 = \frac{V}{R_T} R_2 = \frac{VR_2}{R_1 + R_2 + R_3}$$

$$V_3 = IR_3 = \frac{V}{R_T} R_3 = \frac{VR_3}{R_1 + R_2 + R_3}$$

Voltage across any resistance in the series circuit,

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

Note: If there are n resistors each value of R ohms is series the total Resistance is given by,

RT =*n* * *R*

Series connection

Applications:

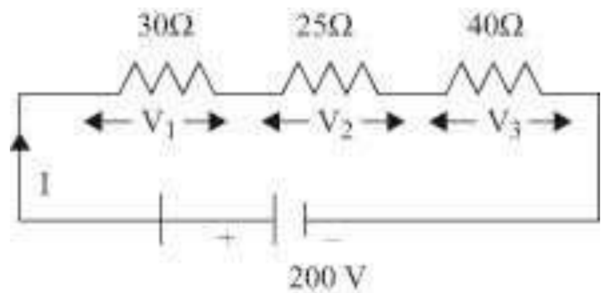
- When variable voltage is given to the load, a variable Resistance (Rheostat) is connected in series with the load. Example: Fan Regulator is connected in series with the fan.
- The series combination is used where many lamp of low voltages are to be operated on the main supply. Example: Decoration lights.
- When a load of low voltage is to be Operated on a high voltage supply, a fixed value of resistance is, connected in series with the load.

Disadvantage of Series Circuit:

- If a break occurs at any point in the circuit, current coil flow and the entire circuit become useless.
- If 5 numbers of lamps, each rated 230 volts are be connected in series circuit, then the supply voltage should be 5 x 230 = 1150volts. But voltage available for lighting circuit in each and every house is only 230v. Hence, series circuit is not practicable for lighting circuits.
- Since electrical devices have different current ratings, they cannot be connected in series for efficient Operation.

Problems based on series combination

Three resistors 30Ω, 25 Ω, 40 Ω are connected in series across 200v as shown in figure Calculate (i) Total resistance (ii) Current (iii) Potential difference across each element.



Total Resistance (R_T) =30+25+40=95

Current=200/95=2.10A

Potential difference across each element,

V30Ω=30*2.10=63V

V25Ω=25*2.10=52.5V

V40Ω=40*2.10=84V

Problems based on series combination

2. An incandescent lamp is rated for 110v, 100w. Using suitable resistor how can you operate this lamp on 220v mains.

Rated current of the lamp, $I = \frac{Power}{Voltage} = \frac{100}{110}$

I = 0.909A

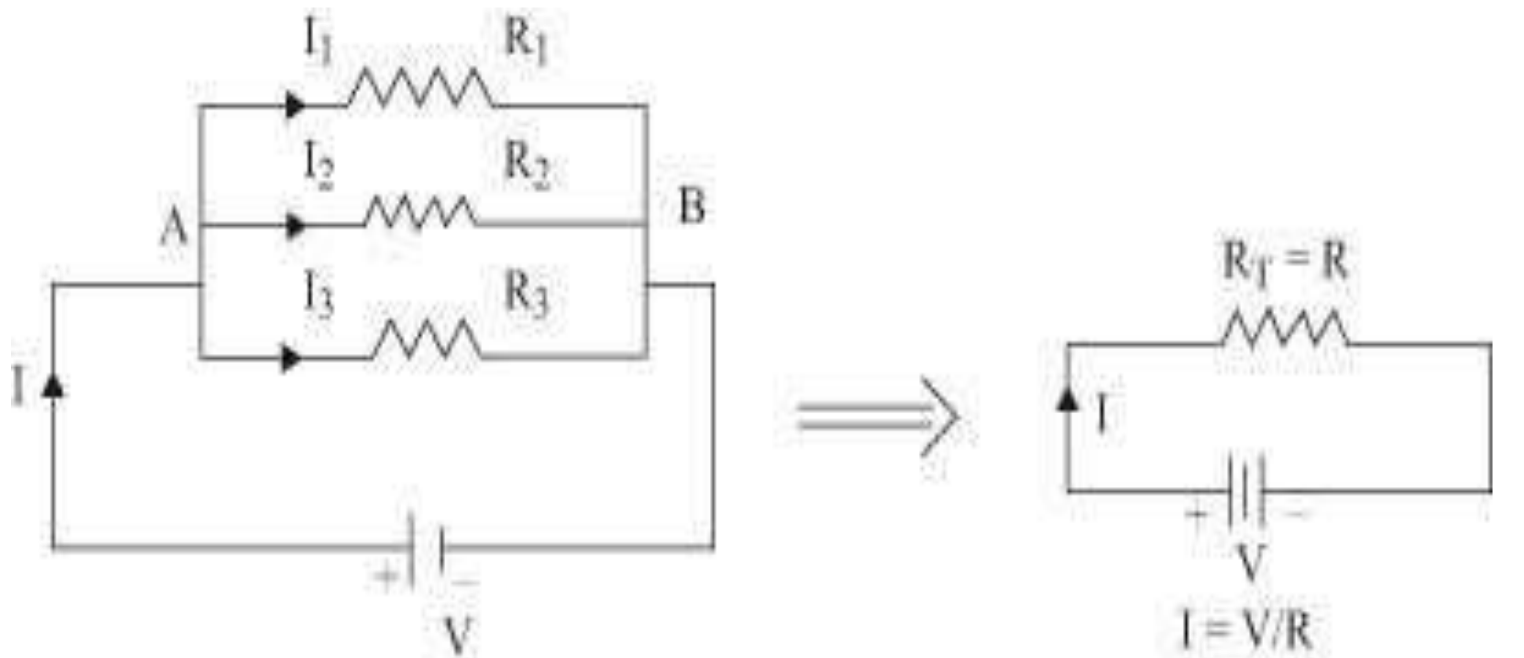
When the voltage across lamp is 110v, then the remaining voltage must be across R

$$\begin{aligned}
Supply\ voltage &= V = 220 Volts \\
Voltage\ across\ R &= V - 110 Volts \\
ie,\ V_R &= 220 - 110 = 110v \\
By\ ohm's\ law,\ V_R &= IR \\
110 &= 0.909 R \\
R &= 121\Omega
\end{aligned}$$

Resistance in Parallel (or) Parallel Combination

If one end of all the resistors is joined to a common point and the other ends are joined to another common point, the combination is said to be parallel combination. When the voltage source is applied to the common points, the voltage across each resistor will be same. Current in the each resistor is different and given by ohm's law.

Let R1, R2, R3 be three resistors connected between the two common terminals A and B,



Resistance in Parallel (or) Parallel Combination

$$I = \frac{V}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Let I_1, I_2, I_3 are the currents through R_1, R_2, R_3 respectively. By ohm's law,

$$\left[I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3} \right] \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Total current is the sum of three individual currents, $I_T = I = I_1 + I_2 + I_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$

Substituting the above expression for the current in equation (3), $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

If $R_T = R$,

Then $\frac{1}{R} = \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$

Hence, in the case of parallel combination the reciprocal of the equivalent resistance is equal to the sum of reciprocals of individual resistances.

Multiplying both sides of equation (4) by V^2, we get

$$\frac{V^2}{R} = \frac{V^2}{R_1} + \frac{V^2}{R_2} + \frac{V^3}{R_3}$$

Power dissipated by R1 = Power dissipated by R1 + Power dissipated by R2 + Power dissipated by R3

We know that reciprocal of Resistance is called as conductance.

$$\text{Conductance} = \frac{1}{\text{Resistance}} \left[G = \frac{1}{R} \right]$$

Equation (4) can be written as,

$G = G1 + G2 + G3$

Concepts of Parallel Circuit

- Voltage is same across all the elements.
- All elements we have individual currents, depends upon the resistance of element.
- The total resistance of a parallel circuit is always lesser than the smallest of the resistance.
- If n resistance each of R are connected in parallel, then

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots\ldots\ldots n\ terms$$

$$\frac{1}{R_T} = \frac{n}{R}$$

$$(or)\ R_T = \frac{R}{n}$$

Powers are additive.

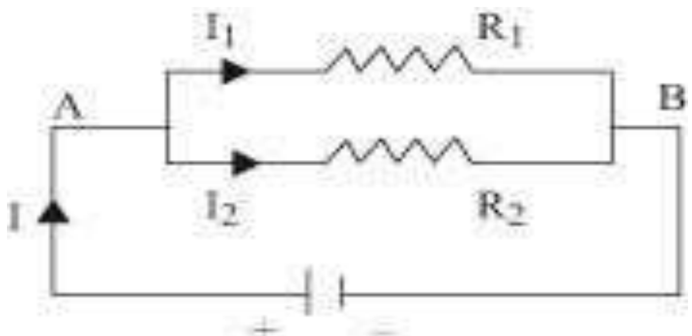
Conductance are additive.

Branch currents are additive.

Current Division Technique

Case (i) When two resistances are in parallel:

Two resistance *R*1 *and R*2 ohms are connected in parallel across a battery of V (volts) Current through *R*2 *is I*2 and through *R*2 *is I*2 as shown in figure 4. The total current is I.



To express I1 and I2 in terms of I, R1 and R2(or) To find Branch Currents I1, I2

I2R2 = I1R1

$$I_2R_2 = I_1R_1$$

$$I_2 = \frac{I_1R_1}{R_2} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Also, The total Current, $I = I_1 + I_2 \ldots\ldots\ldots\ldots\ldots (6)$

Substituting (5) in (6), $I_1 + \frac{I_1R_1}{R_2} = I$

$$\frac{I_1R_2 + I_1R_1}{R_2} = I$$

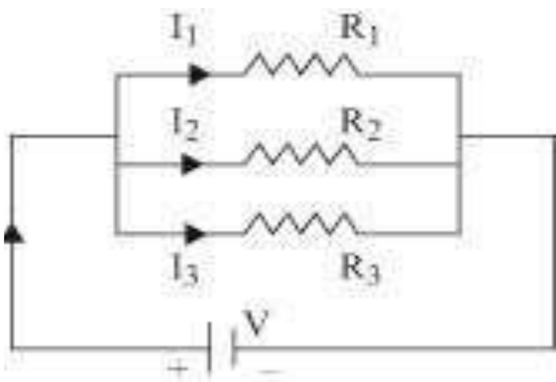
$$I_1(R + R_2) = IR_2$$

$$I_1 = \frac{IR_2}{(R_1 + R_2)}$$

Similarly, $I_2 = \frac{IR_1}{(R_1 + R_2)}$

Current Division Technique

Case (ii) When three resistances are connected in parallel. Let R1, R2 and R3 be resistors in parallel as shown in figure 1.5. Let I be the supply current (or) total curve I1, I2, I3 are the current through R1, R2 and R3.



To find the equivalent Resistance (R_T):

$$\frac{1}{R} = \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_T} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1R_2R_3}$$

$$R_T = \frac{R_1R_2R_3}{R_1R_2 + R_2R_3 + R_3R_1}$$

To find the Branch currents I_1, I_2 and I_3:

We know that, $I_1 + I_2 + I_3 = I$ ……………(7)

Also, $I_3R_3 = I_1R_1 = I_2R_2$

From the above expression, we can get expressions for I_2 and I_3 interms of I_1 and substitute them in the equation (7)

$$I_2 = \frac{I_1R_1}{R_2} ; I_3 = \frac{I_1R_1}{R_3}$$

$$I_1 + \frac{I_1R_1}{R_2} + \frac{I_1R_1}{R_3} = I$$

$$I_1(1 + \frac{R}{R_2} + \frac{R_1}{R_3}) = I$$

$$\frac{I_1(R_2R_3 + R_3R_1 + R_1R_2)}{R_2R_3} = I$$

$$I_1 = \frac{I(R_2R_3)}{(R_1R_2 + R_2R_3 + R_3R_1)}$$

Similarly we can express I_2 and I_3 as,

$$I_2 = \frac{I(R_1R_3)}{(R_1R_2 + R_2R_3 + R_3R_1)}$$

$$I_3 = \frac{I(R_1R_2)}{(R_1R_2 + R_2R_3 + R_3R_1)}$$

Resistors connected in parallel

Advantages of parallel circuits:

- The electrical appliances rated for the same voltage but different powers can be connected in parallel without affecting each other is performance.
- If a break occurs in any one of the branch circuits, it will have no effect on the other branch circuits.

Applications of parallel circuits:

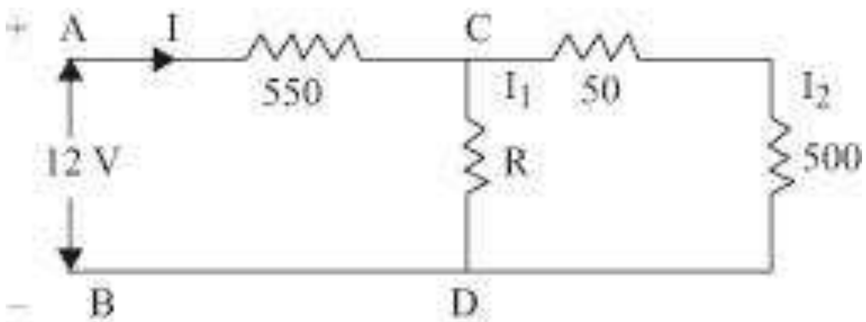
- All electrical appliances are connected in parallel. Each one of them can be controlled individually will the help of separate switch.
- Electrical wiring in Cinema Halls, auditoriums, House wiring etc.

Comparison of series and parallel circuits

Series Circuit	Parallel Circuit
The current is same through all the elements.	The current is divided,
The voltage is distributed. It is proportional to resistance.	The voltage is the same across each element in the parallel combination.
The total (or) equivalent resistance is equal to the sum of Individual Resistance, ie. $RT = R1 + R2 + R3$ Hence, the total resistance is greater than the greatest resistance in the circuit.	Reciprocal of resistance is equal to sum of reciprocals of individual resistances, ie, $\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$ Total resistance is lesser than the smallest of the resistance.
There is only one path for the flow of current.	There are more than one path for the flow of current.

Problems based on parallel Combinations

what is the value of the unknown resistor R in Figure 6, If the voltage drop across the 500Ω resistor is 2.5V. All the resistor are in ohms.



$$V_{500} = 2.5V$$

$$I_2 = \frac{V_{550}}{R} = \frac{2.5}{500} = 0.005A$$

V_{50} - Voltage across 50Ω

$V_{50} = IR = 0.005*50 = 0.25V$

$VCD = V_{50} + V500 = 0.25 + 2.5 = 2.75V$

$V_{550} =$ Drop across 550Ω $= 12 - 2.75 = 9.25V$

$$I = \frac{V_{550}}{R} = \frac{9.25}{550} = 0.0168A$$

$I = I_1 + I_2 \longrightarrow I_1 = I - I_2 = 0.0168 - 0.005$

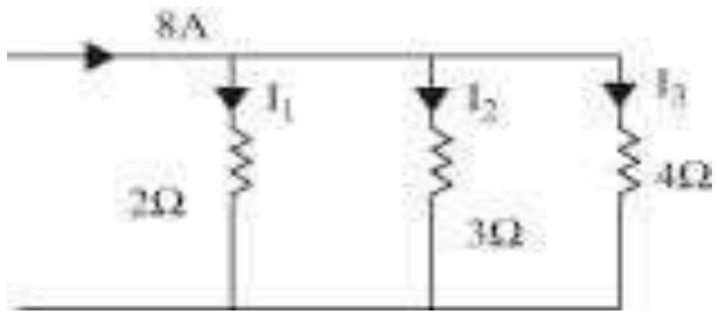
$I_1 = 0.0118A$

$$R = \frac{V_{CD}}{I} = \frac{2.75}{0.018} = 232.69\Omega$$

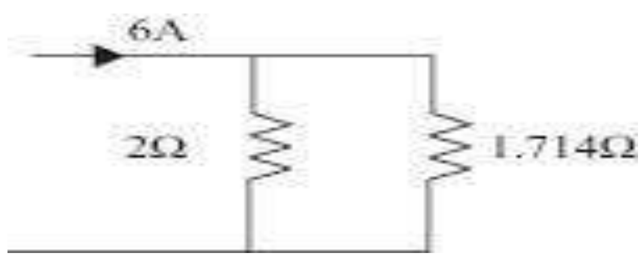
$R = 232.69\Omega$

Problems based on parallel Combinations

Three resistors 2Ω, 3Ω, 4Ω are in parallel. How will a total current of 8A is divided in the circuit shown in fig.

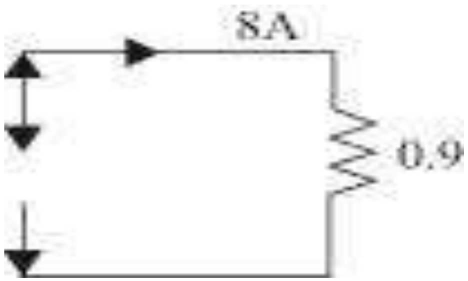


3Ω and 4Ω are connected in parallel. Its equivalent resistances are, $\frac{3*4}{3+4} = \frac{12}{7} = 1.714\Omega$



1.714Ω and 2Ω are connected in parallel, its equivalent resistance is 0.923Ω

$$\frac{1.714*2}{2+1.714} = 0.923\Omega$$



$$V = IR = 8*0.923$$
$$V = 7.385V$$

Branch Currents, $I_1 = \frac{V}{R_1} = \frac{7.385}{2} = 3.69$

$$I_2 = \frac{V}{R_1} = \frac{7.385}{3} = 2.46A$$

$$I_3 = \frac{V}{R_3} = \frac{7.385}{4} = 1.84A$$

Total current, I = 8A is divided as 3.69A, 2.46A, 1.84A.

3. what resistance must be connected in parallel with 10Ω to give an equivalent resistance of

6Ω R is connected in parallel with 10Ω Resistor to given an equivalent Resistance of 6Ω.

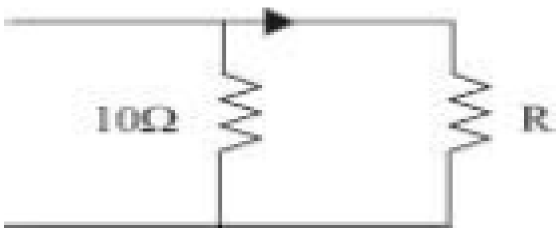


Figure 1.10

$$\frac{10 * R}{10 + R} = 6$$

$$10R = (10 + R)6$$

$$10R = 60 + 6R$$

$$10R - 6R \rightarrow 4R = 60$$

$$R = \frac{60}{4} = 15\Omega$$

$$R = 15\Omega$$

1. Find the equivalent resistance between the terminals A and B in the figure 1.17.

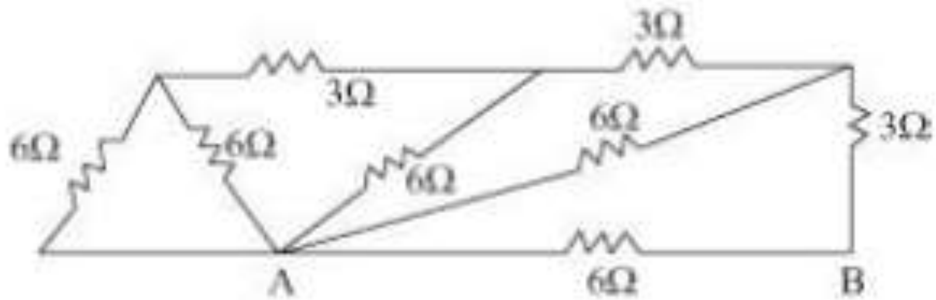


Figure 1.17

Solution: R_{AB}=3Ω.

3. Determine the value of R if the power dissipated in 10Ω Resistor is 90W in figure 1.18.

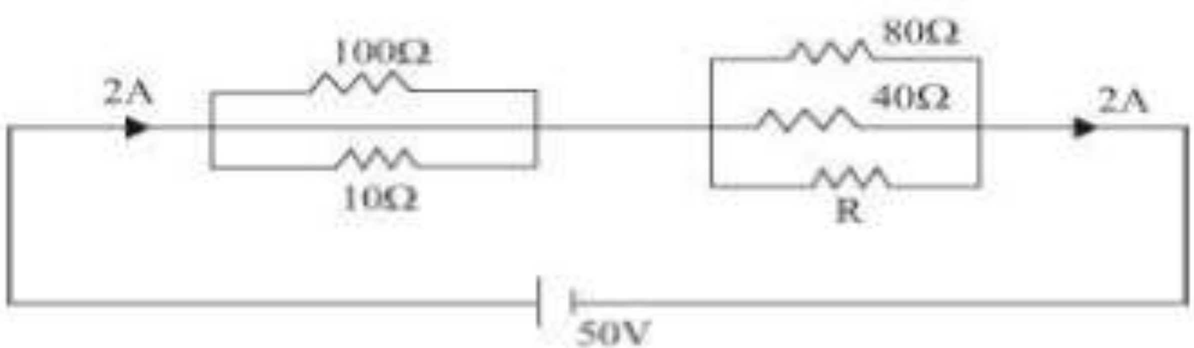
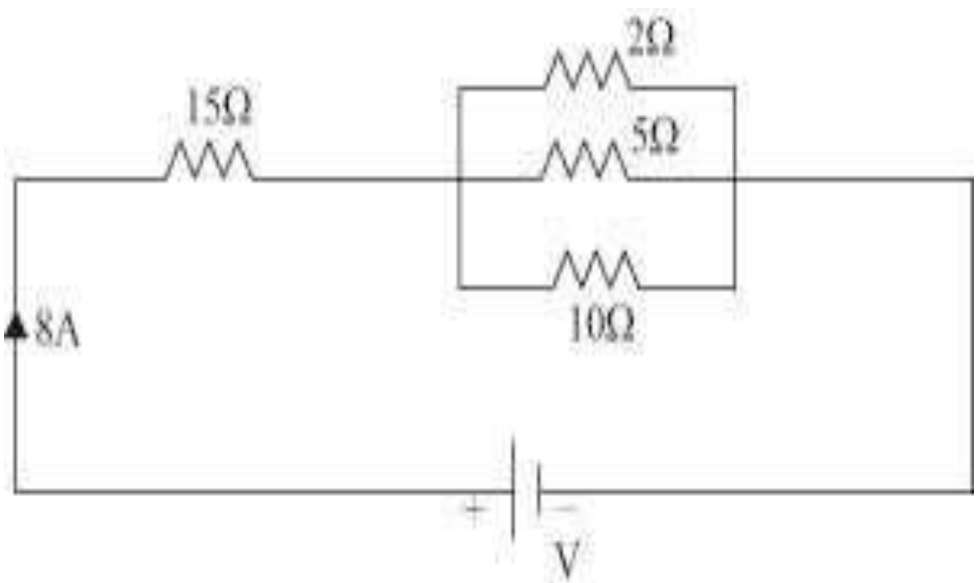


Figure1.18

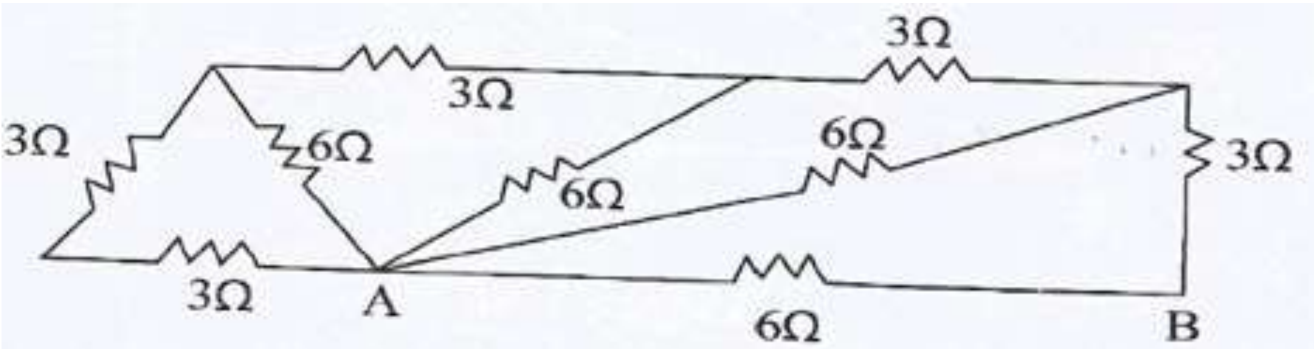
Solution: R = 39.4Ω.

In the Circuit shown in figure, find the Current in all the resist Also calculate the supply voltage.



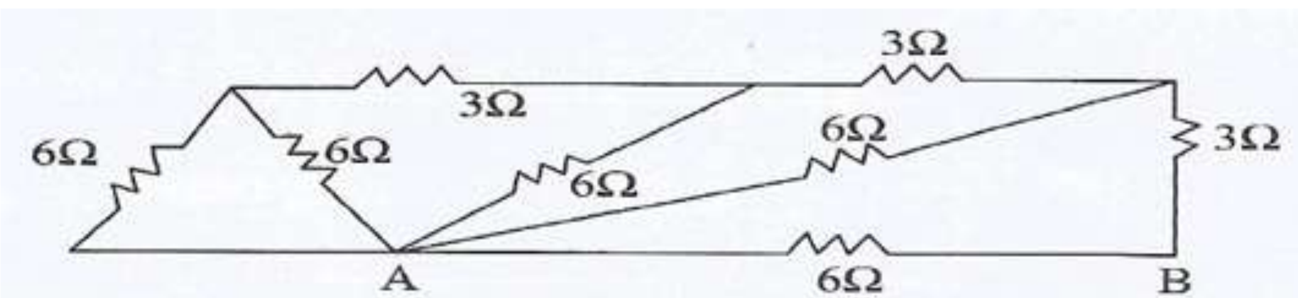
Solution: V=130 Volts.
Current through 2Ω resistor, is 5A.
Current through 5Ω Resistor, 2A
Current through 10Ω Resistor, 1A.

Find the Equivalent Resistance between the terminals A and B

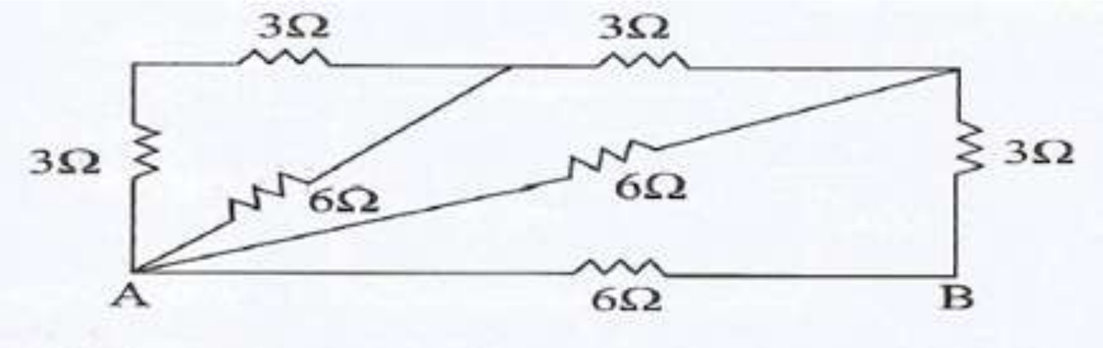


Solution

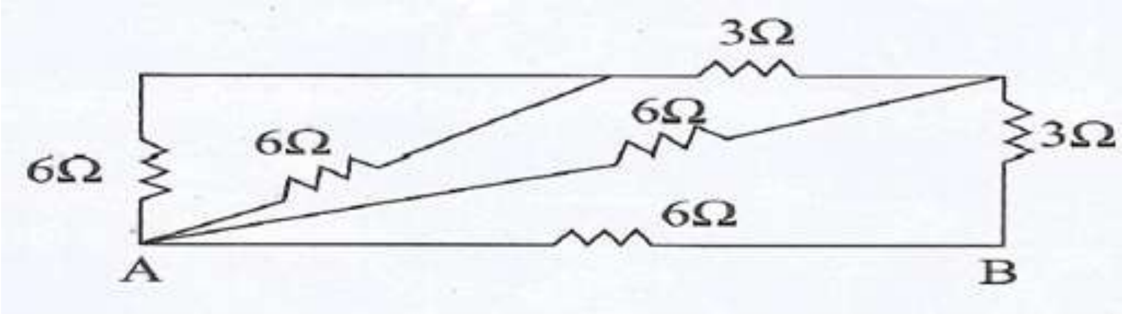
3Ω and 3Ω are connected in Series so 3+3=6 Ω



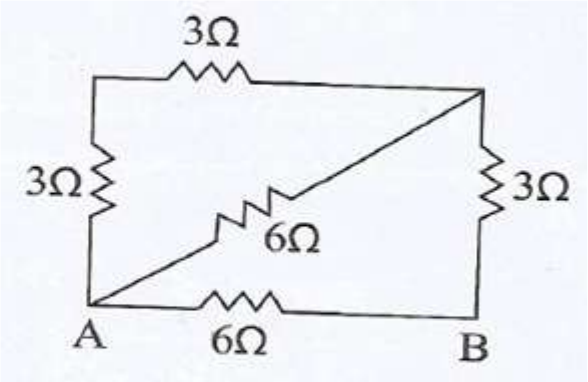
$$\frac{6*6}{6+6} = 3\Omega$$



3Ω and 3Ω are connected in Series so 3+3=6 Ω

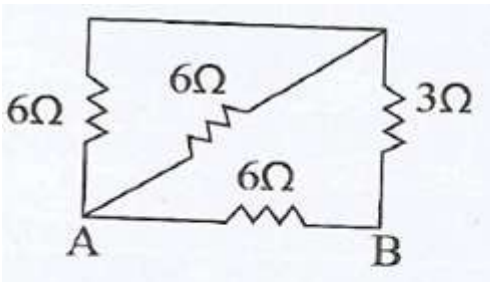


6Ω and 6Ω are connected in Parallel

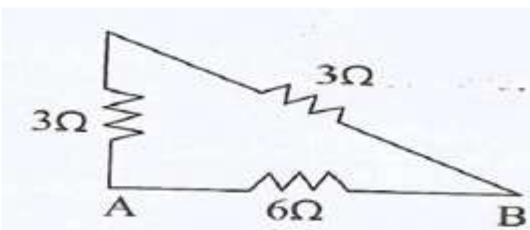


$$\frac{6*6}{6+6} = 3\Omega$$

3Ω and 3Ω are connected in Series so 3+3=6 Ω

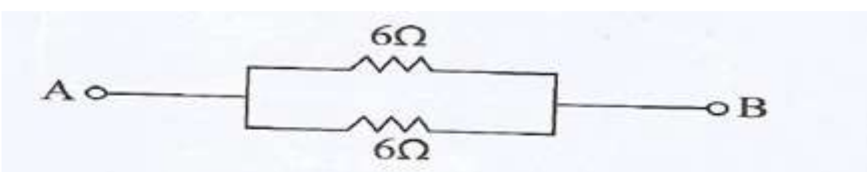


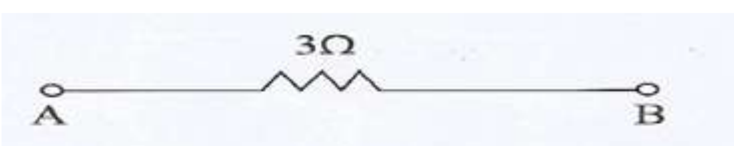
6Ω and 6Ω are connected in Parallel



$$\frac{6*6}{6+6} = 3\Omega$$

3Ω and 3Ω are connected in Series so 3+3=6 Ω





$R_{AB} = 3\Omega$

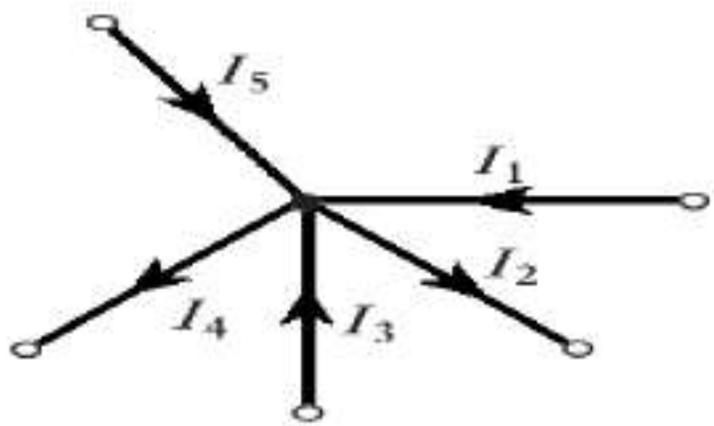
Kirchhoff’s Law

Kirchhoff’s Rules

- Used when a circuit is not a simple series and parallel combination of resistors;
- Often used when there is more than one voltage source in a circuit.

Kirchhoff’s First Law:

- The algebraic sum of the currents flowing through a junction is zero.
- Sum of the Currents approaching the junction are equal to the sum of the currents going away from the junction are Equal.



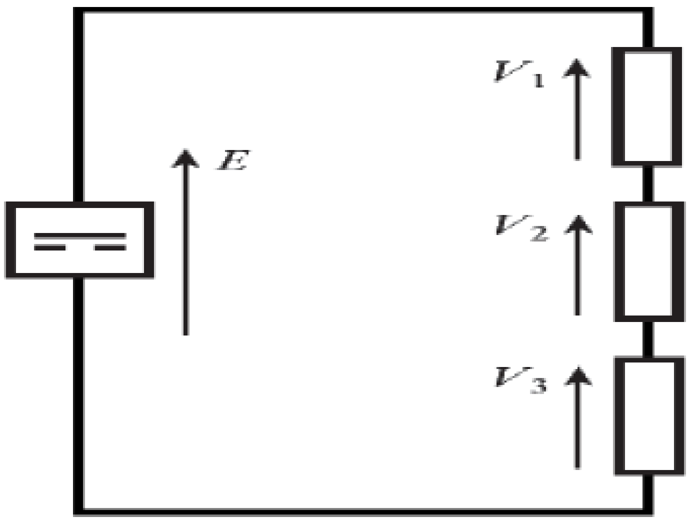
$$I_1 - I_2 + I_3 - I_4 + I_5 = 0$$

Kirchhoff's First Law

$$\sum I_{in} = \sum I_{out}$$

Kirchhoff's Second Law:

- The algebraic sum of the potential differences in a circuit loop must be zero. Potential rises are equal to potential drops in a closed circuit.



$$E - V_1 - V_2 - V_3 = 0$$

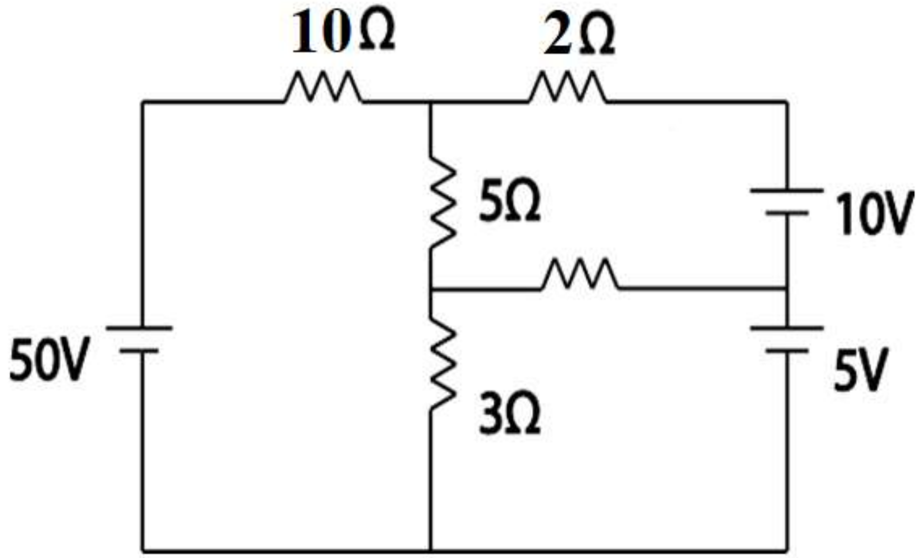
Kirchhoff's Second Law

$$\boxed{\sum \Delta V = 0}$$

Mesh Analysis

- A mesh is a loop which doesn’t contain any other loops within it.
- Loop (mesh) analysis results in a system of linear equations which must be solved for unknown currents.
- Mesh-Current method is developed by applying KVL around meshes in the circuit.
- It is applicable to a circuit with no branches crossing each other. It is only applicable to planar circuits (a circuit that can be drawn on a plane with no branches crossing each other).
- The current through a mesh is known as the mesh/loop current.

1. Find the current in 3Ω resistor using Mesh Analysis.

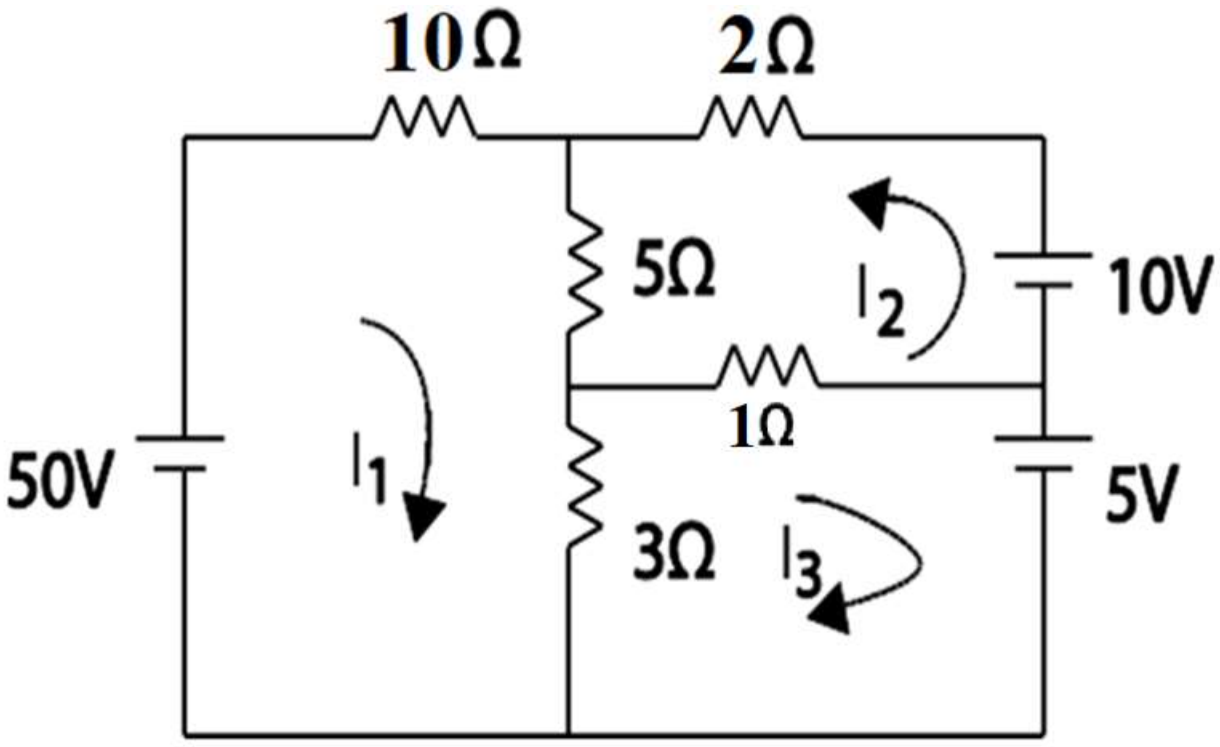


- 2 Methods:
  - Solving by writing linear equation
  - Direct Inspection Method

Equation Method

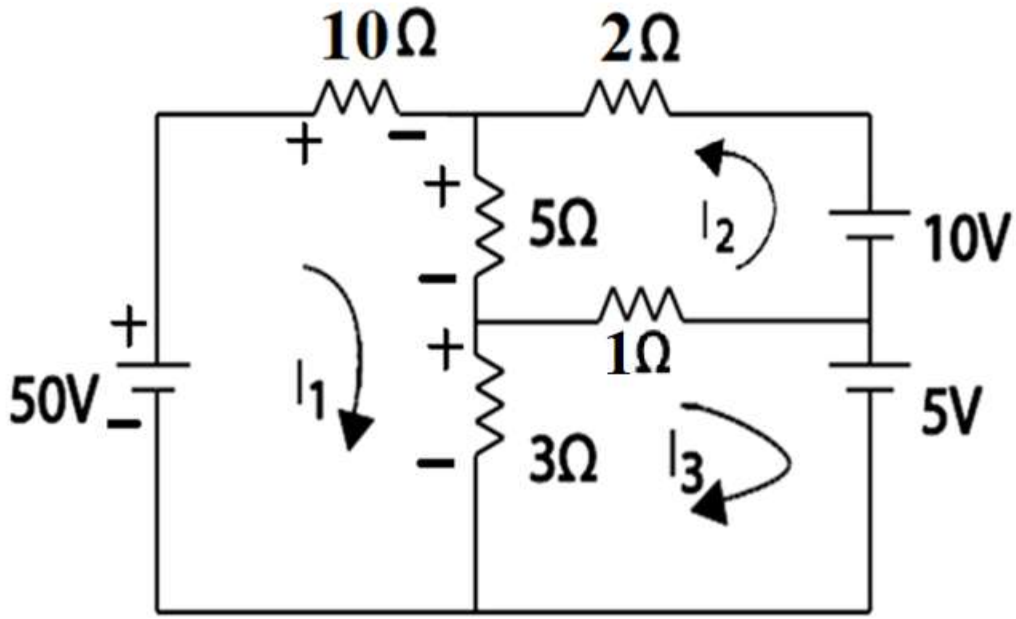
- n Meshes – n Equations / n x n Matrices
- n Meshes – n loops
  - n Loop currents I_1, I_2 …. I_n

- Assume the current direction for each loop



To find: Current in 3 ohms resistance = I1~I3

- Assign the potential for each resistor in the loop
  – Consider the first loop1:

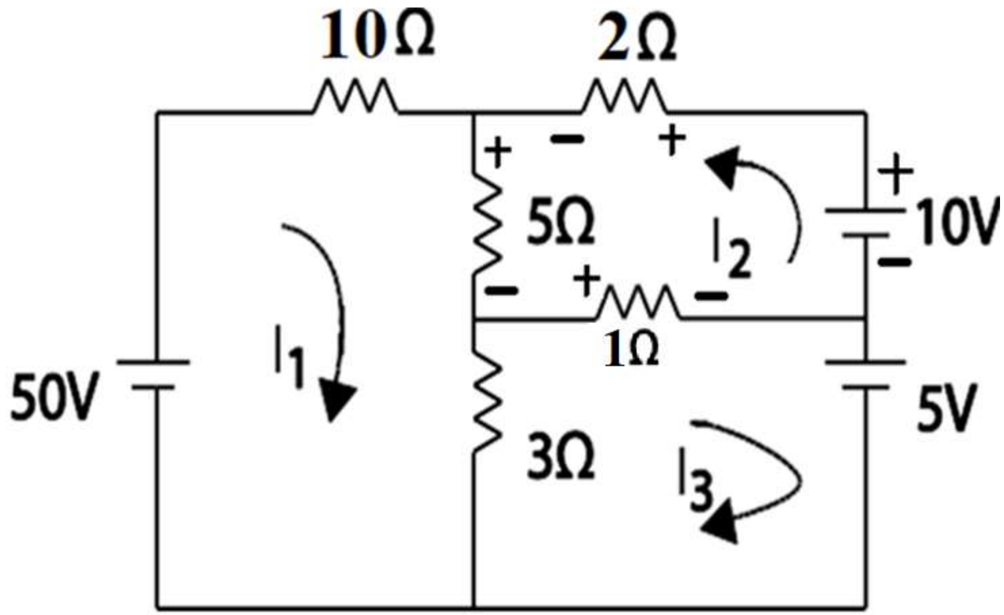


- For loop 1,

$$10I_1 + 5(I_1 + I_2) + 3(I_1 - I_3) = 50$$

$$18I_1 + 5I_2 - 3I_3 = 50 \qquad (1)$$

- Assign the potential in loop2

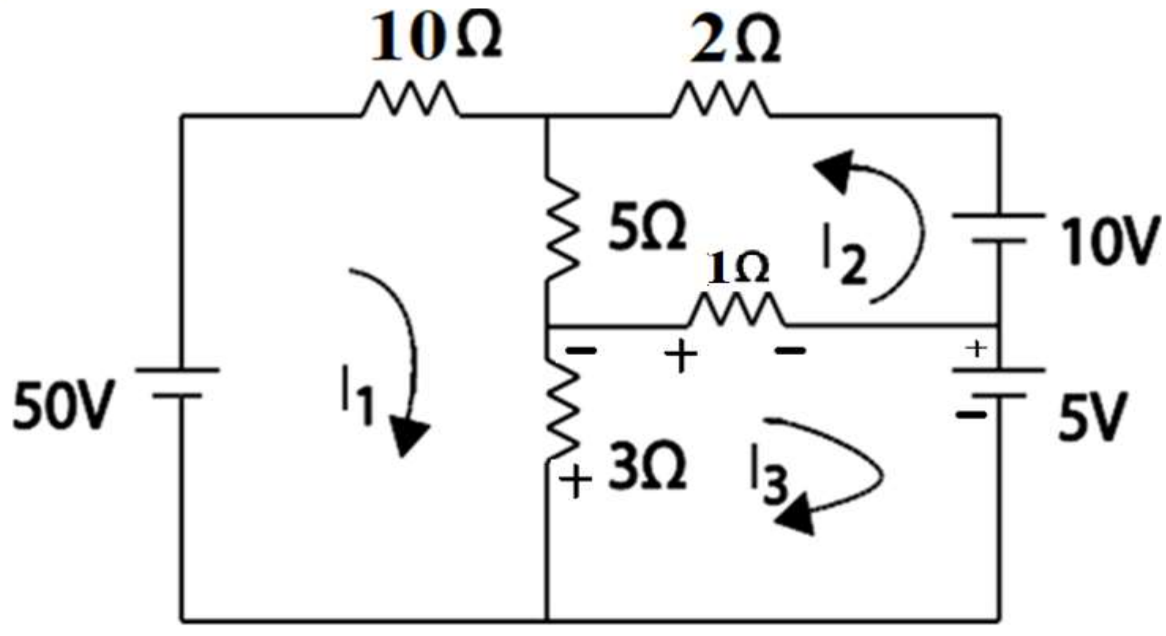


- For loop 2,

$$2I_2 + 5(I_2 + I_1) + 1(I_2 + I_3) = 10$$

$$5I_1 + 8I_2 + I_3 = 10 \qquad (2)$$

- Assign the potential in loop2



- For loop 3,

$$3(I_3 - I_1) + 1(I_3 + I_2) = -5$$

$$-3I_1 + I_2 + 4I_3 = -5 \qquad (3)$$

$$18I_1 + 5I_2 - 3I_3 = 50 \qquad (1)$$

$$5I_1 + 8I_2 + I_3 = 10 \qquad (2)$$

$$-3I_1 + I_2 + 4I_3 = -5 \qquad (3)$$

$$[R]\,[I] = [V]$$

$$\begin{bmatrix} 18 & 5 & -3 \\ 5 & 8 & 1 \\ -3 & 1 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 50 \\ 10 \\ -5 \end{bmatrix}$$

- To identify the current passes through 3 ohms resistance:
  - Current I_1 and I_3 are passing through the 3 ohms resistance in the opposite way.
  - Net current flow through the resistance 3 ohms

$$= I_1 \sim I_3$$

  - Therefore find the current I_3 and I_1 with Krammer's rule

- Krammer’s Rule:
  - Loop current $I_1 = \dfrac{\triangle_1}{\triangle}$
  - Loop current $I_2 = \dfrac{\triangle_2}{\triangle}$
  - Loop current $I_3 = \dfrac{\triangle_3}{\triangle}$

$$\Delta = \begin{bmatrix} 18 & 5 & -3 \\ 5 & 8 & 1 \\ -3 & 1 & 4 \end{bmatrix}$$

$$= 18\left(32-1\right) - 5\left(20+3\right) - 3\left(5+24\right)$$

$$= 356$$

To find $\triangle_1$, replace the first column in $\triangle$, by the voltage matrix

$$\begin{bmatrix} 18 & 5 & -3 \\ 5 & 8 & 1 \\ -3 & 1 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 50 \\ 10 \\ -5 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 18 & 5 & -3 \\ 5 & 8 & 1 \\ -3 & 1 & 4 \end{vmatrix}$$

$$\triangle_1 = \begin{vmatrix} 50 & 5 & 50 \\ 10 & 8 & 10 \\ -5 & 1 & -5 \end{vmatrix}$$

To find I_1

$$\triangle_1 = \begin{vmatrix} 50 & 5 & 50 \\ 10 & 8 & 10 \\ -5 & 1 & -5 \end{vmatrix}$$

$= 50(-40-10) - 5(-50-(-50)) + 50(10-(-40))$

$= -2500 - 0 + 2500 = 0$

$$I_1 = \frac{\triangle_1}{\triangle}$$

- $= 0/356 = 0A$

To find Δ_3 , replace the first column in Δ, by the voltage matrix

$$\begin{bmatrix} 18 & 5 & -3 \\ 5 & 8 & 1 \\ -3 & 1 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 50 \\ 10 \\ -5 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 18 & 5 & -3 \\ 5 & 8 & 1 \\ -3 & 1 & 4 \end{vmatrix}$$

$$\Delta_3 = \begin{vmatrix} 18 & 5 & 50 \\ 5 & 8 & 10 \\ -3 & 1 & -5 \end{vmatrix}$$

To find I_3

$$\Delta_3 = \begin{vmatrix} 18 & 5 & 50 \\ 5 & 8 & 10 \\ -3 & 1 & -5 \end{vmatrix}$$

$= 18(-40-10) -5(-25+30) +50(5+24)$

$= -900-25+1450$

$= 525$

$I_3 = \dfrac{\Delta_3}{\Delta} = 525/356 = 1.47A$

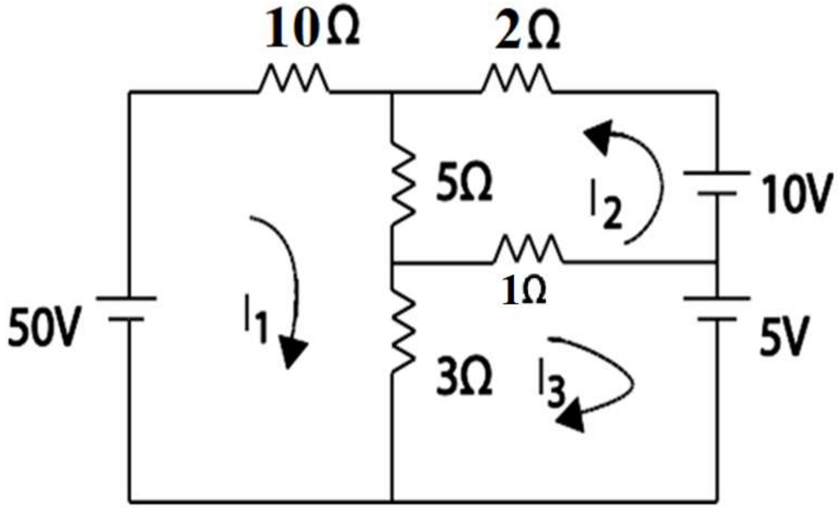
- Current flowing through resistance 3 ohms

$$= I1 \sim I_3$$

$$= 0 \sim 1.47$$

$$= 1.47 \text{ A}$$

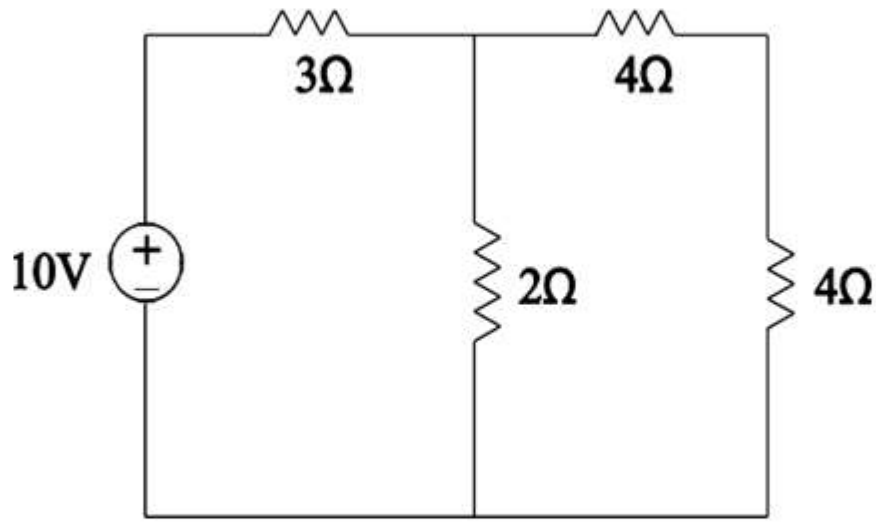
Direct Inspection Method



$$\begin{bmatrix} 18 & 5 & -3 \\ 5 & 8 & 1 \\ -3 & 1 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 50 \\ 10 \\ -5 \end{bmatrix}$$

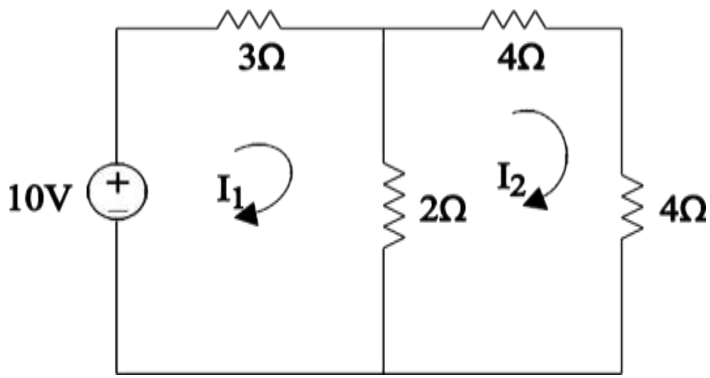
To find: Current in 3 ohms resistance = $I_1 \sim I_3$ = 1.47A

2. Find the branch currents of figure shown below using Mesh current method



- 2 Meshes – 2 Equations / 2X 2 Matrices
- 2 Meshes – 2 loops
  - 2 Loop currents I_1, I_2

Solving using Direct inspection method:



$$\begin{bmatrix} 5 & -2 \\ -2 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 5 & -2 \\ -2 & 10 \end{vmatrix} = 50 - 4 = 46$$

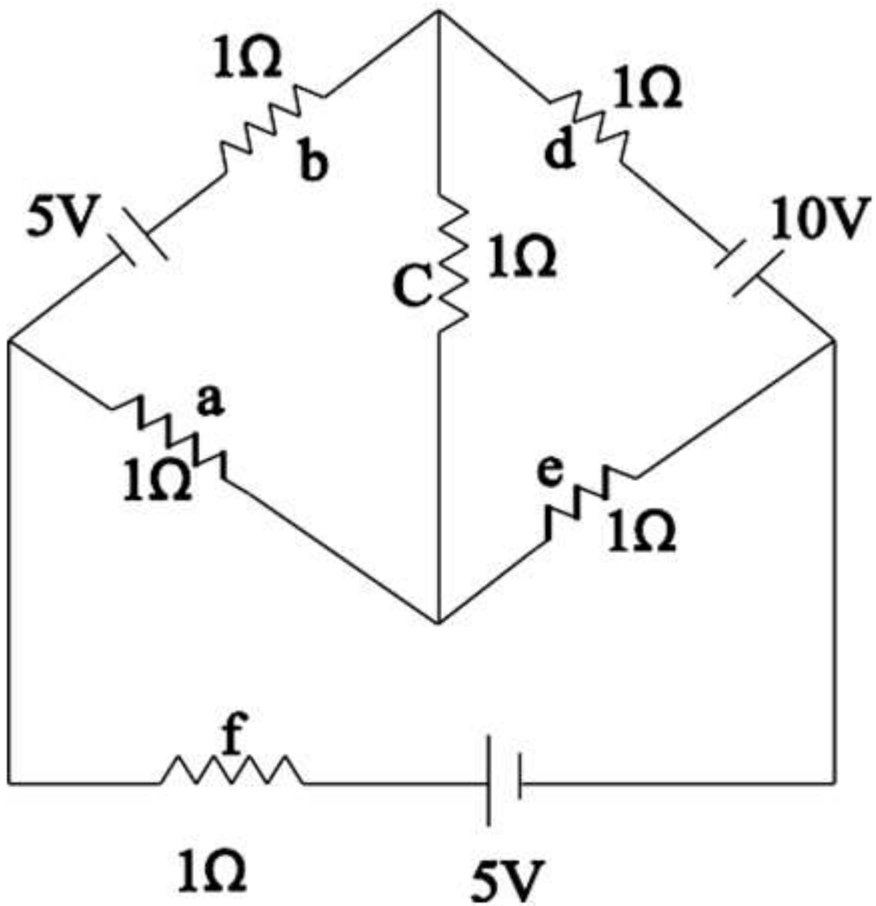
$$\Delta_1 = \begin{vmatrix} 10 & -2 \\ 0 & 10 \end{vmatrix} = 100$$

$$\Delta_2 = \begin{vmatrix} 5 & 10 \\ -2 & 0 \end{vmatrix} = 20$$

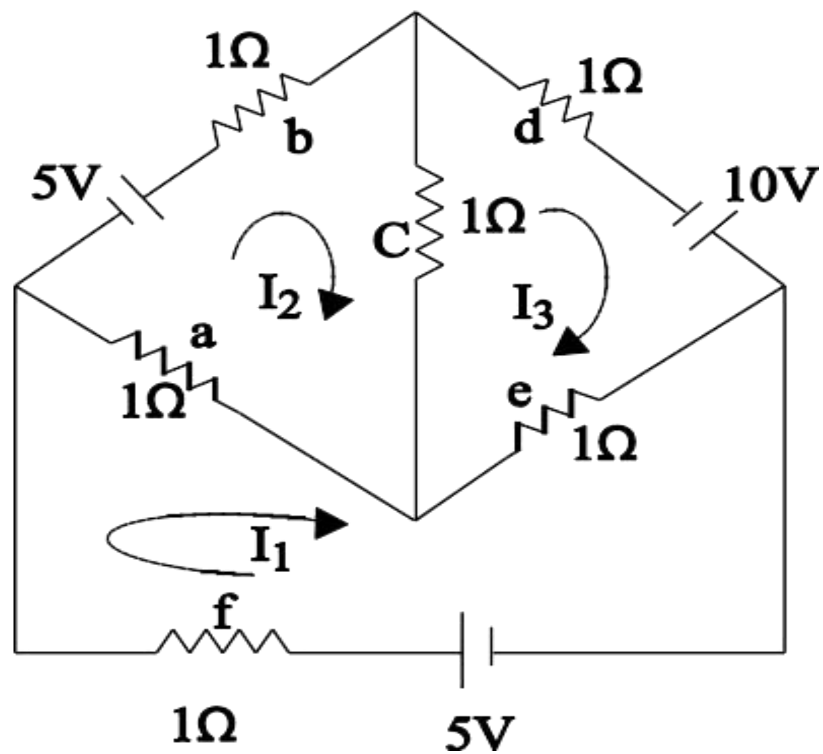
$$I_1 = \frac{\Delta_1}{\Delta} = \frac{100}{46} = 2.174A$$

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{20}{46} = 0.435A$$

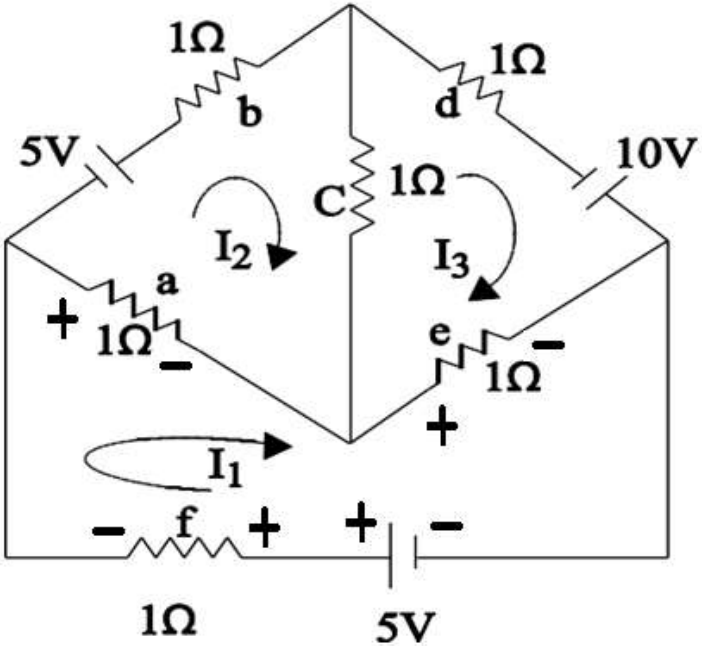
3. Determine the currents in various elements of the bridge circuit as shown below.



- Assume current direction in each loop



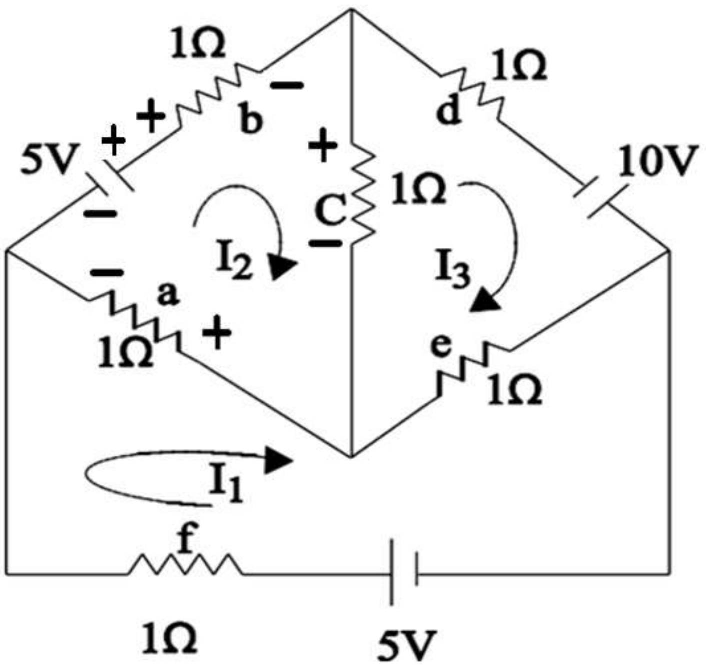
- For loop 1,



$$1I_1 + 1(I_1 - I_2) + 1(I_1 - I_3) = 5$$

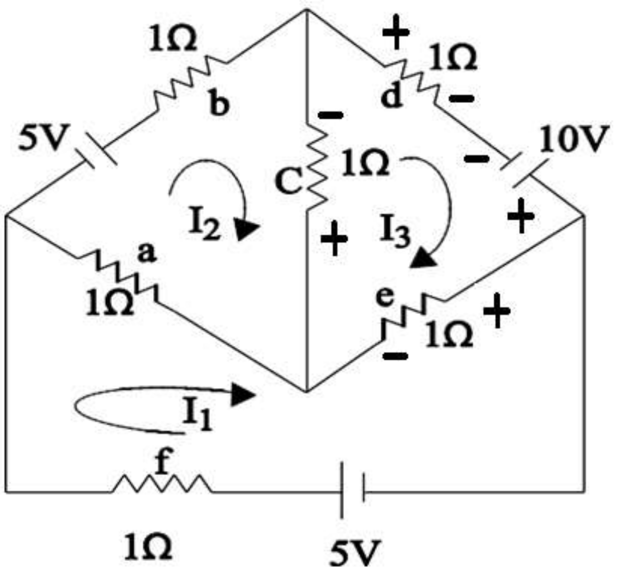
$$3I_1 - I_2 - I_3 = 5 \qquad (1)$$

- For loop 2,



- $1I2 + 1(I2 - I3) + 1(I2 - I1) = 5$
- $-I1 + 3I2 - I3 = 5 \qquad (2)$

- For loop 3,



- $1I_3 + 1(I_3 - I_1) + 1(I_3 - I_2) = 10$
- $-I_1 - I_2 + 3I_3 = 10$ (3)

$$\begin{bmatrix} 3 & -1 & -1 \\ -1 & 3 & -1 \\ -1 & -1 & 3 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 5 \\ 5 \\ 10 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 3 & -1 & -1 \\ -1 & 3 & -1 \\ -1 & -1 & 3 \end{vmatrix}$$

$= 3\ (9-1) + 1\ (-3-1)\ -1(1+3)$

$= 16$

$$\Delta_1 = \begin{vmatrix} 5 & -1 & -1 \\ 5 & 3 & -1 \\ 10 & -1 & 3 \end{vmatrix}$$

$= 40 + 25 + 35$

$= 100$

$$\Delta_2 = \begin{vmatrix} 3 & 5 & -1 \\ -1 & 5 & -1 \\ -1 & 10 & 3 \end{vmatrix}$$

$= 3\,(15 + 10) - 5\,(-3 - 1) - 1\,(-10 + 5)$

$= 100$

$$\Delta_3 = \begin{vmatrix} 3 & -1 & 5 \\ -1 & 3 & 5 \\ -1 & -1 & 10 \end{vmatrix}$$

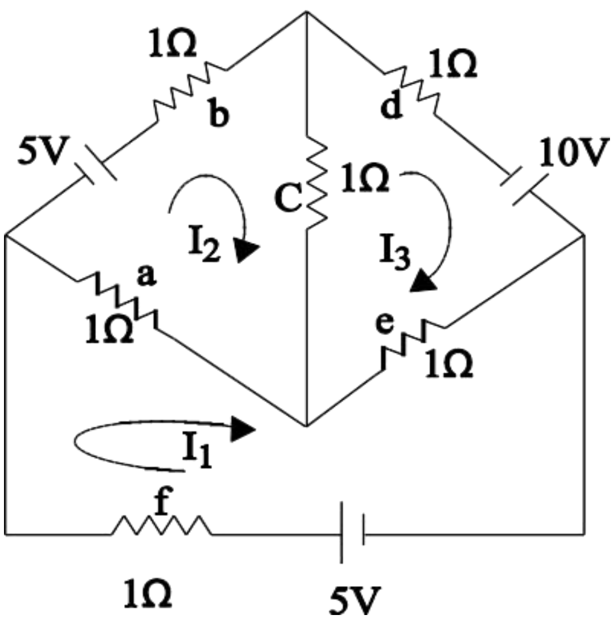
$= 3\,(30 + 5) + 1\,(-10 + 5) + 5\,(1 + 3)$

$= 120.$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{100}{16} = 6.25\,A$$

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{100}{16} = 6.25\,A$$

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{120}{16} = 7.5\,A$$



$I_a = I_1 - I_2 = 6.25 - 6.25 = 0$ A

$I_b = I_2 = 6.25$ A.

$I_c = I_2 - I_3 = 6.25 - 7.5 = -1.25$ A

$I_d = I_3 = 7.5$ A

$I_e = I_1 - I_3 = 6.25 - 7.5 = -1.25$ A.

$I_f = I_1 = 6.25$ A.

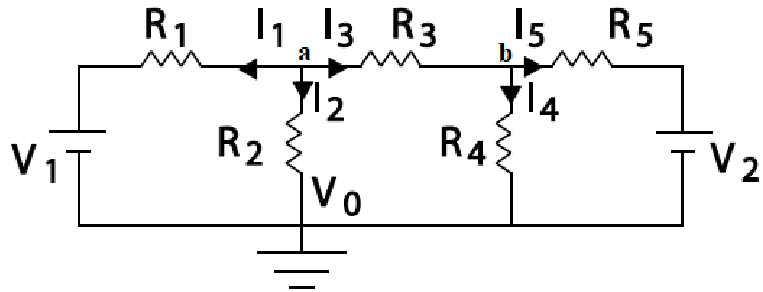
NODAL ANALYSIS

- This method is mainly based on Kirchhoff’s Current Law (KCL) which states that “the total current entering a circuit junction is exactly equal to the total current leaving the same junction”.
- This method uses the analysis of the different nodes of the network. Every junction point in a network, where two or more branches meet is called a node.
- One of the nodes is assumed as reference node whose potential is assumed to be zero. It is also called zero potential node or datum node.
- At other nodes the different voltages are to be measured with respect to this reference node. The reference node should be given a number zero and then the equations are to be written for all other nodes by applying KCL.
- The advantage of this method lies in the fact that we get (n – 1) equations to solve if there are ‘n’ nodes. This reduces calculation work

STEPS FOR THE NODE ANALYSIS

1. Choose the nodes and node voltages to be obtained.
2. Choose the currents preferably leaving the node at each branch connected to each node.
3. Apply KCL at each node with proper sign convention.
4. Obtain the equation for the each branch current in terms of node voltages and substitute in the equations obtained in step 3.
5. Solve all the equations obtained in step 4 and step 5 simultaneously to obtain the required node voltages.

Illustration-1



Let the voltages at nodes a and b be Va and Vb

$$I_1 + I_2 + I_3 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where

$$I_1 = \frac{V_a - V_1}{R_1}; I_2 = \frac{V_a - V_0}{R_2}; I_3 = \frac{V_a - V_b}{R_3};$$

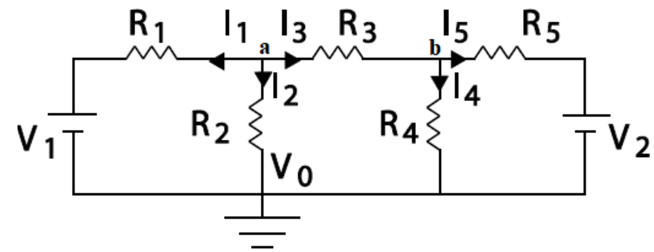
Substituting in eqn .(1)

$$\frac{V_a - V_1}{R_1} + \frac{V_a - V_0}{R_2} + \frac{V_a - V_b}{R_3} = 0$$

On simplifying [$V_o = 0$]

$$\frac{V_a}{R_1} - \frac{V_1}{R_1} + \frac{V_a}{R_2} + \frac{V_a}{R_3} - \frac{V_b}{R_3} = 0$$

$$V_a\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right] - V_b\left[\frac{1}{R_3}\right] = \frac{V_1}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$



Similarly for node b we have

$$I_4 + I_5 = I_3 \quad \dots\dots\dots\dots\dots\dots \text{(3)}$$

$$I_4 = \frac{V_b - V_o}{R_4}; I_5 = \frac{V_b - V_2}{R_5}$$

On substituting in eqn (3)

$$\frac{V_b - V_o}{R_4} + \frac{V_b - V_2}{R_5} = \frac{V_a + V_b}{R_3}$$

WKT

$V_o = 0$ [reference node]

$$V_b\left[\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}\right] - V_a\left[\frac{1}{R_3}\right] = \frac{V_2}{R_5} \quad \dots\dots\dots\dots\dots\dots \text{(4)}$$

Solving equations (2) and (4) we get the values as V_a and V_b.

Method for solving V_a and V_b by Cramers rule.

$$\begin{pmatrix} \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3} & -\frac{1}{R_3} \\ -\frac{1}{R_3} & \frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5} \end{pmatrix} \begin{bmatrix} V_a \\ V_b \end{bmatrix} = \begin{bmatrix} \frac{V_1}{R_1} \\ \frac{V_2}{R_2} \end{bmatrix}$$

$$\Delta = \left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}\right) - \left(\frac{-1}{R_3}\right)\left(\frac{-1}{R_3}\right)$$

To find Δ_1

$$\begin{pmatrix} \frac{V_1}{R_1} & \frac{-1}{R_3} \\ \frac{V_2}{R_5} & \frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5} \end{pmatrix}$$

$$\Delta_1 = \left(\frac{V_1}{R_1}\right)\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}\right)-\left(\frac{-1}{R_3}\right)\left(\frac{V_2}{R_5}\right)$$

To find Δ_2,

$$\begin{pmatrix} \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3} & \frac{V_1}{R_1} \\ \frac{-1}{R_3} & \frac{V_2}{R_5} \end{pmatrix}$$

$$\Delta_2 = \left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)\left(\frac{V_2}{R_5}\right)-\left(\frac{-1}{R_3}\right)\left(\frac{V_1}{R_1}\right)$$

To find v_a:

$$V_a = \frac{\Delta_1}{\Delta};$$

To find v_b:

$$V_b = \frac{\Delta_2}{\Delta}$$

Hence V_a and V_b are found.

CASE II:

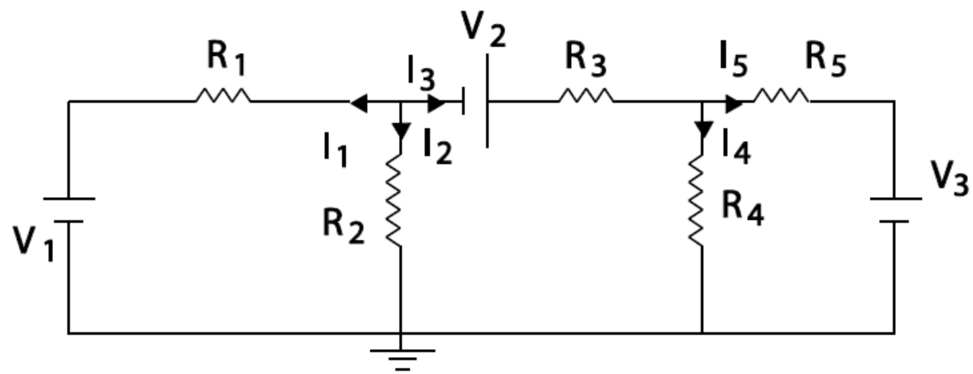


Figure 1.35

Consider the above fig

Let the voltages at nodes a and b be V_a and V_b.

The node equation at node a are

$$I_1 + I_2 + I_3 = 0$$

Where $I_1 = \dfrac{V_a - V_1}{R_1}; \quad I_2 = \dfrac{V_a}{R_2}; \quad I_3 = \dfrac{V_a + V_2 - V_b}{R_3}$

$$\frac{V_a - V_1}{R_1} + \frac{V_a}{R_2} + \frac{V_a + V_2 - V_b}{R_3} = 0$$

$$\frac{V_a}{R_1} - \frac{V_1}{R_1} + \frac{V_a}{R_2} + \frac{V_a}{R_3} + \frac{V_2}{R_3} - \frac{V_b}{R_3} = 0$$

Combining the common terms.

$$V_a\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right] - V_b\left[\frac{1}{R_3}\right] = \frac{V_1}{R_1} - \frac{V_2}{R_3} \quad \text{..................} \quad (5)$$

The nodal equations at node b are

$$I_3 = I_4 + I_5$$

$$\frac{V_a + V_2 - V_b}{R_3} = \frac{V_b}{R_4} + \frac{V_b - V_3}{R_5}$$

On simplifying

$$\frac{V_a}{R_3} + \frac{V_2}{R_3} - \frac{V_b}{R_3} = \frac{V_b}{R_4} + \frac{V_b}{R_5} - \frac{V_3}{R_5}$$

$$\frac{V_a}{R_3} - V_b\left[\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}\right] = -\frac{V_3}{R_5} - \frac{V_2}{R_3}$$

Solving eqn (5) and (6) we get V_a and V_b

Method to solve V_a and V_b.

Solve by cramers rule.

$$\begin{pmatrix} \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3} & \frac{-1}{R_3} \\ \frac{-1}{R_3} & \frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5} \end{pmatrix} \begin{bmatrix} V_a \\ V_b \end{bmatrix} = \begin{bmatrix} \frac{V_1}{R_1}-\frac{V_2}{R_3} \\ \frac{V_2}{R_3}+\frac{V_3}{R_5} \end{bmatrix}$$

$$\Delta = \left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}\right) - \left(-\frac{1}{R_3}\right)\left(-\frac{1}{R_3}\right)$$

$$\Delta_1 = \begin{pmatrix} \frac{V_1}{R_1}-\frac{V_2}{R_3} & -\frac{1}{R_3} \\ \frac{V_2}{R_3}+\frac{V_3}{R_5} & \frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5} \end{pmatrix}$$

$$\left(\frac{V_1}{R_1}-\frac{V_2}{R_3}\right)\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}\right) - \left(-\frac{1}{R_3}\right)\left(\frac{V_2}{R_3}+\frac{V3}{R_5}\right)$$

$$\Delta_2 = \begin{pmatrix} \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3} & \frac{V_1}{R_1}-\frac{V_2}{R_3} \\ \frac{-1}{R_3} & \frac{V_2}{R_3}+\frac{V_3}{R_5} \end{pmatrix}$$

$$\Delta_2 = \left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)\left(\frac{V_2}{R_3}+\frac{V3}{R_5}\right)-\left(-\frac{1}{R_3}\right)\left(\frac{V_1}{R_1}-\frac{V_2}{R_3}\right)$$

$$\Delta_a = \frac{\Delta_1}{\Delta}; \qquad \Delta_b = \frac{\Delta_2}{\Delta}$$

Hence V_a and V_b are found.

Case iii

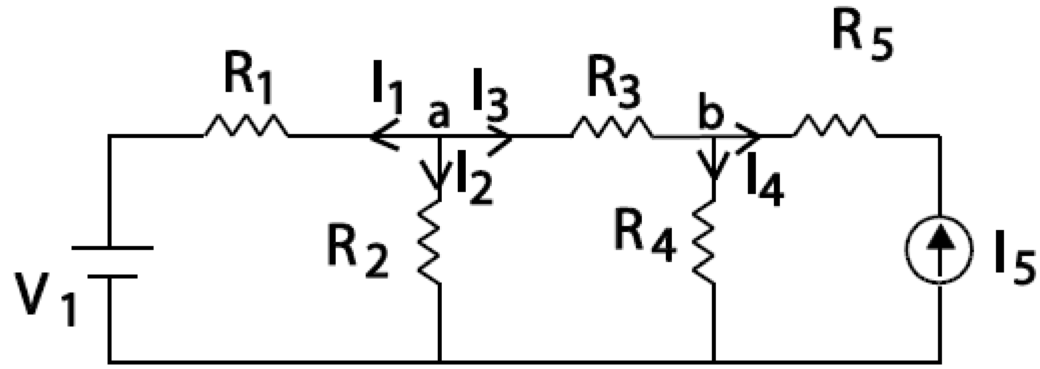


Figure 1.36

Let the voltages at nodes a and b be V_a and V_b as shown in fig

Node equations at node a are

$$I_1 + I_2 + I_3 = 0$$

$$\frac{V_a - V_1}{R_1} + \frac{V_a}{R_2} + \frac{V_a - V_b}{R_3} = 0$$

$$V_a\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}\right] - V_b\left[\frac{1}{R_3}\right] = \frac{V_1}{R_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Similarly Node equations at node b

$$I_3 + I_5 = I_4$$

$$\frac{V_a - V_b}{R_3} + I_5 = \frac{V_b}{R_4}$$

$$I_5 = V_b\left[\frac{1}{R_3} + \frac{1}{R_4}\right] - V_a\left[\frac{1}{R_3}\right] \text{......................}(8)$$

Solving eqn (7) and (8)

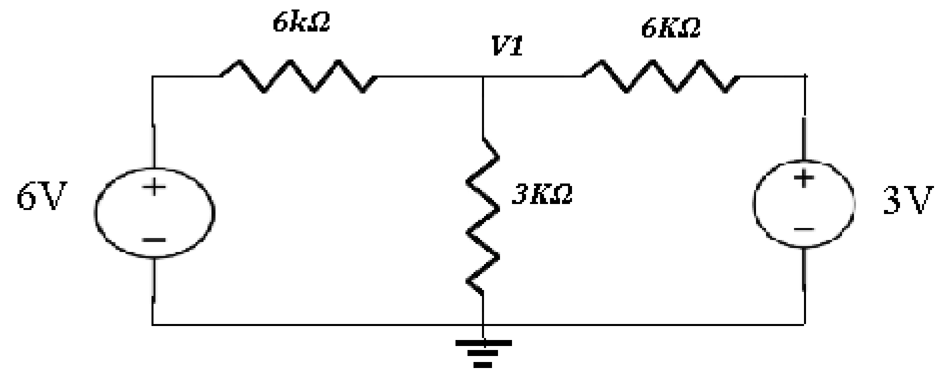
V_a and V_b has been found successfully.

2 Methods to solve the matrix:

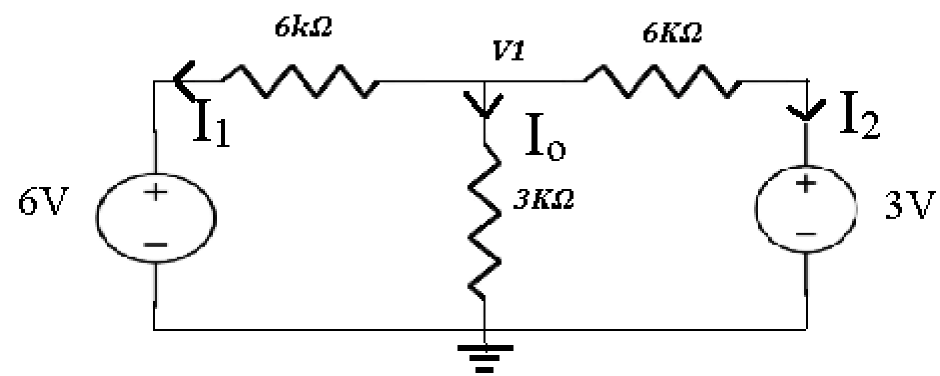
- Solving by writing linear equation
- Direct Inspection Method

1.Find the Current Flowing through 3Kohm Resistor Using Nodal Analysis

Let I_0, I_1 *and* I_2 be the branch Currents and V_1 be the Node Voltage



$I_1 + I_0 + I_2 = 0$



$\frac{V_1 - 6}{6} + \frac{V_1}{3} + \frac{V_1 - 3}{6} = 0$

$V_1 - 6 + 2V_1 + V_1 - 3 = 0$

$4V_1 - 9 = 0$ $\qquad V_1 = 2.25V$ $\qquad I_0 = \frac{V_1}{R} = \frac{2.25}{3 \text{ X } 10^3} = 0.75mA$

Illustration 2 (Node Analysis by Inspection Method)

We Know, Ohm's Law states that

$$[V]=[I][R]$$

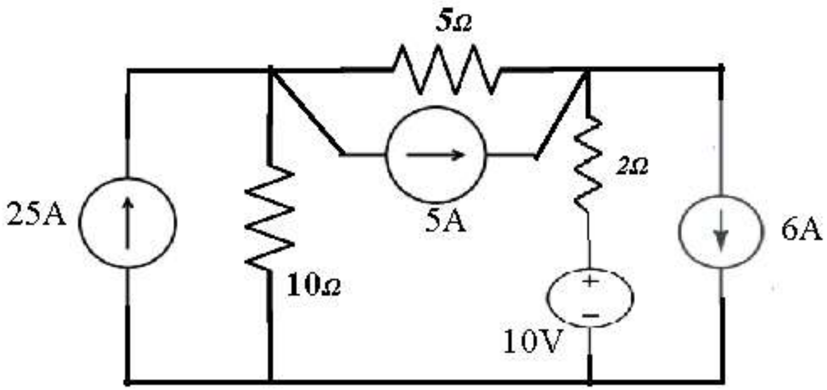
$$[I] = \frac{1}{[R]}[V]$$

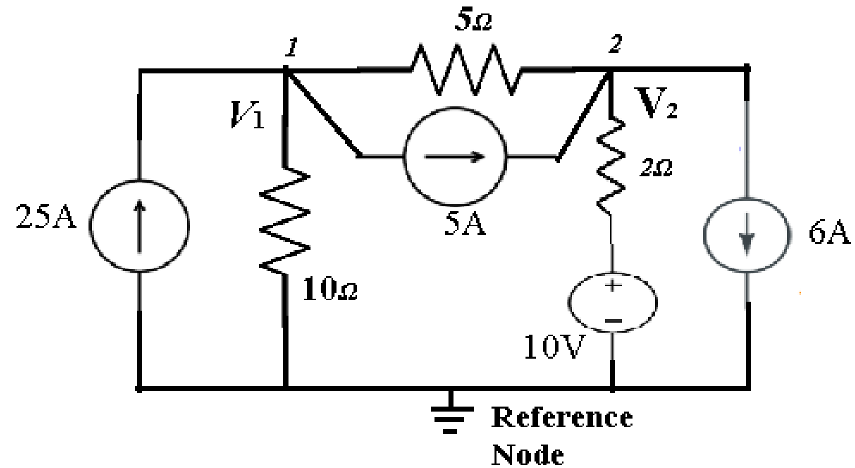
$$[I]=[G][V]$$

If Two Nodes are Present, then $\begin{bmatrix} G_{11} & -G_{12} \\ -G_{21} & G_{22} \end{bmatrix}\begin{pmatrix} V_1 \\ V_2 \end{pmatrix}=\begin{pmatrix} I_1 \\ I_2 \end{pmatrix}$

If three Nodes are present, then $\begin{bmatrix} G_{11} & -G_{12} & -G_{13} \\ -G_{21} & G_{22} & -G_{23} \\ -G_{31} & -G_{32} & G_{33} \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$

2.Find the Node Voltages in the given Circuit





Let the Node Voltages be V_1 and V_2

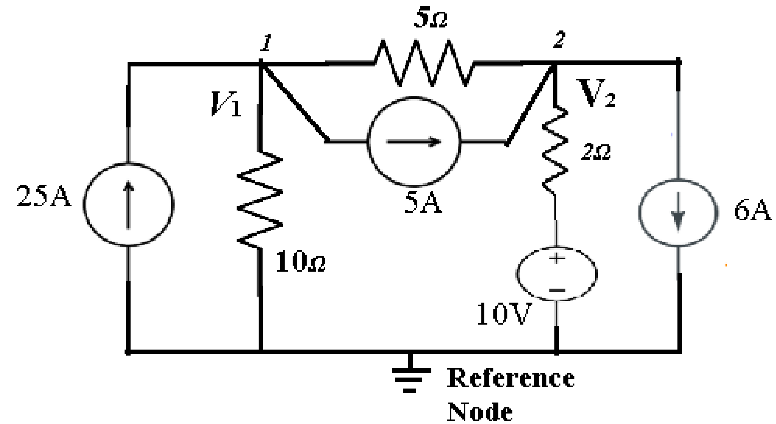
$$\begin{bmatrix} G_{11} & -G_{12} \\ -G_{21} & G_{22} \end{bmatrix} \begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} I_1 \\ I_2 \end{pmatrix}$$

$$\begin{bmatrix} \frac{1}{10}+\frac{1}{5} & -\frac{1}{5} \\ -\frac{1}{5} & \frac{1}{5}+\frac{1}{2} \end{bmatrix} \begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} 25-5 \\ 10-6 \end{pmatrix}$$

$$\begin{bmatrix} 0.3 & -0.2 \\ -0.2 & 0.7 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 4 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 0.3 & -0.2 \\ -0.2 & 0.7 \end{bmatrix} = 0.17$$

$$\Delta_1 = \begin{bmatrix} 20 & -0.2 \\ 4 & 0.7 \end{bmatrix} = 14.8$$

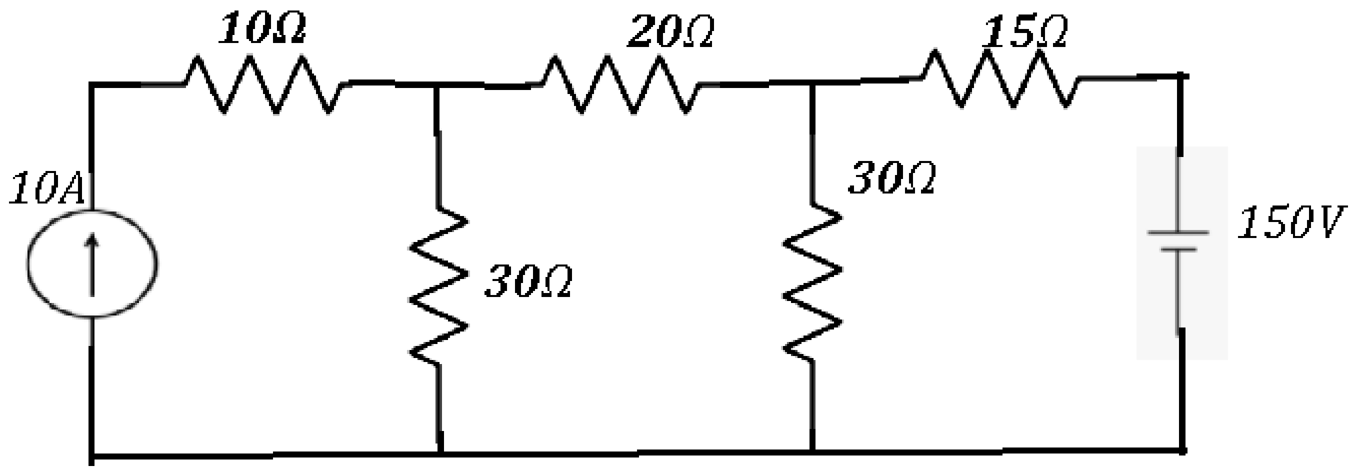


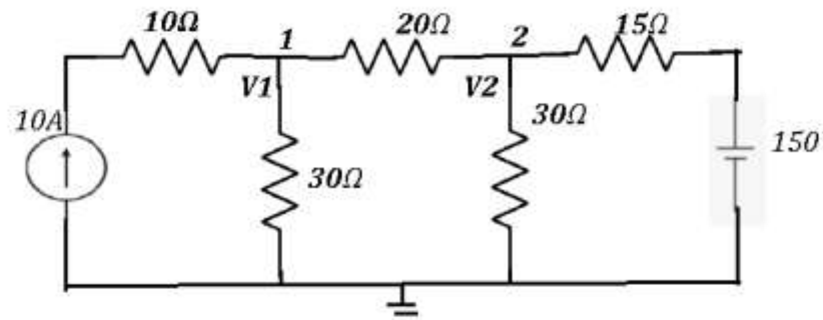
$$\Delta_2 = \begin{bmatrix} 0.3 & 20 \\ -0.2 & 4 \end{bmatrix} = 5.2$$

$$V_1 = \frac{\Delta_1}{\Delta} = \frac{14.8}{0.17} = 87.05V$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{5.2}{0.17} = 30.58V$$

3. Find the Node voltages in the given circuit using nodal analysis. Also find the Current flowing through 20Ω





$$\begin{bmatrix} G_{11} & -G_{12} \\ -G_{21} & G_{22} \end{bmatrix}\begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} I_1 \\ I_2 \end{pmatrix}$$

$$\begin{bmatrix} \frac{1}{10}+\frac{1}{30}+\frac{1}{20} & -\frac{1}{20} \\ -\frac{1}{20} & \frac{1}{20}+\frac{1}{30}+\frac{1}{15} \end{bmatrix}\begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} 10 \\ 10 \end{pmatrix}$$

$$\begin{bmatrix} 0.183 & -0.05 \\ -0.05 & 0.149 \end{bmatrix}\begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} 10 \\ 10 \end{pmatrix}$$

$$\Delta = \begin{bmatrix} 0.183 & -0.05 \\ -0.05 & 0.149 \end{bmatrix} = 0.0247$$

$$\Delta_1 = \begin{bmatrix} 10 & -0.05 \\ 10 & 0.149 \end{bmatrix} = 1.99$$

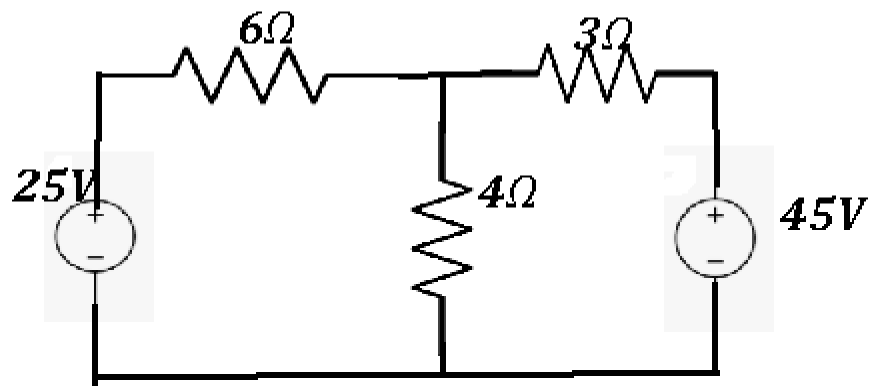
$$\Delta_2 = \begin{bmatrix} 0.183 & 10 \\ -0.05 & 10 \end{bmatrix} = 2.33$$

$$V_1 = \frac{\Delta_1}{\Delta} = \frac{1.99}{0.0247} = 80V$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{2.33}{0.0247} = 94.33V$$

$$I_{20\Omega} = \frac{V_1 - V_2}{20} = \frac{80 - 94.33}{20} = 0.716\text{A}$$

4. Using Nodal Voltage Analysis Method, Obtain the current flowing in the resistors.



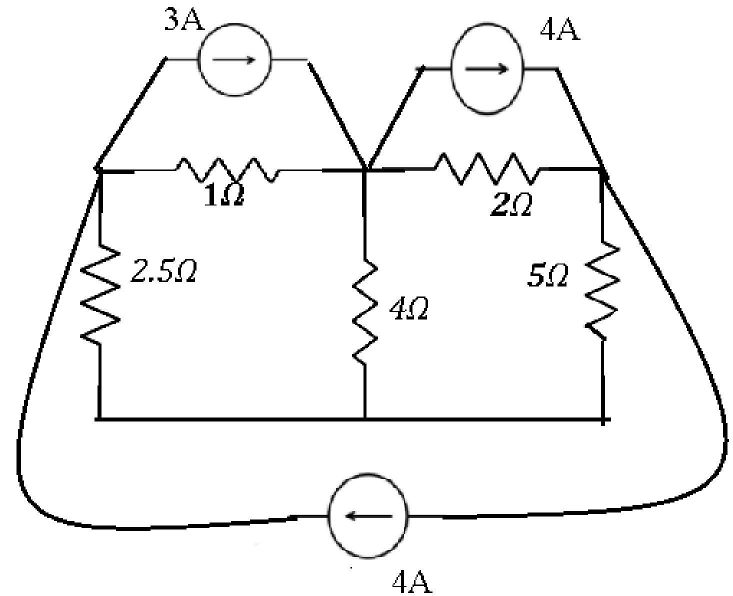
5.Find the Node voltages in the given circuit

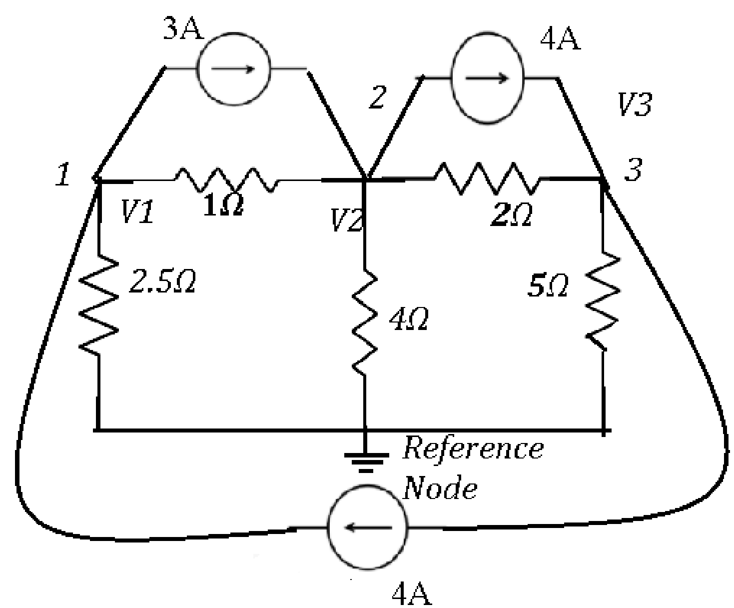
Let the Node Voltages be V_1, V_2, V_3

$$\begin{bmatrix} G_{11} & -G_{12} & -G_{13} \\ -G_{21} & G_{22} & -G_{23} \\ -G_{31} & -G_{32} & G_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\begin{bmatrix} \frac{1}{2.5}+1 & -1 & 0 \\ -1 & 1+\frac{1}{4}+\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{1}{2} & \frac{1}{2}+\frac{1}{5} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 4-3 \\ 3-4 \\ 4-4 \end{bmatrix}$$

$$\begin{bmatrix} 1.4 & -1 & 0 \\ -1 & 1.75 & -0.5 \\ 0 & -0.5 & 0.7 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$





$$\Delta= \begin{bmatrix} 1.4 & -1 & 0 \\ -1 & 1.75 & -0.5 \\ 0 & -0.5 & 0.7 \end{bmatrix} =1.4[1.225-0.25]-0.7$$

$\Delta=0.665$

$$\Delta_1= \begin{bmatrix} 1 & -1 & 0 \\ -1 & 1.75 & -0.5 \\ 0 & -0.5 & 0.7 \end{bmatrix} = 0.975 - 0.7$$

$\Delta_1=0.275$

$$\Delta_2 = \begin{bmatrix} 1.4 & 1 & 0 \\ -1 & -1 & -0.5 \\ 0 & 0 & 0.7 \end{bmatrix} =-0.98+0.7$$

$\Delta_2= -0.28$

$$\Delta_3= \begin{bmatrix} 1.4 & -1 & 1 \\ -1 & 1.75 & -1 \\ 0 & -0.5 & 0 \end{bmatrix} =-0.7+0.5$$

$\Delta_3= -0.2$

$$V_1 = \frac{\Delta_1}{\Delta} = \frac{0.275}{0.665} = 0.413V$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{-0.28}{0.665} = -0.421V$$

$$V_3 = \frac{\Delta_3}{\Delta} = \frac{-0.2}{0.665} = -0.3V$$

THANK YOU