SHARIEF·N

ELECTRICAL CIRCUITS
BASICS

Current :

An electric Current is the movement of electric charges along a definite path. In case of a Conductor the moving Charges are electrons.

Current is the rate of flow of charge with time.

$$I = \frac{Q}{t} \text{ amperes } (C/s) \qquad 1A = 1\,C/s$$

or

$Q = It$ where Q is the charge in Coulombs (C)
I is the Current in amperes.

Voltage :

The voltage V between two points may be defined in terms of energy that would be required if a charge were transferred from one point to the other.

$$V = \frac{W}{Q}\ J/c$$

Potential difference :

The potential difference (p.d) between two points is the energy required to move one Coulomb of charge from one to the other

$$V = W/Q \ J/c$$

W = energy required to transfer the charge
Q = Charge transferred between two points
V = potential difference.

Voltage drop : The Voltage drop between two points of an element is a decrease in energy in transferring a charge of one coulomb from one point to the other. $1V = 1\,J/c$

Work : Work is said to be done by a force when it moves a body through a certain distance.

$$\text{work} = \text{force} \times \text{distance}$$
$$= F \cdot d \qquad 1\,Nm = 1\,J$$

Energy: Energy is the ability to do work.

Both energy and work are expressed in joules (J)

All forms of energy are expressed in joules

Power :

power is the rate of doing work (or) rate of change of energy

$$\text{power} = \frac{\text{work}}{\text{time}} \qquad 1\,W = 1\,J/s$$
$$= W/t \quad J/s \text{ or watt (W)}$$

$$P = \frac{\text{energy}}{\text{time}}$$
$$= W/t$$
$$= VQ/t$$
$$I = Q/t$$

$$\left\{ \begin{aligned} P &= \frac{dW}{dt} \\ &= \frac{dW}{dq} \cdot \frac{dq}{dt} \\ &= V \cdot I \end{aligned} \right\}$$

$$P = W/t$$
$$\text{power} = \frac{\text{force} \times \text{distance}}{\text{time}}$$
$$= \text{force} \times \text{Velocity}$$
$$P = Fu$$

$$P = VI$$
$$V = RI \quad \text{(By Ohm's law)}$$
$$P = VI = (RI)\,I$$
$$= I^2R$$
$$P = V \cdot \frac{V}{R} = \frac{V^2}{R}$$

$$\left\{ \begin{aligned} P &= V I \\ P &= I^2R \\ P &= \frac{V^2}{R} \end{aligned} \right\}$$

Electric energy: Electric energy is required for the movement of electrons in a conductor.

$$\text{Energy} = \text{power} \times \text{time}$$
$$W = VIt$$
$$= I^2Rt$$
$$= \frac{V^2}{R}t$$

Circuit is a loop (or) mesh i.e: a Closed path

The interconnection of two or more circuit element with at least one closed is called electric circuit

Inter connection of circuits is nothing but a network

The inter connection of two or more circuit elements called as electric network.

Eg: Network is like a building where as the circuits are rooms in a building

Passive, lumped R, L, C's

Active (V, I) – Delivering

Passive (R, L, C) – Absorbing

R – memory less – Energy dissipated.

L, C – memory — Energy Stored

↳ in the form of voltage

↓ in the form of Current

Current always flows from +ve to –ve in the presence of Source.

In the "presence of active sources" all the 3 - passive, lumped R, L, C's will always absorbs the energy. When they are absorbing the energy, the Currents through all the three passive lumped R, L, C will always flows from +ve to –ve terminals.

In the "absence of active Sources", the stored energies in the memory elements will be delivered to the memory-less resistors. Whenever the L & C are delivering the energy, the currents through them will always flows from –ve to +ve terminals. As the resistor is always absorbing the energy the current through it will always flows from +ve to –ve terminals.

Open circuit:

An open is a gap, break, or interruption in a circuit path. A circuit element is said to be open circuited or simply open if the current through it is zero regardless of the voltage across it. Any open circuit may be considered as a resistor of infinite resistance. Therefore by ohm's law.

$$I = \frac{V}{R} = \frac{V}{\infty} = 0$$

whatever be the value of V.

Short Circuit:

A circuit element is said to be short-circuited or simply shorted if the voltage across it is zero regardless of the current through it. A short circuit may be considered as a resistor of zero resistance. Therefore by ohm's law.

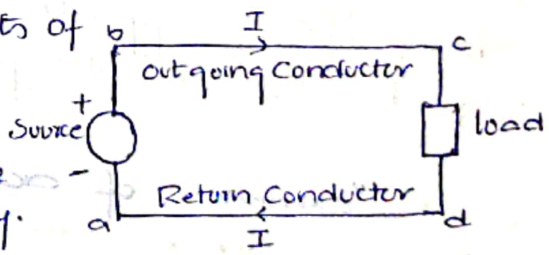
$$V = RI = 0 \times I = 0$$

Whatever be the value of I.

Basic circuit:

The path of current is called a circuit. The basic electric circuit is shown in figure. It consists of

a) a source of energy
b) a load which utilises the energy
c) two conductors connecting the source and the load to transfer the energy.



The conductor bc is carrying energy from the source to load. It is called the outgoing conductor. The conductor da is returning the energy from the load to source. It is called return conductor with respect to the source the conductors and load form the external circuit.

terminal at which current leaves called +ve terminal.
current enters called -ve terminal.

Direction of current is +ve to -ve in external circuit.
-ve to +ve in the source.

INTRODUCTION TO ELECTRICAL CIRCUITS

UNIT - 1 SHARIEF

OBJECTIVE

The basic Concepts of circuit analysis is the foundation for all subjects of the Electrical Engineering discipline

The basic analysis of circuits which includes Single phase circuits
- magnetic circuits
- Theorems
- transient analysis
- and Network topology.

Introduction: (Circuit Concept)

The electrical circuits may consist of one or more sources of energy and number of electrical parameters, connected in different ways. The different electrical parameters or elements are resistors
Capacitors
and
Inductors. The combination of such elements along with various Sources of energy gives rise to Complicated electrical circuits, generally referred as networks. The terms circuit and network are used Synonymously in the electrical literature.

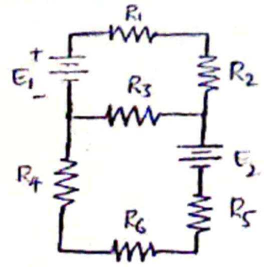
The network analysis or circuit analysis means to find a current through or voltage across any branch of the network, by using the fundamental laws and various network simplification techniques

A physical electrical circuit serves to transfer or transform energy.

To explain any electric or magnetic phenomena two concepts are employed i.e., field concept and circuit concept. The field concept is more fundamental, exact and complex, where as the circuit is simple and practical but involves certain approximation, the circuit concept retains its utility, because we not often interested in field quantities, so much as we are in voltage & current.

Network:

Any arrangement of the various electrical energy sources along with the different circuit elements is called an electrical network.



The circuit Concept favours analysis in terms of voltage and current from which other quantities such as charge, fields, energy, power etc Can be Computed if desired. We regard charge and energy as the primitive quantities in terms of which we can build our Conceptual Schemes of the electric Circuit.

Network Element(s):

Any individual circuit element with two terminals which can be Connected to other Circuit element, is Called a network element.

A physical circuit or network is a system of inter connected network elements. When electric energy is supplied to a circuit element it will respond in one or more of the following ways. If the energy is Consumed, then the Circuit element is a **pure resistor**. If the energy is stored in electric field then the element is a **pure Capacitor**. If the energy is stored in magnetic field, then the element is a **pure inductor**.

Network elements Can be either active elements or passive elements. Active elements are the elements which supply power or energy to the network. Voltage Source, Current Source are the examples of active elements. Passive elements are the elements which either store energy or dissipate energy in the form of heat. Resistor, Inductor & Capacitor are the three basic passive elements. Inductors and Capacitors Can Store energy and resistors dissipate energy in the form of heat.

Classification of Network Elements

The network elements Can be classified as

- Network elements
  - Active elements (Source)
    - Voltage Source
    - Current Source
  - Passive elements (Sink)
    - Resistors (R)
    - Inductors (L)
    - Capacitors (C)

Another Classification is

Network Elements

- Linear or Non linear
- Unilateral or Bilateral
- Time Variant or Time invariant
- Lumped or distributed
- Active & Passive Network

Classification of Electrical Networks

The behaviour of the entire network depends on the behaviour and characteristics of its elements. Based on such characteristics electrical network can be classified as below

Linear Network: A circuit or network whose parameters i.e. elements like resistances, inductances and capacitances are always constant irrespective of the change in time, voltage, temperature etc. is known as linear network (The Ohm's law can be applied to such network. The mathematical equations of such network can be obtained by using the law of superposition. The response of the various network elements is linear with respect to the excitation applied to them)

Non linear Network: A circuit whose parameters change their values with change in time, temperature, voltage etc. is known as non-linear network

The Ohm's law may not be applied to such network.
This n/w does not follow the law of superposition
The response of the various elements is not linear with respect to their excitation.

The best example is a circuit consisting of a diode where diode current does not vary linearly with the voltage applied to it.

Unilateral Network: A circuit whose operation, behaviour is dependent on the direction of the current through various elements is called unilateral network.
Circuit consisting diodes, which allows flow of current only in one direction is good example of unilateral circuit.

Bilateral Network: A circuit whose characteristics, behaviour is same irrespective of the direction of current through various elements of it, is called bilateral network.
Network consisting only resistances is good example of bilateral network.

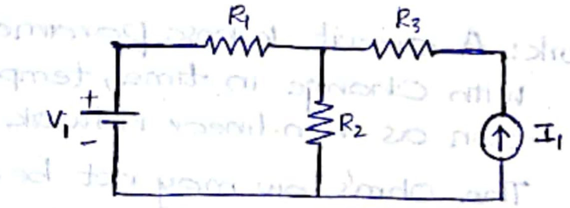
Lumped Network: A network in which all the network elements are physically separable is known as lumped network.

Most of the electric networks are lumped in nature, which consists elements like R, L, C, Voltage source etc.

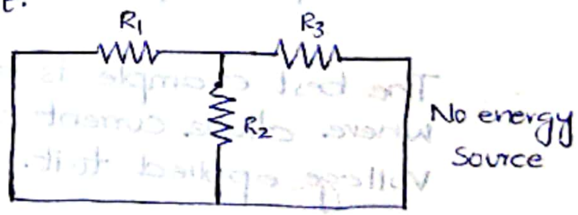
Distributed Network: A network in which the circuit elements like resistance, inductance etc. cannot be physically separable for analysis purposes, is called distributed network.

The best example of such a network is a transmission line where resistance, inductance and capacitance of a transmission line are distributed all along its length and cannot be shown as a separate elements, any where in the circuit.

Active Network: A circuit which contains at least one source of energy is called active. An energy source may be a voltage or current source.



Passive network: A circuit which contains no energy source is called passive circuit.



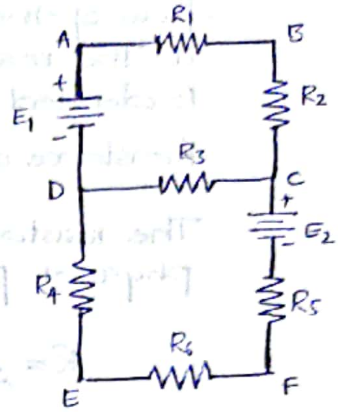
Time Variant and Time Invariant Elements:

If the parameters of network elements do not vary with time, they are called Time invariant elements, otherwise they are called Time Variant.

Normally, we will consider networks whose elements are linear time invariant and lumped.

Branch: A part of the network which connects the various points of the network with one another is called a branch. In the figure shown AB, BC, CD, DA, DE, CF and EF are the various branches. A branch may consist more than one element.

Junction point: A point where three or more branches meet is called a junction point. Point D and C are the junction points in the network shown in the figure.



An electrical network.

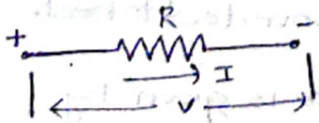
Node: A point at which two or more elements are joined together is called node. The junction points are also the nodes of the network. In the network shown in the figure A, B, C, D, E and F are the nodes of the network.

Mesh (or loop): Mesh (or loop) is a set of branches forming a closed path in a network in such a way that if one branch is removed then remaining branches donot form a closed path. A loop also can be defined as a closed path which originates from a particular node, terminating at the same node, travelling through various other nodes, without travelling through any node twice.

In the figure paths A-B-C-D-A
A-B-C-F-E-D-A
D-C-F-E-D etc. are the loops of the network.

Ohm's law: This law gives relationship between the potential difference (V), the current (I) and the resistance (R) of a dc circuit. Dr. Ohm in 1827 discovered a law called Ohm's law.

The current flowing through the electric circuit is directly proportional to the potential difference across the circuit and inversly proportional to the resistance of the circuit, provided the temperature remains constant.



$I \propto \frac{V}{R}$

$I = \frac{V}{R}$ amperes

$V = IR$ volts

$\frac{V}{I} = \text{const} = R$ ohms

Limitations of Ohm's law.

1) It is not applicable to the nonlinear devices such as diodes, zener diodes, voltage regulators etc.

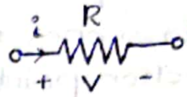
2) It does not hold good for non-metallic conductors such as silicon carbide. The law for such conductors is given by ; $V = KI^m$ K, m are consts

R-L-C Parameters:

or

Basic Circuit Components:

Resistance: It is the property of the material by which it opposes the flow of the current through it. The resistance of element is denoted by the symbol R



Resistance is measured in ohms(Ω)

The resistance of a given material depends on the physical properties of that material and given by.

$$R = \frac{\rho l}{a}$$

where l = length in metres
a = Cross-sectional area in Square metres
ρ = Resistivity in Ohms-metres
R = Resistance in Ohms.

Ohm is defined as the resistance offered by the material when a current of one ampere flows between two terminals with one volt applied across it.

According to ohms law, the current is directly proportional to the voltage and inversly proportional to the total resistance of the circuit.

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

we can write above equation in terms of charge as follows

$$V = RI$$
$$= R\frac{dq}{dt} \quad (\text{or}) \quad i = \frac{v}{R} = GV$$

where G is the Conductance of a conductor, Units are mho ($\mho$)

When current flows through any resistive material, heat is generated by the Collision of electrons with other atomic par-ticles The power absorbed by the resistor is Converted to heat.

The power absorbed by the resistor is given by

$$P = VI$$
$$= (IR)\,I$$
$$= I^2R \text{ Watts}$$

As i^2 term is always +ve, the energy absorbed by the resistance is always +ve.

Where i is the current in the resistor in Amps and v is the Voltage across the resistor in volts

Energy lost in time t is given by

$$W = \int_0^t p\,dt$$

$$= pt$$

$$= i^2Rt$$

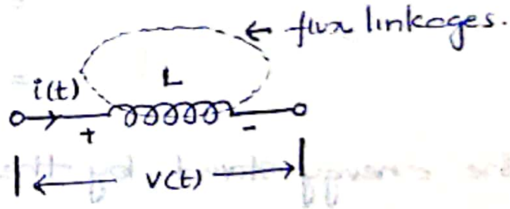
$$W = \frac{V^2}{R}t$$; where V is the volts
R is in ohms
t is in seconds and
W is in joules.

A resistor of 10Ω is connected across a 12V battery. How much current flows through the resistor?

$V = IR$

$I = V/R = 12/10 = 1.2$ Amps.

Inductance: A wire of certain length, when twisted into a coil becomes a basic inductor. If current is made to pass through an inductor, an electro magnetic field is formed. A change in the magnitude of the current changes the emf. Increase in current expands the field and decrease in current reduces. Therefore, a change in current produces change in the emf, which induces a voltage across the coil according to Faraday's law of electro-magnetic induction.



inductance

The inductance is denoted as 'L' and is measured in henries (H)

For an inductance, the voltage across it is proportional to the rate of change of current passing through it.

An inductance is the element in which energy is stored in the form of electro-magnetic field.

$$L = \frac{N\phi}{I}$$ Henries

v(t) and i(t) are the time varying voltage and currents.

①

The Current - Voltage relation is given by

$$v = L\frac{di}{dt}$$ where v is the voltage across inductor in volts and i is the current through inductor in Amperes.

We can write above equation as

$$di = \frac{1}{L} v\,dt$$

Integrating on both sides, we get

$$\int_0^t di = \frac{1}{L}\int_0^t v\,dt$$

$$i(t) - i(0) = \frac{1}{L}\int_0^t v\,dt$$

$$i(t) = \frac{1}{L}\int_0^t v\,dt + i(0)$$

from the above equation we note that the current in an inductor is dependent upon the integral of the voltage across its terminals and the initial current in the coil $i(0)$.

The power absorbed by inductor is

$$P = VI$$

$$= L\frac{di}{dt}\cdot I$$

$$= LI\frac{di}{dt}$$

The energy stored by the inductor is

$$W = \int_0^t p\,dt$$

$$= \int_0^t Li\frac{di}{dt}\cdot dt$$

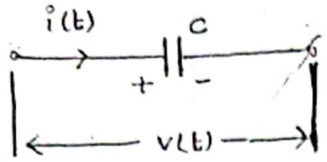
$$W = \frac{Li^2}{2}$$

The current in a 2H inductor varies at a rate of 2 A/s. Find the voltage across the inductor and the energy stored in the magnetic field after 2sec.

$$V = L\frac{di}{dt} = 2\times 4 = 8V \qquad i = 2A/s \times 2s = 4A$$

$$W = \frac{1}{2}Li^2 = \frac{1}{2}\times 2\times(4)^2 = 16 \text{ Joules.}$$

Capacitance:



Any two Conducting Surfaces seperated by an insulating medium exhibit the property of a Capacitor. The Conducting Surfaces are called electrodes and the insulating medium is called dielectric.

A Capacitor stores the energy in the form of an electric field.

(or)

An element in which energy is stored in the form of an electrostatic field is known as Capacitance.

It is denoted as 'c' and is measured in farads(F)

The figure shows a capacitor, the voltage across it is time varying v(t) and current through it is also time varying i(t).

A Capacitor is said to have greater capacitance, if it can store more charge per unit voltage and the capacitance is given by.

$$C = Q/V$$

we can write the above equation in terms of current as

$$i = C\frac{dv}{dt}$$ where v is the voltage across the capacitor, i is the current through it.

$$dv = \frac{1}{C} i\,dt$$

by integrating on both sides

$$\int_0^t dv = \frac{1}{C}\int_0^t i\,dt$$

$$v(t) - v(0) = \frac{1}{C}\int_0^t i\,dt$$

$$v(t) = \frac{1}{C}\int_0^t i\,dt + v(0)$$

from the above equation, the voltage in a capacitor depends upon the integral of the current through it and the initial voltage.

The power absorbed by the capacitor is given by

$$P = VI$$

$$= V \cdot C\frac{dv}{dt}$$

The energy stored by the Capacitor is

$$W = \int_0^t P\,dt$$

$$= \int_0^t V I\,dt$$

$$= \int_0^t V C \frac{dv}{dt}\,dt$$

$$W = \frac{1}{2} C V^2$$

The Capacitor having a capacitance $2\mu F$ is charged to a voltage of 1000V. Calculate the stored energy in Joules.

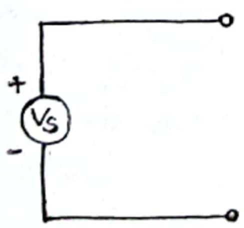
$$W = \frac{1}{2} C V^2 = \frac{1}{2} \times (2 \times 10^{-6}) \times (1000)^2 = 1 \text{ Joule}.$$

Energy Sources : (Voltage and Current sources)

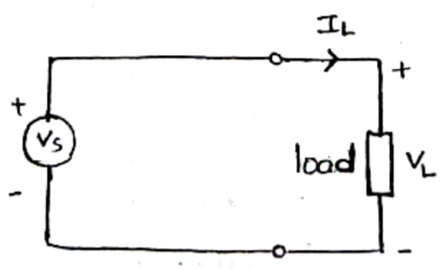
There are basically two types of energy sources : Voltage Source and Current Source. These are classified as
I) Ideal Source
II) Practical Source

Voltage Source :

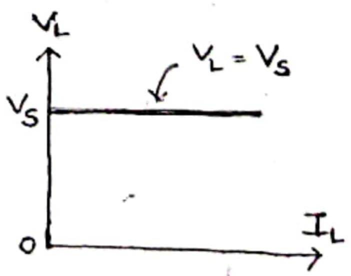
Ideal Voltage Source is defined as the energy source which gives constant voltage across its terminals irrespective of the current drawn through its terminals. The symbol for ideal voltage source is as shown in figure (a)



a) Symbol



b) Circuit



c) Characteristics

Ideal Voltage Source

Ideal voltage source is connected to the load as shown in the figure (b). At any time the value of voltage at load terminals remains same. This is indicated by V-I Characteristics shown in figure (c).

NETWORK ANALYSIS

UNIT - II

SHA RIEF

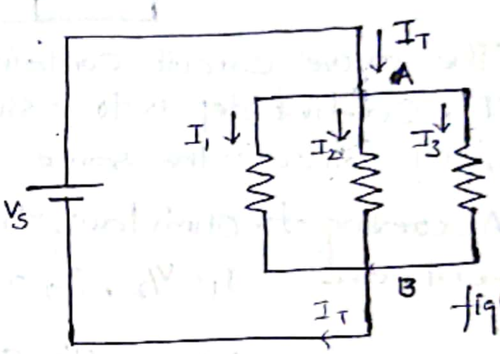
Network Simplification Techniques

Kirchhoff's Laws:

In 1847, a German physicist Kirchhoff, formulated two fundamental laws of electricity. These laws are of tremen-dous importance from network simplification point of view.

Kirchhoffs Current law (KCL)

Kirchhoffs Current law states that the sum of the currents entering into any node is equal to the sum of the currents leaving that node. The node may be an inter connection of two or more branches



fig(a)

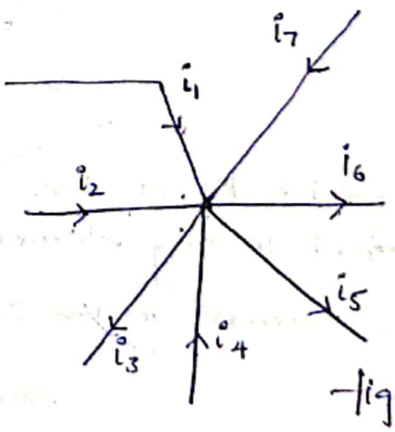
In any parallel circuit, the node is a junction point of two or more branches. The total current entering into a node is equal the current leaving the node.

$\boxed{\Sigma I \text{ at junction point} = 0}$

For example consider the circuit shown in the fig(a) which contains nodes A and B. The total current I_T entering node A is divided into I_1, I_2 and I_3 These currents flow out of node A. According to Kirchhoff's current law, the current into node A is equal to the current out of node A that is,

$$I_T = I_1 + I_2 + I_3.$$

If we consider node B, all three currents I_1, I_2, I_3 are entering B, and the total current I_T is the leaving node B, Kirchoff's current law formula at this node is therefore the same as at node A.



fig(b)

$$I_1 + I_2 + I_3 = I_T.$$

In general, sum of the currents entering any point or node or junction equal to the sum of the currents leaving from the point or node or junction as shown in fig(b)

$$I_1 + I_2 + I_4 + I_7 = I_3 + I_5 + I_6$$

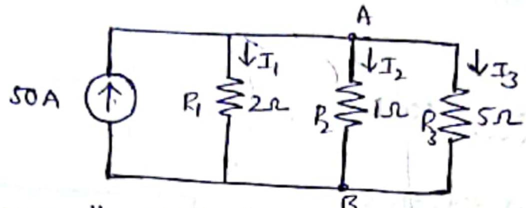
If all of the terms on the right side are brought over to the left side, their signs change to negative and a zero is left on the right side i.e.;

$$I_1 + I_2 + I_4 + I_7 - I_3 - I_5 - I_6 = 0$$

This means that the algebric sum of all the currents meeting at a junction is equal to zero.

Problems:

Determine the current in all resistors in the circuit shown in the figure



Sol: The above circuit contains a single node 'A' with reference node 'B'. Our first step is to assume the voltage V at node A. In a parallel circuit the same voltage is applied across each element. According to Ohm's law, the currents passing through each element are $I_1 = V/2$, $I_2 = V/1$; $I_3 = V/5$

By applying Kirchhoff's current law, we have

$$I = I_1 + I_2 + I_3$$

$$I = \frac{V}{2} + \frac{V}{1} + \frac{V}{5}$$

$$50 = V\left(\frac{1}{2} + \frac{1}{1} + \frac{1}{5}\right)$$

$$= V(0.5 + 1 + 0.2)$$

$$V = \frac{50}{1.7} = \frac{500}{17} = 29.41V$$

Once we know the voltage V at node A, we can find the current in any element by using Ohm's law.

The current in the 2Ω resistor is $I_1 = \frac{V}{R_1} = \frac{V}{2} = \frac{29.41}{2} = 14.705A$

Similarly $I_2 = \frac{V}{R_2} = \frac{29.41}{1} = 29.41\ A$

$I_3 = \frac{V}{R_3} = \frac{29.41}{5} = 5.882\ A$

The currents in all resistors are

$i_1 = 14.705A$

$i_2 = 29.41A$

$i_3 = 5.882A$

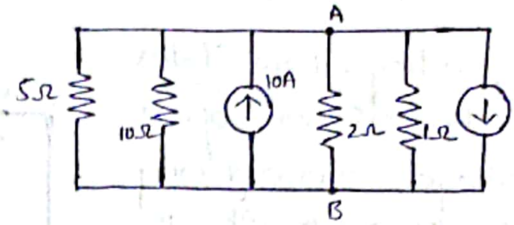
Verification

$I_T = i_1 + i_2 + i_3$

$50 = 14.705 + 29.41 + 5.88$

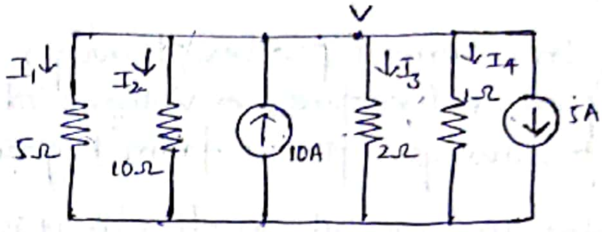
KCL

For the circuit shown in the figure find the voltage across the 10Ω resistor and the current passing through it.



Sol:

The circuit given is a parallel circuit and consists of a single node A. By assuming voltage V at the node A w.r.t B we can find out the current in the 10Ω branch.



According to Kirchhoff's current law

$$I_1 + I_2 + I_3 + I_4 + 5 = 10$$

By using Ohm's law we have

$$I_1 = V/5 \; ; \; I_2 = V/10 \; ; \; I_3 = V/2 \; , \; I_4 = V/1$$

$$\frac{V}{5} + \frac{V}{10} + \frac{V}{2} + \frac{V}{1} + 5 = 10$$

$$V\left(\frac{1}{5} + \frac{1}{10} + \frac{1}{2} + 1\right) = 5$$

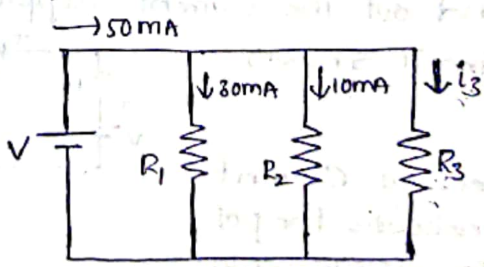
$$V(0.5 + 0.1 + 0.5 + 1) = 5$$

$$V = \frac{5}{1.8} = 2.78\,V$$

The voltage across the 10Ω resistor is 2.78V and the current passing through it is

$$I_2 = \frac{V}{10} = \frac{2.78}{10} = 0.278\,A$$

Determine the current through resistance R_3 in the circuit shown in the figure



Sol:

According to Kirchhoff's current law

$$I_T = I_1 + I_2 + I_3$$

Where I_T is the total current and I_1, I_2 and I_3 are the currents in resistances R_1, R_2 and R_3 respectively.

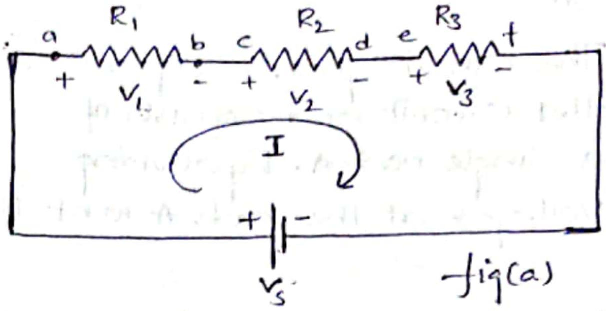
$$50 = 30 + 10 + i_3$$

$$i_3 = 50 - 30 - 10$$

$$= 10\,mA$$

Kirchhoff's Voltage law:

Kirchhoff's Voltage law States that the algebric sum of all branch Voltages around any Closed path in a circuit is always zero at all instants of time.



fig(a)

When the Current passes through a resistor, there is a loss of energy and therefore, a Voltage drop. In any element, the current always flows from higher potential to lower potential

Consider the circuit in fig(a). It is Customary to take the direction of Current I as indicated in the figure ie; it leaves the positive terminal of the voltage source and enters into the negative terminal.

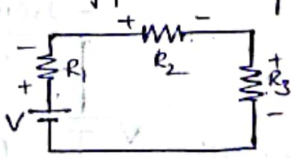
As the current passes through the circuit, the sum of the voltage drop around the loop is equal to the total voltage in that loop. Here the polarities are attribuled to the resistors to indicate that the voltages at point a, c and e are more than the voltages at b, d and f respectively, as the current passes from a to f.

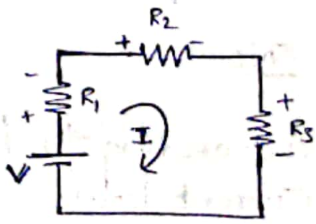
$$V_s = V_1 + V_2 + V_3$$

$$V_s - V_1 - V_2 - V_3 = 0$$

$$\boxed{\text{Around a closed path } \Sigma V = 0}$$

for example: find out the current Supplied by the Source V for the circuit shown





Assume the reference Current direction and indicate the polarities for different elements

By using Ohm's law, we find the voltage across Each resistor as follows

$$V_{R1} = IR_1, \quad V_{R2} = IR_2, \quad V_{R3} = IR_3$$

Where V_{R1}, V_{R2} and V_{R3} are the Voltages across R_1, R_2 and R_3 respectively. Finally, by applying Kirchoff's law, we can form the equation

$$V = V_{R1} + V_{R2} + V_{R3}$$

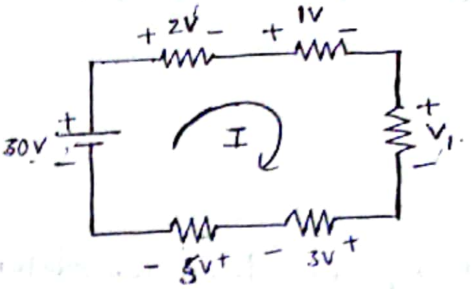
$$V = IR_1 + IR_2 + IR_3$$

from the above equation the Current delivered by the Source is given by

$$I = \frac{V}{R_1 + R_2 + R_3}$$

Problems:

For the circuit shown, determine the unknown voltage drop V_1



Sol:

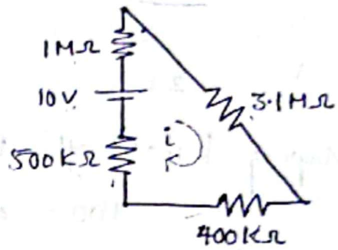
According to Kirchhoff's voltage law, the sum of the potential drops is equal to the sum of the potential rises

Therefore $30 = 2+1+V_1+3+5$

$V_1 = 30-11$

$= 19V$

What is the current in the circuit shown in fig(b). Determine voltage across each resistor.



Sol: We assume current I in the clockwise direction and indicate polarities. By using Ohm's law, we find the voltage drops across each resistor.

$V_{1M} = I \quad V_{3\cdot1M} = 3\cdot1I$

$V_{500K} = 0\cdot5I \quad V_{400K} = 0\cdot4I$

Now by applying Kirchhoff's voltage law, we form the equation

$$10 = \overset{IR}{I} + 3\cdot1I + 0\cdot5I + 0\cdot4I$$

$$10 = 5I$$

$$I = \frac{10}{5} = 2\,\mu A$$

Voltage across each resistor is as follows

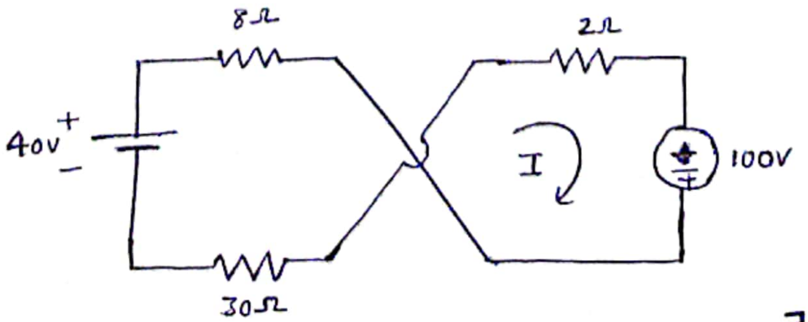
$V_{1M} = 1 \times 2 = 2\cdot0V$

$V_{3\cdot1M} = 3\cdot1 \times 2 = 6\cdot2V$

$V_{400K} = 0\cdot4 \times 2 = 0\cdot8V$

$V_{500K} = 0\cdot5 \times 2 = 1\cdot0V$

In the circuit given fig(c). find (a) the current I and b) the voltage across 30Ω



fig(c)

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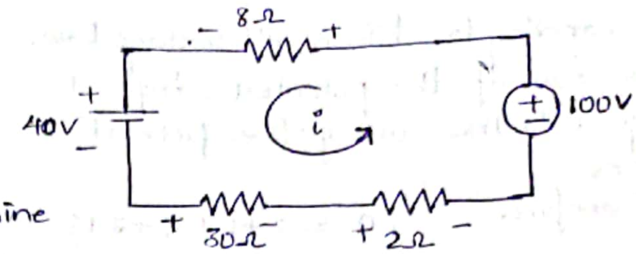
Sol:

KVL

We redraw the circuit as shown and assume current direction and indicate the assumed polarities of resistors



By using Ohm's law, we determine the voltage across each resistor as

$V_8 = 8I$

$V_{30} = 30I$

$V_2 = 2I$

By applying Kirchhoff's law, we get

$$100 = 8I + 40 + 30I + 2I$$

$$40I = 60$$

$$I = \frac{60}{40} = 1.5A$$

$\therefore$ Voltage drop across $30\Omega = V_{30} = 30 \times 1.5 = 45V$

N·SHARIEF

Network Simplification Techniques

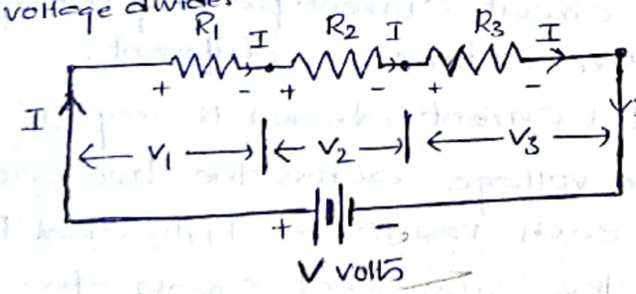
Introduction:

In electrical networks, the elements resistor, inductor and Capacitor are Connected in Various ways alongwith the energy sources. For analysing such Complicated networks, it is necessary to reduce these networks to a simplified for. The tech-niques of reducing Complex networks to simple form are known as network reduction or simplification techniques. The network simplification techniques are used in Various forms and also net-works are analysed by using Kirchoff's laws, loop analysis and Nodal analysis.

Series Circuit: A Series Circuit is one in which several resis-tances are Connected one after the other such connection is also Called end to end or Cascade Connection.
There is only one path for the flow of Current.

Resistors in Series:

Current Same
voltage divides



Series circuit

Consider the resistances shown in the figure, the resistances R_1, R_2 and R_3 are said to be in series, the combi-nation is connected across a source of voltage V volts. Naturally the Current flowing through all of them is same indicated as I amperes

eg: The chain of small lights, used for the decoration purposes is good example of Series Combi-nation.

Voltage distribution:

let V_1, V_2 and V_3 be the voltages across the terminals of resistances R_1, R_2 and R_3 respectively.

$$V = V_1 + V_2 + V_3$$

according to Ohm's law $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$

Current through all of them is same. ie; I

$$V = IR_1 + IR_2 + IR_3$$
$$= I(R_1 + R_2 + R_3)$$

Same current
$V = V_1 + V_2 + \cdots + V_n$
$R > R_1$; $R > R_2$ ---
$R > R_n$

applying Ohm's law to overall circuit.

$$V = I R_{eq}$$

Where R_{eq} = Equivalent resistance of the circuit

$$R_{eq} = R_1 + R_2 + R_3$$

for n (equivalent resistance) resistances in series

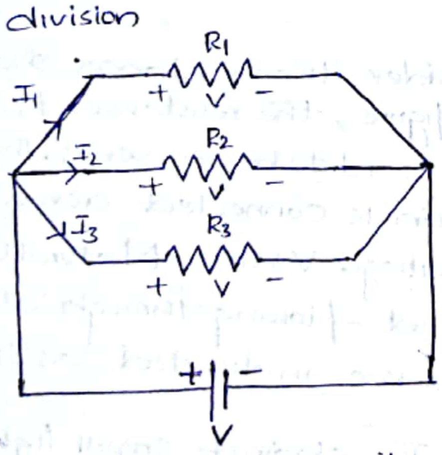
$$R = R_1 + R_2 + R_3 + \cdots + R_n$$

Parallel circuits:

The parallel circuit is one in which several resistances are connected across one another in such a way that one terminal of each is connected to form a junction point while the remaining ends are also joined to form another junction point.

Resistors in parallel:

Voltage same
Current division



Parallel circuit

- Consider a parallel circuit shown in the figure, R_1, R_2 and R_3 are connected in parallel and combination is connected across a voltage source.
- In circuit current passing through each resistance is different.
- Total current drawn is say 'I'
- The voltage across the two ends of each resistances R_1, R_2 and R_3 is the same and equals the supply voltage V.

Applying Ohm's law to each resistance

$$V = I_1 R_1, \quad V = I_2 R_2, \quad V = I_3 R_3$$

$$I_1 = \frac{V}{R_1}, \quad I_2 = \frac{V}{R_2}, \quad I_3 = \frac{V}{R_3}$$

$$I = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

for overall circuit if Ohm's law is applied.

$$V = I R_{eq}$$

and $$I = \frac{V}{R_{eq}}$$

where R_{eq} = Total or equivalent resistance of the circuit.

Comparing the two equations

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

where R is the equivalent resistance of the parallel combination.

In general if 'n' resistances are connected in parallel.

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

Conductance (G)

It is known that $\frac{1}{R} = G$ (Conductance) hence

$$G = G_1 + G_2 + G_3 + \cdots + G_n$$ - for parallel circuit

* If $n=2$, two resistances are in parallel then

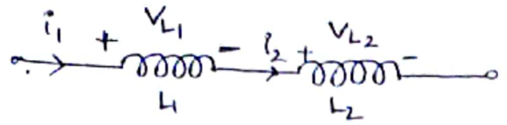
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

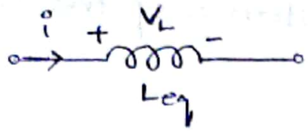
$$R = \frac{R_1 R_2}{R_1 + R_2}$$

This formula is directly used hereafter, for two resistances in parallel.

$$\left\{ \begin{array}{l} \text{Same current flows through each resistance} \\ V = V_1 + V_2 + \cdots + V_n \\ R > R_1,\ R > R_2 \cdots R > R_n. \end{array} \right.$$

Inductors in Series:





$V_{L1} = L_1 \frac{di_1}{dt}$ & $V_{L2} = L_2 \frac{di_2}{dt}$

$V_L = L_{eq} \frac{di}{dt}$

for Series Combination

$i = i_1 + i_2$

and $V_L = V_{L1} + V_{L2}$

$$L_{eq} \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt}$$

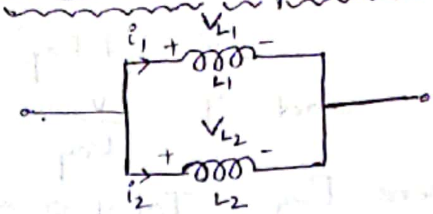
$$L_{eq} \frac{di}{dt} = (L_1 + L_2)\frac{di}{dt}$$

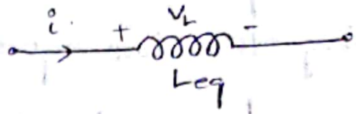
$$L_{eq} = L_1 + L_2$$

For n inductances in series

$$L_{eq} = L_1 + L_2 + L_3 + \dots + L_n$$

Inductors in parallel:





for inductor, we have

$i_1 = \frac{1}{L_1}\int_{-\infty}^{t} V_{L1} dt$, $i_2 = \frac{1}{L_2}\int_{-\infty}^{t} V_{L2} dt$ & $i = \frac{1}{L_{eq}}\int_{-\infty}^{t} V_L dt$

for parallel Combination

$V_L = V_{L1} = V_{L2}$

and $i = i_1 + i_2$

$$\frac{1}{L_{eq}}\int_{-\infty}^{t} V_L dt = \frac{1}{L_1}\int_{-\infty}^{t} V_L dt + \frac{1}{L_2}\int_{-\infty}^{t} V_L dt$$

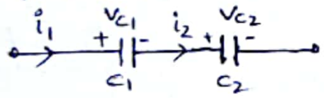
$$= \left(\frac{1}{L_1} + \frac{1}{L_2}\right)\int_{-\infty}^{t} V_L dt$$

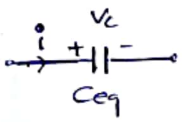
$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} \Rightarrow L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$$

For n inductances in parallel

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \dots \frac{1}{L_n}$$

Capacitors in Series





$V_{C1} = \frac{1}{C_1}\int_{-\infty}^{t} i_1 dt$, $V_{C2} = \frac{1}{C_2}\int_{-\infty}^{t} i_2 dt$. $V = \frac{1}{C_{eq}}\int_{-\infty}^{t} i dt$

for Series Combination

$i = i_1 = i_2$ and

$V_C = V_{C1} + V_{C2}$

$$\frac{1}{C_{eq}}\int_{-\infty}^{t} i dt = \frac{1}{C_1}\int_{-\infty}^{t} i_1 dt + \frac{1}{C_2}\int_{-\infty}^{t} i_2 dt$$

but $i = i_1 = i_2$

$$\frac{1}{C_{eq}}\int_{-\infty}^{t} i dt = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)\int_{-\infty}^{t} i dt$$

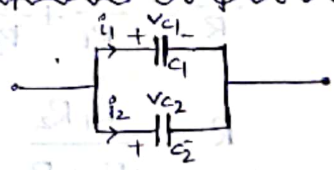
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

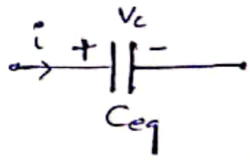
$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

for n Capacitors in Series

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$$

Capacitors in parallel.





for capacitor we have,

$i_1 = C_1 \frac{dV_{C1}}{dt}$, $i_2 = C_2 \frac{dV_2}{dt}$ $i = C_{eq} \frac{dV_C}{dt}$

for parallel Combination

$V_{C1} = V_{C2} = V_C$ and

$i = i_1 + i_2$

$$C_{eq} \frac{dV_C}{dt} = C_1 \frac{dV_{C1}}{dt} + C_2 \frac{dV_{C2}}{dt}$$

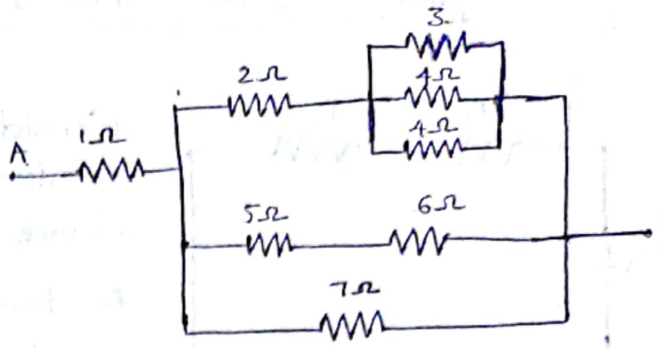
$$C_{eq} \frac{dV_C}{dt} = (C_1 + C_2)\frac{dV_C}{dt}$$

$$C_{eq} = C_1 + C_2$$

for n Capacitors in parallel

$$C_{eq} = C_1 + C_2 + \dots + C_n$$

Find the equivalent resistance between the two points A and B shown in the figure.



(a)

Sol

Identify Combinations of of Series and parallel resistances.

The resistances 5Ω and 6Ω are in Series, as going to carry same current

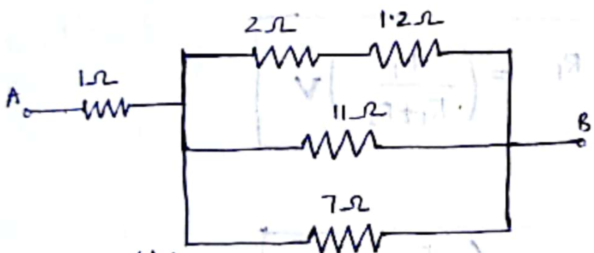
So equivalent resistance is $5+6 = 11\Omega$

While the resistances 3Ω, 4Ω and 4Ω are in parallel, as voltage across them same but current divides

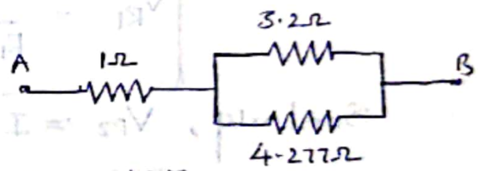
$\therefore$ Equivalent resistance is $\frac{1}{R} = \frac{1}{3} + \frac{1}{4} + \frac{1}{4} = \frac{10}{12}$

$R = \frac{12}{10} = 1{\cdot}2\Omega$

Replacing these Combinations redraw the figure as shown below



(b)



(c)

Now again 1·2Ω and 2Ω are in series So equivalent resistance

$2+1{\cdot}2 = 3{\cdot}2\Omega$. While 11Ω and 7Ω are in parallel.

Using formula $\frac{R_1R_2}{R_1+R_2}$ equivalent resistance is $\frac{11\times7}{11+7} = \frac{77}{18}$

$= 4{\cdot}277\Omega$

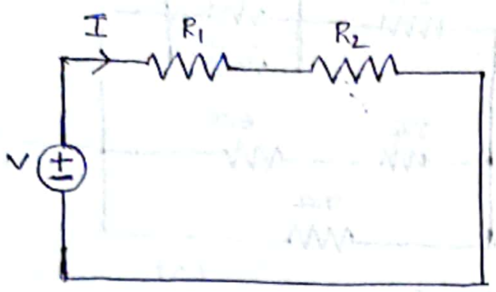
Replacing the respective Combinations redraw the circuit (c)

Now 3·2 and 4·277 are in parallel

Replacing them by $\frac{3{\cdot}2 \times 4{\cdot}277}{3{\cdot}2 + 4{\cdot}277} = 1{\cdot}8304\Omega$

$\therefore R_{AB} = 1 + 1{\cdot}8304 = 2{\cdot}8304\Omega$

Voltage division in series circuit of Resistors:



Consider a series circuit of two resistors R_1 and R_2 connected to source of V volts.

As two resistors are connected in series, the current flowing through both the resistors is same i.e; Then applying KVL, we get,

$$V = IR_1 + IR_2$$

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

Total voltage applied is equal to the sum of voltage drops V_{R1} and V_{R2} across R_1 and R_2 respectively.

$$V_{R1} = I \cdot R_1$$

$$\boxed{V_{R1} = \frac{V}{R_1+R_2} \cdot R_1 = \left(\frac{R_1}{R_1+R_2}\right)V}$$

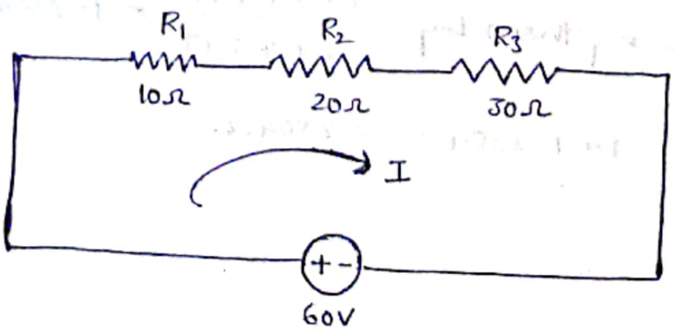
Similarly, $V_{R2} = I \cdot R_2$

$$\boxed{V_{R_2} = \frac{V}{R_1+R_2} \cdot R_2 = \left(\frac{R_2}{R_1+R_2}\right)V}$$

So this circuit is a voltage divider circuit.

In general, voltage drop across any resistor, or combination of resistors, in a series circuit is equal to the ratio of that resistance value to the total resistance, multiplied by the source voltage.

Eg: Find the voltage across the three resistances shown in the figure



Sol: $I = \frac{V}{R_1+R_2+R_3} = \frac{60}{10+20+30} = 1A$

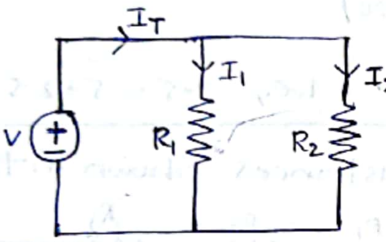
$\therefore V_{R_1} = IR_1 = \frac{V \times R_1}{R_1+R_2+R_3} = 1\times10 = 10V$

$V_{R_2} = IR_2 = \frac{V \times R_2}{R_1+R_2+R_3} = 1\times20 = 20V$

$V_{R_3} = IR_3 = \frac{V \times R_3}{R_1+R_2+R_3} = 1\times30 = 30V$

* It can be seen that voltage across any resistance of series circuit is ratio of that resistance to the total resistance, multiplied by the source voltage.

Current division in parallel circuit of resistors :



Consider a parallel circuit of two resistors R_1 and R_2 connected across a source of V volts.

Current through R_1 is I_1 and R_2 is I_2, while total current drawn from source is I_T

$\therefore I_T = I_1 + I_2$

but $I_1 = \frac{V}{R_1}$, $I_2 = \frac{V}{R_2}$

i.e; $V = I_1R_1 = I_2R_2$

$I_1 = I_2\left(\frac{R_2}{R_1}\right)$

Substuting value of I_1 in I_T,

$$\therefore I_T = I_2\left(\frac{R_2}{R_1}\right) + I_2$$

$$= I_2\left(\frac{R_2}{R_1}+1\right) = I_2\left(\frac{R_1+R_2}{R_1}\right)$$

$$\therefore \boxed{I_2 = \left(\frac{R_1}{R_1+R_2}\right) I_T}$$

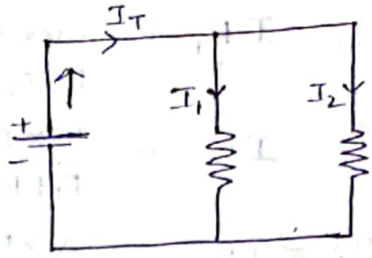
Now $I_1 = I_T - I_2$

$$= I_T - \left(\frac{R_1}{R_1+R_2}\right) I_T = \left(\frac{\cancel{R_1}+R_2-\cancel{R_1}}{R_1+R_2}\right) I_T$$

$$I_1 = \left(\frac{R_2}{R_1+R_2}\right) I_T$$

* In general, the current in any branch is equal to the ratio of opposite branch resistance to the total resistance value, multiplied by the total current in the circuit.

Eg: Find the magnitudes of total current, current through R_1 and R_2, if $R_1 = 10\Omega$, $R_2 = 20\Omega$ and $V = 50V$



Sol: The equivalent resistance of two is

$$R_{eq} = \frac{R_1 R_2}{R_1+R_2} = \frac{10\times 20}{10+20} = 6.67\Omega$$

$$I_T = \frac{V}{R_{eq}} = \frac{50}{6.67} = 7.5A$$

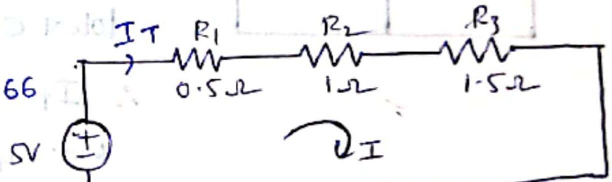
As per the current distribution in parallel circuit:

$$I_1 = I_T\left(\frac{R_2}{R_1+R_2}\right) = 7.5\times\left(\frac{20}{10+20}\right) = 5A$$

and $$I_2 = I_T\left(\frac{R_1}{R_1+R_2}\right) = 7.5\times\left(\frac{10}{10+20}\right) = 2.5A$$

It can be verified that $I_T = I_1 + I_2$ i.e., $7.5 = 5+2.5$

Find the voltage across the three resistances shown in the figure



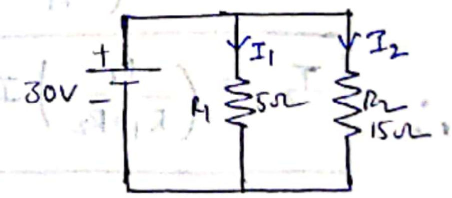
$$I = \frac{V}{R_1+R_2+R_3} = \frac{5}{0.5+1+1.5} = \frac{5}{3} = 1.66$$

$$V_{R_1} = IR_1 = \frac{V}{R_1+R_2+R_3}\cdot R_1 = \frac{5}{3}\times 0.5 = 1.66\times 0.5 = 0.833V$$

$$V_{R_2} = IR_2 = 5/3\times 1 = 1.66V$$

$$V_{R_3} = IR_3 = 5/3\times 1.5 = 2.49V$$

Find the magnitudes of total current, current through R_1 and R_2 is 5Ω and 15Ω and $V = 30V$



$$R_{eq} = \frac{5\times 15}{5+15} = \frac{75}{20} = 3.75\Omega$$

$$I_T = \frac{V}{R_{eq}} = \frac{30}{3.75} = 8A$$

As per the current distribution in parallel circuit

$$I_1 = I_T\left(\frac{R_2}{R_1+R_2}\right) = 8\left(\frac{15}{5+15}\right) = 6A$$

$$I_2 = I_T\left(\frac{R_1}{R_1+R_2}\right) = 8\left(\frac{5}{5+15}\right) = 2A$$

It can be verified that $I_T = I_1 + I_2 = 6+2 = \underline{\underline{8A}}$

Problems

A 100Ω resistance is directly switched on across a 10V battery. What is the Current through the resistor? How much is the power loss? Also find the energy Consumed in 5 sec.

Sol: from the given data

$V = 10V$, $R = 100\Omega$

$I = V/R = \frac{10}{100} = 0.1A$

power loss $= I^2R = (0.1)^2 \times 100 = 1W$

(or)

power loss $= V^2/R = 10^2/100 = 1W$

Energy Consumed $= I^2Rt$

$= 1 \times 5$ Watts sec

$= 5$ joules.

The strength of Current in 1 Henry inductor changes at a rate of 1A/sec. Find the Voltage across it and determine the magnitude of energy stored in the inductor after 2 sec.

Sol from the given data

$L = 1H$; $\frac{di}{dt} = 1A/s$

$V = L\frac{di}{dt} = 1 \times 1 = 1V$

The energy stored is given as

$W = \frac{1}{2}Li^2 = \frac{1}{2} \times 1 \times 2^2 = 2$ joules

---

A Capacitor has a Capacitance of 5μF. Calculate the stored energy in it if a d.c voltage of 100V is applied across it.

Sol: When the Capacitor will be full charged, the voltage across it would be 100V.

Thus we get $V = 100V$

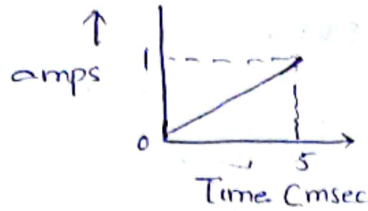
$C = 5 \times 10^{-6} F$

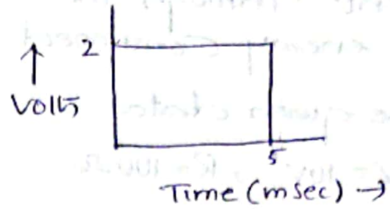
Stored energy is thus given as

$W = \frac{1}{2}CV^2 = \frac{1}{2} \times 5 \times 10^{-6} \times (100)^2$

$= 2.5 \times 10^{-2}$ joules.

The current and voltage profile of an element vs time has been shown in the figure. Determine the element and find its value.





Sol: By observation, it is revealed that since V and I are not proportional, hence the element cannot be resistor. Also at end of 5ms, even if $i \neq 0$, the voltage across the element becomes zero (i.e., the element behaves as a short circuit) Then the element cannot be a capacitor too. On the other hand, the current through it is zero at $t=0$ and the voltage is zero across the element at $t = 5$ msec. Thus element must be a inductor.

It may also be observed from the profiler that

$$\frac{di}{dt} = \frac{1}{5 \times 10^{-3}} = 0.2 \times 10^{3} \text{ A/sec}$$

and $v(\text{initial}) = 2V$

$$V = L\frac{di}{dt}$$

$$L = \frac{V}{di/dt} = \frac{2}{0.2 \times 10^{3}} = 10 \text{ mH}$$

A 50 μF capacitor is charged to retain 10 mJ of energy by a constant charging current of 1A. Determine the voltage across the capacitor.

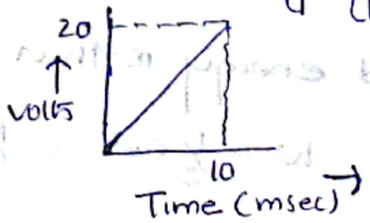
Sol: The energy stored in a capacitor is given by

$$W = \frac{1}{2} CV^2 \quad \text{i.e.,} \quad V = \sqrt{\frac{2W}{C}}$$

V being the voltage developed across the capacitor of capacitance C.

$$V = \sqrt{\frac{2 \times 10 \times 10^{-3}}{50 \times 10^{-6}}} = 20 V$$

Figure exhibits the voltage - time profile of a source to charge a capacitor of 50 μF. What is the charging current



Sol

$$\frac{dv}{dt} = \frac{20}{10} = 2 \text{ V/msec}$$

$$= 2 \times 10^{3} \text{ V/sec}$$

$$i_{\text{charging}} = C\frac{dv}{dt} = 50 \times 10^{-6} \times 2 \times 10^{3}$$

A Capacitor of 100 μF stores 10 mJ of energy. Obtain the amount of charge stored in it. How much time does it take to build up this charge if the charging current is 0.1 A?

Sol: As the energy stored in a capacitor is given by

$$W = \frac{1}{2}CV^2 \text{ and as } Q = CV,\ V = Q/C$$

We can write $W = \frac{1}{2}C\left(\frac{Q}{C}\right)^2 = \frac{Q^2}{2C}$

$$Q = \sqrt{2CW}$$

Here Q, the stored charge is then

$$Q = \sqrt{2 \times 100 \times 10^{-6} \times 10 \times 10^{-3}}$$

$$= 1.414 \times 10^{-3} \text{ Coulomb.}$$

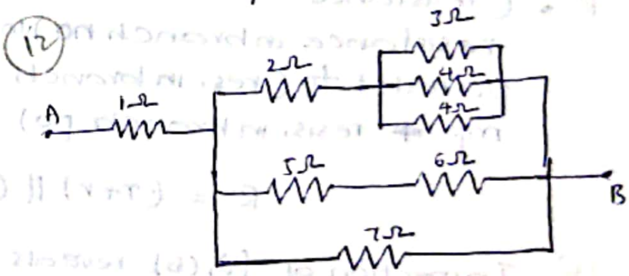
As $Q = it$ 'I' being the constant charging current and 't' the charging time.

$$t = Q/I = \frac{1.414 \times 10^{-3}}{0.1} = 14.14 \text{ ms}$$

(Problems on Series, parallel, Series parallel connections) NETWORK REDUCTION TECHNIQUES

Find the equivalent resistance between the two points A and B shown in the figure

12



Identify the combinations of series and parallel resistances

The resistances 5Ω and 6Ω are in series

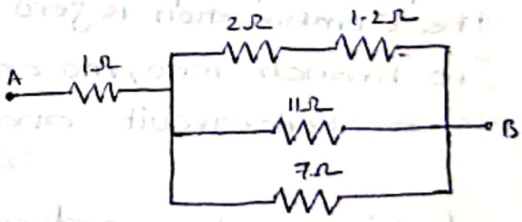
$$R_{eq} = 5 + 6 = 11\Omega$$

Res's 3Ω, 4Ω and 4Ω are in parallel

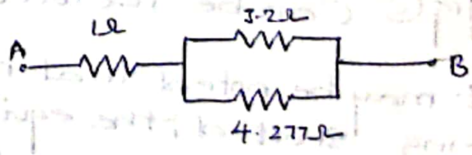
Equivalent Res's $\frac{1}{R} = \frac{1}{3} + \frac{1}{4} + \frac{1}{4}$

$$= \frac{10}{12}$$

$$R = 1.2\Omega$$

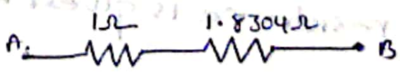


1.2Ω and 2Ω are in series, so equivalent resistance is $2 + 1.2\Omega = 3.2\Omega$

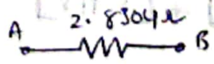


11Ω and 7Ω are in parallel

$$R_{eq} = \frac{11 \times 7}{11 + 7} = 4.277\Omega$$



3.2Ω and 4.277Ω are in parallel



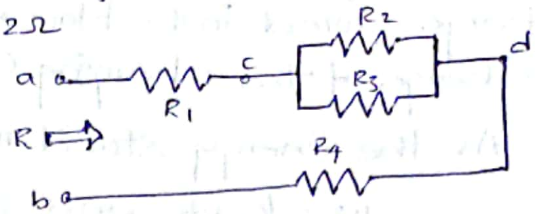
Replacing them by $\frac{3.2 \times 4.277}{3.2 + 4.277} = 1.8304\Omega$

$$R_{AB} = 1 + 1.8304$$

$$= 2.8304\Omega$$

Find the equivalent resistance of the circuit shown in figure

Given, $R_1 = R_4 = 5\Omega$ and $R_2 = R_3 = 2\Omega$



(4)

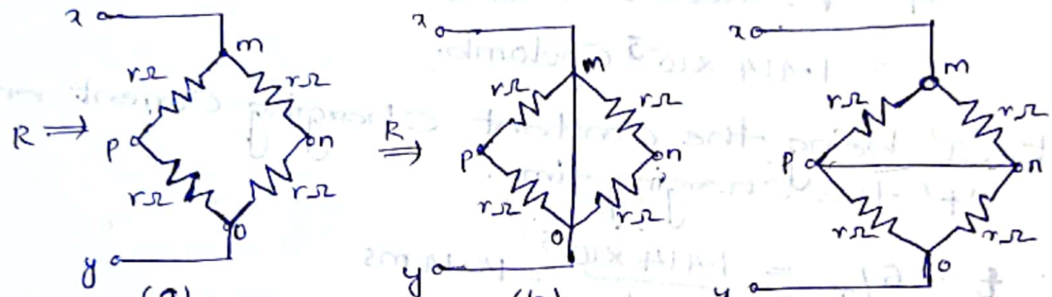
Sol Equivalent resistance across c-d is given by

$$R_{cd} = \frac{R_2 R_3}{R_2 + R_3} = \frac{2 \times 2}{2+2} = 1\Omega$$

$$R_{eq} = R_1 + R_{cd} + R_4 = 11\Omega$$

· Determine Equivalent resistance R across x-y in fig (a) (b) & (c)

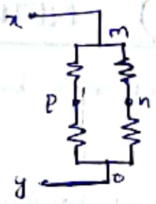
(10)



(a) (b) (c)

Sol:

ⓐ fig a can be reduced as



R = (resistance in branch mn + resistance in branch no) in parallel to (res. in branch mp + resis. in branch po)

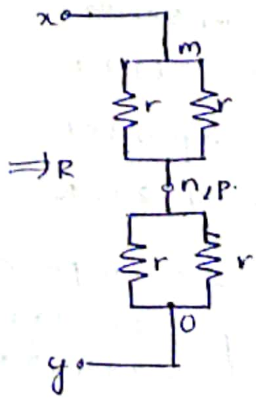
$$R = (r+r) \parallel (r+r) = 2r \parallel 2r = r\Omega$$

ⓑ Inspection of fig (b) reveals that the equivalent resistance of the combination is zero as out of three parallel branches (ie branch mno, mo and mpo) one of the branch (mo) is a short circuit and does not have any resistance

$(2r \parallel 2r) \parallel 0$

ⓒ fig ⓒ can be reduced as shown in the figure following

It may be noted that n-p being shorted, the equivalent resistance is given by

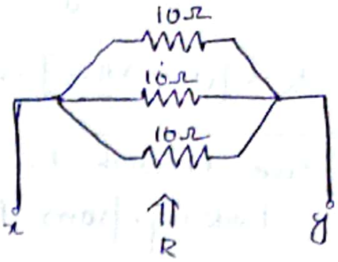


$$R = [r \parallel r] + [r \parallel r]$$

$$= \frac{r}{2} + \frac{r}{2}$$

$$= r\Omega$$

Find the equivalent resistance of the circuit shown



Sol The three resistances each of 10Ω are connected in parallel (11)

$$\frac{1}{R} = \frac{1}{10}+\frac{1}{10}+\frac{1}{10} = \frac{3}{10}$$

R being the equivalent resistance

$$R = \frac{10}{3} = 3.33\,\Omega \quad (\text{across } xy)$$

A current of 10A flows into a circuit consisting of 2, 4, 10 and 20Ω resistances respectively in parallel. Determine the current in each resistance.

Sol: let R being the equivalent resistance of the parallel circuit.

$$\frac{1}{R} = \frac{1}{2}+\frac{1}{4}+\frac{1}{10}+\frac{1}{20} = \frac{18}{20} \text{ mho}$$

$$R = \frac{20}{18}\,\Omega$$

The potential difference, V, across the circuit (also across each branch of it) is given by (12)

$V = RI$, I being the total current

$$= \frac{20}{18} \times 10$$

$$= 11.11\,V$$

$I_1 = V/R_1 = 11.11/2 = 5.55A$

$I_2 = V/R_2 = 11.11/4 = 2.78A$

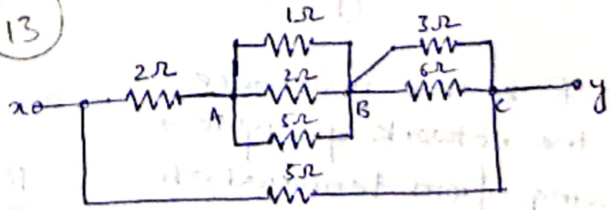
$I_3 = V/R_3 = 11.11/10 = 1.11A$

$I_4 = V/R_4 = 11.11/20 = 0.55A$

It may be seen that

$I = I_1+I_2+I_3+I_4 = 10A$

Find the equivalent resistance across x-y of the circuit (13)

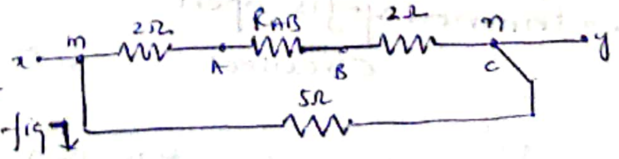


$$\frac{1}{R_{AB}} = 1+\frac{1}{2}+\frac{1}{5} = \frac{17}{10}$$

$$R_{AB} = \frac{10}{17}\,\Omega$$

also $$\frac{1}{R_{BC}} = \frac{1}{3}+\frac{1}{6} = \frac{1}{2}$$

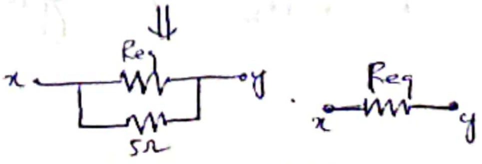
$$R_{BC} = 2\,\Omega$$



Assuming R_{eq} to be the equivalent series resistance of path m-n in fig

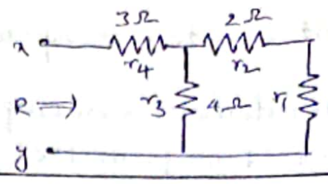
$$R_{eq} = 2+\frac{10}{17}+2 = 4.59\,\Omega$$

The resistance across x-y becomes



$$R = \frac{5\times R_{eq}}{5+R_{eq}} = \frac{5\times 4.59}{5+4.59} = 2.39\,\Omega$$

Find R across x-y terminals



(1)

Sol:

$$R = [(r_1+r_2) \parallel r_3] + r_4 = 5\Omega$$

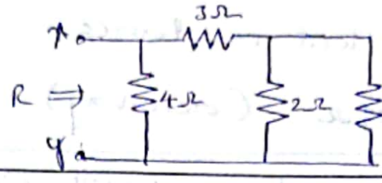
A resistive network is shown in figure. Find the equivalent resis-tance looking from terminal x-y

(Ladder N/w)

Sol

$$R = [(2\parallel 2)+3]\parallel 4$$

$$= 2\Omega$$

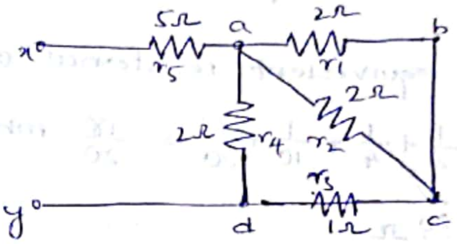


(2)

Find the equivalent resistance of the circuit shown, across x-y

Sol

The net resistance across a-b terminals is



(3)

$$r_{ab} = [(r_1 \parallel r_2)+r_3] \parallel r_4 = 1\Omega$$

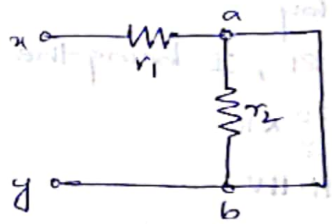
$$R = r_5 + r_{ab} = 5+1 = 6\Omega$$

Find R across terminals x-y in fig

Sol

As a-b terminal is shorted in figure, hence r_2 is of no use. Hence R is the equivalent to only r_1

$$R = r_1$$



(5)

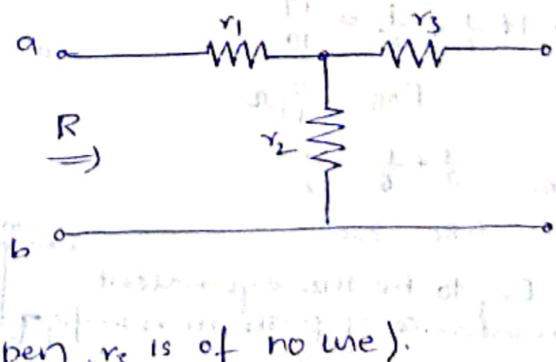
$$\frac{r_2 \times 0}{r_2+0} = 0$$

$$R = 0 + r_1 = r_1$$

The figure represents a resistance circuited, open circui-ted at terminal y-z. Find the equivalent resistance of the network looking towards it from the terminals a-b

(6)

Let R be the resistance of the network of figure → looking from terminal a-b when terminal y-z is open circuited



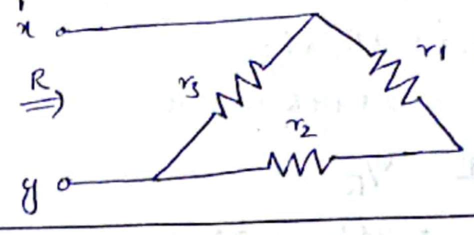
$$R = r_1 + r_2 \quad (\because y \text{ is open}, r_3 \text{ is of no use}).$$

Find R across x-y in the figure

Sol

$R = (r_1 + r_2) \parallel r_3 = 2\Omega$

(7)



$r_1 = 1\Omega$
$r_2 = 3\Omega$
$r_3 = 4\Omega$

Find the resistance R across x-y in the network shown in the following figure.

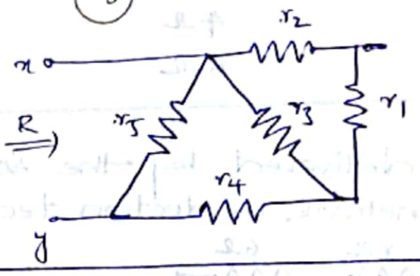
Sol:

(8)

$$R = [\{(r_1+r_2) \parallel r_3\} + r_4] \parallel r_5$$

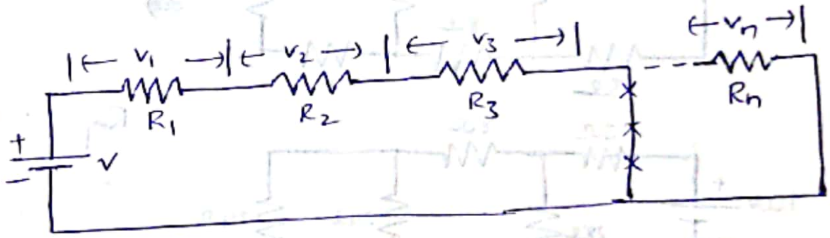
$$= [\{(2+3) \parallel 5\} + 1.5] \parallel 4$$

$$= 2\Omega$$



$r_1 = 2\Omega$
$r_2 = 3\Omega$
$r_3 = 5\Omega$
$r_4 = 1.5\Omega$
$r_5 = 4\Omega$

In a series circuit of fig, determine the voltage drop of the nth resistor in terms of the other resistances and the supply voltage.



[V_n = drop in the nth resistor R_n
V = supply voltage]

Sol $V_1 = IR_1$, $V_2 = IR_2$, ---- $V_n = IR_n$

$$V_n = \frac{V}{R_1 + R_2 + \text{----} R_n} \cdot R_n \qquad \left(\because \; I = \frac{V}{R_1 + R_2 + \text{----} + R_n} \right)$$

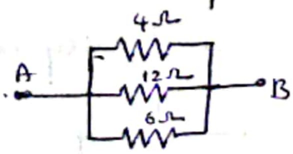
ie, $V_n = \dfrac{R_n}{R} \cdot V$ (assuming the equivalent resistance of R_1, R_2, R_3 ---- , R_n to be R)

---

(18)

Three resistors 4Ω, 12Ω & 6Ω are connected in parallel. If the total current taken 12 Amperes. Find the current through resistor.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{4} + \frac{1}{12} + \frac{1}{6} = \frac{6}{12} = \frac{1}{2}$$



$R_{eq} = 2\Omega$

$V = IR = 12 \times 2 = 24V$

(19)

I across $4\Omega = \frac{V}{R_1} = 24/4 = 6A$, $I_{12\Omega} = \frac{V}{R_2} = \frac{24}{12} = 2A$, $I_{6\Omega} = \frac{24}{6} = 4A$

Find the voltage across each resistance.

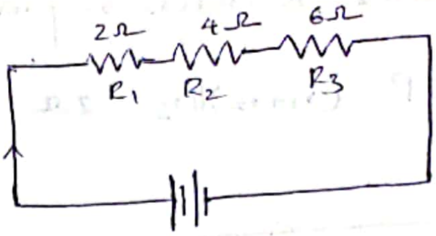
19

$R = R_1 + R_2 + R_3$

$R = 2 + 4 + 6 = 12\Omega$

$I = V/R$

$= 24/12 = 2A$



$2A = I(A)$

$V = 24V$

Current is flowing through the circuit is $I = 2A$

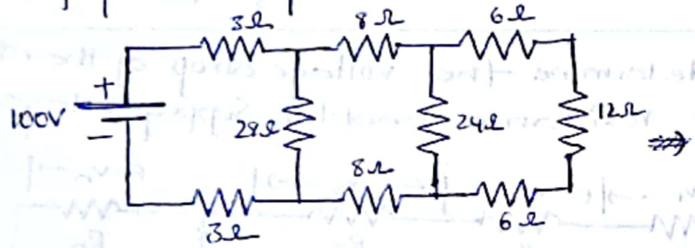
Voltage drop across 2Ω resistor $= I \times R_1 = 2 \times 2 = 4V$

4Ω $= I \times R_2 = 2 \times 4 = 8V$

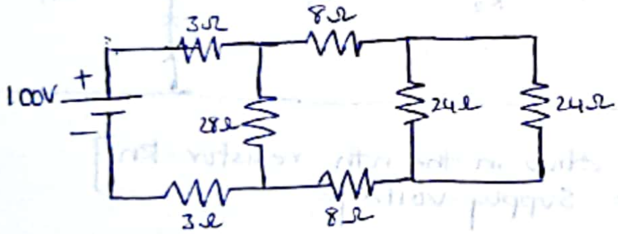
6Ω $= I \times R_3 = 2 \times 6 = 12V$

Find the current delivered by the source for the network shown in figure using network reduction technique.

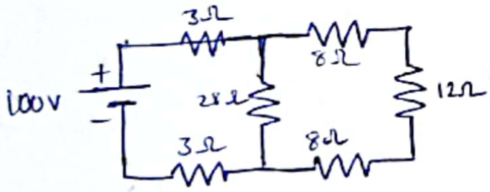
14



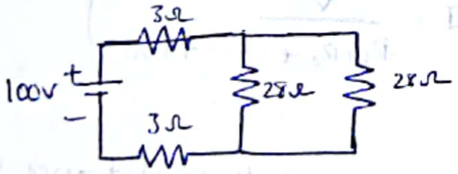
$R_{eq} \cdot 6 + 12 + 6 = 24\Omega$



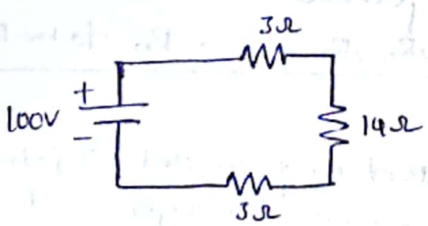
$24 \| 24 \quad \frac{24 \times 24}{24 + 24} = 12\Omega$



$8 + 12 + 8 = 28\Omega$

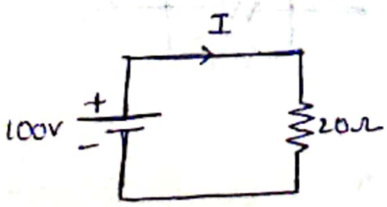


$28 \| 28\Omega \quad \frac{28 \times 28}{28 + 28} = 14\Omega$



$3\Omega + 14\Omega + 3\Omega = 20\Omega$

The circuit finally reduces to as shown in the below figure



The equivalent resistance $R_{eq} = 20\Omega$

According to ohm's law

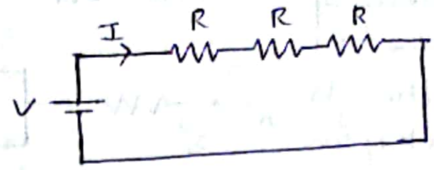
$V = IR$

$I = V/R = 100/20 = 5A$

Three equal resistances are available find the equivalent resistance in series and parallel.

9

<u>Series Connection</u>

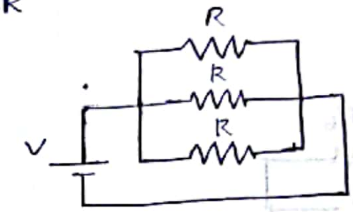


Where V is applied voltage and I is the Current flow through the circuit.

The equivalent resistance when they are connected in series

$$R_{eq} = R+R+R$$
$$= 3R$$

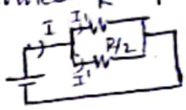
<u>Parallel Connection</u>:



$$R_{eq} = (R \| R) R$$
$$= \left(\frac{R \times R}{R+R}\right) \| R$$
$$= \left(\frac{R^2}{2R}\right) \| R$$
$$= \frac{R}{2} \| R$$
$$= \frac{\left(\frac{R}{2}\right) R}{R/_2 + R} = \frac{R^2/_2}{3R/_2} = R/_3$$

<u>Case ii</u>

Ratio of Current through each element when they are connected in parallel

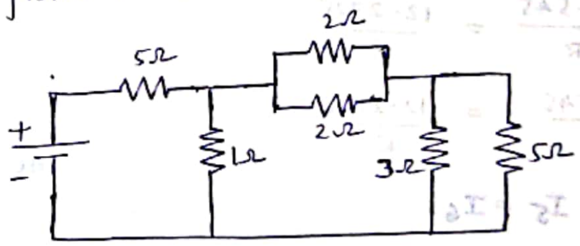


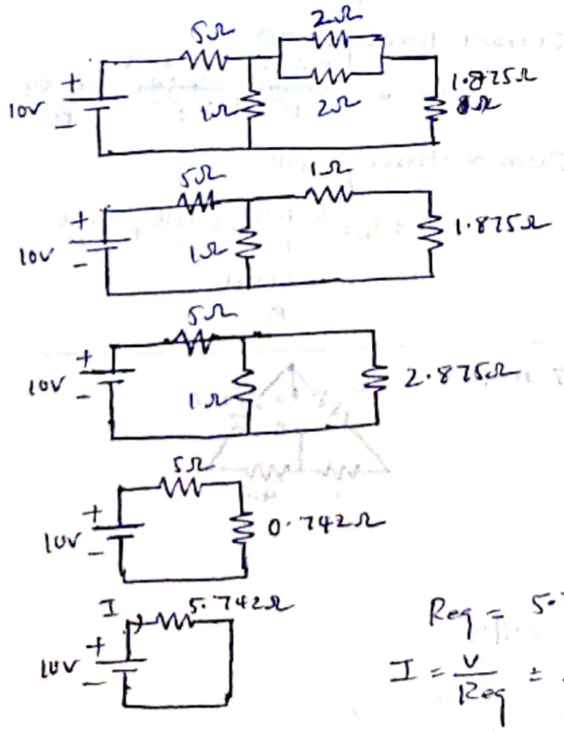
$$I_1 = I \times \frac{R/_2}{R/_2 + R}$$
$$= I/_3$$
$$\left(I' = I \times \frac{R}{R + R/_2}\right.$$
$$= 2/_3 I$$

$$I_2 = I/_3$$
$$I_3 = I/_3.$$

Find the total current flows in the circuit.

15

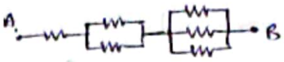


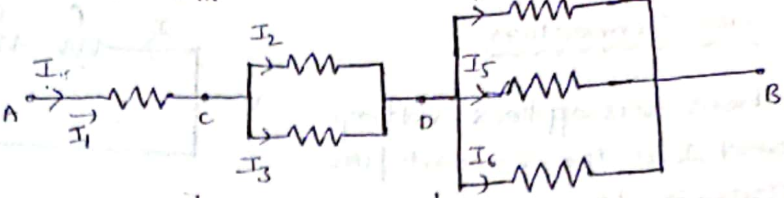


$$R_{eq} = 5.742\Omega$$

$$I = \frac{V}{R_{eq}} = \frac{10}{5.742} = 1.75A$$

Find the equivalent resistance between terminals AB in the network as shown in the figure each has a resistance of R ohms and find the total Current, current through each of the element if the voltage is 45V.





R | $R \| R$ | $R/2 \| R$

$$\frac{R\times R}{R+R} = \frac{R^2}{2R} = R/2$$

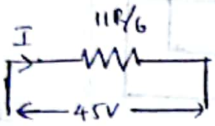
$$\frac{R/2 \times R}{R/2+R} = \frac{R^2/2}{3R/2} = \frac{R}{3}$$

(Total) Equivalent resistance

$$R_{AB} = R + \frac{R}{2} + \frac{R}{3}$$

$$= \frac{6R+3R+2R}{6}$$

$$= 11R/6$$



20

$$I = \frac{V}{R_{AB}} = \frac{45}{11R/6} = \frac{270}{11R} = \frac{24.545}{R}$$

$$I_1 = I = \frac{24.545}{R}$$

$$I_2 = I/2 = I_3$$

$$I_2 = \frac{24.545}{2R} = \frac{12.2725}{R}$$

$$I_3 = \frac{24.545}{2R} = \frac{12.2725}{R}$$

$$I_4 = I/3 = I_5 = I_6$$

$$I_4 = \frac{24.545}{3R} = \frac{8.1816}{R}$$

$$I_5 = \frac{24.545}{3R} = \frac{8.1816}{R}$$

$$I_6 = \frac{8.1816}{R}$$

Verification

AC, CD and DB

AC $I_1 = I$ (current through AC)

$$= \frac{24.545}{R}$$

Current through CD

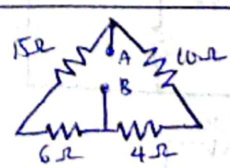
$$I_2 + I_3 = \frac{\cancel{24.545}\ 12.2725}{R} + \frac{\cancel{24.545}\ 12.2725}{R} = \frac{24.545}{R}$$

Current through DB

$$I_4 + I_5 + I_6 = \frac{8.1816}{R} + \frac{8.1816}{R} + \frac{8.1816}{R}$$

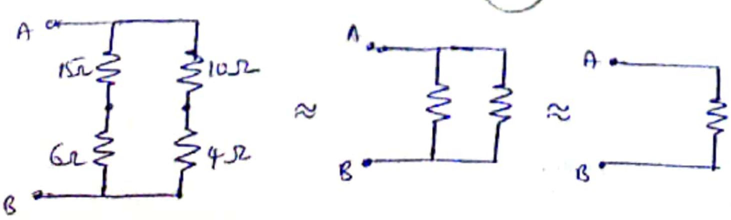
$$= \frac{24.545}{R}$$

Find equivalent resistance between points A-B



Redrawing the circuit

33

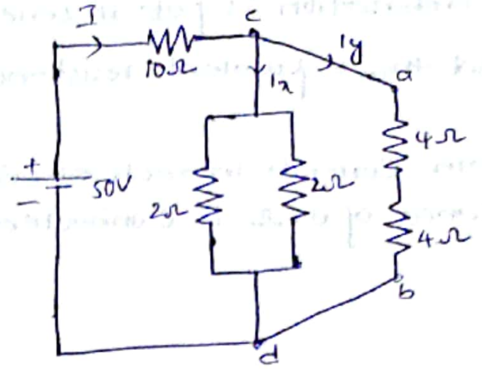


$R_{AB} = 21 \| 14$

$$R_{AB} = \frac{21\times 14}{21+14} = 8.4\Omega$$

Determine the current drawn from the battery of figure

(16)



Sol The equivalent resistance in a-b path is 8Ω and that of c-d is 1Ω.

Hence, the net resistance of the circuit across the battery is

$$\left(\frac{1\times 8}{1+8}+10\right)\Omega = 10.89\Omega$$

$\therefore$ I, the battery Current $= \frac{50}{10.89} = 4.6A$

A battery has an internal resistance of 0.5 ohm and open circuit voltage of 12V. What is the power lost within the battery and the terminal voltage on full load if a resistance of 8 ohms is connected across the terminals of the battery.

Sol The internal resistance will be in series with the load. Hence the circuit current will be

$$I = \frac{12}{8.5} = 3.43A$$

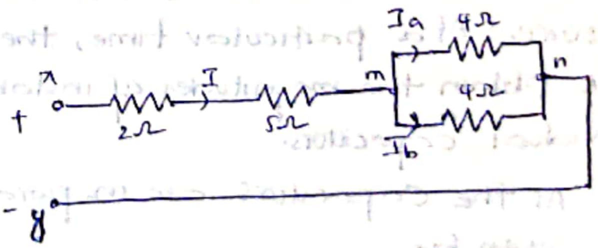
Terminal voltage $= IR_L = 3.43\times 8 = 10.3V$ (22)

Powerloss in the battery $= I^2 R_{int}$

$= (3.43)^2 \times 0.5$

$= 5.88W$

Calculate the voltage that is to be connected across terminals x-y in figure such that the voltage across the 2Ω resistor is 10V. Also find Ia and Ib. What is the total power loss in the circuit.



The equivalent resistance across the terminals x-y is

$$R = \frac{4\times 4}{4+4} + 5 + 2 = 9\Omega$$

However if the drop across 2Ω resistor is to be 10V, the current through it (I) should be $I = \frac{10}{2} = 5A$

(23)

The total drop across x-y is $I\times R = 5\times 9 = 45V$

Hence the supply voltage across x-y must be 45V

again $V_{m-n} = 45 - 5\times(2+5) = 10V$

$I_a = 10/4 = 2.5A$

$I_b = 10/4 = 2.5A$

The total power loss in the circuit is I^2R

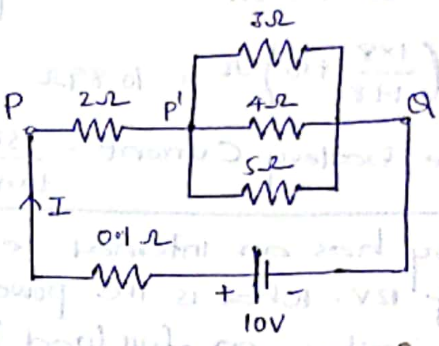
$= 5^2\times 9 = 225W$

f Three resistances of 3, 4 and 5Ω are connected in parallel and this combination is put in series with 2Ω resistor.

a) Find the equivalent resistance of the combination (at terminals P-Q)

b) Obtain current in each circuit when a battery of 10V with internal resistance of 0·1Ω is connected across P-Q

Sol (21)



a) $R_{eq} = \dfrac{1}{\frac{1}{3}+\frac{1}{4}+\frac{1}{5}} + 2 = 3{\cdot}28\,\Omega$ (across P-Q)

b) $I = \dfrac{10}{3{\cdot}28+0{\cdot}1} = 2{\cdot}96A$

Voltage across

$P\text{-}Q = 10 - 2{\cdot}96 \times 0{\cdot}1 = 9{\cdot}704V$

Drop in $P'Q = 9{\cdot}704 - (2{\cdot}96 \times 2) = 3{\cdot}784V$

$\therefore \quad I_{3\Omega} = \dfrac{3{\cdot}784}{3} = 1{\cdot}26A$

$I_{4\Omega} = \dfrac{3{\cdot}784}{4} = 0{\cdot}946A$

$I_{5\Omega} = \dfrac{3{\cdot}784}{4} = 0{\cdot}7568A.$

Check $I = 1{\cdot}26 + 0{\cdot}946 + 0{\cdot}7568 = 2{\cdot}96A.$

A 20μF capacitor is connected in parallel with a 40μF capacitor and the combination is connected across a time-varying voltage source. At a particular time, the current supplied by the source is 5A. Obtain the magnitudes of instantaneous currents through the individual capacitors.

Sol As the capacitors are in parallel, the voltage V across them is given by.

$$V = \frac{1}{C_1}\int i_1 dt = \frac{1}{C_2}\int i_2 dt$$ (28)

$$i_1 = C_1 \frac{dv}{dt} \quad \text{and} \quad i_2 = C_2 \frac{dv}{dt}$$

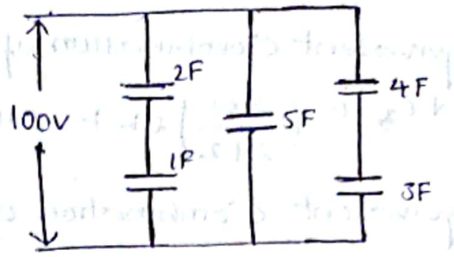
$$\frac{i_1}{i_2} = \frac{C_1}{C_2} = \frac{20}{40} = \frac{1}{2}$$

Also $i_1 + i_2 = 5A$

Solving 1 & 2, $i_1 = 1{\cdot}67A$ & $i_2 = 3{\cdot}33A.$

2[illegible]

Find the equivalent Capacitance, total energy stored if the applied Voltage is 100V for the circuit shown in the figure.



Capacitances 4F and 3F are Connected in series

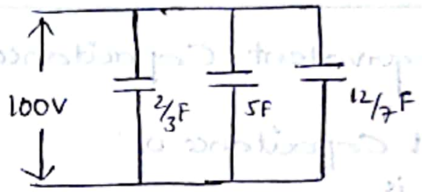
$$\frac{1}{C_s} = \frac{1}{4} + \frac{1}{3} = \frac{3+4}{12} = \frac{7}{12}$$

$$C_s = \frac{12}{7} F$$

Similarly for 2F and 1F

$$\frac{1}{C_s} = \frac{1}{2} + \frac{1}{1} = \frac{1+2}{2} = \frac{3}{2}$$

$$C_s = \frac{2}{3} F$$



Capacitors $2/3$F, 5F & $12/7$F are in parallel, equivalent Capacitance is given as

$$C_{eq} = \frac{2}{3} + 5 + \frac{12}{7} = 7.38F$$

23

Energy stored in the Capacitor

$$W_C = \frac{1}{2} CV^2$$

$$= \frac{1}{2} (8.52)(1000)^2$$

$$= 42600 \text{ mJoules}$$

Three Inductances of 4H each are Connected in series. What is the equivalent inductance?

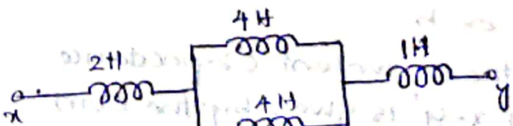
Sol

24

The equivalent inductance L is given by

$$L = L_1 + L_2 + L_3 = 4+4+4 = 12H$$

Three pure inductances, as shown in figure, are Connected. Find the equivalent inductance.



Sol

The equivalent inductance of the parllel Connection

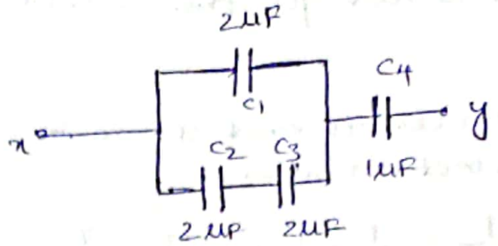
$$L = \frac{4 \times 4}{4+4} = 2H$$

25

The net inductance of the circuit across x-y is

$$L_{x-y} = 2+2+1 = 5H$$

Find the equivalent Capacitance of the Combination shown in figure across x-y.



Sol

The equivalent Combination of C_2 and C_3 is $\left(\frac{2\times 2}{2+2}\right)$ μF i.e; 1μF

The equivalent Combination of this 1μF and C_1 is (C_1+1)μF $= 3$μF

The net Capacitance across x-y is

$$\frac{3\times C_4}{3+C_4} = \frac{3\times 1}{3+1} = \frac{3}{4}\,\mu F$$

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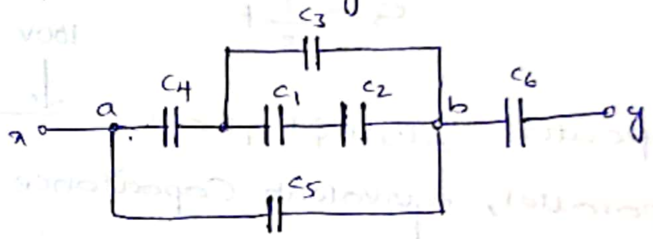
Find the equivalent Capacitance across x-y



The equivalent Capacitance of C_1, C_2 and C_3 is

$$C_{eq_1} = \left[\frac{C_1C_2}{C_1+C_2} + C_3\right]$$

C_{eq_1} is in series with C_4

The equivalent Combination is $C_{eq_2} = \dfrac{C_4 \times C_{eq_1}}{C_4 + C_{eq_1}}$

Again C_{eq_2} is in parllel with C_5

$$C_{eq_3} = C_5 + C_{eq_2}$$

$$= C_5 + \frac{C_4 C_{eq_1}}{C_4 + C_{eq_1}}$$

$$= C_5 + \left(\frac{C_4\left(\frac{C_1C_2}{C_1+C_2} + C_3\right)}{C_4 + \frac{C_1C_2}{C_1+C_2} + C_3}\right)$$

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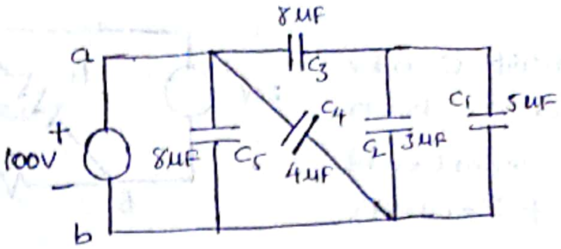
Then C_{eq_3} is the equivalent capacitance between terminals a-b

Hence, the equivalent Capacitance between x-y is given by the Combination of C_{eq_3} and C_6 (in Series)

$$C_{x-y} = \frac{C_{eq_3} \times C_6}{C_{eq_3} + C_6} = \frac{\left(\left\{C_5 + \frac{C_4\left(\left(\frac{C_1C_2}{C_1+C_2}\right) + C_3\right)}{C_4 + \frac{C_1C_2}{C_1+C_2} + C_3}\right\} \times C_6\right)}{\left(\left\{C_5 + \frac{C_4\left(\frac{C_1C_2}{C_1+C_2} + C_3\right)}{C_4 + \frac{C_1C_2}{C_1+C_2} + C_3}\right\} + C_6\right)}$$

Determine equivalent Capacitance across terminal (a-b) in fig. Also find the charging time to charge these capacitances by a steady direct current of constant magnitude of 10A



$$C_{a-b} = \left[\frac{(C_1+C_2)C_3}{(C_1+C_2)+C_3} \parallel C_4\right] \parallel C_5$$

$= 16\mu F$

$\therefore \; Q_{net} = C_{a-b} \times V \qquad (C = Q/V)$

$= 16 \times 10^{-6} \times 100$

$= 1600 \mu C$

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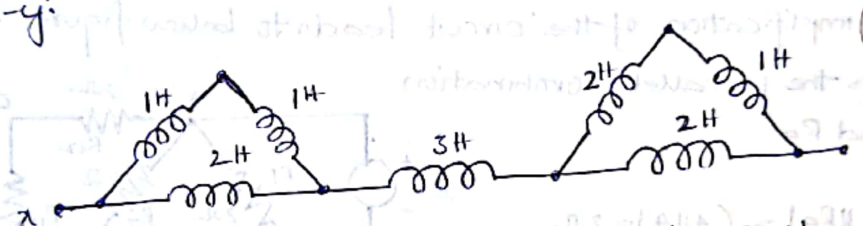
Hence charging time,

$$t = \frac{Q_{net}}{I} = \frac{1600 \times 10^{-6}}{10} = 160 \mu sec.$$

Find the equivalent inductance for the figure shown, between x-y.

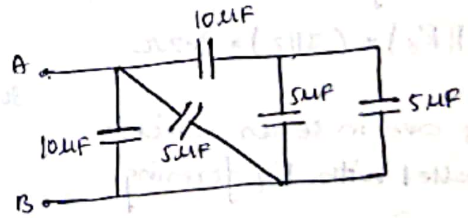
30



$L = 5.2H$

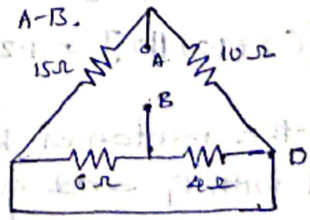
Find the equivalent capacitance between the terminals A and B in the circuit shown in figure

32



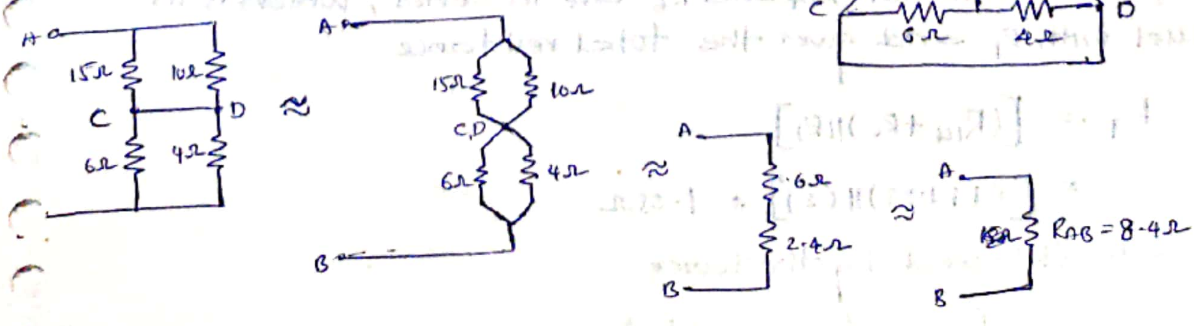
Ans $C_{eq} = 50\mu F$

Find the equivalent resistance between points A-B.

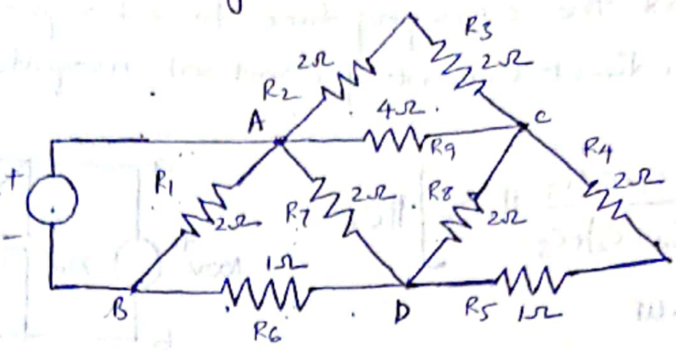


34

Redraw the circuit



Determine the current delivered by the source in the circuit shown in the figure.



Sol:

The circuit can be modified as shown

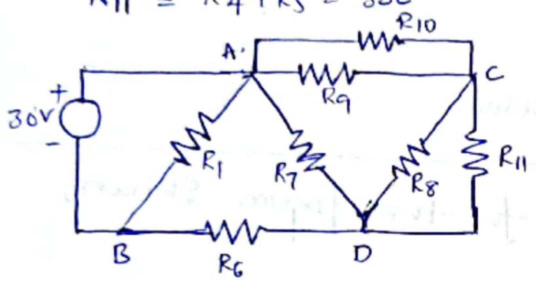
R_{10} is the series Combination of R_2 and R_3

$$R_{10} = R_2 + R_3 = 4\Omega$$

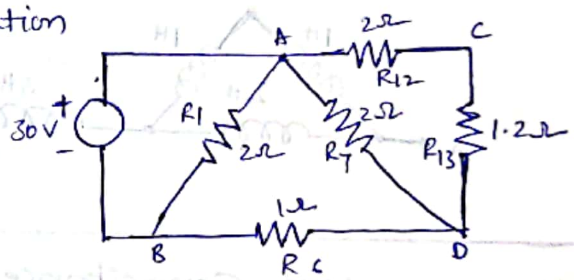
35

R_{11} is the Series Combination of R_4 and R_5

$$R_{11} = R_4 + R_5 = 3\Omega$$



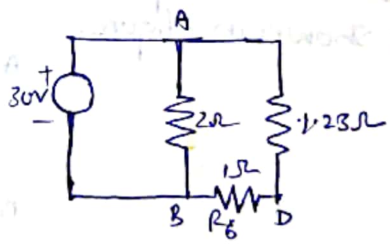
further simplification of the circuit leads to below figure where R_{12} is the parallel Combination of R_{10} and R_9



$$R_{12} = (R_{10} \parallel R_9) = (4 \parallel 4) = 2\Omega$$

Similarly, R_{13} is the parallel Combination of R_{11} and R_8

$$R_{13} = (R_{11} \parallel R_8) = (3 \parallel 2) = 1.2\Omega$$



R_{12} and R_{13} are in series, which is in parallel with R_7 forming R_{14}.

$$R_{14} = [(R_{12} + R_{13}) \parallel R_7]$$

$$= [(2 + 1.2) \parallel 2] = 1.23\Omega$$

further, the resistances R_{14} and R_6 are in Series, which is in parallel with R_1 and given the total resistance

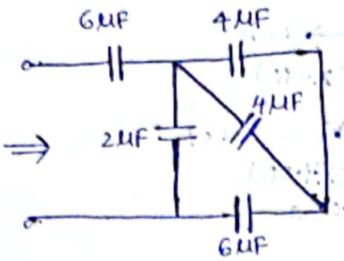
$$R_T = [(R_{14} + R_6) \parallel R_1]$$

$$= [(1 + 1.23) \parallel (2)] = 1.05\Omega$$

The current delivered by the Source

$$I = 30/1.05 = 28.57A.$$

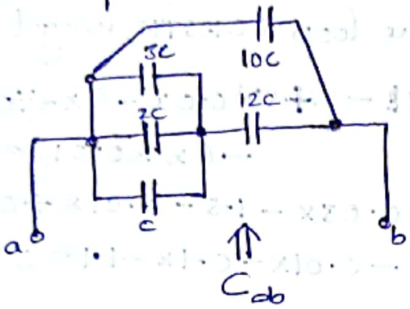
Find equivalent Capacitance of the Combination shown in the figure. (36)



Sol

$$C = \frac{\left\{\left(\frac{(4+4)\times 6}{8+6}\right)+2\right\}\times 6}{\left(\frac{(4+4)6}{8+6}\right)+2+6} = 2.85\,\mu F$$

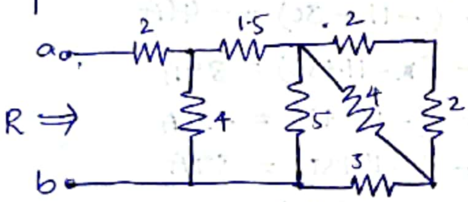
Find the equivalent Capacitance of the Combination shown in the figure (37)



Sol

$C_{ab} = 14C$

Find the equivalent resistance of the circuit between a-b as shown in figure (38)



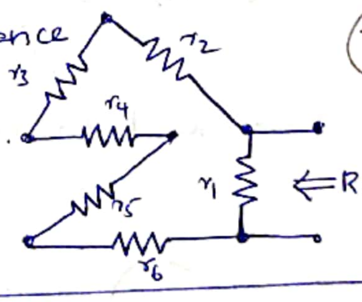
Sol

$R = [[(\{((2+2)\parallel 4)+3\}\parallel 5)+1.5]\parallel 4]$

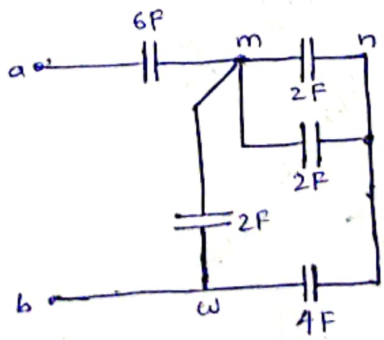
Find the equivalent resistance (39)

Sol

$R = (r_1) \parallel (r_2+r_3+r_4+r_5+r_6)$



Find equivalent Capacitance of the system of Capacitances shown in figure (40)

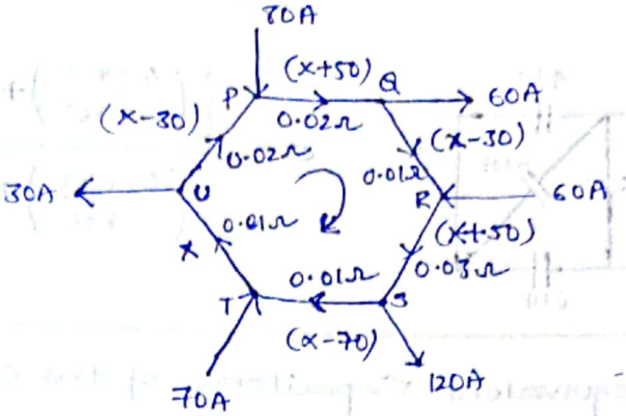


Sol

$C_{eq\,ab} = 2.4F$

SHA
RIEF

Find the current in all branches in the circuit shown in the figure.



Applying Kirchhoff's voltage law, for the loop PQRSTU, we get

$$-(x-30)\times 0.02-(x+50)0.2-(x-10)0.01-(x+50)0.03-(x-70)0.01$$
$$-(x\times 0.01)=0$$

$$-0.02x+0.6-0.02x-1-0.01x+0.1-0.03x-1.5-0.01x+0.7$$
$$-0.01x-0.1x-1.1=0$$

$$x=\frac{-1.1}{0.1}=-11A$$

Current in branch TU $= x = -11A$

$UP=(x-30)=(-11-30)=-41A$

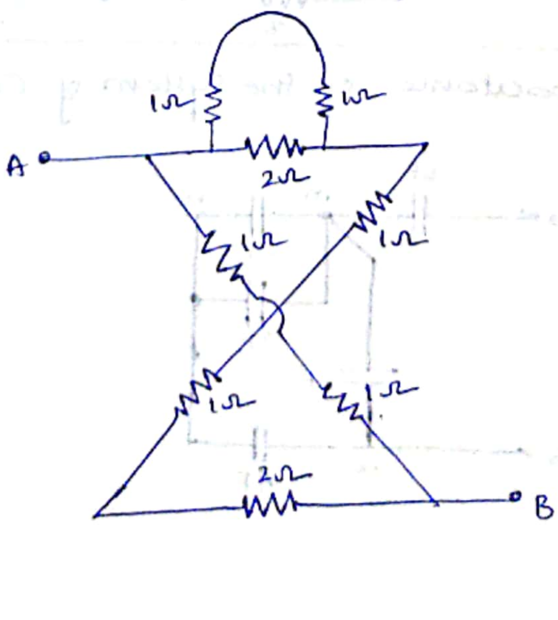
$PQ=(x+50)=(-11+50)=39A$

$QR=(x-10)=(-11-10)=-21A$

$RS=(x+50)=(-11+50)=39A$

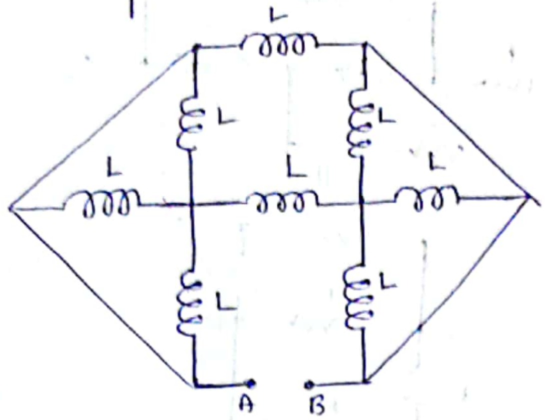
Current in branch $ST=(x-70)=(-11-70)=-81A$

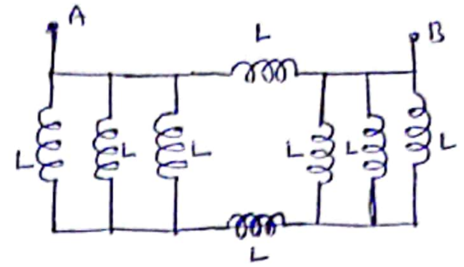
* Find the equivalent resistance between the terminals AB.

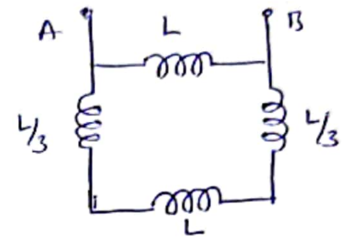


$R_{AB}=?$

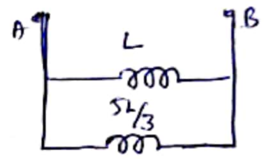
Find equivalent inductance w.r.to terminals A&B.





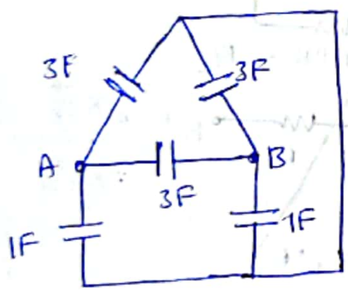


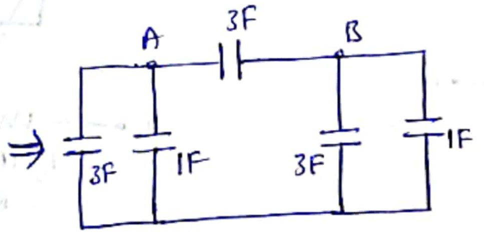
$L + L/3 + L/3 = 5L/3$

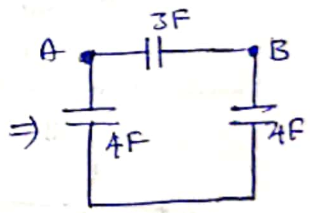


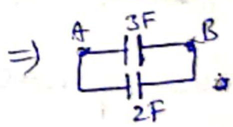
$\Rightarrow L_{eq} = \dfrac{L \times \frac{5L}{3}}{L + \frac{5L}{3}}$

Find equivalent Capacitance w.r.to terminals A&B



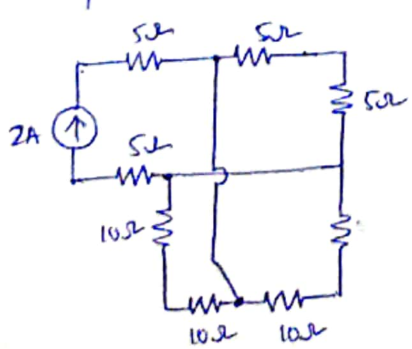


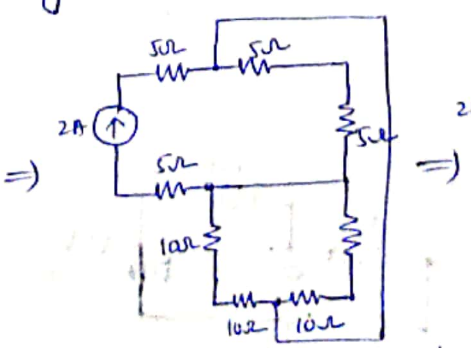


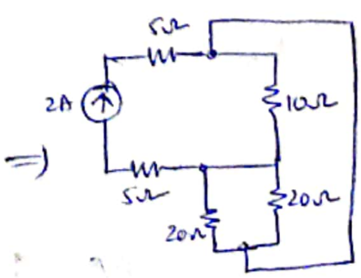


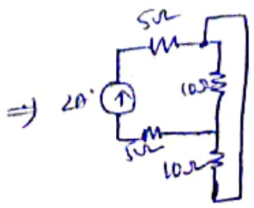
$C_{eq} = 5F$

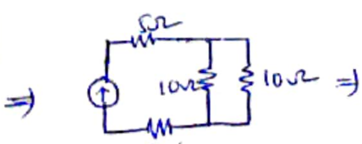
Find power delivered by the Source.











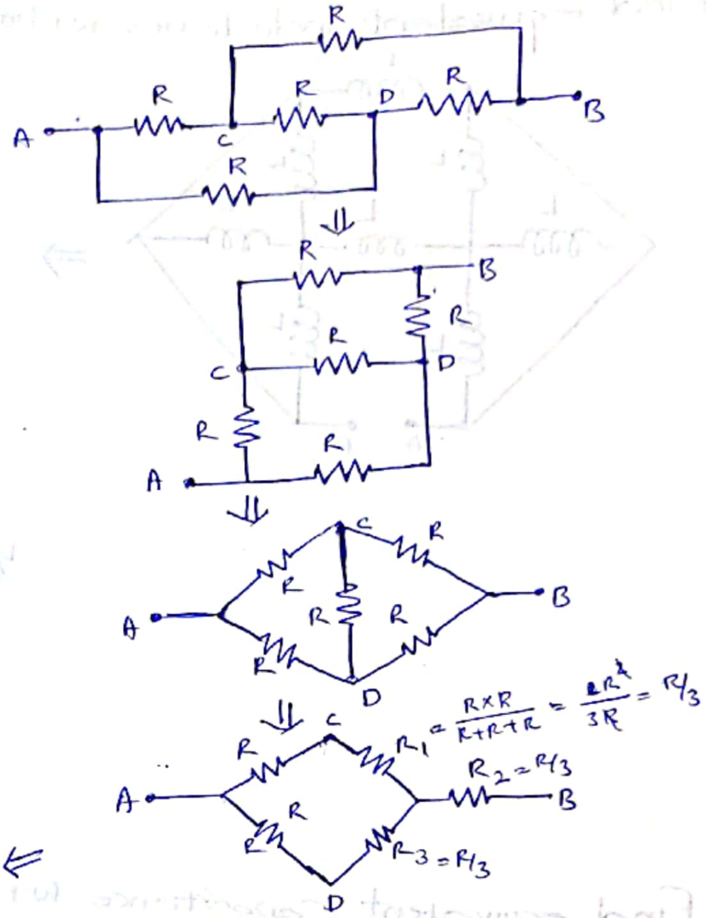
$\Rightarrow R_{eq} = 15\Omega$

(25)

$P = I^2R = 2^2 \times 15 = 60W$

Find the equivalent resistance R_{AB} for the circuit shown in the figure

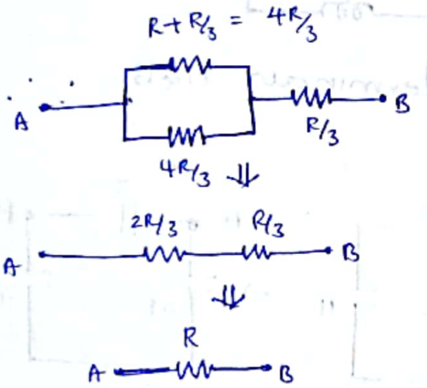
$(\Delta \rightarrow Y)$



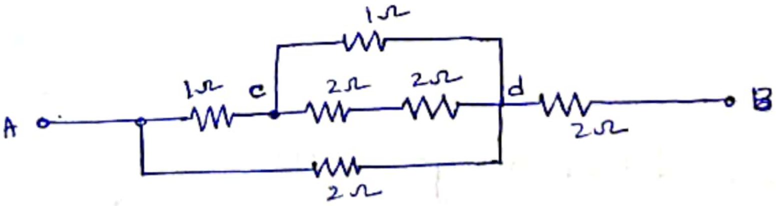
$R_1 = \frac{R \times R}{R+R+R} = \frac{R^2}{3R} = R/3$

$R_2 = R/3$

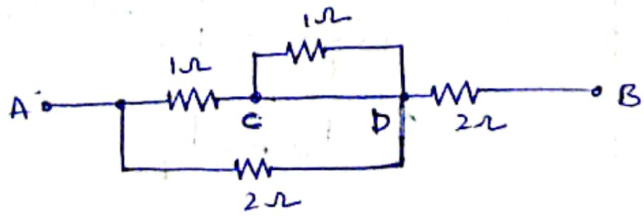
$R_3 = R/3$



Find the equivalent resistance across A-B



$R_{AB} = ?$



$R_{AB} = ?$