12) Explain about Current, voltage, Power and energy ?

Current : It is a flow of electrical charge Carries usually electrons or electron - deficients atoms.

The common symbol for current is the uppercase letter I. The standard unit is the ampere, symbolized by A. It is negatively charged Continous flow of electrons constitute. (or) Current flow from negative Potential to Private Potential of the field. This current is known as electron current Conventional Current

$$\boxed{i = \frac{df}{dt} \text{ Amperes}}$$

Voltage : The work done in moving a unit positive charge from one point in the electric field to another field in the electric field is known as the Potential difference b/w the two Points and is measured in volts

$\boxed{V = \frac{dw}{dQ} \text{ volts}}$ Units - volts

Power : Power con be defined as the rate of doing work, it is the work done in unit time. The SI unit of Power is watt (W) which is joules per second (J/s). Sometimes the Power of motor vehicles and other machines is given in terms of those Power (hp), which is approximately equal to 745.7 watts.

$$\boxed{P = \frac{\text{work}}{\text{time}}} \qquad \text{unit} = \text{watt}$$

Energy :- Energy is the ability to do work to do work, scientists define energy as the ability to do work, modern civilization is possible becouse People have learned how to change energy from one form to another and then use it to do work.

Energy con be converted from one form to another

1. What are the basic parameters used in electric circuits and write the voltage and current relationships of circuit elements.

There are three basic circuit parameters:

They are

1. Resistor
2. Inductor
3. Capacitor

1. Resistance (R): The property of an element by which it opposes the flow of current through it is called resistance denoted by R. The resistance is measured in ohms (Ω).

According to ohm's law;

$$V \propto I \longrightarrow (1)$$

proportionality constant is replaced by resistance (R).

$$V = IR \longrightarrow (2)$$

It is known as voltage eqn of resistor or voltage drop equation.

From (2),

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

It is current eqn of a resistor.

→ The power consumed is given by,

$$P = V \cdot I$$

$$P = \frac{V^2}{R} = I^2R \qquad \left[\because I = \frac{V}{R}\right] \left[\because V = IR\right]$$

The energy consumed is given by

$$W = \int_{-\infty}^{t} P dt = pt$$

$$= \int_{-\infty}^{t} VI dt = VIt$$

$$= \frac{V^2}{R} t$$

$$= I^2Rt$$

Inductance (L): The coils having N no. of turns made up of various materials and having various materials sizes are called inductors. The property of a coil by which it opposes any changes in magnitude or direction of electric current passing through the conductor.

The unit of inductance is given by "henry", it is given by faraday's law of electromagnetic induction. In Inductance, the voltage across it is proportional to the rate of the change of current and constant of proportionality is an inductance L.

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

It is known as voltage eqn of inductor.

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

It is known as current eqn of inductor.

The power in the inductor is

$$P = V_L \cdot I$$

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

The energy stored in an inductor is,

$$W = \int_0^t P\,dt = \int_0^t L \cdot I \cdot \frac{di}{dt}\,dt = \frac{1}{2}LI^2 \cdot J.$$

capacitance (C): Two conducting plates seperated from each other by an insulating material is called a capacitor. The insulating material is called dielectric.

A capacitor stores electric energy in the form of electric field being established by the two polarities of charges on the two electrodes of a capacitor.

Quantitavely capacitance is a measure of charge per unit voltage that can be stored in an element. The units of capacitance (C) is farad (F).

q being the amount of charge that can be stored in a capacitor of capacitance C against a potential difference of V volts, we can write

$$C = \frac{q}{V}$$

$$i = C\frac{dv}{dt}.$$

It is known as current eqn of capacitance.

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

$$V_t = \frac{1}{C}\int i dt + V_0 \quad \left[V = \frac{1}{C}\int i dt\right]$$

V_0 - initial voltage of capacitor
V_t - final voltage of capacitor

The power absorbed by the capacitor is given by

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

The energy stored by the capacitor is

$$W = \int_0^t P dt$$
$$= \int_0^t V \cdot C \frac{dv}{dt} dt$$

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

Circuit Element	Voltage	Current	Power
Resistance R (Ω)	$V = IR$	$I = \frac{V}{R}$	$P = V \cdot I$ or $\frac{V^2}{R}$ or I^2R
Inductance L (H)	$V = L\frac{di}{dt}$	$i = \frac{1}{L}\int V dt$	$P = LI\frac{di}{dt}$.
Capacitance C (F)	$V = \frac{1}{C}\int i dt$	$i = C\frac{dv}{dt}$	$P = VC\frac{dv}{dt}$

Table: voltage and current relationships of circuit parameters.

* Types of Elements

Electrical Elements are categorized in many ways.

1. Active and passive Elements
2. Linear and Non linear Elements
3. Unilateral and Bilateral elements
4. Time variant and Time invariant elements
5. Lumped and Distributed elements.

Active and passive elements

Active elements are those which

- provide power to an electrical circuit for along time
- Can control the flow of charge in a circuit
- It has ability to amplify the power of a signal (voltage or current)
- It requires an external source for operation.

Ex: Voltage source, current sources generators

Transistors [BJT, MOSFET, FET, JFET] - Transistors are used to amplify electrical signals. So it is an active element.

* Passive Element

Passive elements are those which

- Not capable of providing energy on their own.
- It utilizes, stores energy in a circuit
- It is used for energy storage, discharge, oscillating, filtering and phase shift operation.
- It does not require any external source for operation.
- It cannot control or amplify the signal.

Ex:- Resistance, Inductance, Capacitance.

Linear and Non Linear

A function is linear if it has three properties.

1. which satisfies, homogeneity and superposition principles.
2. Additivity
3. Scaling property as well.

Ex:- 1. $f(ax) = a f(x)$

2. $f(x_1 + x_2) = f(x_1) + f(x_2)$

3. $V = IR$

A linear element has its V-I characteristics linear

Called Time invariant elements

Ex: R,L,C elements

Lumped and Distributed elements

Lumped elements are those which are very small in size as compared to the wavelength of voltage and current.

Ex:- R, L, C elements in electronic circuits

Distributed elements are those which we use when size of elements is comparable with wavelength of voltage and current.

Ex: Transmission and Distribution lines.

* Nonlinear Elements

The elements are said tobe Non linear if it does not satisfies principles of superposition and homogeneity also additivity and scaling properties. A Non linear element has V-I characteristics Non linear.

Ex:-

Unilateral and Bilateral

Elements which allow conduction of current in only one direction.

Ex:- Diode, Transistor.

Elements which allows conduction of current in both directions

Ex: Resistor, inductor, capacitor.

Time Variant and Time invariant

When elements changes with respect to time those elements are called time variant elements. Ex:- Space vehicles leaving earth.

Elements which doesnot changes with respect to time are

potential Difference (or) voltage

The work done in moving a unit positive charge from one point in the electric field to another field in the electric field is known as the potential difference between the two points and is measured in volts.

If V_A is the potential at point A and V_B is the potential at point B then the potential difference between the two points A and B will be $V_{AB} = V_A - V_B$.

If $V_A > V_B$ then V_{AB} will be positive and is known as potential drop from point A to point B.

If $V_A < V_B$ then V_{AB} will be negative and is known as voltage rise from point B to point A. The voltage raise from point B to point A is generally denoted by the letter E.

$$E_{AB} = (E_A - E_B) = (V_B - V_A) = V_{BA} = -V_{AB}$$

$$\boxed{V = \frac{dw}{dQ}} \text{ volts}$$

- Units of voltage difference (or) simply voltage is volts

(7) Current

An electron placed in an electric field will experience a force and move towards the positive potential of the field since it is negatively charged. Continous flow of electrons constitute a current flow from negative potential to positive potential of the field. This current is known as electron current. Conventional current flow is opposite to that of the electron current in direction. The conventional current flow which is in opposite direction to electron current flow, will be flowing from a point of higher potential to a point of lower potential.

$$\boxed{i = \frac{dq}{dt} \text{ Amperes}}$$

- Unit of current is "Amperes"

Steady current $\boxed{I = \frac{Q}{t} \text{ Ampere}}$ Q is charge in coloumbs, t is time in seconds.

(or) Charge $\boxed{Q = \int i \, dt \text{ Coloumbs}}$

2. State and Explain ohm's law.

Ohm's law:

This law gives the relationship between the potential difference (V), the current (I) and resistance (R) of a dc circuit.

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

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

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

I - Current flowing

V - voltage applied

R - Resistance of the conductor

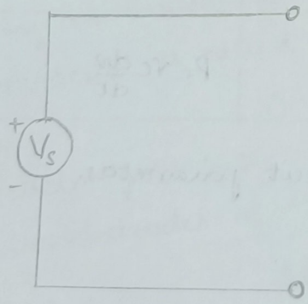
The unit of potential difference is defined in such a way that the constant of proportionality is unity.

3. Distinguish between ideal voltage, current sources and practical voltage, current sources. Draw the V-I characteristics.

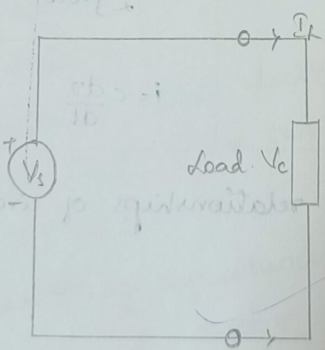
Voltage Source:

Ideal voltage source:

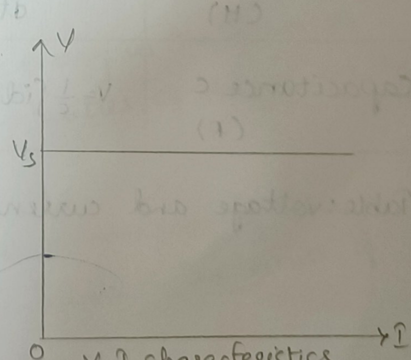
It is defined as the energy source which gives constant voltage across its terminals irrespective of current drawn through its terminal.



Symbol of Ideal voltage source.



V_s connected to load.



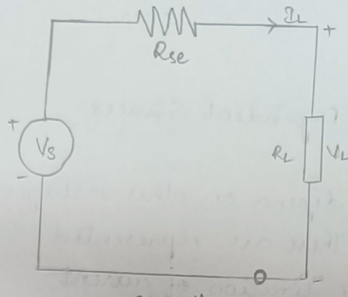
V-I characteristics

capacitance -

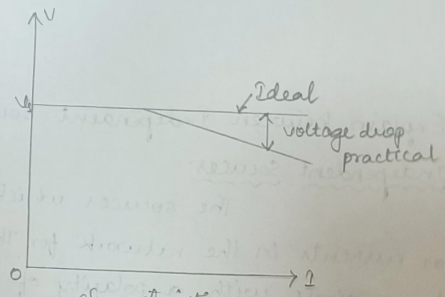
Practical voltage source:

Every voltage source has small internal resistance. with voltage source and is represented by R_{se}. Because of this R_{se}, voltage across terminals decreases slightly with increase in current. Given by,

$$V_L = V_S - I_L \cdot R_{se}.$$



Circuit

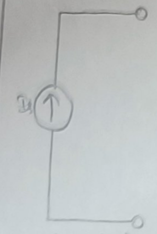


Characteristics

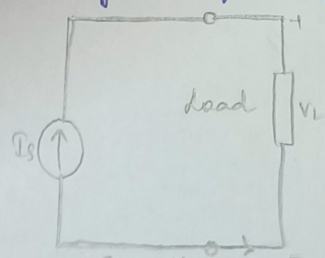
Current Source:

Ideal current source:

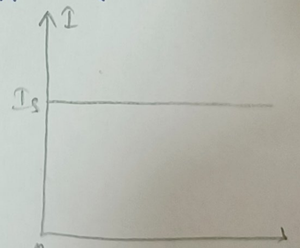
It is the source which gives constant current at its terminals irrespective of voltage appearing across its terminals.



Symbol



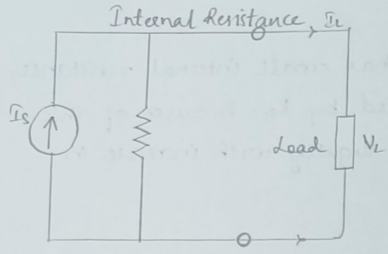
Circuit



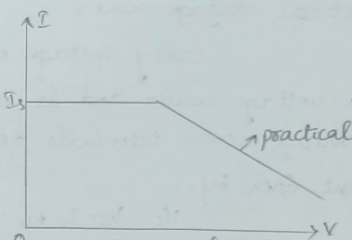
Characteristics

Practical Current Source:

Every current source has high internal resistance, parallel with current source and it is represented by R_{sh}. Because of R_{sh} current through its terminals decreases slightly with increase in voltage at its terminals.



Circuit



V-I characteristics

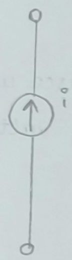
Practical Current Source

4. Explain between Independent Sources and Dependent Sources.

Independent sources:

The sources which doesn't depend on other voltages or currents in the network for their value. These are represented by a circle with a polarity of voltage or direction of current indicated inside.

Independent voltage source



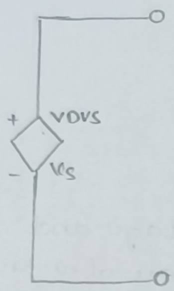
Independent current source.

Dependent Sources:

Dependent sources are those whose value of source depends on voltage or current in the circuit. Such sources are indicated by diamond. These are further classified as:

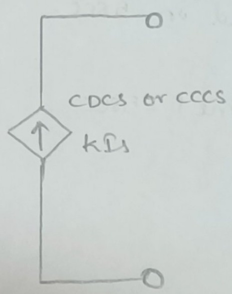
(i) Voltage dependent voltage source:

It produces a voltage as a function of voltages elsewhere in the given circuits. This is VDVS (or) VCVS.



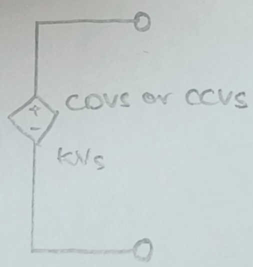
(ii) Current dependent current source:

It produces current as a function of currents elsewhere in the given circuit. This is called CDCS (or) CCCS.



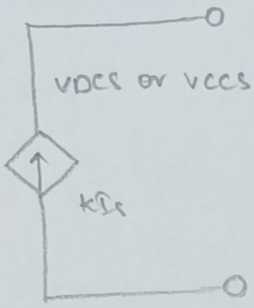
(iii) Current dependent voltage source:

It produces a voltage as a function of current elsewhere in the given circuit. This is called CDVS or CCVS.



(iv) Voltage dependent current source:

It produces a current as a function of voltage elsewhere in the given circuit. This is called VDCS or VCCS.



K is constant and V_s and I_s are the voltage and current sources respectively. The dependent sources are also known as controlled sources.

5. 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: Given

Voltage $V = 10V$; Resistance $R = 100\Omega$; Time $t = 5sec$

current through the resistor

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

$$= \frac{10}{100}$$

$$I = 0.1A$$

Power loss

$$P = \frac{V^2}{R} = \frac{100}{100}$$

$$P = 1W$$

Energy consumed

$$W = \frac{V^2}{R}t = 1 \times 5$$

$$W = 5 \text{ Joules}$$

6. The strength of current in 1 henry inductor changes at a rate at a rate of 1 Amp/sec. Find the voltage across it and determine the magnitude of energy stored in the inductor after 2 secs.

Sol: Given

Inductance $L = 1H$

Rate of change of current $\frac{di}{dt} = 1 \text{Amp}/\text{sec}$.

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

$= 1 \times 1$

$V = 1V$

The energy stored is given as

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

$i = \frac{1}{L}\int v\,dt$

$i = 1\int 1\,dt$

$i = t$

$I = 2$.

$W = \frac{1}{2} \times 1 \times 4$.

$W = 2$ Joules

7. A capacitor has a capacitance of $5\mu F$. Calculate the stored energy in it. If a dc voltage of 100V is applied across it.

Given

Voltage $V = 100V$; Capacitance $C = 5\mu F = 5 \times 10^{-6} F$.

The energy stored is given as

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

$= \frac{1}{2} \times 5 \times 10^{-6} \times 100 \times 100$

$= 25000 \times 10^{-6}$

$W = 2.5 \times 10^{-6}$ Joules

8. A $50\mu F$ capacitor is charged to retain 10mJ of energy by a constant charging current of 1A. Determine the voltage across the capacitor.

Given

Capacitance $C = 50\mu F = 50 \times 10^{-6} F$

Energy $W = 10mJ = 10 \times 10^{-3} J = 10^{-2} J$

Current $I = 1$ Amp.

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

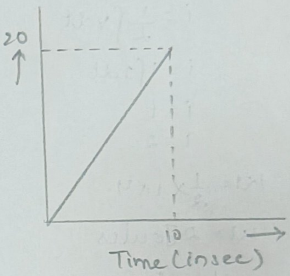
$V^2 = \frac{2W}{C}$

$V = \sqrt{\frac{2W}{C}}$

$$V = \sqrt{\frac{20\times10^{-2}}{50\times10^{-6}}}$$

$$= \sqrt{400} = 20V$$

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



Given

Capacitance $C = 50\mu F$

$= 50\times10^{-6} f$

From figure,

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

$$= 2\times10^{3} V/sec$$

Charging current

$$i_{charging} = C\frac{dv}{dt}$$

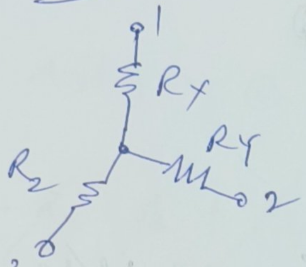
$$= 50\times10^{-6}\times2\times10^{3}$$

$$= 100\times10^{-3}$$

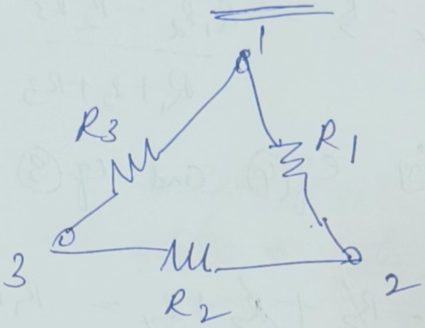
$$i_{charging} = 0.1A.$$

(*) State Necessary equations to convert a star network into a Delta network:

Ans:- Star



Delta



Delta - star Transformation

Between Terminals (1) and (2) of star and Delta

$$R_{12_Y} = R_x + R_y \qquad R_{12_\Delta} = R_1 \,||\, (R_2 + R_3)$$

$$R_{23_Y} = R_y + R_z \qquad R_{23_\Delta} = R_2 \,||\, (R_3 + R_1)$$

$$R_{31_Y} = R_z + R_x \qquad R_{31_\Delta} = R_3 \,||\, (R_1 + R_2)$$

Equating Resistances between (1) & (2) terminals of star and delta

$$R_x + R_y = \frac{R_1 (R_2 + R_3)}{R_1 + R_2 + R_3} \rightarrow eq (1)$$

$$R_y + R_z = \frac{R_2 (R_3 + R_1)}{R_1 + R_2 + R_3} \rightarrow eq (2)$$

$$R_z + R_x = \frac{R_3 (R_1 + R_2)}{R_1 + R_2 + R_3} \rightarrow eq (3)$$

Subtracting eq (2) from eq (1) we get

$$R_x + \cancel{R_y} - \cancel{R_y} - R_z = \frac{R_1R_2 + \cancel{R_1R_3} - \cancel{R_1R_3} - R_2R_3}{R_1+R_2+R_3}$$

$$R_x - R_z = \frac{R_1R_2 - R_2R_3}{R_1+R_2+R_3} \rightarrow \text{eq } (4)$$

Adding eq (4) and eq (3).

$$R_x - \cancel{R_z} + \cancel{R_z} + R_x = \frac{R_1R_3 - \cancel{R_2R_3} + R_1R_3 + \cancel{R_2R_3}}{R_1+R_2+R_3}$$

$$\cancel{2}R_x = \cancel{2}\,\frac{R_1R_3}{R_1+R_2+R_3}$$

$$R_x = \frac{R_1R_3}{R_1+R_2+R_3} \rightarrow (a).$$

Subtracting eq (3) from eq (2)

$$R_y + \cancel{R_z} - \cancel{R_z} - R_x = \frac{\cancel{R_2R_3} + R_1R_2 - R_1R_3 - \cancel{R_2R_3}}{R_1+R_2+R_3}$$

$$R_y - R_x = \frac{R_1R_2 - R_1R_3}{R_1+R_2+R_3} \rightarrow \text{eq } (5)$$

Adding eq (5) and eq (a).

$$R_y - \cancel{R_x} + \cancel{R_x} + R_y = \frac{R_1R_2 - \cancel{R_1R_3} + \cancel{R_1R_3} + R_1R_2}{R_1+R_2+R_3}$$

$$\cancel{2}R_y = \cancel{2}\,\frac{R_1R_2}{R_1+R_2+R_3} \Rightarrow R_y = \frac{R_1R_2}{R_1+R_2+R_3} \rightarrow (b)$$

Subtracting eq ④ from eq ③.

$$-\cancel{R_x} + R_y + R_z + \cancel{R_x} = \frac{-R_1R_2 - \cancel{R_1R_3} + \cancel{R_1R_3} + R_2R_3}{R_1+R_2+R_3}$$

$$-R_y + R_z = \frac{-R_1R_2 + R_2R_3}{R_1+R_2+R_3} \rightarrow \text{eq ⑥}.$$

Adding eq ⑥ and eq ②.

$$-\cancel{R_y} + \cancel{R_z} + \cancel{R_y} + R_z = \frac{-\cancel{R_1R_2} + R_2R_3 + R_2R_3 + \cancel{R_1R_2}}{R_1+R_2+R_3}$$

$$\cancel{2}R_z = \frac{\cancel{2}R_2R_3}{R_1+R_2+R_3}$$

$$R_z = \frac{R_2R_3}{R_1+R_2+R_3} \rightarrow ⑥.$$

Star to Delta Transformation

we have $R_x = \frac{R_1R_3}{R_1+R_2+R_3}$ $R_y = \frac{R_1R_2}{R_1+R_2+R_3}$ $R_z = \frac{R_2R_3}{R_1+R_2+R_3}$

$$R_xR_y + R_yR_z + R_zR_x = \frac{R_1R_3 \times R_1R_2 + R_1R_2 \times R_2R_3 + R_2R_3 \times R_1R_3}{(R_1+R_2+R_3)^2}$$

$$R_xR_y + R_yR_z + R_zR_x = \frac{R_1R_2R_3\,\cancel{(R_1+R_2+R_3)}}{(R_1+R_2+R_3)^{\cancel{2}}} \rightarrow \text{eq ⑦}$$

$$\because \frac{R_1R_2}{R_1+R_2+R_3} = R_y$$

$$R_3 \cdot R_y = R_y R_x + R_y R_z + \frac{R_x R_z}{\cancel{R_y}}$$

$$\boxed{R_3 = R_x + R_z + \frac{R_x R_z}{R_y}} \rightarrow eq\ 8$$

$\because \frac{R_2 R_3}{R_1+R_2+R_3} = R_z$ From eq 7

$$R_x R_y + R_y R_z + R_z R_x = \frac{R_1 R_2 R_3 \cancel{(R_1+R_2+R_3)}}{\cancel{(R_1+R_2+R_3)}}$$

$$R_x R_y + R_y R_z + R_z R_x = R_1 \cdot R_z$$

$$\boxed{R_1 = R_x + R_y + \frac{R_x R_y}{R_z}} \rightarrow eq\ 9$$

$\because \frac{R_1 R_3}{R_1+R_2+R_3} = R_y$ From eq 7

$$R_x R_y + R_y R_z + R_z R_x = \frac{R_1 R_2 R_3}{R_1+R_2+R_3}$$

$$R_x R_y + R_y R_z + R_z R_x = R_2 \cdot R_y$$

$$\boxed{R_2 = R_y + R_z + \frac{R_y R_z}{R_x}} \rightarrow eq\ 10$$

$R_1+R_2+R_3$ $\quad$ $R_y = \frac{\ldots}{R_1+R_2+R_3} \rightarrow (b)$

laws (KVL).

✓ KCL : The algebraic sum of currents at any node* of a circuit is zero.

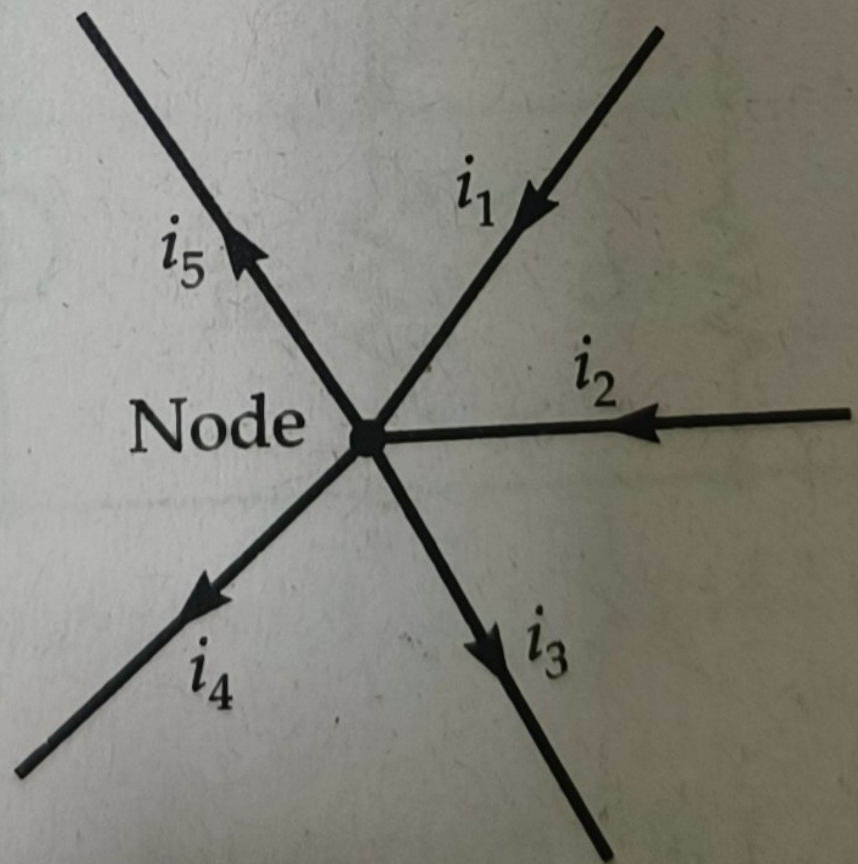


Fig. 2.1 **Currents meeting at a point in a network**

...electrical...

In Fig. 2.1, as per KCL,

$$i_1 + i_2 - i_3 - i_4 - i_5 = 0 \ldots\ldots$$

(the direction of incoming currents to a node being +ve, the outgoing currents should be taken –ve. The reverse sense of directions can also be taken).

Thus $$i_1 + i_2 = i_3 + i_4 + i_5 \qquad \ldots(2.1)$$

i.e., the algebraic sum of currents entering a node must be equal to the algebraic sum of the currents leaving a node**.

2.3 KIRCHHOFF'S VOLTAGE LAW (KVL)

2)

The algebraic sum of voltages (or voltage drops) in any closed path of network that is traversed in a single direction is zero.

3)

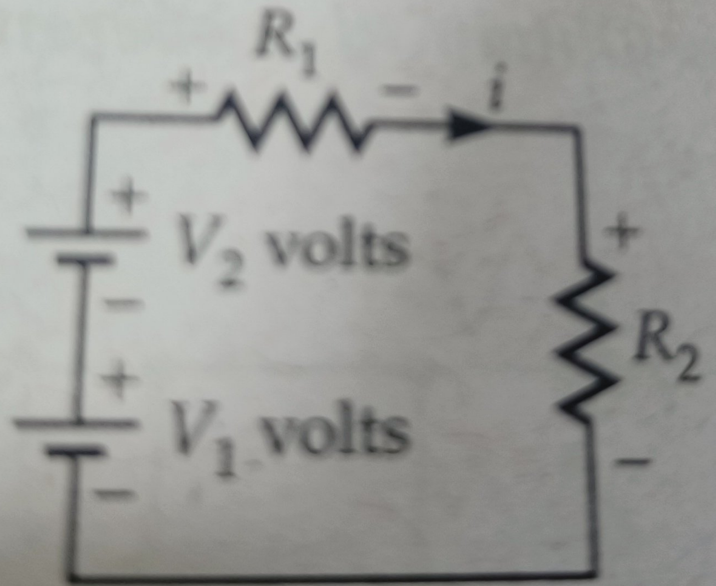
Both the Figures (Fig. 2.3 and Fig. 2.4) show closed circuits (also termed as mesh). As per KVL, in Fig. 2.3,

$$-V_1 + (-V_2) + iR_1 + iR_2 = 0 \qquad ...(2.6)$$

[Here, the assumed current i causes a +ve drop of voltage when flowing from +ve to –ve potential while –ve drop while the current flowing from –ve to +ve potential]

or, $$i(R_1 + R_2) = V_1 + V_2$$

giving $$i = \frac{V_1 + V_2}{(R_1 + R_2)}.$$



SOLU

Fig. E2.1

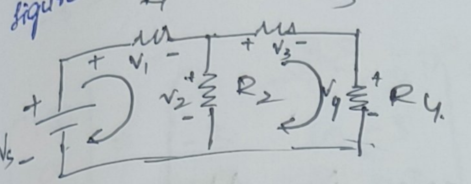
In b

3

Mesh Analysis :- The method of analysing an electrical network for the closed loops is mesh analysis. In this method a distinct current is assumed in the loop and the polarities of the drop in each element in the loop is determined by the assumed direction of loop current for that loop.

KVL is then applied around the each closed loop by solving these loop equations the branch currents are determined. let us consider

Ex :- A simple electrical net work is as shown in figure



KVL to loop ① :

$-V_s+V_1+V_2=0$

$V_s = i_1R_1 + (i_1-i_2)R_2$

$V_s = (R_1+R_2)i_1 - R_2 i_2$ —①

KVL to loop ② :

$V_2+V_3+V_4=0$

$(i_2-i_1)R_2 + i_2R_3 + i_2R_4 = 0$

$0 = -i_1R_2 + i_2[R_2+R_3+R_4]$ —②

$$\begin{bmatrix} V_s \\ 0 \end{bmatrix} = \begin{bmatrix} R_1+R_2 & -R_2 \\ -R_2 & R_2+R_3+R_4 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

$i_1 = \frac{\Delta_1}{\Delta}$ $\quad i_2 = \frac{\Delta_2}{\Delta}$

$\Delta = (R_1+R_2)(R_2+R_3+R_4) - (R_2 \cdot R_2)$

$$\Delta_1 = \begin{vmatrix} V_s & -R_2 \\ 0 & R_2+R_3+R_4 \end{vmatrix}$$

$\Delta_1 = V_s(R_2+R_3+R_4)$

$$\Delta_2 = \begin{vmatrix} R_1+R_2 & V_s \\ -R_2 & 0 \end{vmatrix}$$

$= R_2V_s$

$$i_1 = \frac{V_s(R_2+R_3+R_4)}{(R_1+R_2)(R_2+R_3+R_4)-(R_2 \cdot R_2)}$$

$$i_2 = \frac{R_2 V_s}{(R_1 + R_2)(R_2 + R_3 + R_4)}$$