BASIC ELECTRICAL ENGINEERING

Lecture Material
Unit-I
DC CIRCUITS

for

B.Tech (CSE,IT,CSD,CSC) I year – I semester

R18 Regulation

Course Objectives:

- To introduce the concepts of electrical circuits and its components
- To understand magnetic circuits, DC circuits and AC single phase & three phase circuits

Course Outcomes:

- To analyze and solve electrical circuits using network laws and theorems.
- To understand and analyze basic Electric and Magnetic circuits

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SHORT ANSWER QUESTIONS:

1) Define voltage or potential difference.

The Workdone or Energy required to bring the positive unit charge from infinite distance to particuler point is called voltage.Voltage is indicated by ‘V’

$$V = \frac{dw}{dq}$$

Units of voltage is ‘Volt’

2) Define current.

The rate of flow of charge or free electronics is called current.Current is indicated by ‘I’.

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

Units of current is ‘Ampere’

3) Define Electrical Energy or Energy.

The caopacity required to do electrical work is called energy.Eenrgy is indicated ny E or W.

Units of Electrical energy is Watt-hour (Wh) or KWh

4) Defirn power.

The rate of change of electrical energy is called as power.power is indicated by ‘P’.

Units of power is ‘Watt’

$$P = \frac{dw}{dt}$$

$$\frac{dw}{dt} = \frac{dw}{dq} \times \frac{dq}{dt}$$

But $V = \frac{dw}{dq}$ & $I = \frac{dq}{dt}$

$$P = VI$$

5) State the Ohm’s law.

Ohm's Law states that “At constant temperature, the voltage is directly proportional to the current flowing through the electric circuit”.

$$V \,\alpha\, I$$

$$V = \mathbf{R}\, I$$

I- current ; V-voltage ; R- resistance;

6) Define Active and Passive elements.

An element is said to be an Active element,for all time 't' if it supplies electrical energy to load.

Examples of active elemnts:V(voltage) , I(current)

An element is said to be a Passive element,for all time 't' if it obsorbs electrical energy.

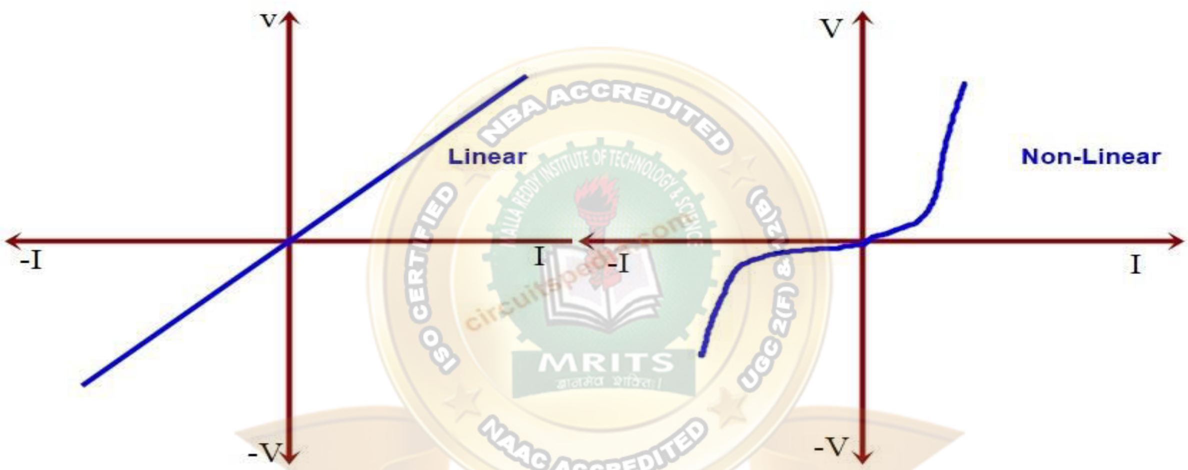
Examples of passiveelemnts: R,L,C

7) Define Linear and non Linear elements.

An element said to be a linear element, for all time `t' whose characteristics are straight line passing through origin, otherwise element is a non linear element.

Examples of linear elements : resistor ,inductor, capacitor

Examples of non linear elements : Diode, BJT



8) Define Unilateral ann Bilateral elements.

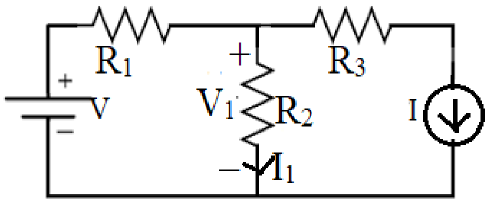
An element is said to be a Bilateral element,for all time 't' if that element offers same resistance for different directions of same current,otherwise it is unilateral element.

Ex: of bilateral elements :R,L,C

Ex: of unilateral elements: diode,BJT

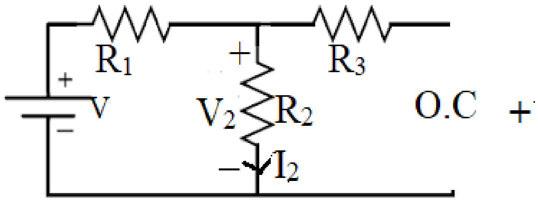
9) State Super Position Theorem.

In any linear and bilateral circuit ,the response at any branch when all independent sources acted together is equal to linear sum of individual responses at the same branch when each independent source acted alone.



both V,I acted together

=



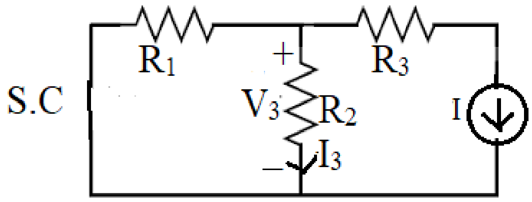
only voltage V acted alone

+

by super position theorem

$$V_1 = V_2 + V_3$$

$$I_1 = I_2 + I_3$$

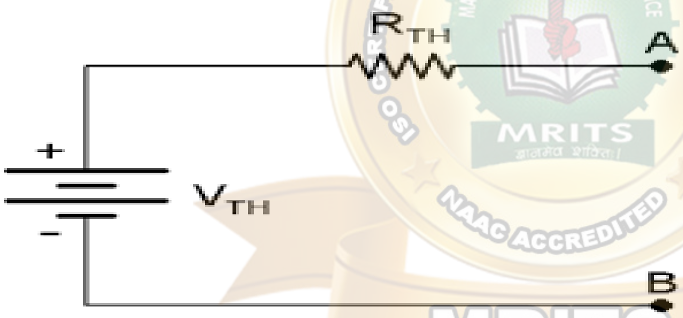


only current I acted alone

10) State Thevenin's Theorem:

The any linear and bilateral circuit consist of any number of active elements and passive elements is replaced by an equivalent circuit consist of one voltage source and resistor connected in series.

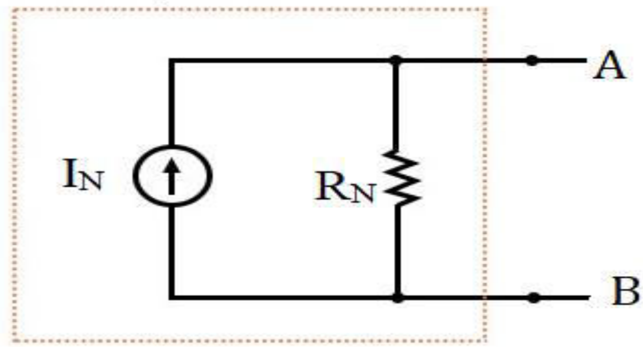
Thevenin's equivalent circuit is



11) State Norton's Theorem.

The any linear and bilateral circuit consist of any number of active elements and passive elements is replaced by an equivalent circuit consist of one current source and resistor connected in parallel.

Norton Equivalent Circuit



12) Define Steady State Response and Transient State Response.

Steady State Response is the part of total response of circuit or network ,which is fixed as the time reaches to infinite (t=∞).

Transient State Response is the part of total response of circuit or network , which is reaches to zero as time is large. Transient response is existed in 4 to 5 cycles of supply.

total response= Transient state response + Steady state response

13) What is initial conditions?

Initial conditions are the voltages across the capacitor and currents through the inductors before switching operation(either close or open).

LONG ANSWER QUENTIONS:

1) Explain about Electrical Circuit Elements.

RESISTOR:

Resistor is passive element,which obsorbs the electrical energy and dissipate the energy in it.

RESISTANCE:

It is the propority of of resistor,it oppose the flow of current throuth it,indicted by 'R'.

Units of resistance is 'Ohm' or Ω

As per Ohm's Law V=IR

Power obsorbs by resistor is $P=VI=(IR)I=I^2R$

$$\text{or } P=VI=V(\frac{V}{R})=\frac{V^2}{R}$$

$$P = VI = I^2R = \frac{V^2}{R}$$

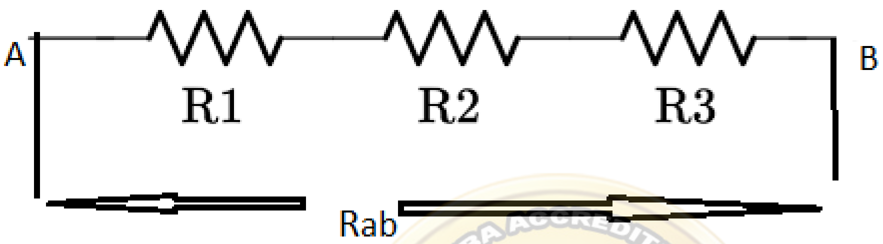
Resistance of onductor is calculated by $R = \frac{\rho l}{a}$

Where ρ is resistivity of conductor (Ω-m)

l is length of conductor (m)

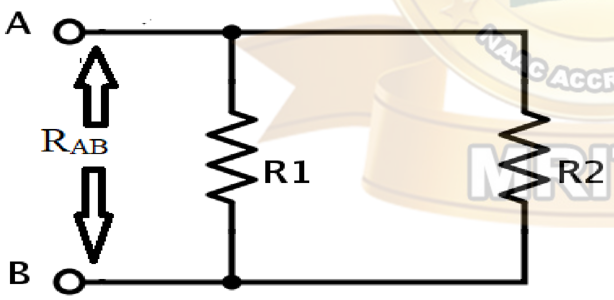
a is cross sectional area(m^2)

SERIES CONNECTED RESISTORS:



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

PARALLEL CONNECTED RESISTORS:



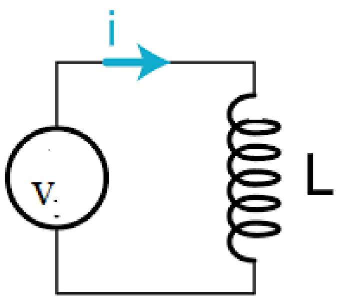
$$\frac{1}{Rab} = \frac{1}{R1} + \frac{1}{R2}$$

$$R_{ab} = \frac{R1 \times R2}{R1+R2}$$

INDUCTOR:

Inductor is a passive element ,which absorbs the energy and store the energy in the form of electro magnetic field.

Units of inductance is `Henry'(H). The symbol of inductor is



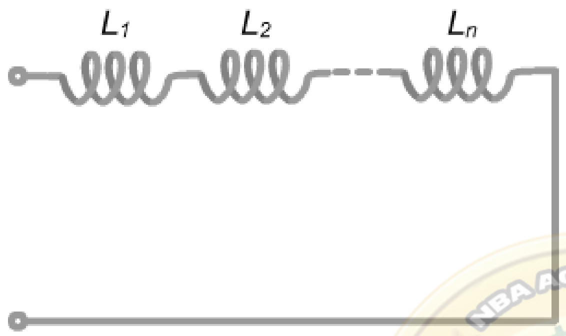
Current through the inductor I $= \frac{1}{L}\int V \; dt$

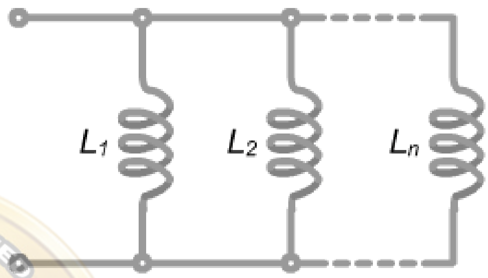
Voltage across inductor is $V = L\,\frac{dI}{dt}$ $\quad L = \frac{V}{\frac{dI}{dt}}$ $\quad L \propto \frac{1}{\frac{dI}{dt}}$

The basic property of Inductor is it does not allow the sudden changes in current

The energy stored in inductor is $E = \frac{1}{2} LI^2$ (joule)

Inductors connected in series and parallel:





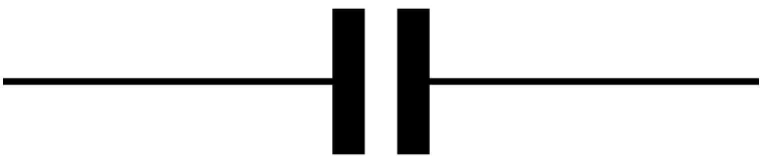
$$L_T = L_1 + L_2 + L_3 + \ldots L_n$$

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots \frac{1}{L_n}$$

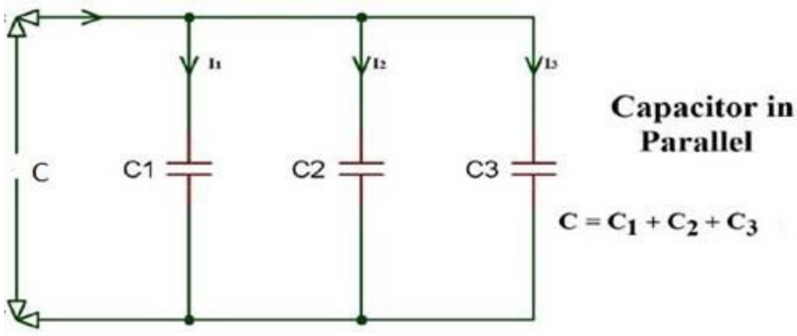
CAPACITOR:

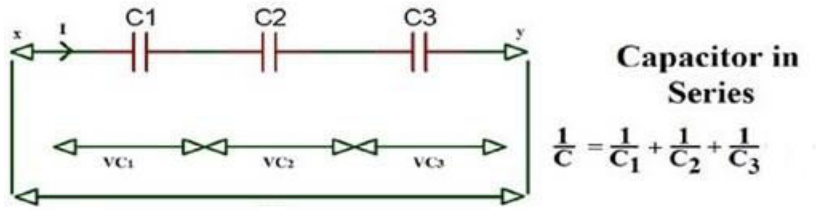
Capacitor is a passive element ,which absorbs the energy and store the energy in the form of electro static field. Units of capacitance is ‘Farad’(F).

The symbol of inductor is



Capacitors connected in series and parallel:





Capacitance formula:

$C=\frac{A\varepsilon}{d}$

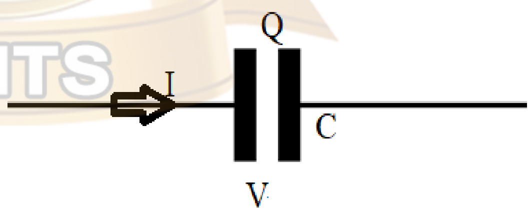
where A is cross secttional area between the two plates

ε is permitivity of material(F/m)

d is width between two plates(m)

Voltage across the capacitor V = $\frac{1}{C}\int I\ dt$

Current through capacitor is $I = C\,\frac{dV}{dt}$



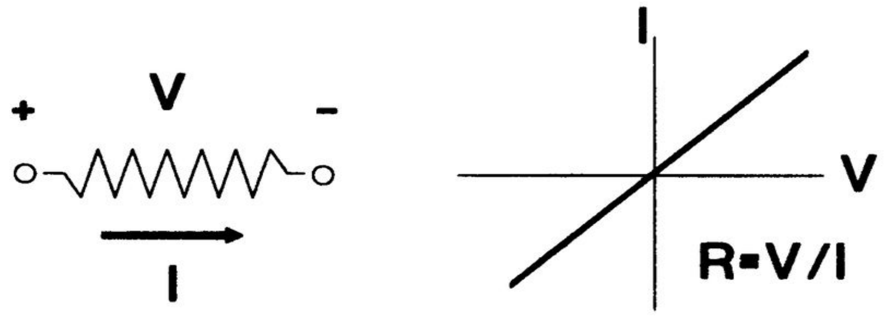
$C = \frac{I}{\frac{dV}{dt}}$ $\quad C \propto \frac{1}{\frac{dV}{dt}}$

The energy stored incapacitor is E=$\frac{1}{2}Cv^2$ (Joule)

The basic property of Capacitor is it does not allow the sudden changes in voltage.

2) Explain V-I relationship of circuit elements R,L & C.

RESISTOR:
the voltage across the resistor is directly proportional to the current flowing through it.



V α I

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

I- current ;V-voltage ;R- resistance

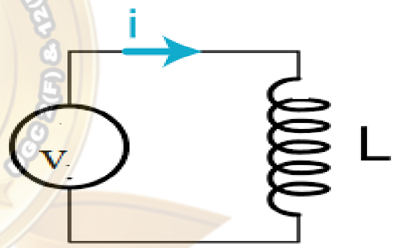
INDUCTOR:

Current through the inductor I = $\frac{1}{L}\int V\ dt$

Voltage across inductor is V= L$\frac{dI}{dt}$

L = $\frac{V}{\frac{dI}{dt}}$ L ∝ $\frac{1}{\frac{dI}{dt}}$

The basic property of Inductor is it does not allow the sudden changes in current.

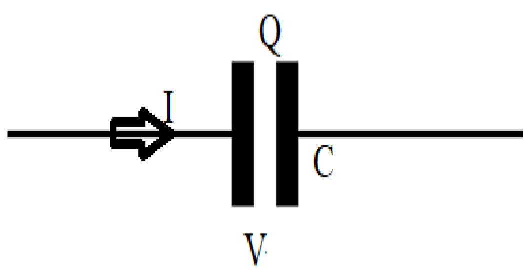


CAPACITOR:

Voltage across the capacitor V = $\frac{1}{C}\int I\ dt$

Current through capacitor is I = C$\frac{dV}{dt}$

C = $\frac{I}{\frac{dV}{dt}}$ C ∝ $\frac{1}{\frac{dV}{dt}}$



The basic property of Capacitor is it does not allow the sudden changes in voltage.

3) Explain about different types of sources.

Sources are classified into two types

1) Independent sources 2) Dependent sources

Independent sources are classified as two types

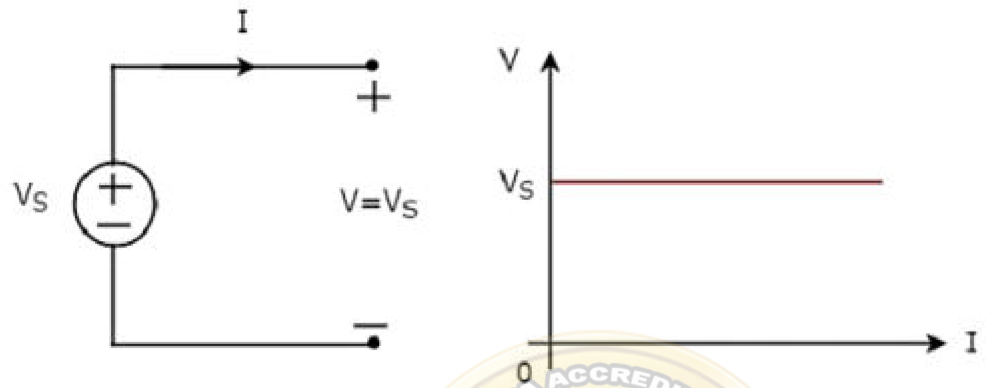
1) voltage source   2) current source

Voltage source classifed as two types:

1) ideal voltage source   2) practical voltage source

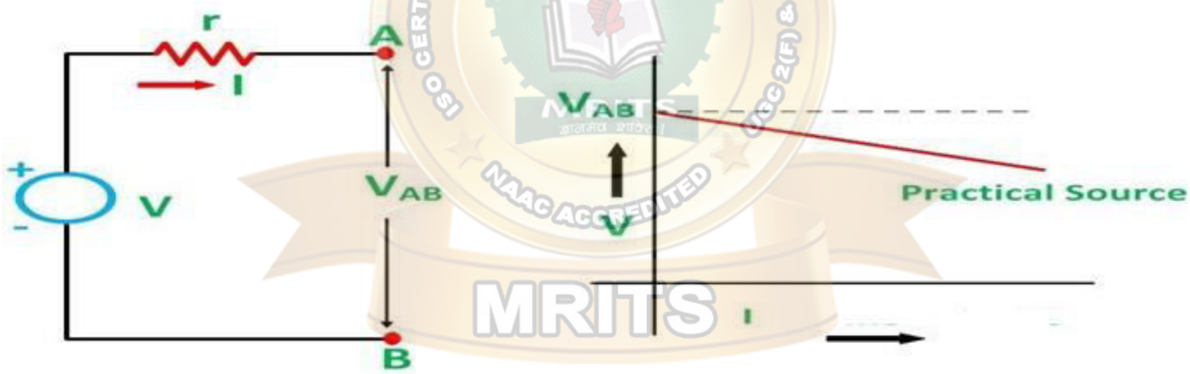
IDEAL VOLTAGE SOURCE: voltage source has voltage which is independent on current supplied or received.

IDEAL VOLTAGE SOURCE CHARACTERISTICS:



the internal resistance of ideal voltage source is zero.

PRACTICAL VOLTAGE SOURCE CHARACTERISTICS:



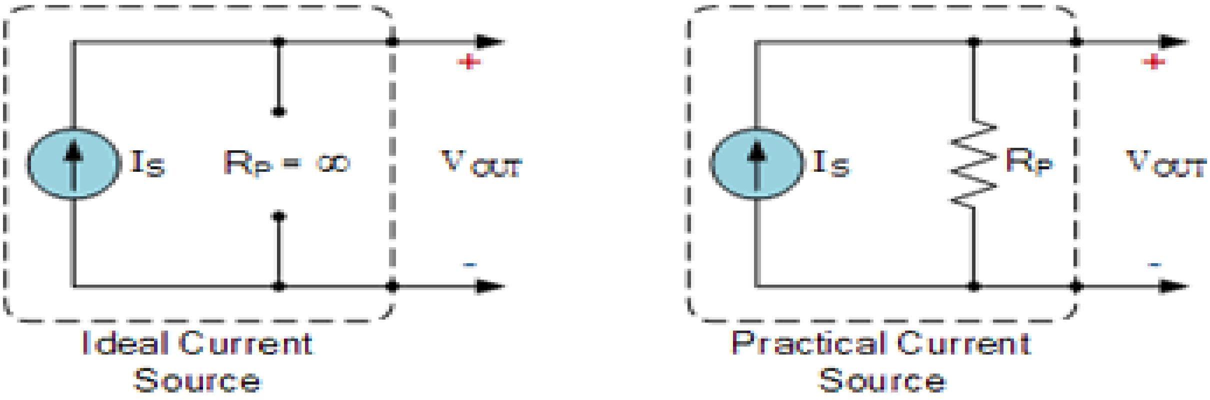
V_{AB} =V-IR

The internal resistance of practical voltage source is small value (not zero) .

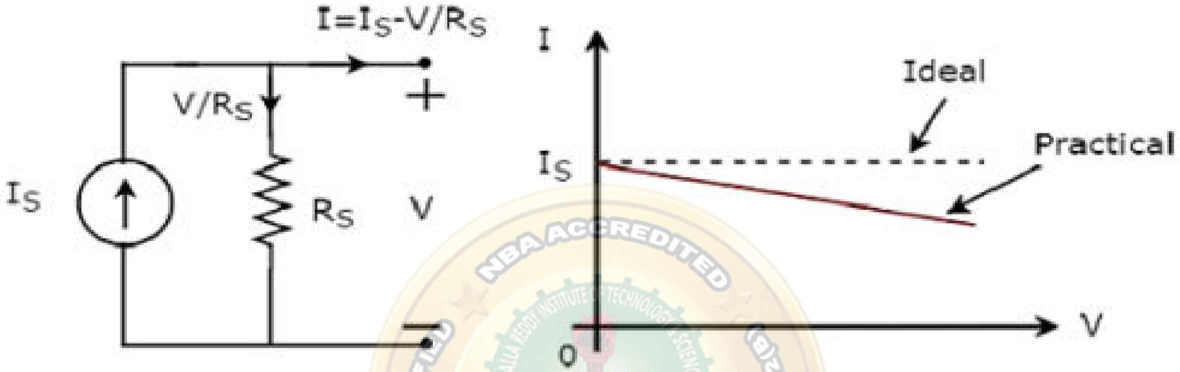
CURRENT SOURCE: Current source classifed as two types

IDEAL CURRENT SOURCE: The current source has current value which is independent on voltage across it's terminals.

CHARACTERISTICS:



PRACTICAL CURRENT SOURCE:



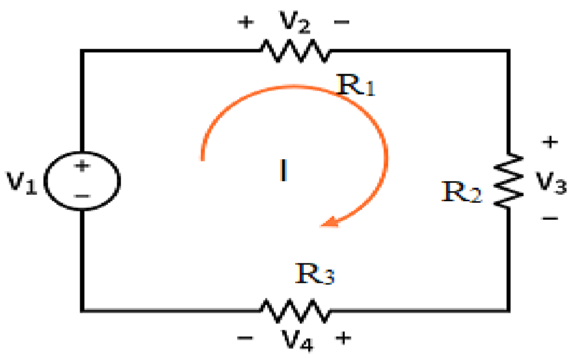
The internal resistance of ideal current source is infinite.

The internal resistance of practical current source is large value.

4) State and Explain Kirchhoff'S LAWS:

1) Kirchhoff's Voltage Law:

The algebraic sum of voltages across all the elements in a closed loop is always equal to zero.



apply kvl to the loop

$-V_1+V_2+V_3+V_4= 0$
$V_1=V_2+V_3+V_4$

as per ohm's Law

The voltage across resistor R_1 is V_2

$=> \quad V_2 = IR_1$

The voltage across resistor R_2 is $V_3 = IR_2$

The voltage across resistor R_3 is $V_4 = I R_3$

$V_1= IR_1 + IR_2 + IR_3$

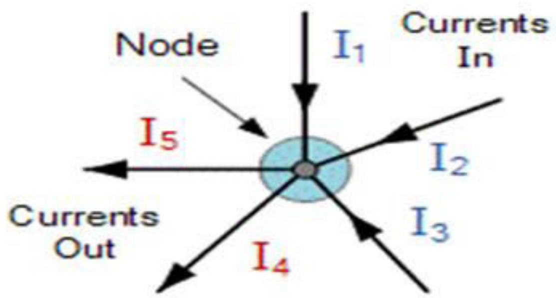
2) Kirchhoff's Current Law:

The sum of currents enter to the node is equal to sum of the currents leave from the same node.

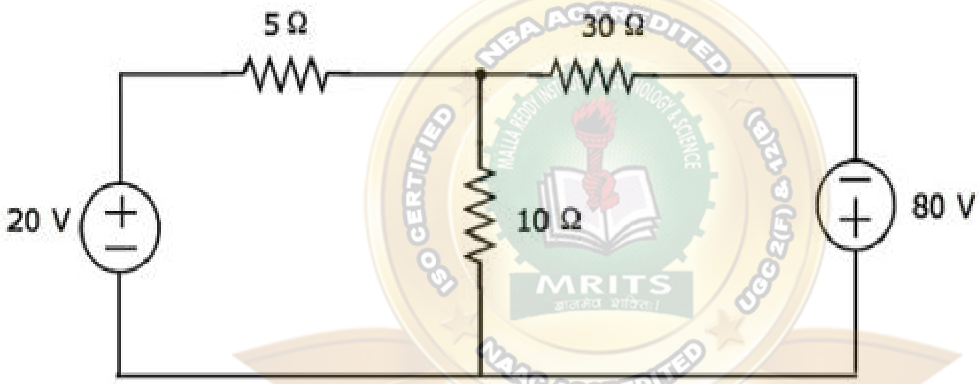
as per kcl

$I_1+I_2+I_3 = I_4+I_5$

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

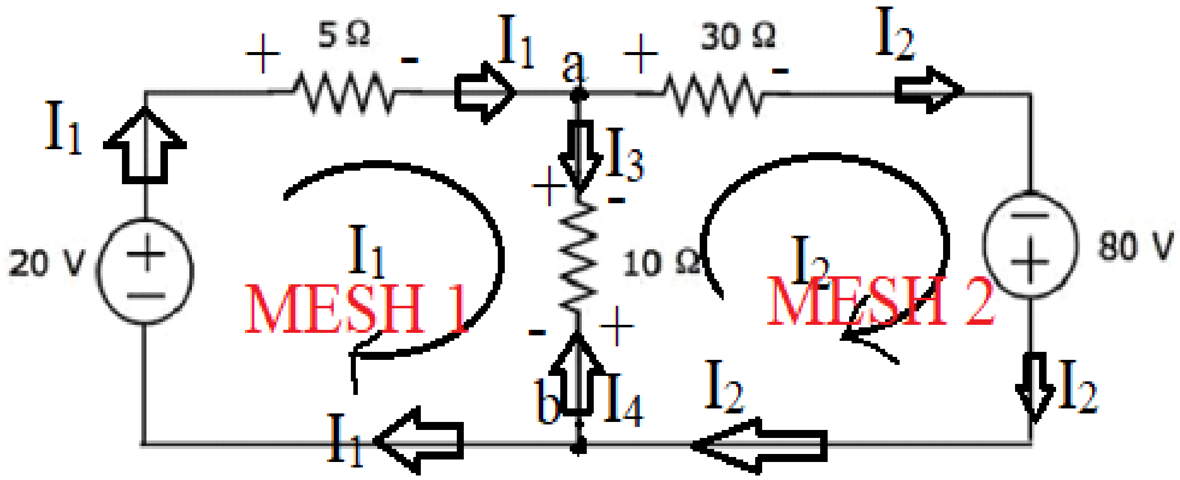


5) Find current ,voltage, power through each resistor using mesh analysis for the following circuit?



total number of meshes are 2

Assume that currents are flowing in clockwise direction in each mesh I_1 , I_2



Apply KCL at node `a' & apply KCL at node `b'

$I_1 = I_2 + I_3$ $\quad\quad$ $I_2 = I_1 + I_4$

$I_3 = I_1 - I_2$ $I_4 = I_2 - I_1$

Apply KVL to mesh `1' Apply KVL to mesh `2'

$-20 + 5I_1 + 10I_3 = 0$ $10I_4 + 30I_2 - 80 = 0$

$-20 + 5I_1 + 10(I_1 - I_2) = 0$ $10(I_2 - I_1) + 30I_2 - 80 = 0$

$15I_1 - 10I_2 = 20$ → eqn 1 $-10I_1 + 40I_2 = 80$ → eqn 2

$I_1 = 3.2$ A $I_2 = 2.8$ A

Current through the resistor 5Ω is $I_1 = 3.2$A

Current through the resistor 10Ω is $I_1 - I_2 = 3.2 - 2.8 = 0.4$A

Current through the resistor 30Ω is $I_2 = 2.8$A

Voltage across the resistor 5Ω is $5I_1 = 5\times3.2 = 16$V

Voltage across the resistor 10Ω is $10(I_1 - I_2) = 10\times(3.2 - 2.8) = 4$V

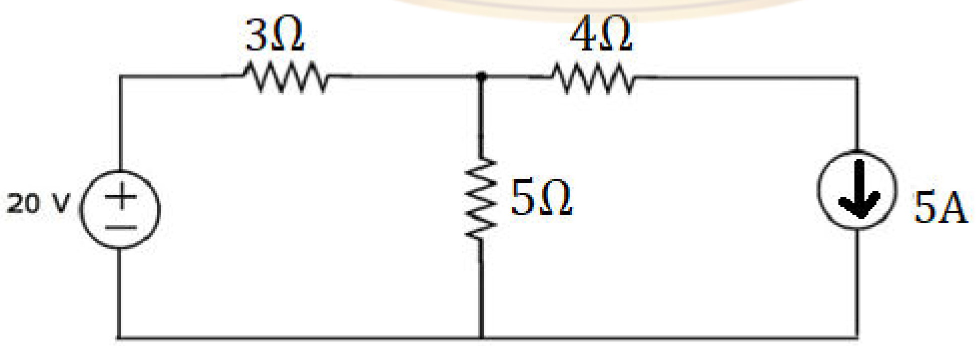
Voltage across the resistor 30Ω is $30I_2 = 30\times2.8 = 84$V

Power consumed by the resistor 5Ω is $I_1^2R = 3.2^2\times5 = 51.2$W

Power consumed by the resistor 10Ω is $I_3^2R = 0.4^2\times\times10 = 1.6$W

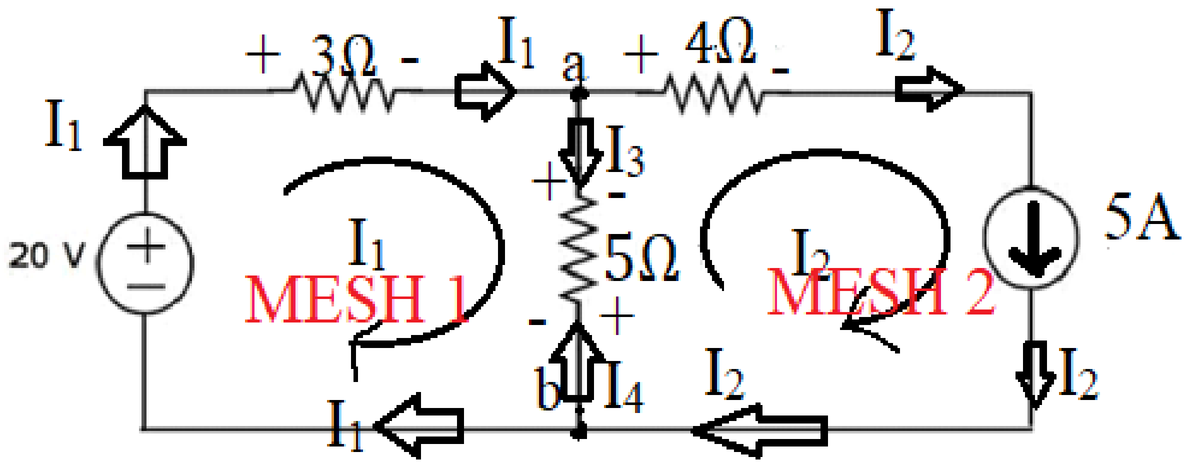
Power consumed by the resistor 30Ω is $I_2^2R = 2.8^2\times30 = 235.2$W

6) Find voltage across the resistors using mesh analysis for the following circuit?



Sol: total number of meshes are 2

Assume that currents are flowing in clockwise direction in each mesh I_1 , I_2



Apply kvl in mesh 1

$-20+3I_1+5I_3=0$

$-20+3I_1+5(I_1-I_2)=0$

$8I_1-5I_2=20$ →Eqn 1

in mesh 2 ,the direction of 5A and I_2 are same

so $I_2 = 5A$

Substitute I_2=5A in eqn 1

$8I_1-5(5)=20$

I_1= 5.625A

Voltage across the resistor 3Ω is $3I_1=3\times5.625=16.875V$

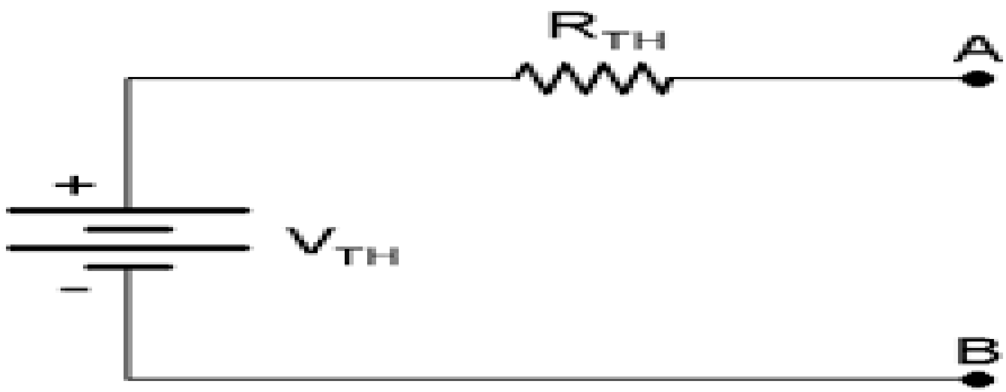
Voltage across the resistor 5Ω is $5(I_1-I_2)=5\times(5.625-5)=3.125V$

Voltage across the resistor 4Ω is $4I_2=4\times5=20V$.

7) Sate and explain Thevenin's Theorem.

The any linear and bilateral circuit consist of any number of active elements and passive elements is replaced by an equivalent circuit consist of one voltage source and resistor connected in series.

Thevenin's equivalent circuit is



Procedure to find Thevenin's voltage:

1) Open circuit the terminals where the thevenin's theorem is applied and mark the voltage across open circuit terminals as thevenin's voltage $V_{TH.}$

2) Find V_{TH} using mesh or nodal analysis.

Procedure to find thevenin's resistance R_{TH}

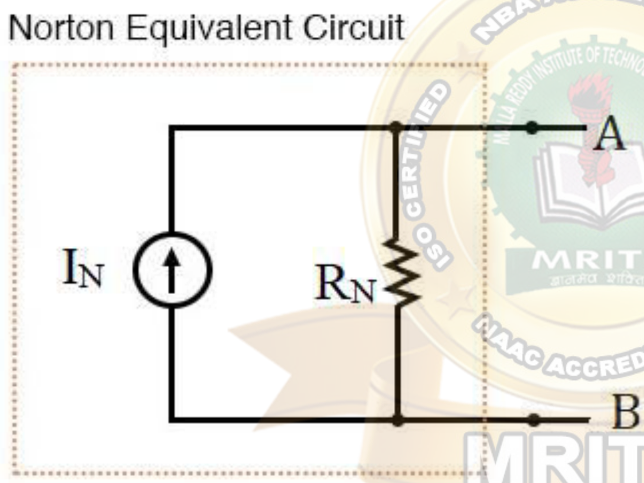
1) To find R_{TH} ,Short circuit the voltage source and open circuit the current source in the circuit.

2) Find R_{TH} at open circuit terminals in the circuit by using equivalent resistance method.

Draw the equivalent circuit which contain $V_{TH,}$ R_{TH} both are connected in series.

8) State and Explain Norton's Theorem.

The any linear and bilateral circuit consist of any number of active elements and passive elements is replaced by an equivalent circuit consist of one current source and resistor connected in parallel.



Procedure to find Norton's current I_N :

1) Short circuit the terminals where the Norton'ss theorem is applied and mark the current through the short circuit terminals as norton's current I_N .

2) Find I_N using mesh or nodal analysis.

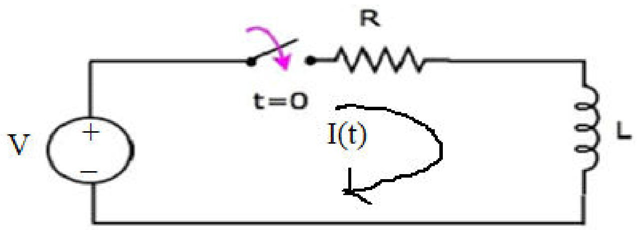
Procedure to find Norton's resistance R_N

1) To find R_N ,Short circuit the voltage source and open circuit the current source in the circuit.

2) Find R_N at short circuit terminals in the circuit by using equivalent resistance method.

Draw the equivalent circuit which contain $I_{N,}$ R_N both are connected in parallel.

9) Obtain the expression for transinentcurrent flowing through R-L series circuit excited by DC excitation at t=0^{+}.



Assume that the current through the inductor is zero before the switch is closed at time t = 0 sec

Apply KVL after switch closed at time t=0

$$-V+I(t)R+L\frac{dI(t)}{dt}=0$$

$$V=I(t)R+L\frac{dI(t)}{dt}$$

$$\frac{dI(t)}{dt}+\frac{R}{L}I(t)=\frac{V}{L}$$

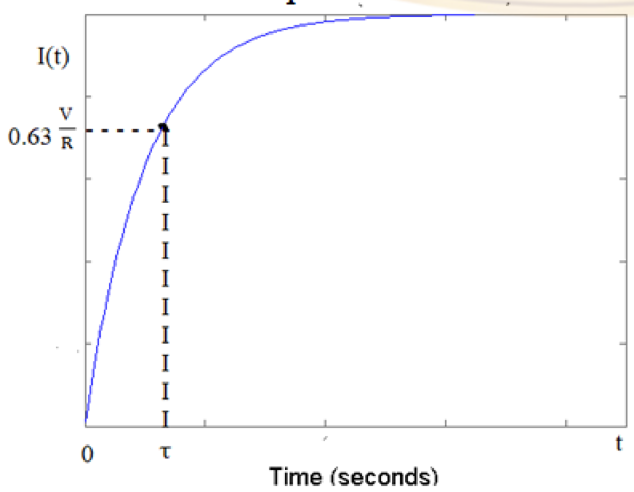
Use Integration factor method,

The current response through the series RL circit is

$$I(t)=\frac{V}{R}(1-e^{\frac{-Rt}{L}})$$

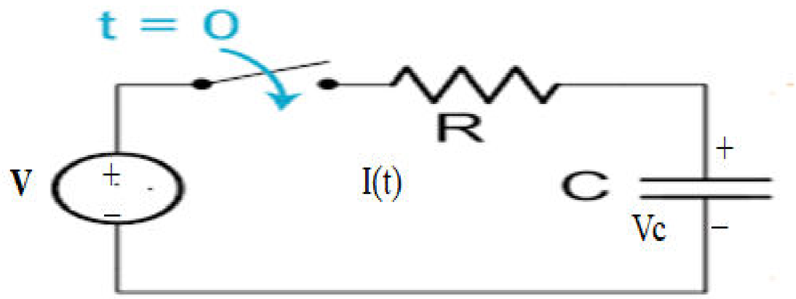
$$I(t)=\frac{V}{R}(1-e^{\frac{-t}{\tau}}) \quad \text{where } \tau=\frac{L}{R} \quad \Rightarrow \text{time constant}$$

current response in RL circiut



At t= τ the current response reaches to 63% of steady state current.

10) Obtain the expression for transinentcurrent flowing through R-C series circuit excited by DC excitation at t=0⁺.



Apply KVL after switch closed at time t=0

$$-V+RI(t)+V_C(t)=0$$

$$V= RI(t)+V_C(t)$$

$$I(t)=C\frac{dV_C(t)}{dt}$$

$$V= RC\frac{dV_C(t)}{dt}+V_C(t)$$

$$\frac{dV_C(t)}{dt}+\frac{1}{RC}V_C(t)=\frac{V}{RC}$$

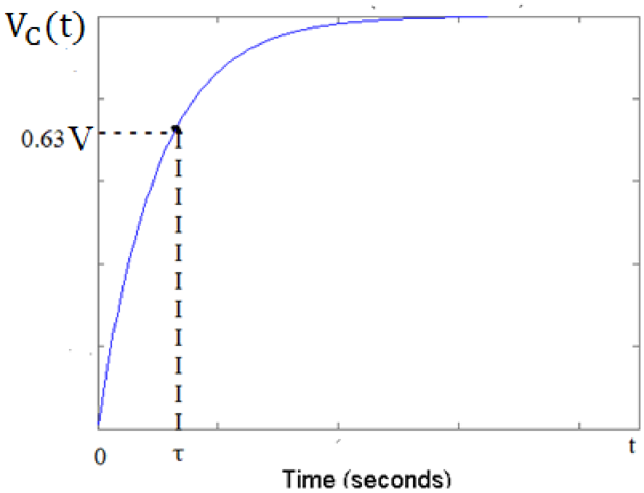
Use Integration factor method,

The voltage across the capacitor is

$$V_C(t) = V(1- e^{\frac{-t}{RC}})$$

$$V_C(t) = V(1-e^{\frac{-t}{\tau}})$$ where $\tau = RC$ =>time constant

Voltage responce at capacitor



At t= τ the voltage response reaches to 63% of input DC voltage.