Introduction of Circuit Elements:

Charge: charge is the electrical quantity is a property of the atomic particles of which all matter consists. we know that the atom may be pictured as composed of a nucleus with a positive charge surrounded by negatively charged particles called electrons. If the number of electrons in the atom equals to the number of protons in the nucleus then the atom is said to be in neutral. If one electron is removed then the atom is said to be positively charged one. If one electron is added then the atom acquires & gains negative charge.

The SI unit of charge is the coulomb (C)

It is the charge contained in 6.24×10^{18} electrons & 6.28×10^{18}

charge can not be created & destroyed, ie the law of conservation of charge.

Current: The drift & movement & flow of electrons in a conductor in one direction is known as the electric current ie The flow of electric current takes place by the movement of the electrons in a conductor. Since the electrons are negatively charged so the direction of their motion is opposite to the direction of conventional current which is from high potential to low potential

Electric current = Rate of flow of electrons

$$= \frac{\text{Quantity of electricity passed during a given time}}{\text{Time}}$$

$I \Rightarrow \frac{Q}{T} \Rightarrow$ coulombs/sec & Ampere

The ampere is the current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed one metere apart in a vaccum, would produce between these conductors a force of 2×10^{-7} N/meter length.

Voltage = The energy required to bring & moving a unit positive charge from infinite distance to the point in the electrical field is called as potential. The ratio of work to charge is given the name voltage. The unit of voltage is volts & Jouls/columb

Power = power is the rate of doing work and is expressed in joules per second. When one coulomb of electrical charge moves through a potential difference of one volt in one second the work done is one joule/second and in electrical engineering it is expressed as one watt and is denoted by symbol P.

$P = V \times I$ watts. $P = I^2R$ & $\frac{V^2}{R}$

Energy :- The capacity of to dowok & is the total amount wok done and is expressed in Joules & in watt-seconds in electrical engineering. It is denoted by W

$$W = P \times t = I^2 R t = \frac{V^2}{R} t = V I t \text{ watt sec}$$

The electrical power utility compenies measure energy in watt-hours (Wh) 1 Wh = 3600 joule

cirucit Element :- circuit element refers to the mathematical model of a physical device. voltage source, current source, Resistor, Inductor and capacitor are the circuit elements.

Types of circuit elements :-

(i) Simple circuit elements.

(ii) General circuit elements.

(i) simple circuit elements :- A simple circuit element is the mathematical model of a two Terminal electrical device, and it can be completely characterised by the voltage current relationship, but cannot be sub-devided into another two Terminal devices

ex :- Resistor, inductor and capacitor

(ii) General circuit elements :- A general circuit element may be composed of more than one simple circuit elements. ex :- Transformer

Electric Network:- The inter connection of two or more circuit elements called as electric network.

Electric circuit:- The inter connection of two or more circuit element with atleast one closed path is called as electric circuit.

Resistance (R) Resistance is the property of a material by virtue of which it opposes the flow of electrons (current) through it. Thus, resistance restricts the flow of electric current through. The unit of resistance is ohms (Ω)

ohm's law:- ohm's law may be defined as the temperature remaining constant, the potential difference across the ends of the conductor is directly proportional to the current flowing through it.

$I \propto V$

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

$V \propto I \Rightarrow V = IR$

where R is Resistance and is a proportional constant

$$\boxed{1\Omega = \frac{1V}{1A}}$$

Limitations of ohm's law:-

ohm's law cannot be applied to circuits consisting of electronic valves or transistors because these elements are not bilateral.

ohm's law cannot be applied to circuits consisting of non-linear elements such as powdered carbon, thyrite, electric arc..

Laws of Resistance :-

The resistance of the wire depends upon its length, area of cross-section, type of material, purity and hardness of material of which it is made of and working temperature.

Resistance of wire is

(i) directly propotional to its length, ie $R \propto l$.

(ii) Inversily propotional to its area of cross section

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

combining above two facts, $R \propto \frac{l}{a}$

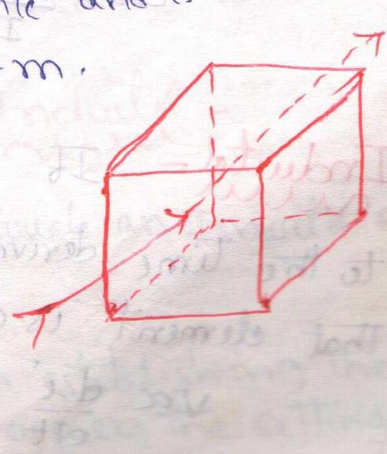
$$\therefore \boxed{R = \rho \frac{l}{a}} \ \Omega$$

where ρ is the proportionality constant and is denoted by specific resistance or resistivity in Ω-m

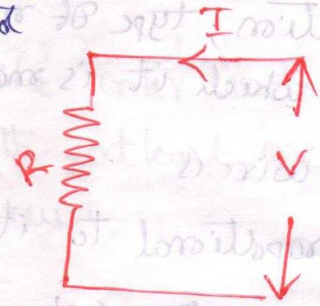
Specific resistance (ρ) :- Specific resistance or resistivity is defined as the resistance between opposite faces of a unit cube of that material.

(or)

The resistance of a material of unit length (ie $l = 1$) having unit cross-sectional area ($a = 1$) is defined as the resistivity or specific resistance and is denoted by letter 'ρ' and the unit is Ω-m.



Resistor:- If the voltage across the element is directly proportional to the current through it, then that element is a Resistor



$V \alpha I$

$V = IR$

where R is Resistance in Ω.

power absorbed by a resistor is given by

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

Inductance:- (L) Inductance is the property of a material by virtue of which it oppose any change of current through it. Thus the current through inductance cannot change instantaneously.

Inductance is denoted by 'L' and is given by

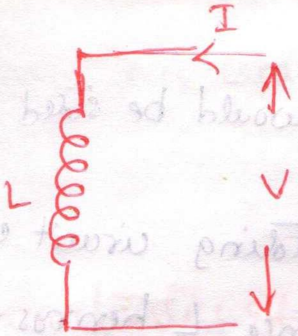
$$L = \frac{\psi}{I} \qquad \psi = \text{flux linkages total}$$

$$\psi = N\phi$$

$$L = \frac{N\phi}{I} \text{ henerys}$$

Inductor:- If the terminal voltage is proportional to the time derivative of current through it then that element is an inductor.

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



where L is inductance in henerys

$1H = 1 \frac{V-S}{A}$.

Characteristics of Inductor :-

(I) There is no voltage across an inductor if the current through it is not changing with time i.e and inductor acts as a short circuit to DC.

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

(II) A finite amount of energy can be stored in an inductor even if the voltage across inductor is zero

$$E = \frac{1}{2} L I^2 \text{ joules.}$$

(III) An Inductor opposes the change in current through it.

(IV) An Inductor stores energy in magnetic form and is given by $E(t) = \frac{1}{2} L i^2(t)$

(V) The avarage power absorbed by it is zero.

Energy stored in an Inductor -

When a current flows through an Inductor a magnetic field is established.

work needs to be done in establishing the magnetic field. since the inductor opposes the setting up of the field due to its inherent property of electrical inertia i.e inductance.

The energy supplied to the inductor would be stored in its magnetic field.

Thus an inductor is a energy storing circuit element.

consider an inductor of inductance L henrys.

let a current I A is forced through it. The current increases from zero to a finite value I. At any time the emf developed across inductance is e

$$e = L \frac{di}{dt} \text{ volts}$$

Instantaneous work done /sec = $P = vi = \left(L \frac{di}{dt}\right) i\, dt$

Total work done in establishing current varying from 0 to I is given by $W = \int_0^I L i\, di = \frac{1}{2} L I^2$ joules

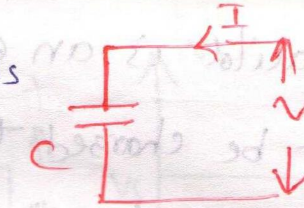
Energy stored in the inductor $W = \frac{1}{2} L I^2$ joules

Capacitance :- Capacitance is the property of a circuit element to store electric charge. It opposes any change of voltage across it. Thus, the voltage across the capacitor cannot change instantaneously. It is denoted by 'c' and measured in Farads (F).

Capacitor :- If the terminal voltage is proportional to the integral of current through it then that element is a capacitor $v \propto \int i\, dt$

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

Where c is capacitance in Farads



Characteristics of capacitor :-

(i) The current Through capacitor is zero, if the voltage across it is not changing with time. ie a capacitor acts as an open circuit to D.C under steady state.

$$\therefore I = C\frac{dv}{dt}$$

(ii) A finite amount of energy canbe stored in a capacitor even if the current Through The capacitor is zero.

ie $E = \frac{1}{2}CV^2$ joules

(iii) It is impossible to change the voltage across a capacitor by a finite amount in zero time, for This it requires an infinite current through the capacitor ie a capacitor resists abrupt change in voltage across it.

(iv) The capacitor stores energy in an electric field and given by $E(t) = \frac{1}{2}CV^2(t)$ joules

(v) The average power absorbed by it is zero.

Energy stored in a capacitor :-

The capacitor opposes the changes in voltage, Therefore when a capacitor is to be charged, work needs to be done in overcoming This opposition, and the energy supplied by The charging source is stored in the electrostatic field of the dielectric.

A capacitor is an energy storing circuit element. Let it be charged to a final voltage V. Let the instantaneous charging current be 'i'

$$i = C\frac{dv}{dt}$$ (i and v are instantaneous values)

Total work done is establishing voltage V across the capacitor is

$$W = \int_0^V vi\,dt = \int_0^V v\left[C\frac{dv}{dt}\right]dt$$

$$= C\int_0^V v\,dv$$

& $W = C\frac{V^2}{2}$ joules or watt-sec

$$\boxed{\text{Energy stored in the capacitor} = \frac{1}{2}CV^2 \text{ joules}}$$

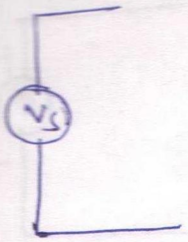
Types of Sources:-

There are two types of sources.

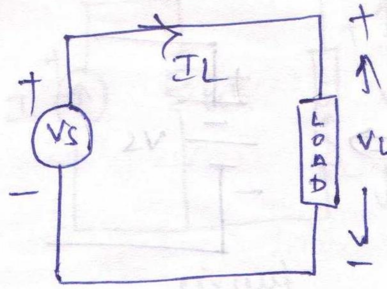
(1) voltage source (2) current source

These are classified as Ideal source and practical source

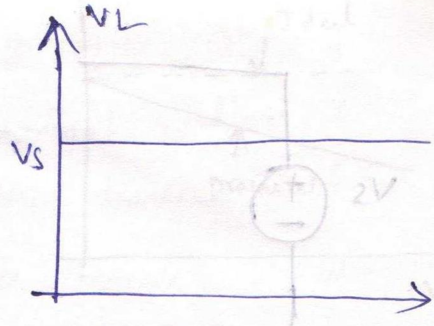
(a) Ideal voltage source:- An Ideal voltage source is a device that provides a constant voltage across its terminals (V=E) irrespect of current flowing it ie The internal resistance is zero or negligible



Symbol



circuit



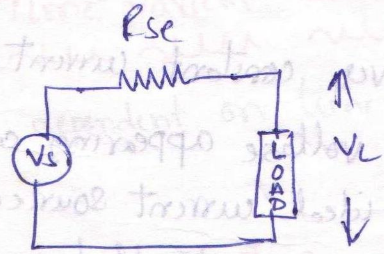
characteristics I_L

(b) practical voltage source :-

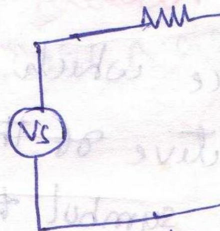
practically, every voltage source has smaller internal resistance shown in series with the voltage and is represented by R_{se} as shown in fig. Because of the R_{se}, voltage across the terminals decreases slightly with increase in current and is given by.

$$\boxed{V_L = V_s - I_L R_{se}}$$

for ideal voltage source $R_{se} = 0$



circuit



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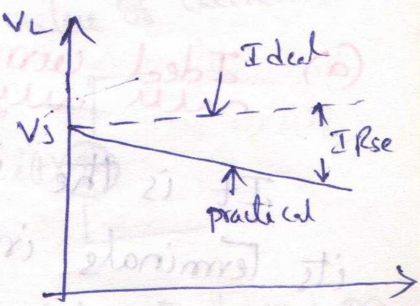


characteristics I_L

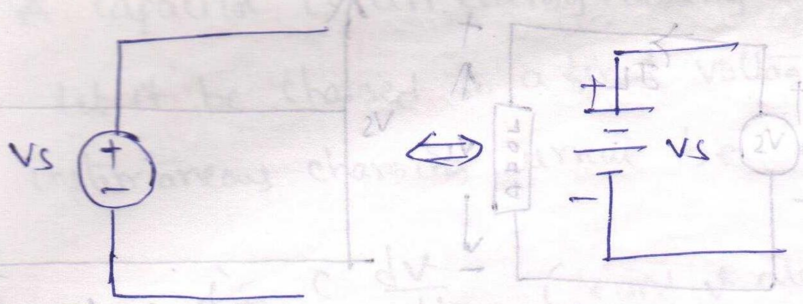
voltage sources are further classified in to

(i) Time invarient voltage source (or) DC source.

(ii) Time varient voltage source (or) AC source

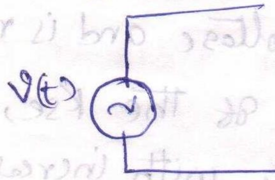
(i) Time invarient voltage source :-

The source in which voltage is not varying with time are known as time invarient voltage source



(ii) Time varient voltage source :-

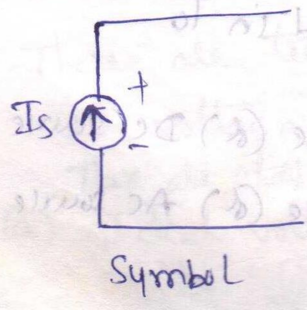
The source in which voltage is varying with respect to time is called A.C. source.



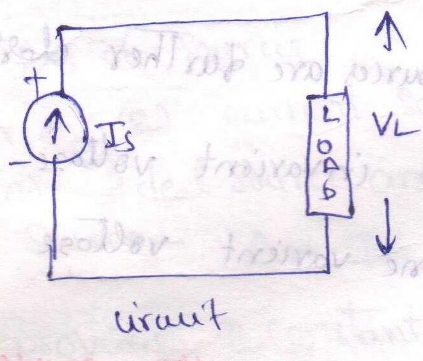
(2) Current source :-

(a) Ideal current source :-

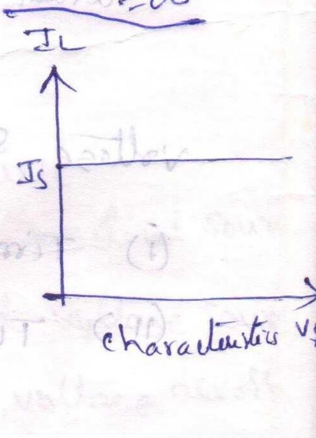
It is the source which gives constant current as its terminals irrespective of the voltage appearing across its terminals. The symbol for ideal current source and its characteristics are shown in fig. internal resi $=\infty$



Symbol



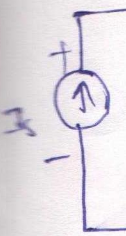
circuit



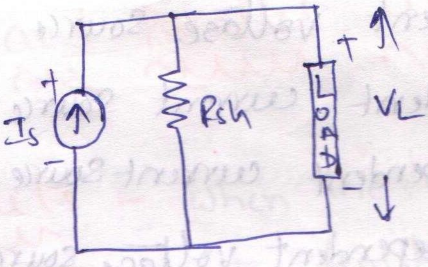
characteristics

(b) practical current source :-

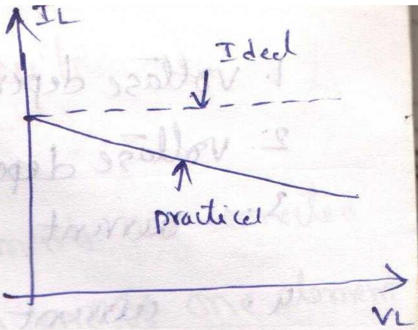
practically every current source has high internal resistance shown in parallel with current source and it is represented by Rsh.



symbol



circuit

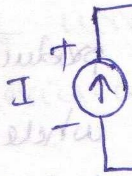


~~Rsh=0~~

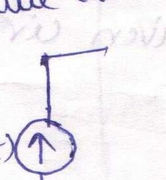
$I_L = I_s - I_{sh}$

Time invarient current source (or) DC source :-

The source in which current is not varying with time are known as Time invarient current source.



Time varient current source :- The value of current source dependent on time is called A.C source



Independent sources :- The sources does not depend on other voltages (or) currents in the network for Their value. These are represented by circle with a polarity of voltage (or) direction of current indicated inside.

Dependent sources :- Dependent sources are those whose value of source depends on voltage (or) current in the circuit. such sources are indicated by dimond and these are further classified as

1. voltage dependent voltage source (VDVS)

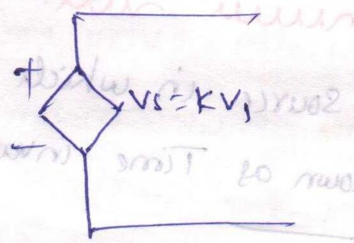
2. voltage dependent current source (VDCS)

3. current dependent current source (CDCS)

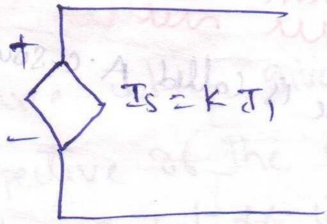
4. current dependent voltage source (CDVS)

1. voltage dependent voltage source :-

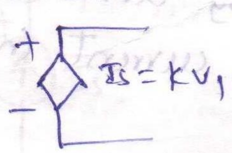
It produces a voltage as a function of voltages else where in the given circuit. This is called voltage dependent voltage source.



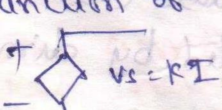
2. current Dependent current source :- It produces a current as a function of currents else where in the given circuit. This is called current dependent current source.



3. voltage dependent current source :- It produces a current as a function of voltage else where in the given circuit



4. current dependent voltage source :- It produces a voltage as a function of current else where in the given circuit

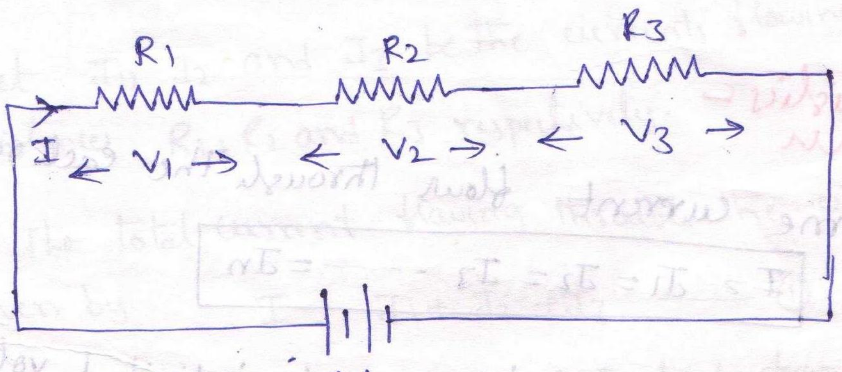


where K is the constant. V_1, I_1 are the voltage and current value in the given circuit. Dependent sources are also called control sources.

Series and parallel circuits

Series circuits :- when the elements are connected in such a way that the finishing end of one element is connected to the starting end of another element and so on and the current having only one path then that circuit is called series circuit.

Resistors in series :- when the resistors are connected end to end so that they form only one path for the flow of current. Then resistors are said to be connected in series and such circuits are known as series circuits.



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.

$$\therefore \boxed{V = V_1 + V_2 + V_3} \quad \text{— (1)}$$

Now according to ohms law

$$\left.\begin{aligned} V_1 &= I_1 R_1 \\ V_2 &= I_2 R_2 \\ V_3 &= I R_3 \end{aligned}\right\} \text{— (2)}$$

For overall circuit

$$V = I R_{equ} \quad \text{——— (3)}$$

We know that for series circuit the current having only one path $I = I_1 = I_2 = I_3$ — (4)

Substitute the equations (2), (3) and (4) in (1)

$$I R_{equ} = I R_1 + I R_2 + I R_3$$

$$\boxed{R_{equ} = R_1 + R_2 + R_3}$$

For n resistors connected in series, the equivalent resistance $\boxed{R_{equ} = R_1 + R_2 + R_3 + \cdots + R_n}$

characteristics –

(1) same current flows through the each resistance

$$\boxed{I = I_1 = I_2 = I_3 \cdots = I_n}$$

(2) supply voltage 'V' is sum of individual voltage drop across the resistances ie $\boxed{V = V_1 + V_2 + V_3 + \cdots + V_n}$

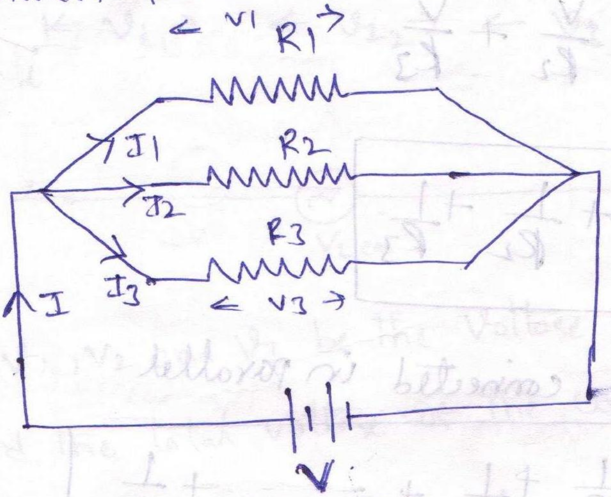
(3) The equivalent resistance $\boxed{R_{equ} = R_1 + R_2 + R_3 + \cdots + R_n}$

(4) R_{equ} is greater than R_1, $R_{equ} > R_2$ ---

$R_{equ} > R_n$.

Resistors in parallel :-

When number of resistors are connected in such a way That one end of each of them is joined to a common point and the other ends being joined to another common point, then resistors are said to be in parallel.



Let I_1, I_2 and I_3 be the currents flowing through The resistances R_1, R_2 and R_3 respectively.

The total current flowing through the circuit is given by $I = I_1 + I_2 + I_3$ —— ①

For parallel circuits, the potential drops across all the elements equal to the source voltage.

$$V = V_1 = V_2 = V_3 \quad \text{—— ②}$$

According to ohms law, the current flowing through each resistor is given by

$$\left.\begin{aligned} I_1 &= \frac{V_1}{R_1} \\ I_2 &= \frac{V_2}{R_2} \\ I_3 &= \frac{V_3}{R_3} \end{aligned}\right\} \text{—— ③}$$

Total current flowing through equivalent resistance R_{eq} is

$$I = \frac{V}{R_{eq}} \quad \text{—} \ (4)$$

Substitute eqn (2), (3) & (4) in (1)

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

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

If n resistors are connected in parallel

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

Characteristics:-

1. The same potential difference gets across all the resistance in parallel. $V = V_1 = V_2 = V_3 = \cdots = V_n$

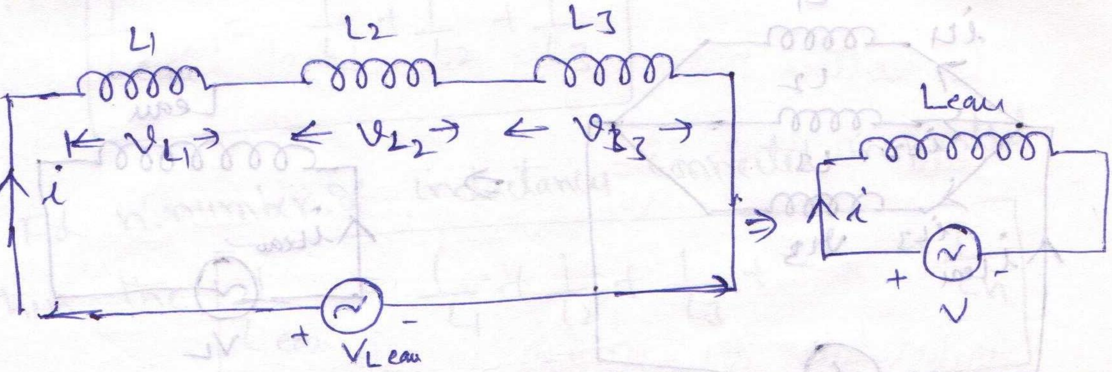
2. The total current I is given by
$$I = I_1 + I_2 + I_3 + \cdots + I_n$$

3. $$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$$

4. $R_{eq} < R_1 < R_2 < R_3 \cdots < R_n$

Inductances in Series :-

Let L_1, L_2 and L_3 are the three inductances connected in series as shown in fig bellow



v_1, v_2 and v_3 be the voltase produced by each inductor and the total voltase of the circuit is given by

$$v_{Leau} = v_{L1} + v_{L2} + v_{L3} \quad — ①$$

Voltase produced by each inducter is given by

$$v_{L1} = L_1 \frac{di_1}{dt}, \quad v_{L2} = L_2 \frac{di_2}{dt}, \quad v_{L3} = L_3 \frac{di_3}{dt} \rightarrow ②$$

The voltase produced by equivalent inductor is given by $v_{Leau} = \cancel{v_L} \, L_{eau} \frac{di}{dt} \quad — ③$

substitute ③ & ② in ①

$$\cancel{v} \quad L_{eau} \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di_2}{dt} + L_3 \frac{di}{dt}$$

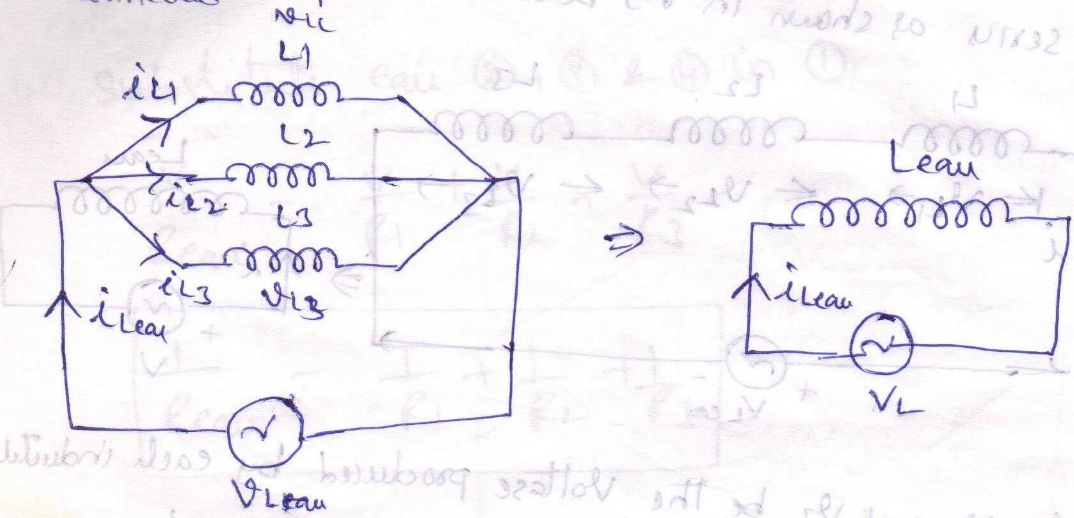
$$\therefore \boxed{L_{eau} = L_1 + L_2 + L_3}$$

For n number of inductances connected in series

$$\boxed{L_{eau} = L_1 + L_2 + L_3 + \cdots + L_n}$$

Inductancy in parallel :-

Let L_1, L_2 and L_3 be the three inductancy connected in parallel shown in fig



The total current flowing through the circuit is givenby $i_{L_{eq}} = i_{L_1} + i_{L_2} + i_{L_3}$ — ①

For parallel circuits, the voltage produced across each inductor is equal to the total voltage, i.e.

$$v_{L1} = v_{L2} = v_{L3} = v_{Leq} \quad — ②$$

The current flowing through the each inductor is givenby

$$\left.\begin{aligned} i_{L1} &= \frac{1}{L_1}\int v_{L1}\,dt \\ i_{L2} &= \frac{1}{L_2}\int v_{L2}\,dt \\ i_{L3} &= \frac{1}{L_3}\int v_{L3}\,dt \end{aligned}\right\} \quad — ③$$

The current flowing in the equivalent inductance leq is givenby

$$i_{eq} = \frac{1}{L_{eq}}\int v_L\,dt \quad — ④$$

Substitute equation ④, ③ and ② in ①

$$\frac{1}{L_{eq}} \int v_L\,dt = \frac{1}{L_1} \int v_L\,dt + \frac{1}{L_2} \int v_L\,dt + \frac{1}{L_3} \int v_L\,dt$$

$$\therefore \boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$$

For n number of inductancy connected in parallel then the

$$\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_n}}$$

Capacitancy in series :-

Let C_1, C_2 and C_3 be the capacitancy connected in series shown in fig(a) and its equivalent capacitancy shown in fig(b)

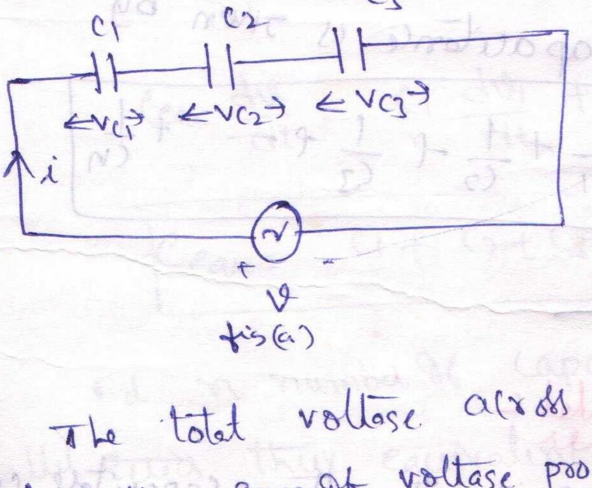


fig (a)

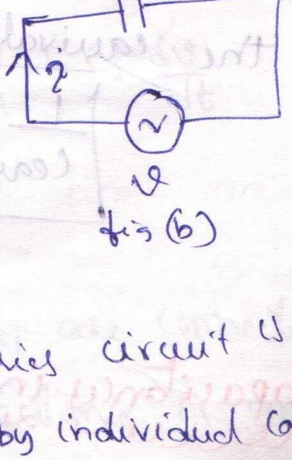


fig (b)

The total voltage across the series circuit is given by the sum of voltage produced by individual capacitancy

$$v_C = v_{C1} + v_{C2} + v_{C3} \quad \text{— ①}$$

According to series circuits concept the current having only one path i.e $i = i_1 = i_2 = i_3$ — ②

We know that the voltage produced by individual capacitancy are given by

$$\left.\begin{aligned} v_{c1} &= \frac{1}{C_1}\int i_1\,dt \\ v_{c2} &= \frac{1}{C_2}\int i_2\,dt \\ v_{c3} &= \frac{1}{C_3}\int i_3\,dt \end{aligned}\right\} \text{ --- } (3)$$

The voltage produced by equivalent capacitance C_{eq} is given by

$$v_{ceq} = \frac{1}{C_{eq}}\int i\,dt \text{ --- } (4)$$

substitute (2) & (3) & (4) in (1)

$$\frac{1}{C_{eq}}\int i\,dt = \frac{1}{C_1}\int i\,dt + \frac{1}{C_2}\int i\,dt + \frac{1}{C_3}\int i\,dt$$

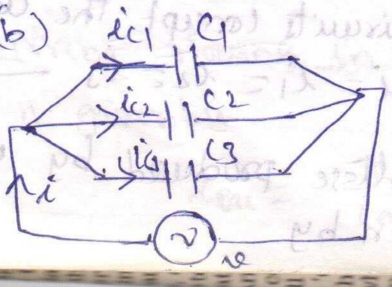
$$\therefore \boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

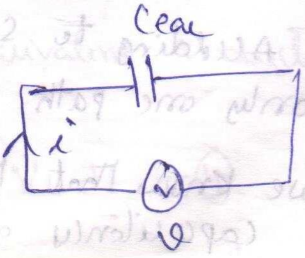
For n capacitances are connected in series then the equivalent capacitance is given by

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \text{---} + \frac{1}{C_n}}$$

Capacitances in parallel :-

Let C_1, C_2 and C_3 be the three capacitors connected in parallel shown in fig (a) its equivalent circuit shown in fig (b)





The total current flowing through the parallel circuit is the sum of individual currents flowing through the each capacitor $i = i_1 + i_2 + i_3$ —— (1)

For parallel circuits the total voltage is equal to the ~~sum of~~ individual voltage produced by each capacitor

$$v = v_1 = v_2 = v_3 \quad \text{—— (2)}$$

The current flowing through the individual capacitor are given by

$$\left.\begin{aligned} i_1 &= C_1 \frac{dv_1}{dt} \\ i_2 &= C_2 \frac{dv_2}{dt} \\ i_3 &= C_3 \frac{dv_3}{dt} \end{aligned}\right\} \text{—— (3)}$$

The total current is given by $i = C_{eq} \frac{dv}{dt}$ —— (4)

substitute equation (2), (3) & (4) in (1)

$$C_{eq} \frac{dv}{dt} = C_1 \frac{dv_1}{dt} + C_2 \frac{dv}{dt} + C_3 \frac{dv}{dt}$$

$$\boxed{C_{eq} = C_1 + C_2 + C_3}$$

For n number of capacitors are connected in parallel ~~series~~ their equivalent capacitance is given by

$$\boxed{C_{eq} = C_1 + C_2 + C_3 + - - + C_n}$$