CHAPTER - 1

BASIC CONCEPTS OF NETWORK

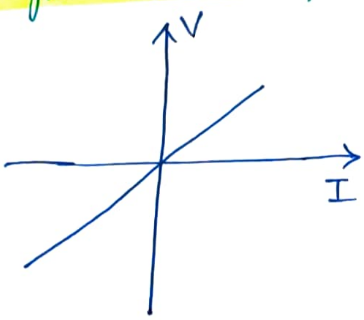
Lecture - 01 :

TYPES OF NETWORK ELEMENTS :

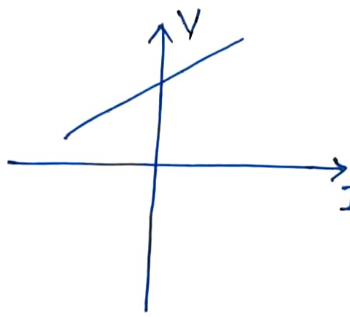
1. LINEAR AND NON-LINEAR ELEMENTS :

Linear Elements :

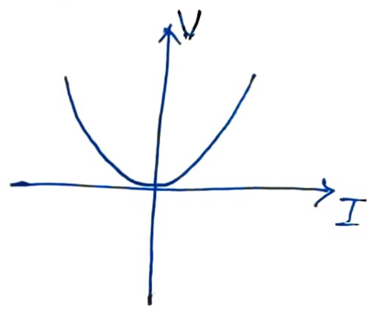
The characteristics of linear elements always passes through the origin, in the form of straight line.



linear



Non-linear

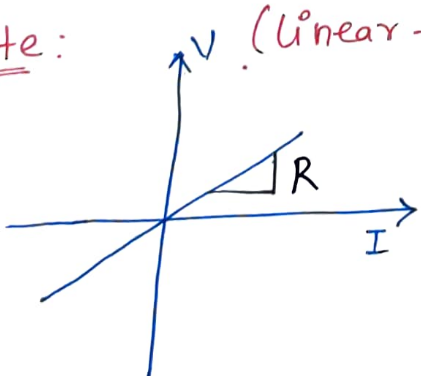


Non-linear

Example of linear elements : (N/w elements like R, L, C)

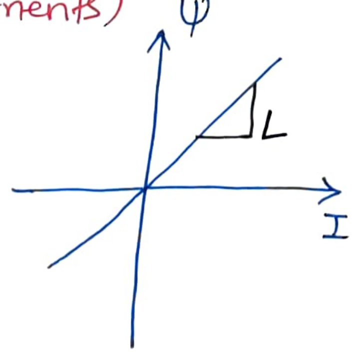
Example of non-linear elements : (Device elements like Diode, BJT, MOSFET, JFET, OP-AMP)

Note : (linear - elements)



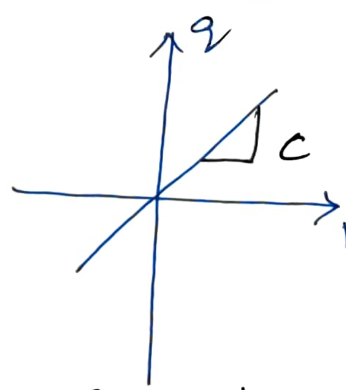
V-I plane

Slope = R



ψ-I plane

Slope = L

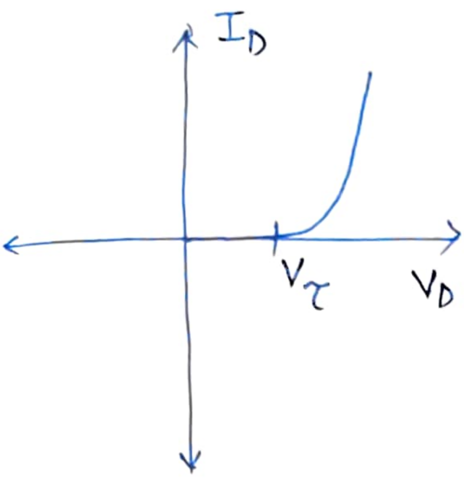


q-V plane

Slope = C

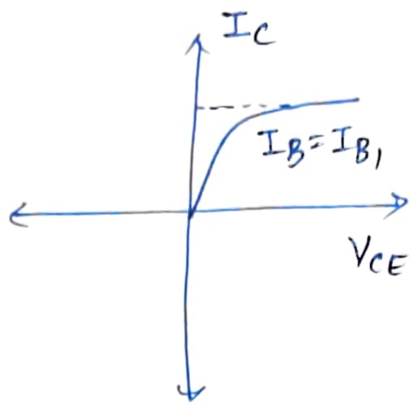
Note: Graphs of Non-linear elements:

Diode



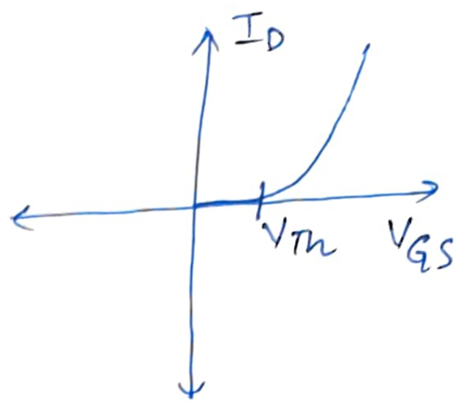
Forward-bias c/s of Diode (Non-linear)

BJT



o/p c/s of BJT (Non-linear)

MOSFET



Transfer c/s of MOSFET (Non-linear)

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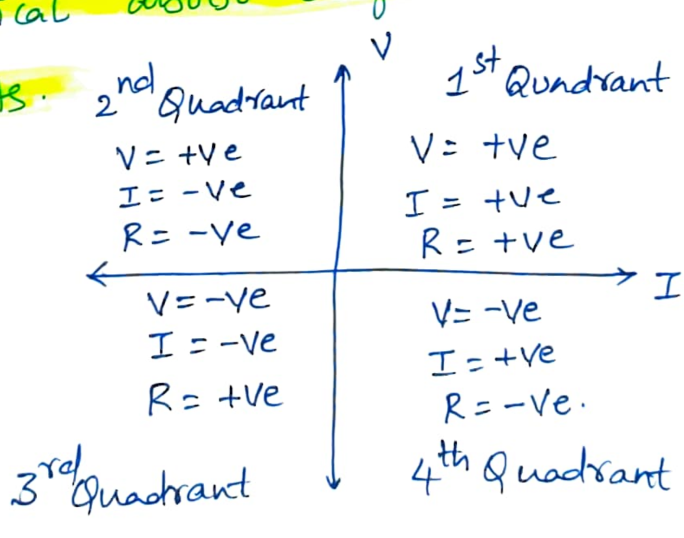
2. BILATERAL AND UNILATERAL ELEMENTS:

In case of V-I plane c/s of bilateral elements offer same impedance throughout the c/s. plane. whereas the c/s of unilateral elements offer different impedance in different region.

(Or)

In case of any generalised plane, c/s of bilateral elements is symmetrical about origin. If it is non symmetrical about origin then they are unilateral elements.

Note:



Note:

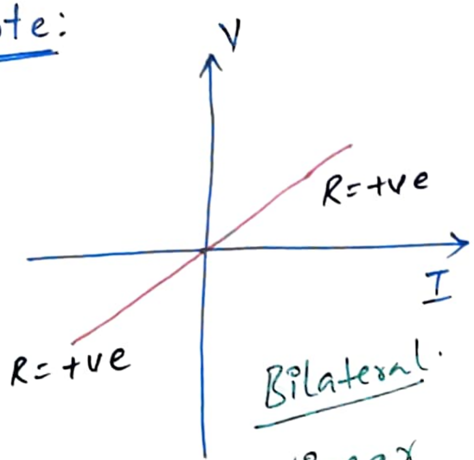
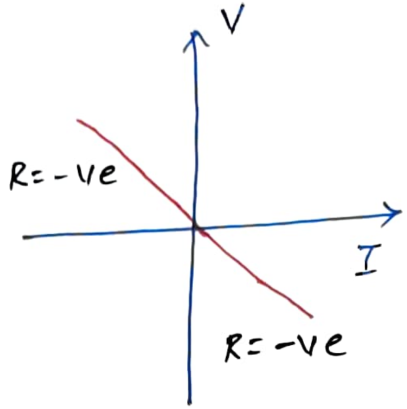


fig (a)

Bilateral.

linear



fig(b)

Bilateral.

linear

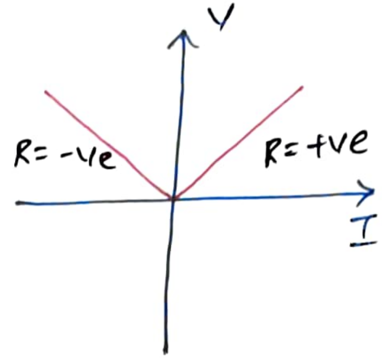


fig (c)

Unilateral.

non- linear

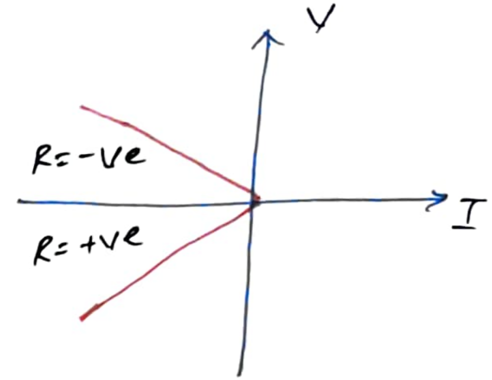


fig (d)

Unilateral

non- linear

Analysis:

In fig(a) : Impedance is same throught the plane and it is symmetrical about origin. (Bilateral)

In fig (b) : Impedance is same throughout the plane & it is symmetrical about origin. (Bilateral)

In fig (c) : Impedance is different in different regions & So unilateral.

In fig (d) : Impedance is different in different regions. So unilateral.

In fig (e) : Impedance is same throught the plane & it is symmetrical about origin. (Bilateral).

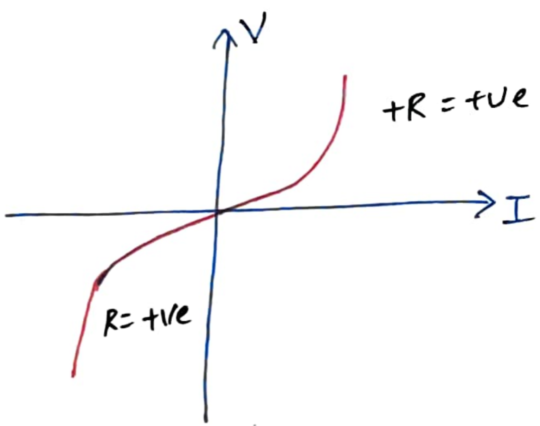


fig (e)

Bilateral.

Non- linear

Note: All linear elements are bilateral elements. It is true for any n/w in all cases.

but

All bilateral elements ~~ar~~ may not be linear elements.

Note: (i) All n/w elements R, L, C are bilateral.

(ii) All device elements (diode, BJT, MOSFET) are unilateral.

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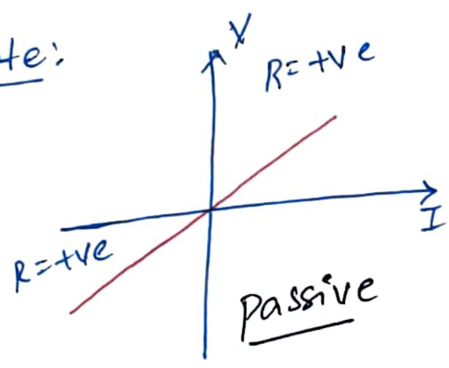
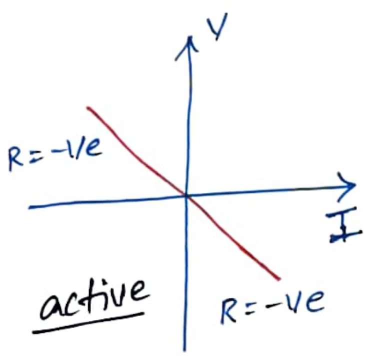
3. PASSIVE AND ACTIVE ELEMENTS :

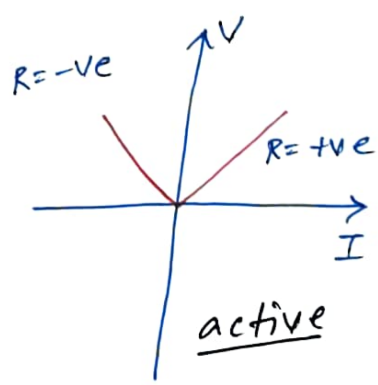
→ In case of V-I plane c/s of passive elements offer only positive impedance.

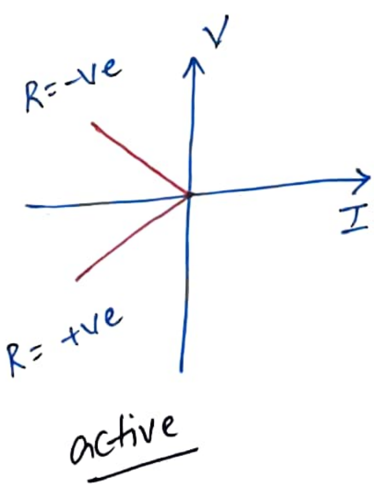
→ $|||^{ly}$ In case of V-I plane c/s of active elements offer only negative impedance.

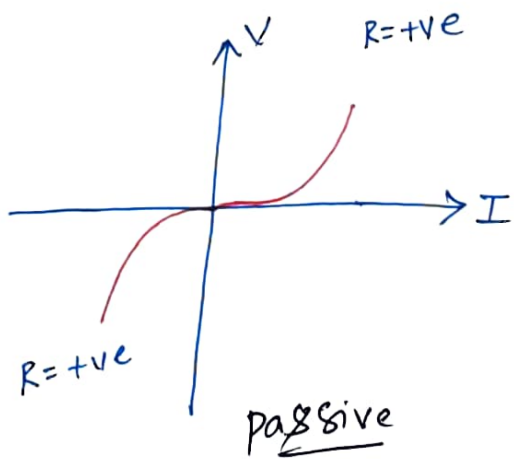
Note:











Eg: of active elements are:

(i) Voltage source (ii) Current source (iii) Generator.

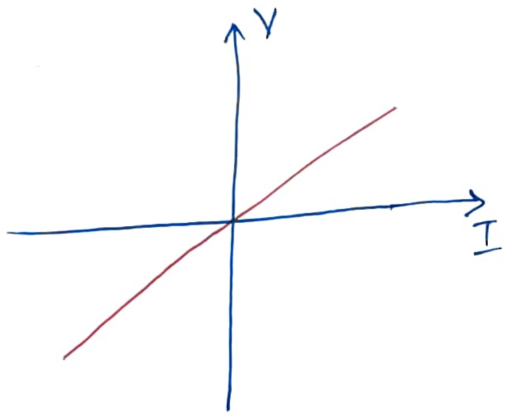
(iv) Op-amp (v) Biased BJT.

<u>Note:</u> Globally R, L, C elements are passive elements. But in case of transients during discharging L & C behave as active elements.

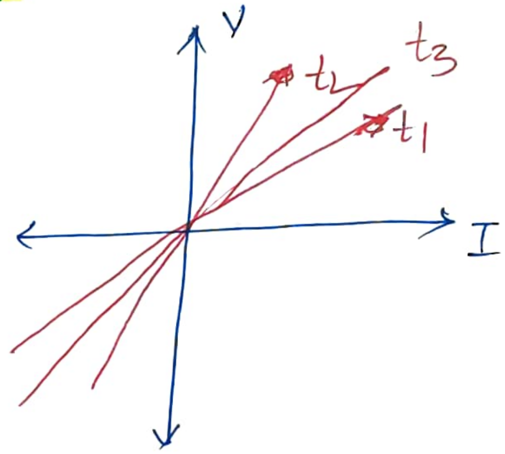
<u>4. TIME INVARIANT & TIME VARIANT ELEMENTS:</u>

The c/s of time invariant elements donot vary w.r.t time.

The c/s of time variant elements vary w.r.t time.



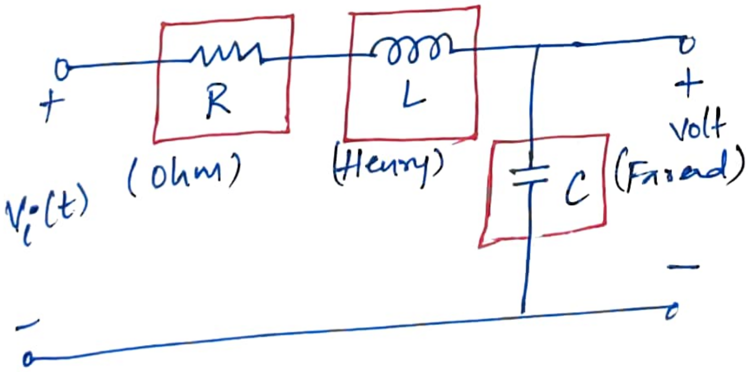
<u>time invariant</u>



<u>Time Variant</u>

<u>5. LUMPED AND DISTRIBUTED ELEMENTS:</u>

Physically separated elements in the n/w are called lumped elements.



Here R, L & C are the lumped elements.

If the elements are distributed along the line then those elements are called distributed elements.

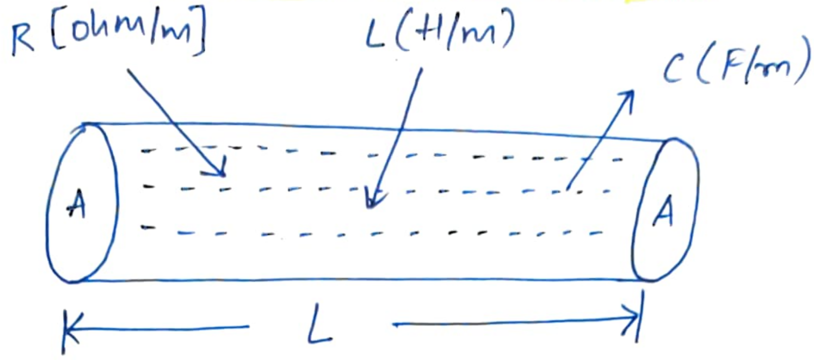


fig: Cable wire of length L.

Generally the distributed elements cannot be separated.
Concept of network theory involves lumped elements.
Field theory (transmission lines) involves distributed elements.

PROPERTIES OF NETWORK ELEMENTS: (R, L, C)

All the network elements R, L & C are

(i) Linear

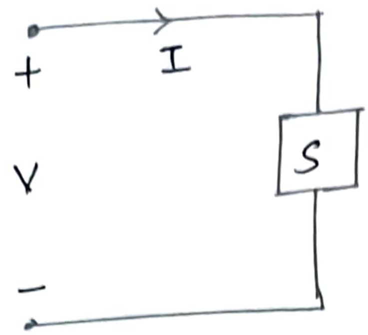
(ii) Bilateral

(iii) Passive

(iv) Time Invariant

(v) Lumped.

Problem: Consider the network shown in below figure.



The reln b/w V & I is given in the following plot. Find whether those plots are linear, bilateral passive, time invariant or lumped elements?

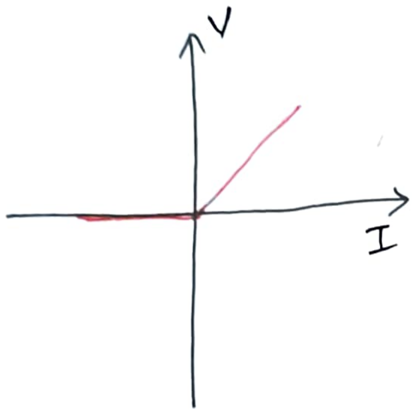


fig (a)

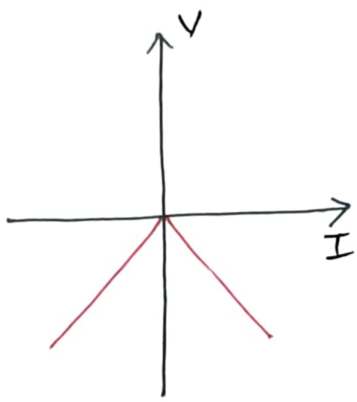


fig (b)

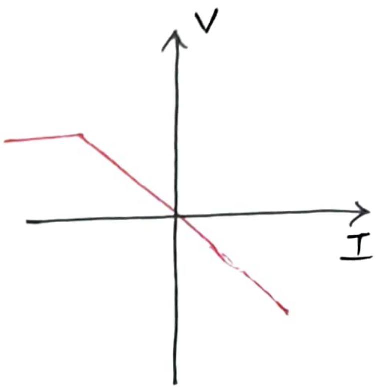


fig (c)

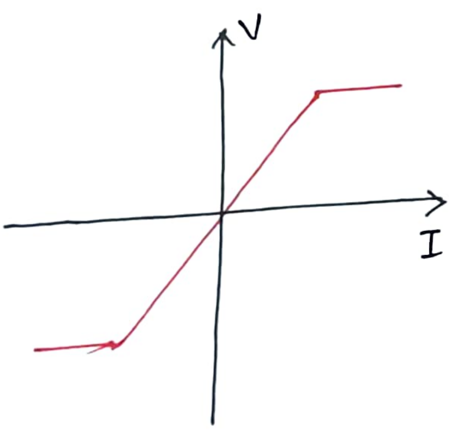


fig (d)

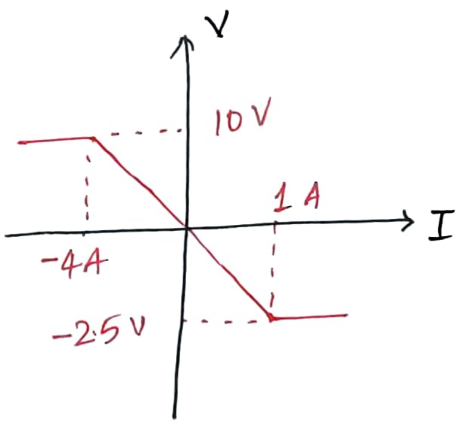


fig (e)

Ans: fig (a) → It has a constant line. So Non-linear.

→ It is not symmetrical about origin. So Unilateral

→ It offers only positive impedance. So passive

→ Clearly it is both time invariant & lumped.

fig (b) : → It is non - linear ($\because$ not a straight line)

→ It is symmetrical about ~~ax~~ y-axis but not the origin. So it is Unilateral.

→ It ~~is~~ has both negative & positive impedances. So it is active

→ Clearly it is time invariant & lumped.

fig (c) : → It is non- linear ($\because$ presence of constant line)

→ It is not symmetrical about origin. So it is Unilateral.

→ It ~~is~~ has the impedance as negative throughout. So, it is active.

→ Clearly it is time invariant & lumped

fig (d) : → It is non- linear ($\because$ not a straight line)

→ It is symmetrical about origin. So Bilateral.

→ It has only positive impedances. So passive.

→ Clearly it is time invariant & lumped.

fig (e) : → It is non-linear ($\because$ not a straight line)

→ It is not symmetrical about origin. So Unilateral

→ It has only negative impedances. So active.

→ Clearly it is time invariant & lumped

LECTURE-2

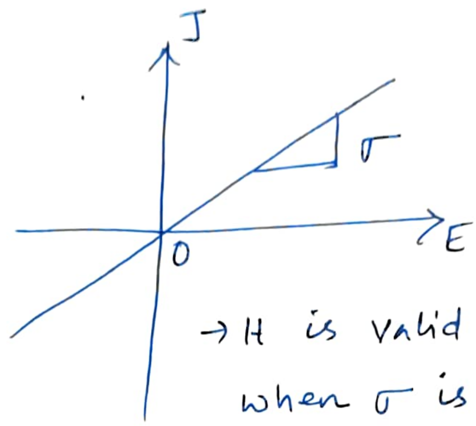
ANALYSIS OF PASSIVE ELEMENTS (RESISTOR)

RESISTOR: Resistance is the property of resistor which opposes the flow of current.

From field theory:

$J \propto E$

$$\boxed{J = \sigma E}$$



This is a form of ohms law in field theory.

$\sigma = f(\text{Temp})$

→ It is valid only when σ is const in J-E plane.

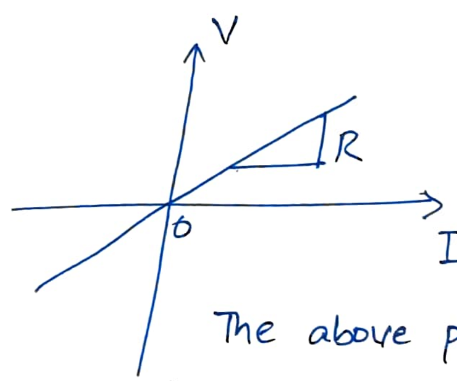
In conductor if $T \uparrow$ then $\sigma \downarrow$

In semiconductor if $T \uparrow$ then $\sigma \uparrow$.

From circuit theory:

$V \propto I$

$$\boxed{V = IR}$$



This is the form of ohm's law in circuit theory.

The above plot is valid only when the resistance is kept const.

$R = f(\text{Temp})$

$R = R_0 [1 + \alpha T]$

Ohm's law is valid only when the temperature is kept constant.

Now we have

$J = \sigma E$

$\frac{I}{A} = \sigma \frac{V}{l}$

$\frac{V}{I} = \frac{1}{\sigma} \frac{l}{A}$

$\boxed{R = \rho \frac{l}{A}}$; $\rho = \frac{1}{\sigma}$

Units:

R : ohm

ρ : ohm-cm

σ : $1/\rho$

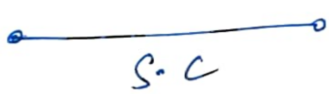
σ : $(\text{ohm-cm})^{-1}$

→ $V = IR \Rightarrow R = \frac{V}{I} = \frac{\text{Volt}}{\text{amp}}$ $[\text{ohm} = \Omega]$

Case-(i): $V = 0$

$I =$ Any value = Norton current

$R = 0$, which implies short circuit

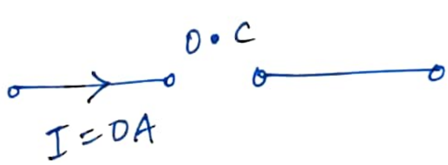


$\left.\begin{array}{l} R = 0 \\ V = 0 \\ I = \text{any value} \end{array}\right\}$ ⇒ It is also known as norton current $I_N = I_{sc}$.

Case-(ii): $I = 0$

$V =$ Any value = Thevenin voltage.

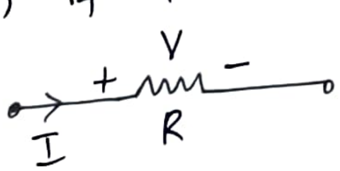
$R = \infty$; which is an open circuit



} The voltage is also known as thevenin voltage.

For a resistor :

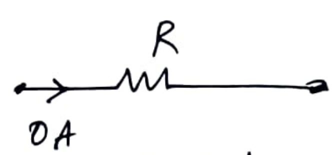
(i) If $V = 0 \Rightarrow I = 0$



$V = 0$ volt

$I = 0A$

(ii) If $I = 0 \Rightarrow V = 0$



$I = 0A$

$V = 0V$.

Note:
But the above is not valid for inductor & capacitor.

i.e, if $V=0 \nRightarrow I=0$ & vice-versa.

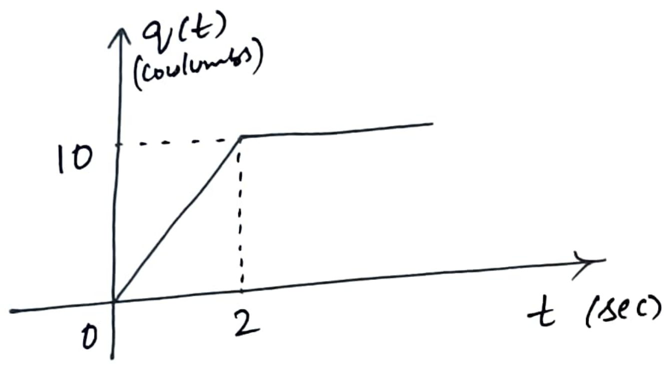
Now $\quad R = \frac{V}{I} = \frac{v}{i}$

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

$$i(t) = \frac{d}{dt} q(t) \quad \text{columb/sec (or) Amp}$$

$$q(t) = \int i(t)\,dt$$

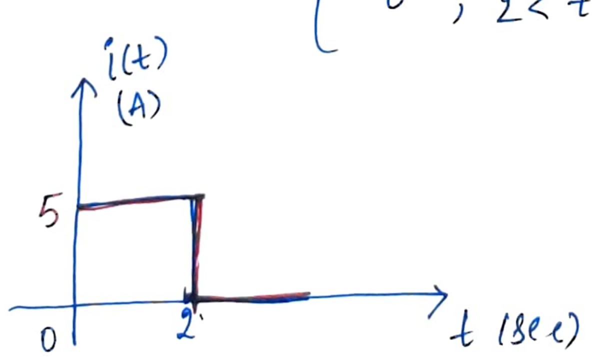
Problem: Given the graph of $q(t)$. Find $i(t)$.



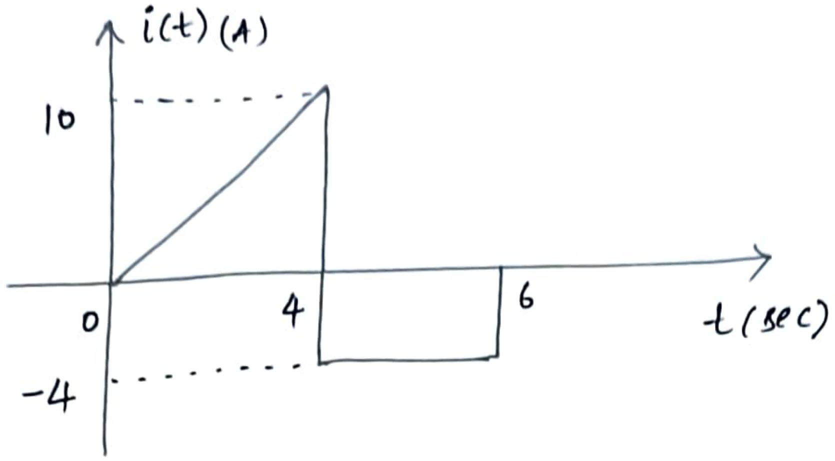
sol:

$$q(t) = \begin{cases} 5t & ; \ 0<t<2 \\ 10 & ; \ 2<t<\infty \end{cases}$$

$$i(t) = \frac{dq}{dt} = \begin{cases} 5 & ; \ 0<t<2 \\ 0 & ; \ 2<t<\infty \end{cases}$$



Problem: Given the graph of $i(t)$. Find the graph of $q(t)$.



sol: $i(t) = \frac{dq(t)}{dt}$; $q(t) = \int i(t)\,dt$.

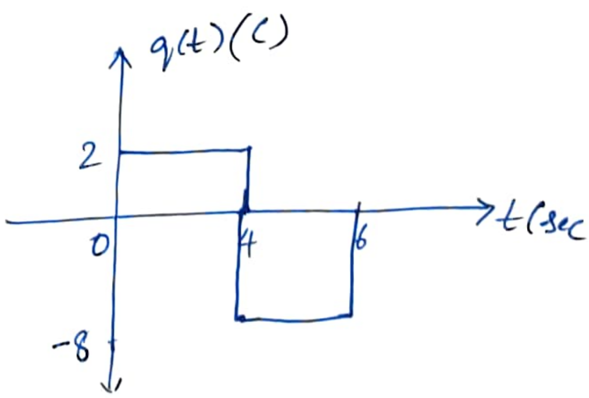
$$i(t) = \begin{cases} 2.5t & ; 0 < t < 4 \\ -4 & ; 4 < t < 6 \\ 0 & ; 6 < t < \infty \end{cases}$$

(i) $0 < t < 4$

$$q(t) = 2.5\int_0^4 t\,dt = \frac{2.5}{2} \times \left[t^2\right]_0^4 = \frac{2.5}{2} \times 16 = 25 \times 8 = 20\,C$$

(ii) $4 < t < 6$:

$$q(t) = -4\int_4^6 dt = -4\left[t\right]_4^6 = -4 \times 2 = -8\,C$$



~~(iii)~~

$$q(t) = \begin{cases} 20 & ; 0 < t < 4 \\ -8 & ; 4 < t < 6 \end{cases}$$

for $q(t)$ $0 < t < 6$

$q(t) = 20 - 8 = 12\,C$

Potential: Energy per unit charge

$$\boxed{V = \frac{dw}{dq}}$$ J/c (or Volt

Power: Energy per unit time

$$\boxed{P(t) = \frac{dw(t)}{dt}}$$ J/sec (or Watt

$$P = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = V \cdot i \quad \text{(watt)}$$

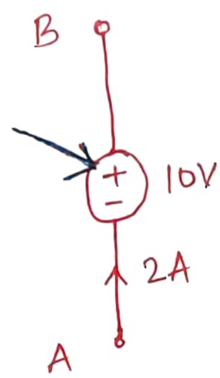
$$\therefore \boxed{P = V \cdot i = \frac{V^2}{R} = i^2 R} \text{ watt}$$

LECTURE - 3

ABSORBED AND DELIVERED POWER

NOTE: (i) If the current enters into the positive terminal of voltage source then it is referred as the absorbed power.

(ii) If the current leaves from the positive terminal of voltage source then it is referred as the delivered power.

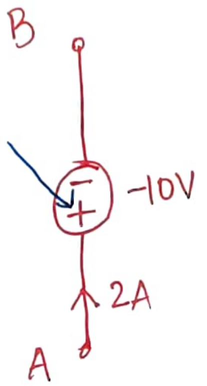


fig(a)

$P_{del} = 10 \times 2$ W

$P_{del} = 20$ W

≅

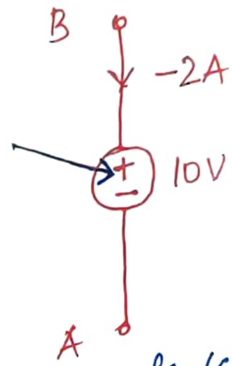


fig(b)

$P_{abs} = 2 \times (-10)$ W

$P_{abs} = -20$ W.

≅

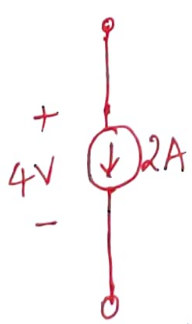


fig(c)

$P_{abs} = (-2)(10)$ W

$P_{abs} = -20$ W.

*** Always remember if $P_{abs} = -20$ W then we can say that $P_{del} = 20$ W.



fig(d)

$P_{abs} = 4 \times 2 = 8$ W

≅

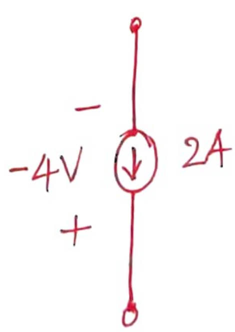
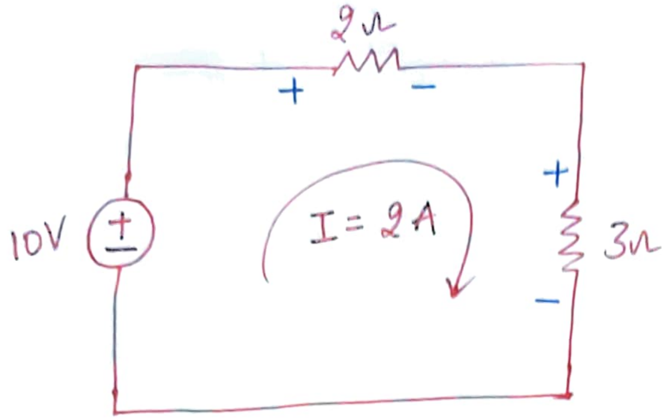


fig e

$P_{del} = 2 \times (-4) = -8$ W.

Example:



Sol:

$$I = \frac{10}{2+3} = 2A$$

$$P_{10V} = P_{del} = 2 \times 10 = 20\,\text{Watt} \longrightarrow (1)$$

$$P_{2\Omega} = P_{abs_1} = i^2 R = 2^2 \times 2 = 8\,\text{Watt}$$

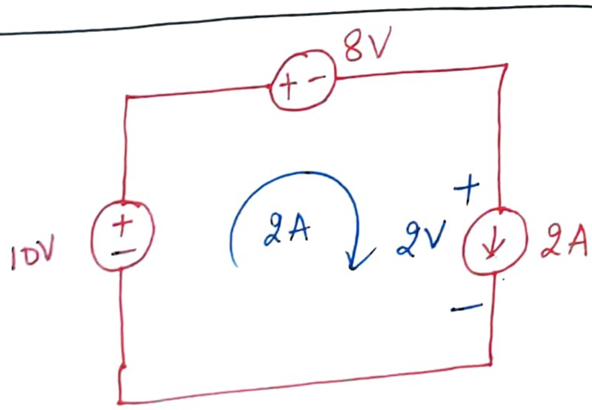
$$P_{3\Omega} = P_{abs_2} = i^2 R = 2^2 \times 3 = 12\,\text{Watt}$$

$$P_{abs} = P_{abs_1} + P_{abs_2} = 8 + 12 = 20\,\text{Watt} \longrightarrow (2)$$

From (1) & (2). Clearly

$$\boxed{P_{del} = P_{abs} = 20\,\text{Watt}}$$ → This is power conservation Theorem (or) Tellegans Theorem.

Example:



$P_{10V} = P_{del} = 2 \times 10 = 20\,\text{Watt}$ (or) $P_{10V} = P_{abs} = -20\,\text{Watt}$

$P_{8V} = P_{abs} = 2 \times 8 = 16\,\text{Watt}$ (or) $P_{8V} = P_{del} = -16\,\text{Watt}$

$P_{2A} = P_{abs} = 2 \times 2 = 4\,\text{Watt}$ (or) $P_{2A} = P_{del} = -4\,\text{Watt}$

$\sum P_{del} = 20-16-4 = 0$

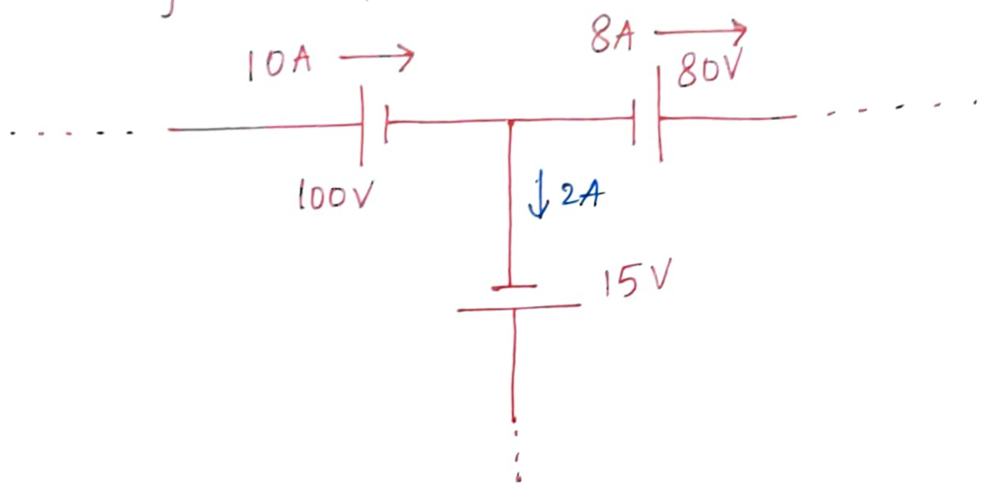
$\sum P_{abs} = -20+16+4 = 0$

$\Rightarrow \boxed{\sum P_{del} = \sum P_{abs} = 0}$

This is Tellegans Theorem.

Gate EE 2014: The three circuit elements shown in the fig are part of an electric circuit. The total power absorbed by the three circuit elements in watts is ——

Refer



sol: $(P_{abs})_{100V} = 100 \times 10 = 1000 \text{ Watt}$ (or) $(P_{del})_{100V} = -1000 \text{ Watt}$

$(P_{abs})_{15V} = \cancel{(-2)}\ (2 \times -15) = -30 \text{ Watt}$ (or) $(P_{del})_{15V} = 30 \text{ Watt}$

$(P_{abs})_{80V} = 8 \times (-80) = -640 \text{ Watt}$ (or) $(P_{del})_{80V} = 640 \text{ Watt}$

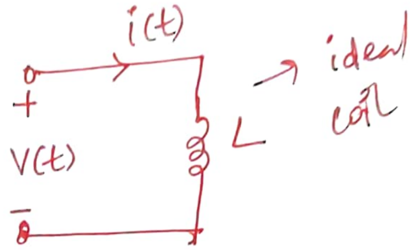
Total (P_{abs}) by 3 elements $= 1000 - 30 - 640 = 330 \text{ Watt}$.

LECTURE - 4

ANALYSIS OF PASSIVE ELEMENTS (INDUCTOR)

Note:. Inductance is the property of inductor which opposes the change in current.

(ii) Time varying current across ideal coil produces the time varying magnetic flux which is proportional to time varying current.



i.e, $\psi(t) \propto i(t)$

$$\psi \propto i$$

$$\psi = L i$$

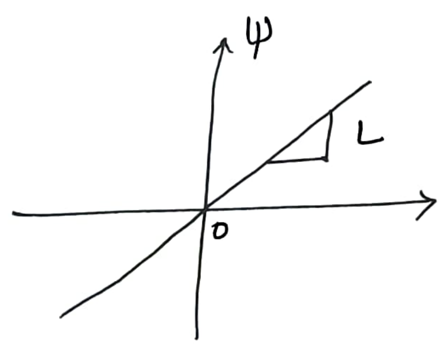
$$L = \frac{\psi}{i} \left[\text{Weber}/\text{Ampere} \right] \text{ (or) Henry.}$$

L

B

P

$$L = \frac{N\phi}{i}$$



ψ-i plane.

N = No. of turns in coil

ϕ = flux per turn.

$$\phi = \frac{\text{MMF}}{\text{Reluctance}} = \frac{Ni}{l/a\mu}$$

$$L = \frac{N}{i} \times \frac{Ni}{l/a\mu} = \frac{N^2 a\mu}{l} \text{ Henry}$$

$$\boxed{L \propto N^2}$$ important ***

Now $V(t) = \frac{d\psi}{dt} = \frac{N d\phi}{dt}$; $V(t) = L \frac{d}{dt} i(t)$

* $v(t) = L \frac{d}{dt} i(t)$

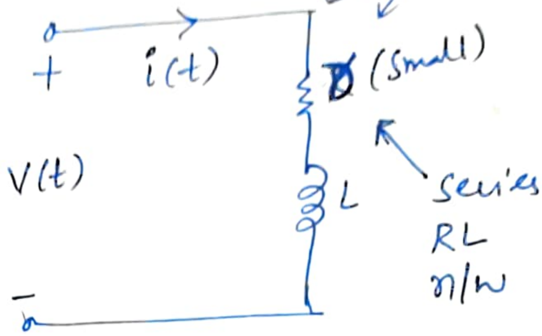
* $i(t) = \frac{1}{L} \int v(t)\,dt.$

Consider practical coil / practical inductor

$\tau = L/r$

τ = time const.

for ideal coil $\Rightarrow r = 0$

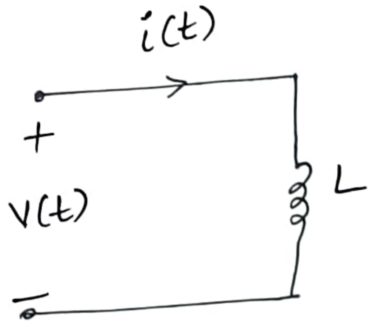


Types of Inductors :

1. Energized inductor
2. Unenergized inductor

1. Energized Inductor :

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



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

Dynamic or running inductor.

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

initial current of 'L'

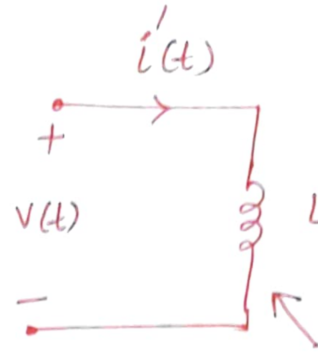
Note :

$E_L(t) = \frac{1}{2} L\, i(t)^2$ Joule

$E_L(0^-) = \frac{1}{2} L\, i(0^-)^2$ Joule

2. Unenergized Current Inductor:

$$i'(t) = \frac{1}{L}\int_0^t V(t)\,dt$$



In an unenergized inductor there is no initial energy.

$E_L(0^-) = 0$ Joule

$i(0^-) = 0$ Amp

By comparing both energized & unenergized inductors.

We get $\boxed{i(t) = i(0^-) + i'(t)}$

where $i(0^-) =$ initial current

$i(t) =$ Energized inductor current.

$i'(t) =$ Unenergized " "

Power:

Power $P(t) = \frac{dW}{dt}$; $W = \int P(t)\,dt$; $W = \int V(t)\, i(t)\, dt$

$$W(t) = \int L\frac{di(t)}{dt} \times i(t)\,dt = L\int i(t)\,di(t) = \frac{1}{2}L\,i^2(t)$$

$\boxed{W_L(t) = \frac{1}{2}L\,i^2(t) \text{ Joule}}$; $W_L(0^-) = \frac{1}{2}L\,i^2(0^-)$

$W_L(\infty) = \frac{1}{2}L\,i^2(\infty)$

$\boxed{W_L(t) \propto i^2(t)}$

LECTURE - 5

ANALYSIS OF PASSIVE ELEMENTS (CAPACITOR)

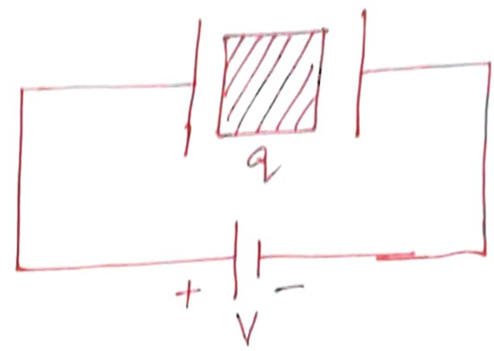
CAPACITOR:

$q \propto V$

$q = CV$

$C = \frac{q}{V}$ [Coulomb/Volt] (or)

Farads.



Note: Capacitance is the property of capacitor which opposes the change in voltage.

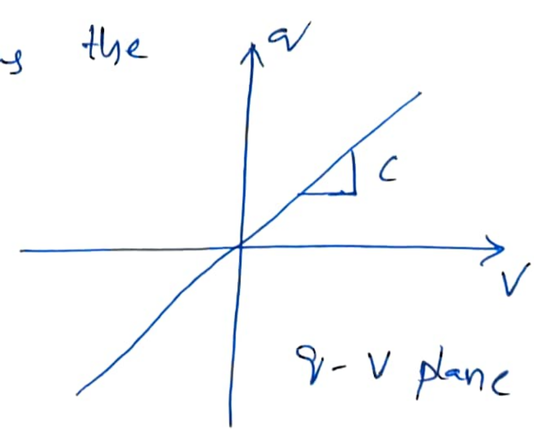
i.e,

$$\boxed{V(0^+) = V(0^-)}$$

$$\boxed{q(0^+) = q(0^-)}$$

$$\boxed{E_c(0^+) = E_c(0^-)}$$

Now Capacitor is also called as the charge storage device

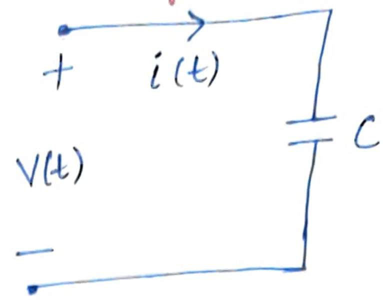


$$i(t) = \frac{dq(t)}{dt}$$

$$\boxed{i(t) = C\frac{dv(t)}{dt}}$$

$$\boxed{V(t) = \frac{1}{C}\int i(t)\,dt}$$

$$V(t) = \frac{1}{C}\int_{-\infty}^{t} i(t)\,dt$$ → memory or dynamic or running integrator.



$$V(t) = \frac{1}{C}\int_{-\infty}^{0} i(t)\,dt + \frac{1}{C}\int_{0}^{t} i(t)\,dt$$

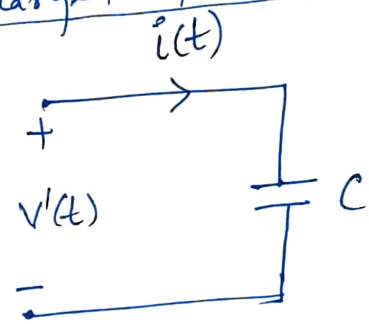
$$V(t) = V(0^-) + \frac{1}{C}\int_{0}^{t} i(t)\,dt \longrightarrow (1)$$

Any capacitor which has initial voltage is called as the energized capacitor.

i.e $V(0^-) \neq 0$; $q(0^-) \neq 0$; $E_C(0^-) \neq 0$

for unenergized capacitor / uncharged capacitor :

Here $v'(t) = \frac{1}{C}\int_{0}^{t} i(t)\,dt \longrightarrow (2)$

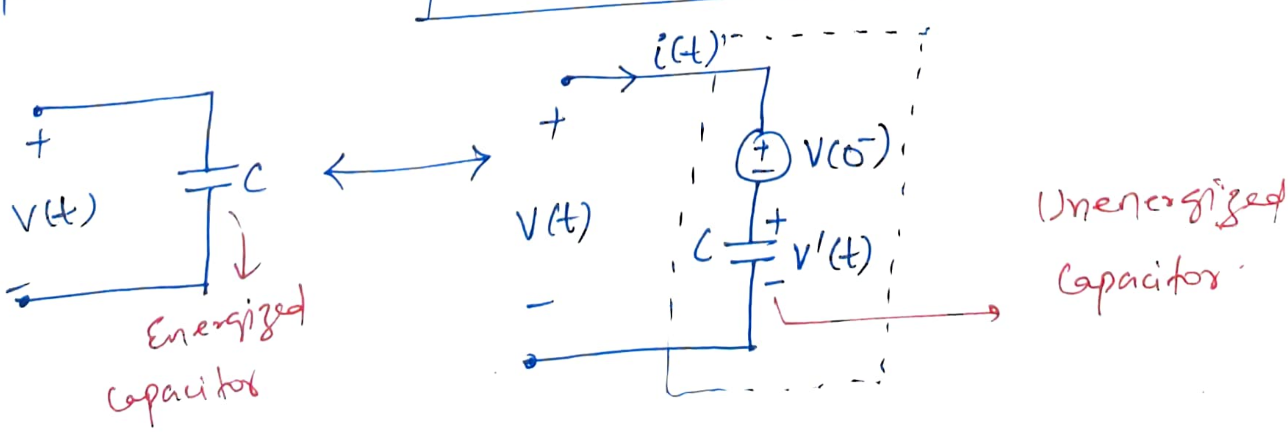


$V(0^-) = 0$ volt.

$q(0^-) = 0$ C

$E_C(0^-) = 0$ J

from (1) & (2) $\boxed{V(t) = V(0^-) + v'(t)}$



Practical Capacitor / lossy Capacitor:

for Ideal capacitor

$R = \infty$

Practical capacitor is parallel RC N/W

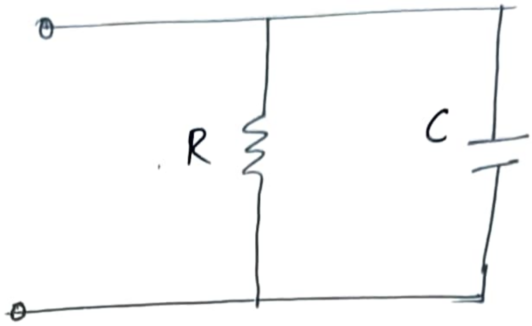


fig parallel RC N/W.

Power:

$$P(t) = \frac{dw}{dt} \; ; \quad W = \int P(t)\,dt \; ; \quad W = \int V(t) \times i(t)\,dt$$

$$W_c = \int V \times C\frac{dV}{dt} \times dt = C\int V\,dV = \frac{1}{2}CV^2 \text{ Joule}$$

$$\boxed{W_c = \frac{1}{2}CV^2 \text{ Joule}} \; ; \quad \boxed{W_c(t) = E_c(t) = \frac{1}{2}C\,V_c(t)^2 \text{ J}}$$

$$E_c(0^-) = \frac{1}{2}CV(0^-)^2 \text{ Joule}$$

$$E_c(0^+) = \frac{1}{2}C\,V(0^+)^2 \text{ Joule.}$$

$$\boxed{\begin{array}{c} E_c(0^-) = E_c(0^+) \\ \hline V(0^+) = V(0^-) \end{array}}$$