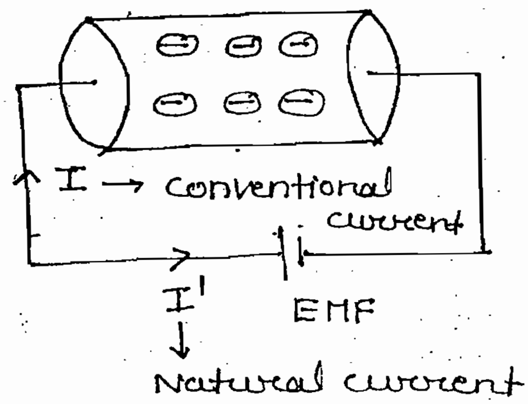
Lecture-1

Charge :-



- The basic quantity in the electric circuit is charge
- The charge on the electron is given $(-1.6 \times 10^{-19} C)$
- The flow of $\bar{e}$'s is called as current

OR

The time rate of charge is also called as current.

$$\boxed{I = \frac{dQ}{dt}} \quad C/s \text{ or } A$$

- By using conventional current direction KVL and KCL equations are developed
- To move the $\bar{e}$ from one point to other point in particular direction external force is required. In electric ckt external force is provided by EMF and it is given by

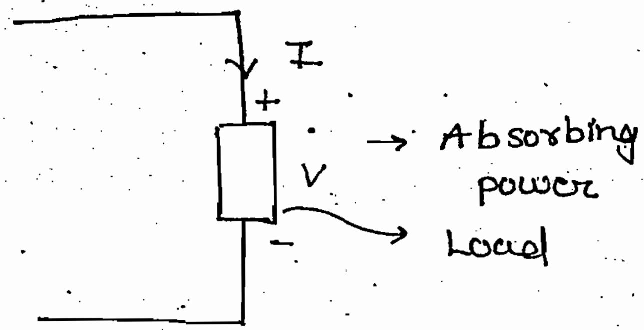
$$\boxed{V = \frac{dW}{dQ}} \quad J/C \text{ or volts}$$

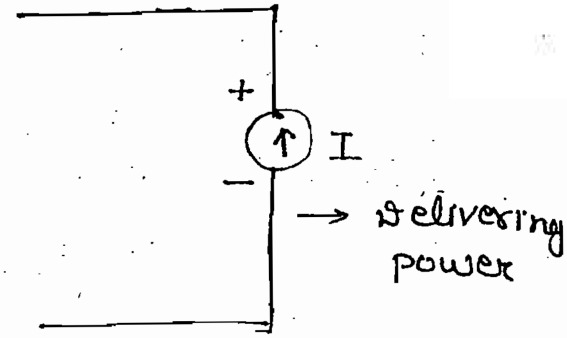
- The time rate of energy is called as power

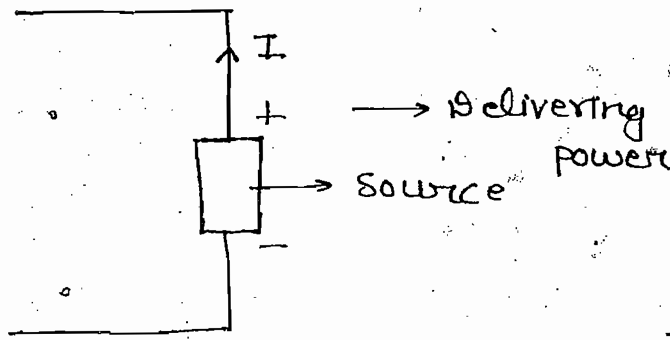
$$P = \frac{dW}{dt} \quad J/s \text{ or Watts}$$

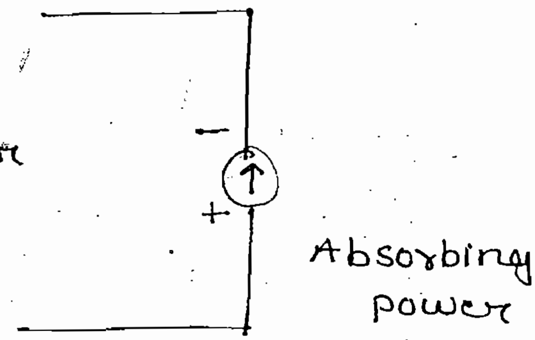
$$P = \frac{dW}{dQ} \cdot \frac{dQ}{dt}$$

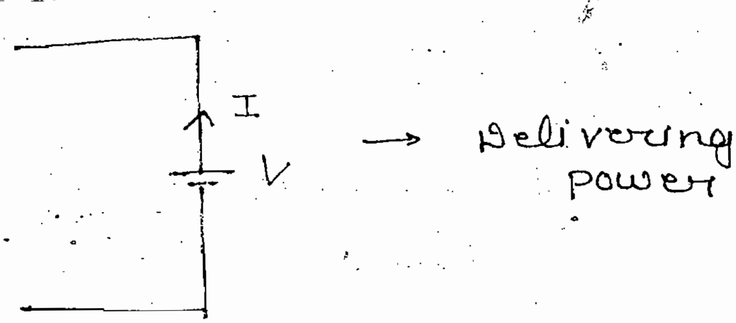
$$\boxed{P = V \cdot I}$$

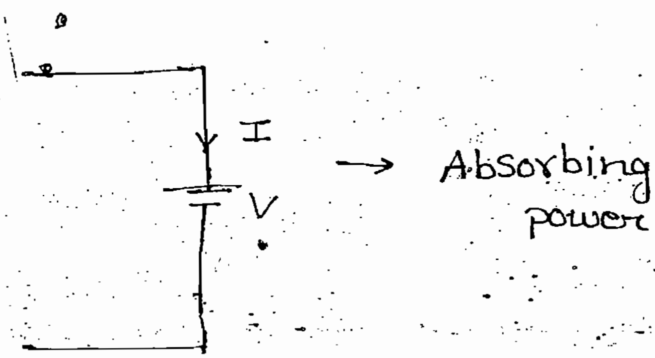










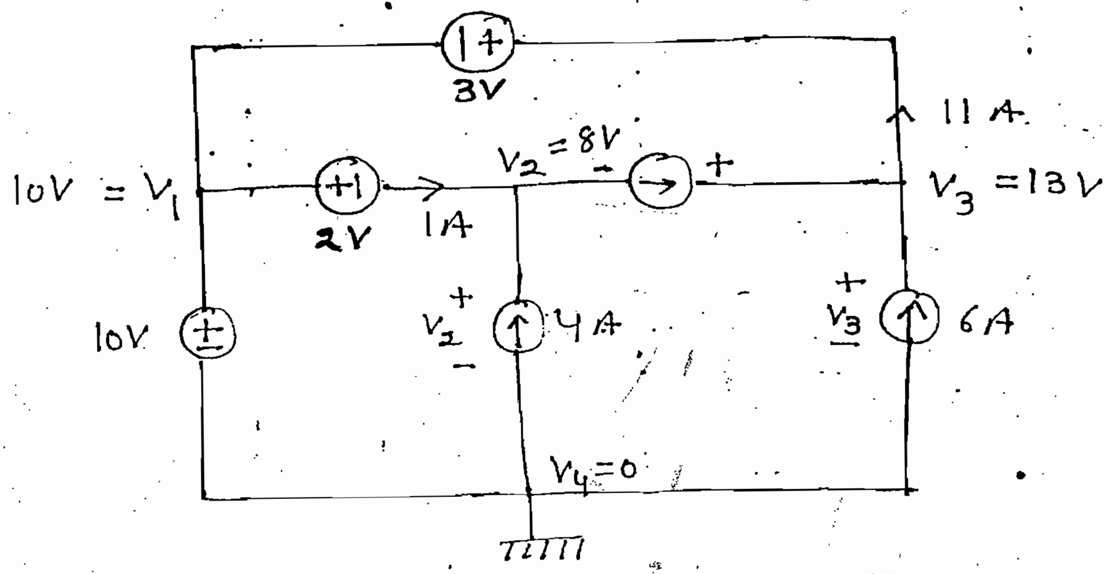


Note :-

→ When current is entering into the terminal element is absorbing power

→ When current is leaving from the terminal element is delivering power

Ques:- Find power of each element of the circuit shown



Soln:- $V_1 - V_2 = 2 \Rightarrow V_2 = 8V$

$V_3 - V_1 = 3 \Rightarrow V_3 = 13\ V$

$P_4 = 4 \times 8 = 32W$ (Delivering Power)

$P_6 = 13 \times 6 = 78W$ (" ")

$P_5 = 5 \times 5 = 25W$ (" ")

$P_{10} = 10 \times 10 = 100W$ (Absorbing Power)

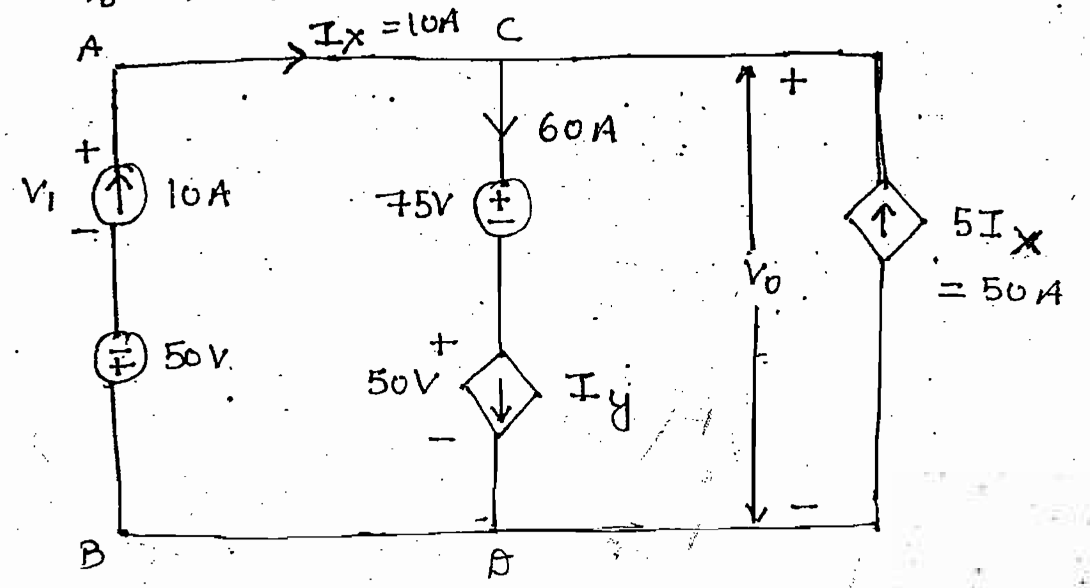
$P_3 = 3 \times 11 = 33W$ (" ")

$P_2 = 1 \times 2 = 2W$ (" ")

$(P_T)_{Absorbing} = (P_T)_{Delivering}$

$\Rightarrow 135W = 135W$

Ques:- Find power developed in a ckt when V_0 = $V_0 = 125\,V$



Soln:-

$$V_{AB} = V_1 - 50$$

$$\Rightarrow 125 = V_1 - 50 \quad \Rightarrow V_1 = 175$$

$$P_{5I_x} = 125 \times 50 = 6250\,W$$

$$P_{10} = 175 \times 10 = 1750\,W$$

$$P_T = 6250 + 1750 = 8000\,W$$

Classification of elements :-

(I) Active and Passive

(II) Linear and Non-linear

(III) Uni-direction and Bi-direction

(IV) Time varient and invarient

(V) Lumped and Distributed

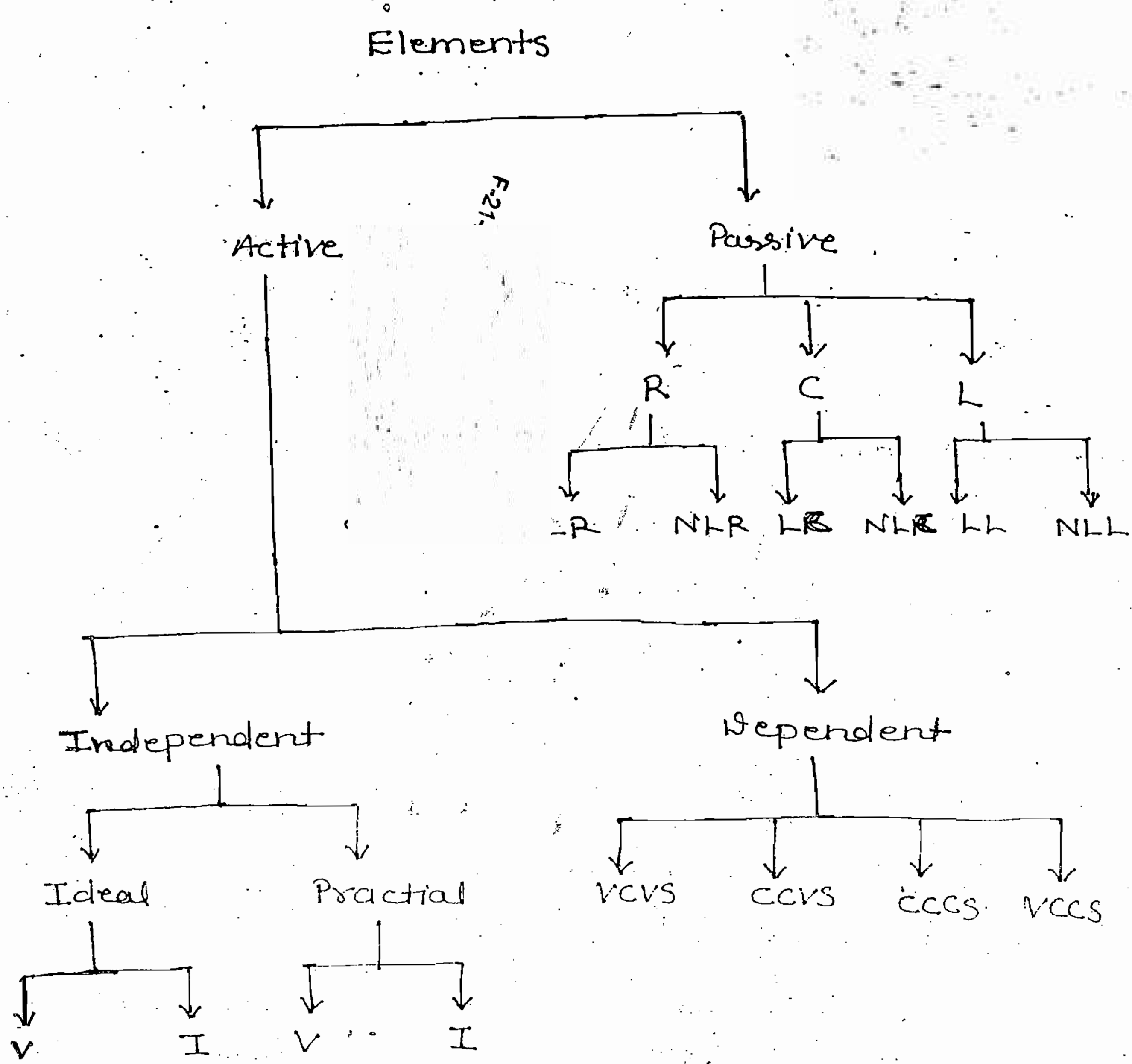
Active & Passive Element :-

Active Element :-

When the element is capable of delivering energy for long time (approximately ∞ time) → A·E

OR When the element is having property of internal amplification then the element is called as active element

... transistors



Voltage source , current source → Independent

Transient , op-amp → Dependent

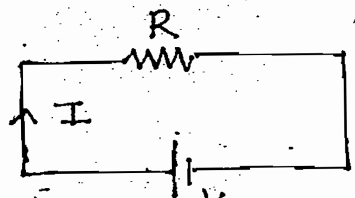
→ During discharging capacitor (inductor) can deliver energy independtly for a short time and capacitor (inductor) is not having property of internal amplification

Passive Elements :-

When the element is not capable of delivering energy independtly then the element is called as passive element.

eg:- Resistor, bulb, transformer
↓
It cann't step-up or down power

Resistor :-



→ Resistance is a property of resistor.. It always opposes the current. By doing so it converts electric energy to heat energy

→ Resistance is nothing but a friction to flow of $\bar{e}$'s

$$P = I^2 R$$

$$W = I^2 R t$$

↓
Heat

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

ρ → $\Omega - m$
- → conductors
- → semi-conductors
- → Insulators

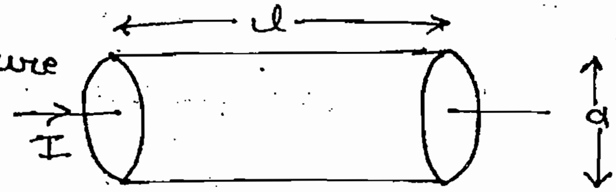
Super conductor
$\rho = 0$.
eg:- Mercury at 4·15 K

$$R_1 = R_0 (1 + \alpha_0 t)$$

where R_0 = Resistance at 0°C
t = Change in tempt.

Ohm's Law :-

→ At constant temperature current density is directly proportional to electric field intensity



→ At constant tempt. potential diff. across the element is directly proportional to current flowing into element.

$$J = \frac{I}{a} \quad A/m^2$$

$$E = \frac{V}{l} \quad Volts/m$$

$$\sigma = \frac{1}{\rho} \quad mho/m$$

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

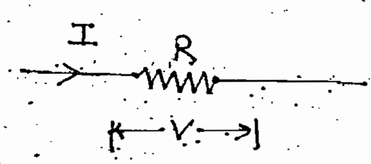
$$J \propto E$$

$$\Rightarrow J = \sigma E$$

$$\Rightarrow \frac{I}{a} = \frac{1}{\rho} \frac{V}{l}$$

$$\Rightarrow \boxed{\frac{V}{I} = \rho \frac{l}{a} = R}$$

$$V \propto I$$



$$V = RI$$

$$\boxed{R = \frac{V}{I} = \text{constant}}$$

Different forms of Ohm's law :-

$$J = \sigma E \quad \text{—(I)}$$

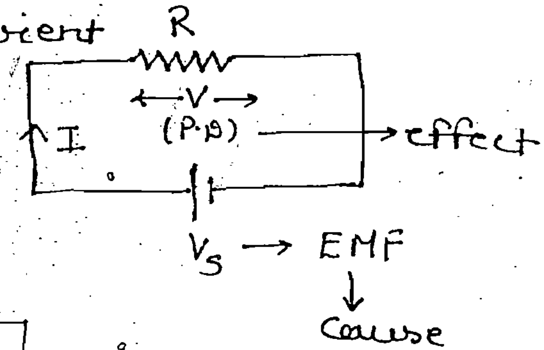
$$V = RI \quad \text{—(II)}$$

$$I = GV \quad \text{—(III)} \qquad \boxed{G = \frac{1}{R}} \text{ mho}$$

$$V = R\frac{d\theta}{dt} \quad \text{—(IV)}$$

→ EMF is independent on current and resistance magnitude

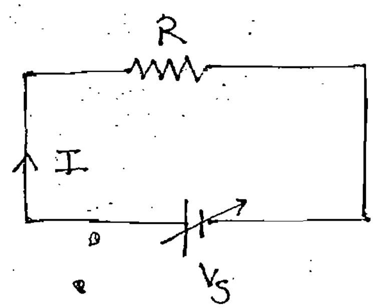
→ Potential difference depends on current and resistance magnitude



$\boxed{I \propto V_S}$ → EMF

$\boxed{V \propto I}$ → P.D / Voltage drop

→ When element properties and characteristics independent on the direction of current then the element is called as bi-directional element (bilateral)

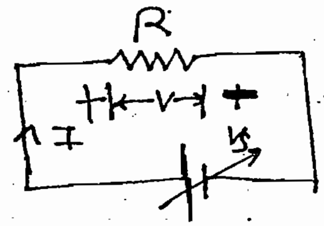


→ When element obeys ohm's law then the element is called as linear resistor

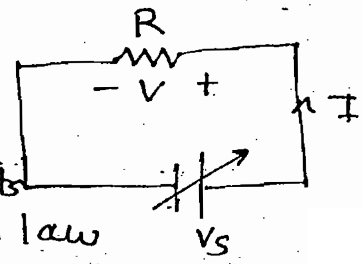
→ Every linear element should obey the bidirectional properties but not vice-versa

$I \uparrow 10\%$, $V \uparrow 10\%$

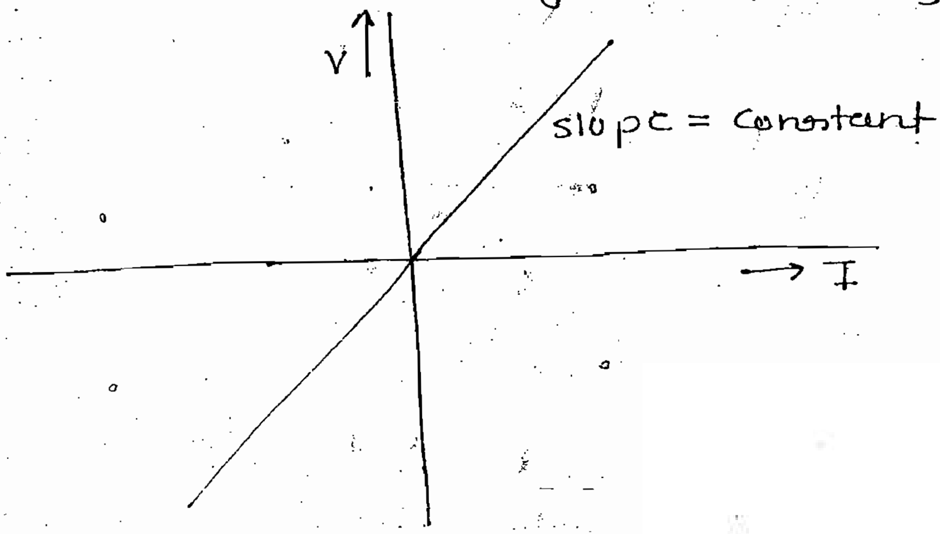
$I \uparrow 90\%$ $V \uparrow 10\%$



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

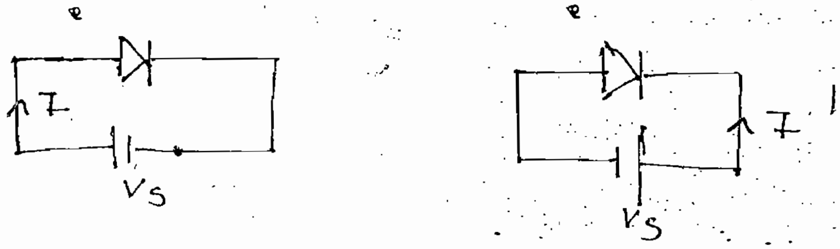


$\frac{V}{I} = \text{constant}$ then elements obey ohm's law



→ When element properties and characteristics depends on the direction of current then element is called as unidirectional element

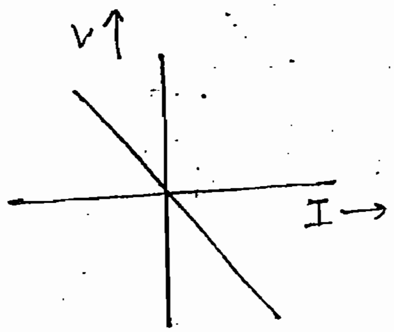
→ When element does n't obeys the ohm's law then the element is called as non-linear resistor



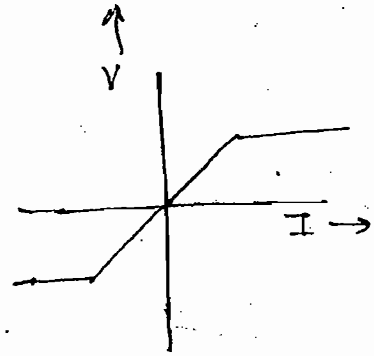
$|I| \neq |I'|$

Note :-

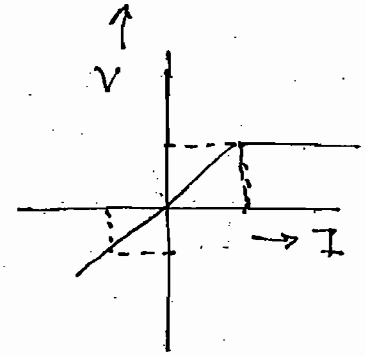
→ $\boxed{\frac{V}{I} = +ve}$ then element is passive



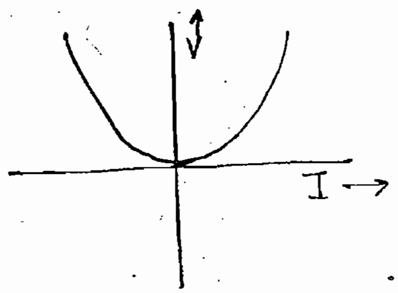
→ Linear
→ Bi-directional
→ Active



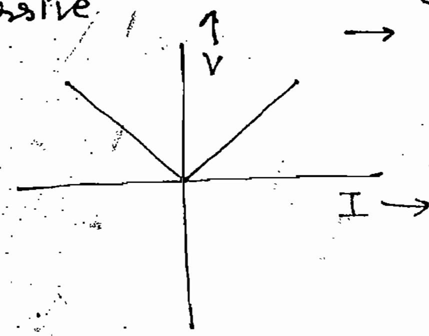
→ ~~Non~~Linear
→ Bi-directional
→ Passive



→ Non-linear
→ Unidirectional
→ Passive



→ Non-linear
→ Uni-directional
→ Active



→ Non-linear
→ Uni-directional
→ Active

Note :-

→ If in any of the quadrant $\frac{V}{I} = -ve$ then the element is active

→ Every linear element should obey the bidirectional property but not vice-versa

→ If $\frac{V}{I} = +ve$ in both coordinates then the element is passive —(I)

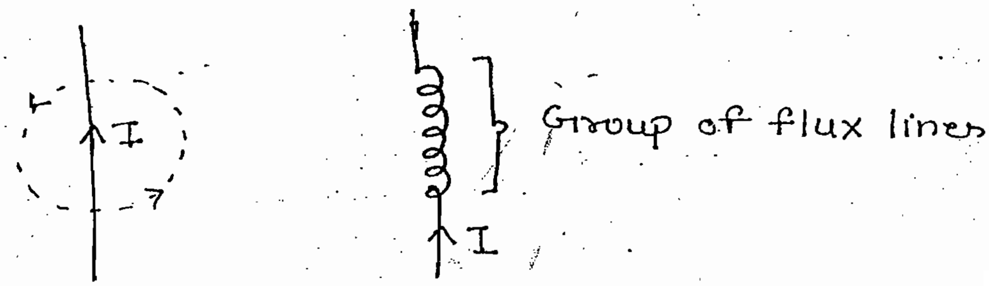
→ ~~In the~~ above

→ If $\frac{V}{I} = -ve$ either in any of the coordinates or both the coordinates then the element is active —(II)

→ In the above two cases waveform should passes through origin

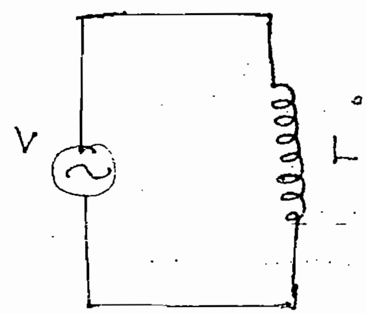
→ When the element obeys the bi-directional property characteristic should be identical in the opposite coordinates but not in the adjacent coordinates

Inductor (L) :—



Weak Magnetic Field   Strong magnetic field.

→



Faraday's Laws :—

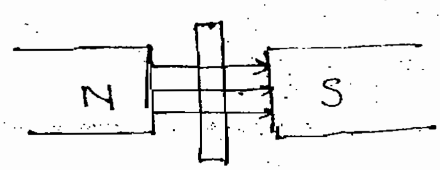
1st Law :—

When conductor cuts a magnetic lines of force an emf induced in the conductor

Second Law :—

An emf induced in the conductor is directly proportional to rate of change of flux

$e = B\,l\,v \sin\theta \;,\; e \propto \frac{d\phi}{dt}$



where

B = flux density

l = length of conductor

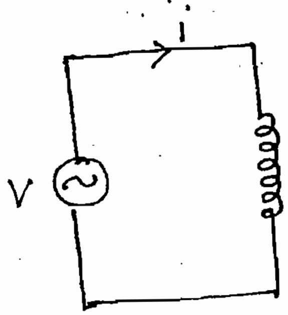
V = velocity of conductor

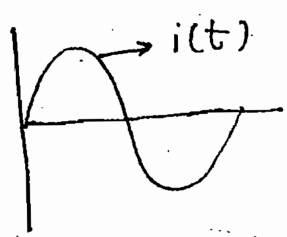
ϕ = Phase displacement b/w conductor & magnetic field

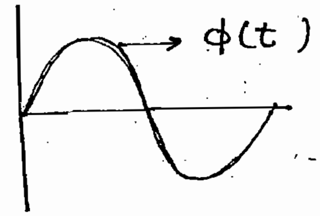
e = dynamically induced emf (eg:- generator

L

Inductor (L) :-







$$e \propto \frac{d\phi}{dt}$$

$$\Rightarrow \boxed{e = -N\frac{d\phi}{dt}}$$ → Lenz's Law

→ v, i, ϕ, e (Lenz's Law) $\Rightarrow V = N\frac{d\phi}{dt}$

→ $\psi = N\phi$
(Flux linkage)

$$V = \frac{d\psi}{dt}$$

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

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

$\psi \propto \phi$
$\psi \propto i$

$\psi \propto i$

$$\boxed{\psi = Li}$$

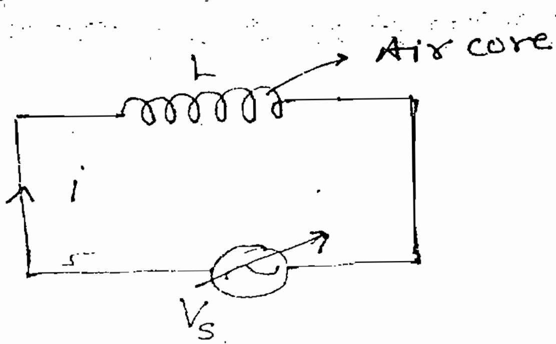
$\psi = N\phi$
$\psi = Li$

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

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

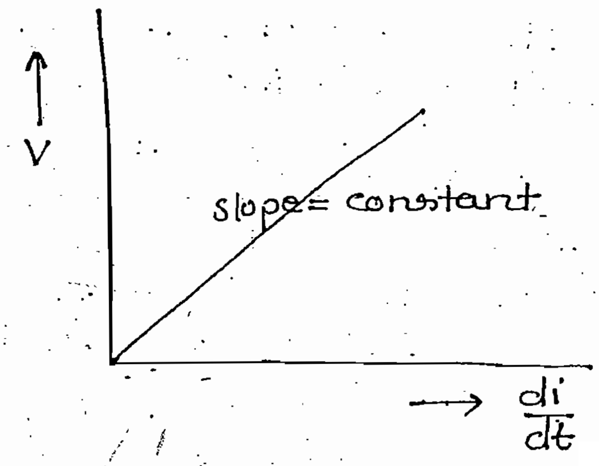
$i \uparrow 10\%$, $\phi \uparrow 10\%$

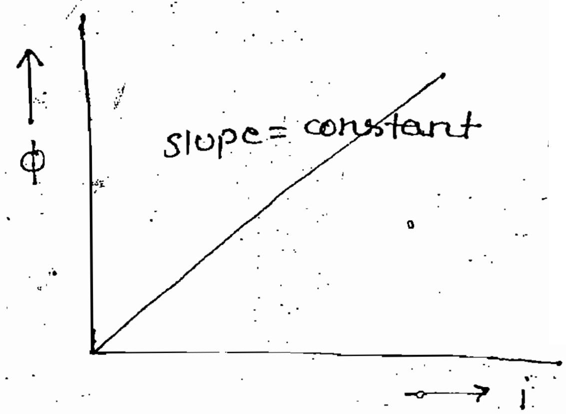
$i \uparrow 90\%$, $\phi \uparrow 90\%$

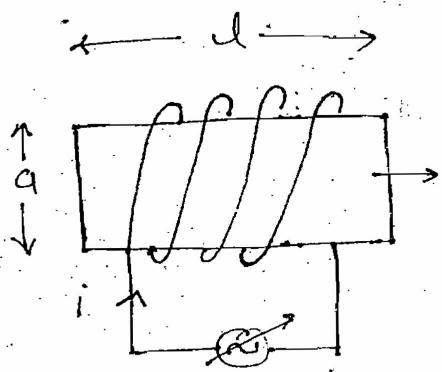


$$V = L\frac{di}{dt}$$

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







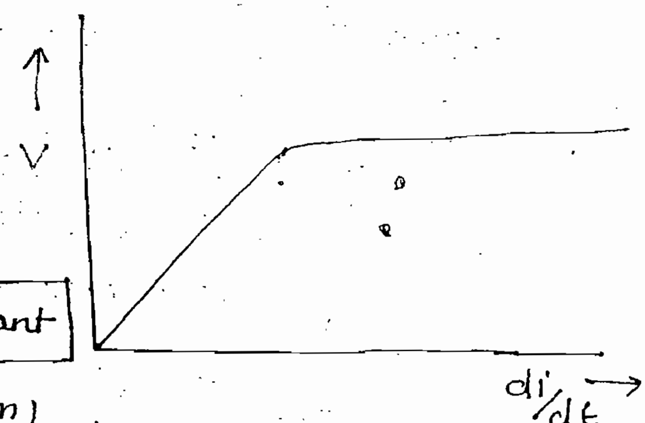
→ Iron core . $L = \frac{N\phi}{i}$ —(1)

If $i \uparrow 10\%$, $\phi \uparrow 10\%$

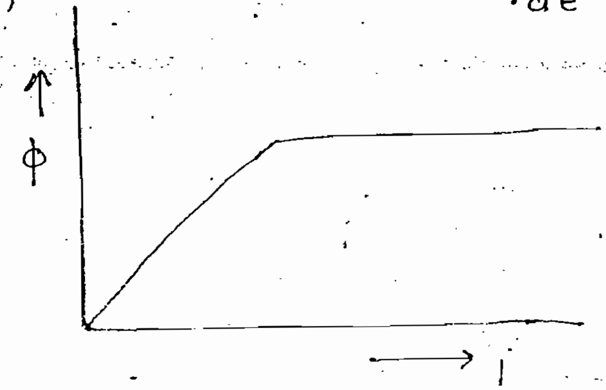
If $i \uparrow 60\%$, $\phi \uparrow 60\%$

If $i \uparrow 90\%$, $\boxed{\phi = \text{constant}}$

(saturation)



→ The flux linked with iron-core is upto a certain limit.

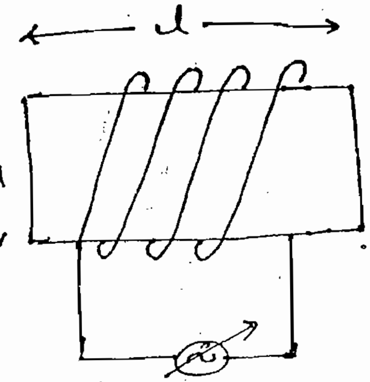


→ When inductance of a inductor is independent on the current magnitude then inductor is called as linear inductor.

eg:- Air core inductor

→ When inductance of a inductor depends on current magnitude then inductor is called as non-linear inductor

eg:- iron core inductor.



Electric Circuit	Magnetic Circuit
1. $i = \frac{EMF}{R}$	$\phi = \frac{MMF}{S(\text{Reluctance})}$
2. $i = \frac{EMF}{\frac{\rho l}{a}}$	$\phi = \frac{NI}{\frac{l}{a\mu_0\mu_r}}$ —(II)

Substitute eq-(II) in eq-(I)

**
$$L = \frac{N^2 \mu_0 \mu_r a}{l}$$

where $\mu_0 = 4\pi \times 10^{-7}$ H/m

μ_r = Relative permeability

a = Area of cross-section of core

$$L = \frac{N^2}{\frac{l}{a\mu_0\mu_r}} \Rightarrow L = \frac{N^2}{S}$$

→ $V = L\frac{di}{dt}$ $\Rightarrow$ $i = \frac{1}{L}\int_{-\infty}^{t} V dt$

↓ shows ohm's law 5th form & 6th form

→ The above formula is only applicable for linear inductor.

$$P = Vi$$

$$\boxed{P = L\frac{di}{dt}\, i}$$ → Instantaneous Power

$$W = \int P\,dt$$

$$\Rightarrow \boxed{W = \int L\frac{di}{dt}\, i\cdot dt = \frac{1}{2}Li^2}$$

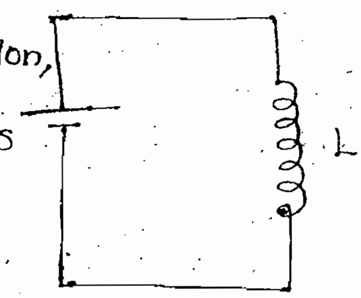
→ Power dissipation in ideal ~~capacitor~~ inductor is zero since internal resistance is zero

→ Inductor stores energy in the form of magnetic field (K.E)

→ Due to energy storage property inductor is also called as dynamic element

<u>Conclusions</u> :-

1. Under steady state condition, for a dc source inductor behave as a short circuit



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

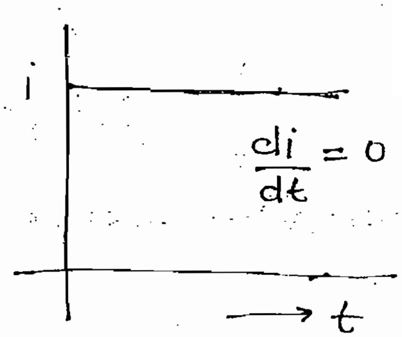
For dc, $\frac{di}{dt} = 0$

↓

$V = 0$

↓

S.C



2 Inductor does not allow sudden change of current since

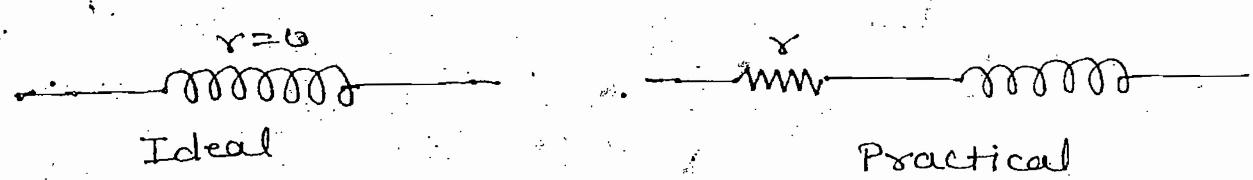
(a) For sudden change of current infinite voltage is required but practically it is not possible

(b) Practical inductive circuit having finite value of time constant i.e. $\tau = \frac{L}{R}$

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

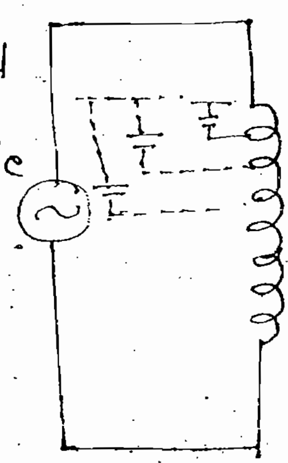
$$dt \longrightarrow 0 \quad \Rightarrow \quad V = \infty$$

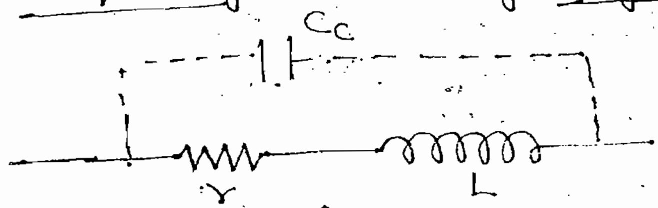
3.



$r \simeq m\Omega$

Inter-turn capacitance is present when inductor is operated at either at very high frequency or very high voltage



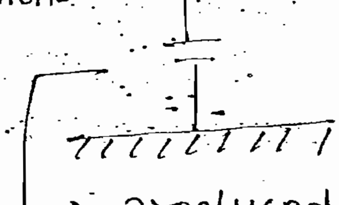


where C_c = inter-turn capacitance

or

self capacitance

Transmission line



→ produced due to high potential diff.

$$X_L = 2\pi f L$$

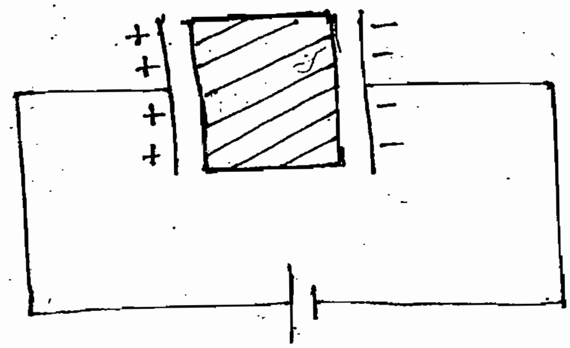
$$X_C = \frac{1}{2\pi f C}$$

Capacitor :—

$Q \propto V$

$\Rightarrow Q = CV$

$\Rightarrow \boxed{C = \frac{Q}{V}}$ C/Volt or F



Again $Q = CV$

$\Rightarrow \frac{dQ}{dt} = C\frac{dV}{dt}$

$\Rightarrow i = C\frac{dV}{dt}$

$\Rightarrow \boxed{C = \frac{i}{\frac{dV}{dt}}}$

→ capacitor opposes rate of change of voltage

$\boxed{i = C\frac{dV}{dt}}$ → Ohm's law 7th form

$\boxed{V = \frac{1}{C}\int_{-\infty}^{t} i\,dt}$ → Ohm's law 8th form

$P = Vi$

$\Rightarrow \boxed{P = VC\frac{dV}{dt}}$ → Instantaneous power

$W = \int P dt$

$W = \int V.C\frac{dV}{dt}\,dt$

$\Rightarrow \boxed{W = \frac{1}{2}CV^2}$ → Potential Energy

→ Power dissipation in ideal capacitor = 0

→ Capacitor stores energy in the form of electric field (Potential Energy)

→ Due to energy storage property capacitor is also called as dynamic element

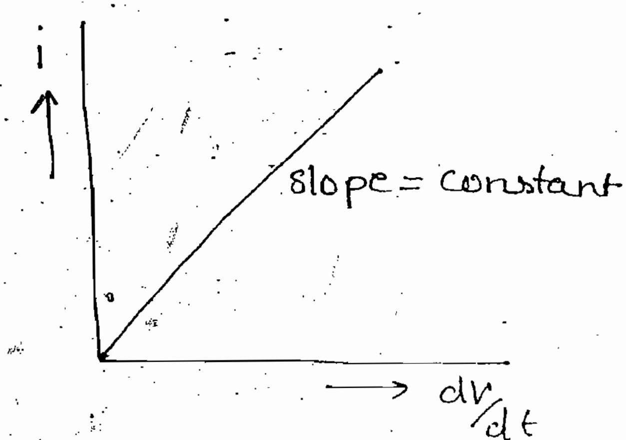
→

$C = \frac{Q}{V}$ = constant

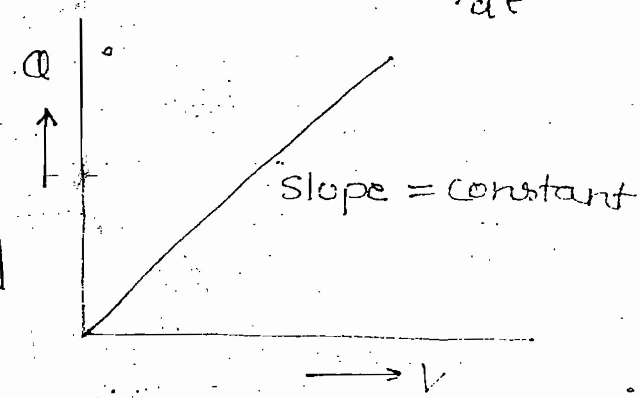
V↑ 10% , Q↑ 10%

V↑ 90% , Q↑ 90%

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



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



$C = \frac{Q}{V}$ = Variable

↓

Non-linear

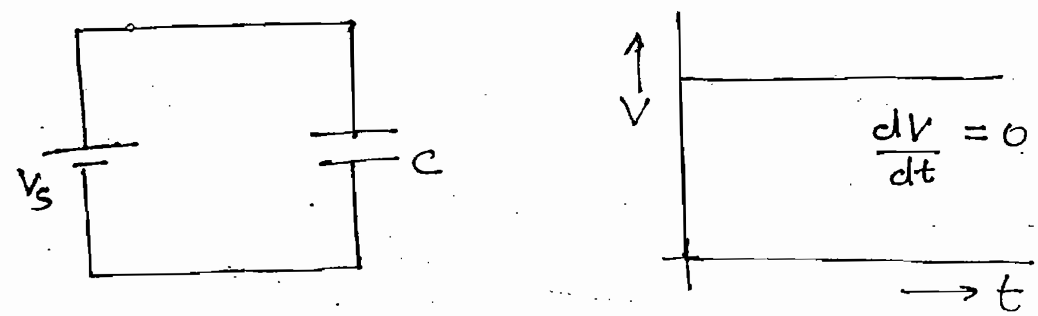
→ When capacitance of a capacitor independent on the voltage magnitude then the capacitor is called as linear capacitor.

→ When capacitance of a capacitor depends on the voltage magnitude then capacitor is called as non-linear capacitor

eg:- Varactor diode

Conclusion:-

1. Under steady state condition for a dc source capacitor behaves as an open circuit



$$i = C\frac{dV}{dt}$$

$$\frac{dV}{dt} = 0 \longrightarrow i = 0 \Rightarrow O \cdot C$$

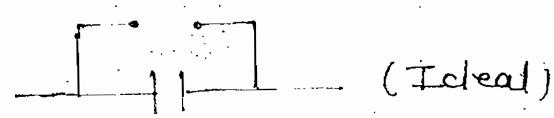
2. Capacitor does not allow sudden change of voltages since
(a) For sudden change of voltages infinite current is required but practically it is not possible
(b) Practical capacitive circuit has finite value of time constant

(a) $i = C\frac{dV}{dt} = \infty \qquad dt \to 0$

(b) $T = RC$

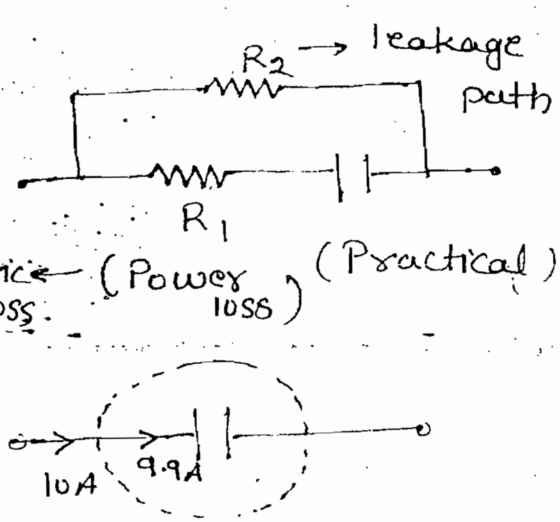
3. For ideal capacitor :-

$R_1 = 0$
$R_2 = \infty$



For Practical capacitor :-

$R_1 \simeq$ very less
$R_2 \simeq$ very high.



R_2 = leakage path