IES/GATE

Electronics & Telecommunication Engineering

VOLUME-III

Network Theory

Contents

NETWORK THEORY

1. Basics
2. Steady state A.C. Circuits [Resonance]
3. Theorems
4. Transients] ** } Frequently asked
5. Two-port
6. Graph Theory
7. Magnetic Coupled Circuits /* Not in syll */
8. Filters /* Not in syll */

- Fundamentals of Electric Circuits :- by Alexander & Sadiku | *only exercises*
- Engg Circuit Analysis :- Hayt & Kemmerly
- Network Analysis [Transients and two port ⇒ conventional] :- Van Valkenburg

1] Gate – EC (

Problems

2] IES < Memory (40% repeated) / Problems

3] Workbook

4] Home work

5] IAS

6] Test -series → old / → new.

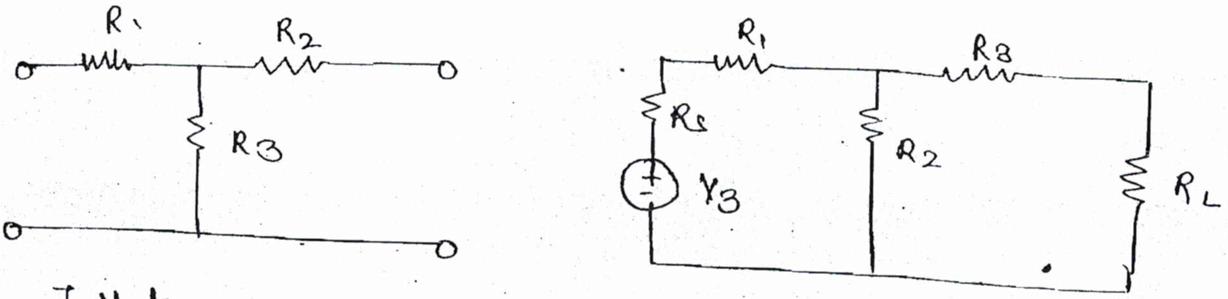
* goo.gl/2xnUr3 → sadiku → Text book / → soln

* goo.gl/HWKKZz → Home Work (Nodal & Mesh analysis)

* goo.gl/6Fa34E → Steady state + Theorems

* goo.gl/dJnhu8 → RL, RC, RLC → conv.

• Network vs Circuit :→



T-Network

N/w or circuit

→ Network is a combination of elements, it may or may not consist of closed path

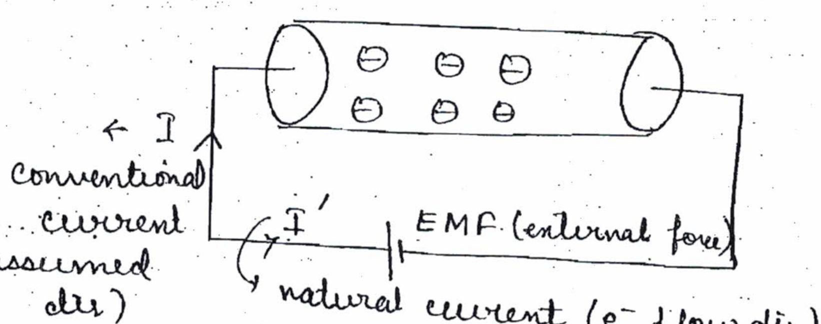
→ Circuit is a combination of elements and it should consist of closed path.

→ All circuits are N/w but all N/ws are not circuits.

• $q = -1.602 \times 10^{-19} C$

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

rate of flow of charge with time



[higher pot → lower pot]

$Q = \int I \cdot dt$

• In KCL, KVL we always use conventional direction

• $\boxed{|I| = I'}$ but opposite in direction.

• $Q = \int_{-\infty}^{t} I \cdot dt = \underbrace{\int_{-\infty}^{0} I \cdot dt}_{(Q_0)} + \int_{0}^{t} I \cdot dt$ or $\boxed{Q = Q_0 + \int_0^t I \, dt}$

Q_0 → initial charge

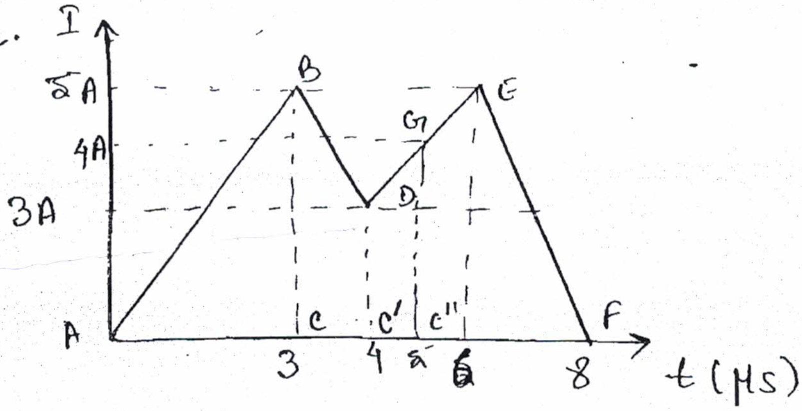
• $\boxed{V = \frac{dW}{dQ} = \frac{J}{C} \text{ or Volt}}$

• $\boxed{P = \frac{dW}{dt} \ \frac{J}{s} \text{ or Watt}}$ → time rate of energy.

$= \frac{dW}{dQ} \times \frac{dQ}{dt}$ ∴ $\boxed{P = VI = I^2 R = \frac{V^2}{R} = G V^2 = I^2/G}$

∵ $\left[\frac{1}{R} = G\right]$

Q.



Find charge acquired by cap in 5 μsec

:→ $Q = \int I\,dt$

2 methods: ① Developing mathematical eqn
② finding area under curve.

2. $Q = \int I\,dt$

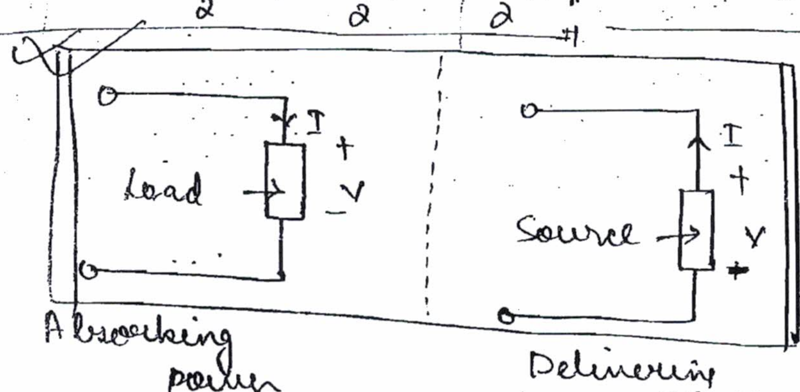
= $\Delta ABC + \square BDC'C + \square C'DGC''$

$= \frac{1}{2}(3\times5) + \frac{1}{2}\times(3+5)\times1 + \frac{1}{2}\times(3+4)\times1$

1* Area of Trapezoid = $\frac{1}{2}\times$(sum of ht of 2 sides) × dist btw sides*

1* DE - linear, slope constant m = 1 ∴ at 5 μs ; I = 4A*

$= \frac{1}{2}\times15 + \frac{1}{2}\times8 + \frac{1}{2}\times7 = 7.5 + 4 + 3.5 = 15\ \mu C$

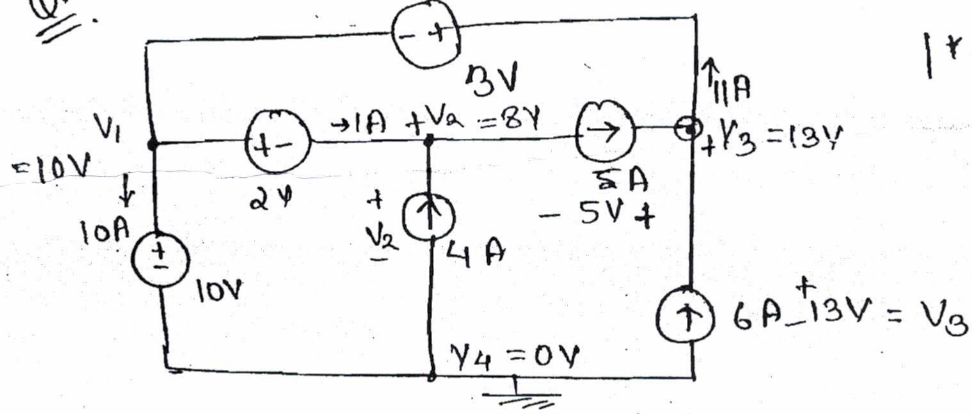


** => Absorbing & Delivering Source / Load (element)

* When the current is entering at +ve terminal element is absorbing power.

* When the current is leaving from +ve terminal element is delivering power

Q.



|* To find power, find voltage & current of each element *|

Find power of each element of the N/w shown.

:> potential btwn V_1 & gnd = 10V ∴ $V_1 = 10$ V -

at node V_1 & V_2 :- $V_1 - V_2 = 2V$ ∴ $V_2 = 8V$

at node V_1 & V_3 :- $V_3 - V_1 = 3V$ $V_3 = 13V$

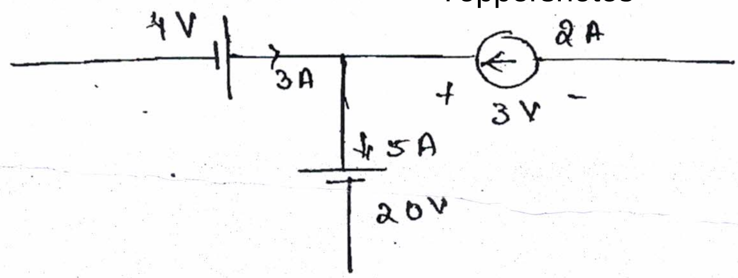
In 4A :- $P = 4 \times 8 = 32$ W (Delivering)
In 6A :- $P = 6 \times 13 = 78$ W (Delivering)
In 5A :- $P = 5 \times 5 = 25$ W (Delivering)
} current leaving +ve terminal

In 3V : $P = 11 \times 3 = 33$ W (Absorbing)
In 2V :- $P = 1 \times 2 = 2$ W (Absorbing)
In 10V :- $P = 10 \times 10 = 100$ W (Absorbing)
} I entering +ve terminal or going from lower to higher pot.

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

$P_{T\,del} = 32 + 78 + 25 = 135$ W
$P_T\,abs = 33 + 2 + 100 = 135$ W
} verified.

Q:



Find total power absorbed in the figure shown.

In 4V :- $P = 4 \times 3 = 12W$ (Del) $= -12W$ (Abs)

In 2A :- $P = 2 \times 3 = 6W$ (Del) $= -6W$ (Abs)

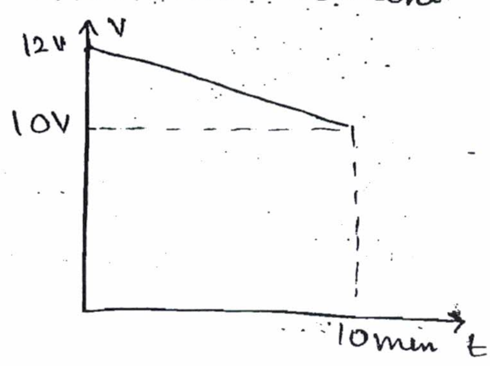
In 20V :- $P = 20 \times 5 = 100W$ (Absorbing)

$P_T = 82W$ (Absorbing)

• The capacity to do work is called energy.

$$W = \int_0^t P\,dt$$ watt-sec or Joule

Q. A fully charged mb. phone is good for 10 min talktime. During talktime battery delivers a constant current of 2A. Find energy on the battery during talktime.



= 600sec.

$\Rightarrow$ $W = \int_0^t P\,dt = \int_0^t VI\,dt$

$= I \int_0^t V.\,dt$ $\quad I = 2A$ (constant)

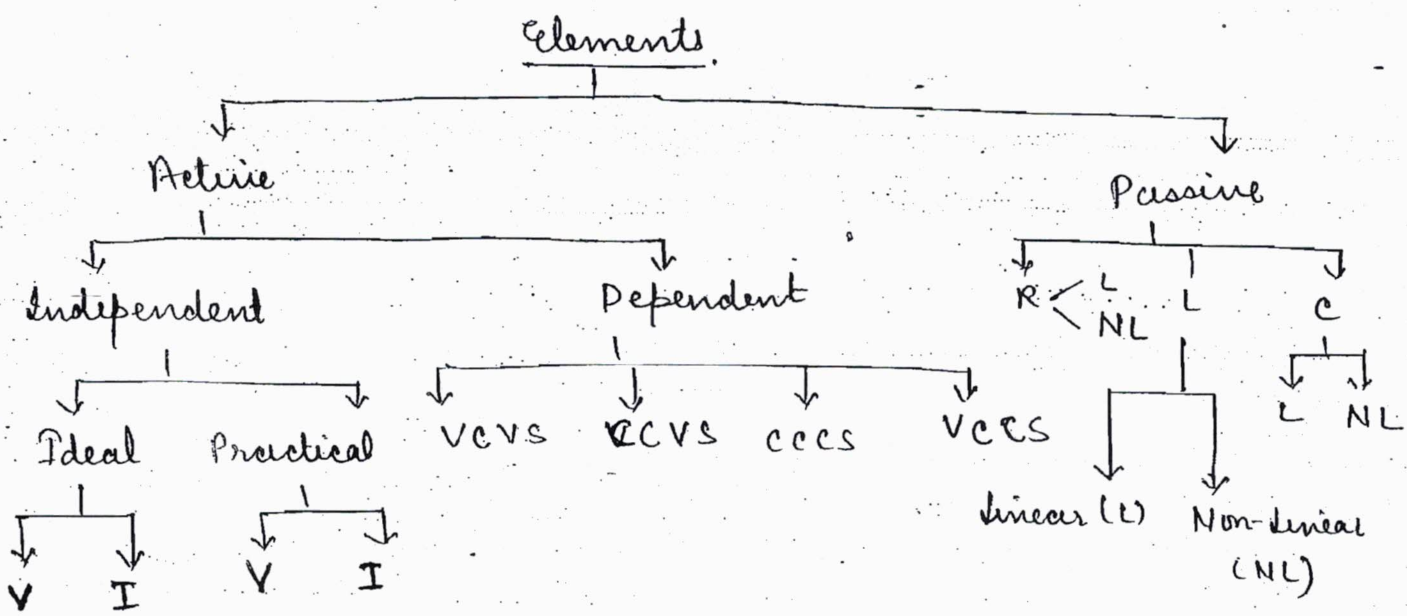
$= 2 \times \frac{1}{2} \times (12+10) \times 600$

$= 22 \times 600$

$= 13\,200 = 13.2\,KJ.$

Classification of Elements :-

1. Active + Passive Elements :-
2. Linear and Non Linear Elements
3. Unidirectional and bi-directional elements
4. Time Variant and Invariant
5. Lumped + Distributed



- **ACTIVE ELEMENT :-** ◦ When the element is capable of delivering energy independently for long time (approximately infinite time). <u>Or</u>
◦ When the element is having property of <u>internal amplification</u>.

eg :- Voltage source (V), Current source (I), } Independent
Transistor + op-amp. } Dependent

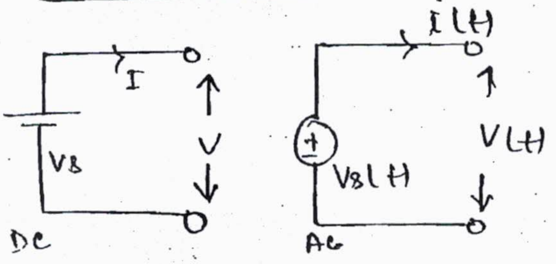
* <u>Cap vs independent sources</u>:
• During discharging capacitor can deliver the energy independently for <u>short time</u> (1) and capacitor is <u>not having internal amplification</u> (2) property.

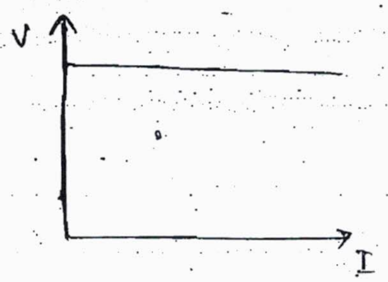
• **PASSIVE ELEMENT** :- When the element is not capable of delivering energy independently.

eg:- Resistor, bulb, transformer $(V_1 I_1 = V_2 I_2)$ ⇒ no internal amplification.

$$P_{in} = P_{out}$$

• Ideal V source:





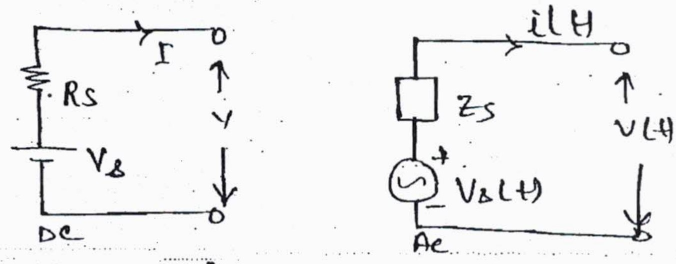
DC → no time mentioned
AC → time mentioned

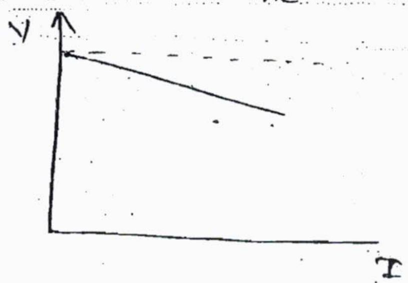
$R_s = 0$ $V = V_s$ $V \neq f(I)$

→ Ideal voltage source delivers energy at specified voltage (V) which is independent on current delivered by source.

→ Internal Resistance of ideal voltage source = 0.

• Practical V source:





For DC :→ $V_s = V + I R_s$

$V = f(I)$ or $V = V_s - I R_s$ V ↓ as I ↑

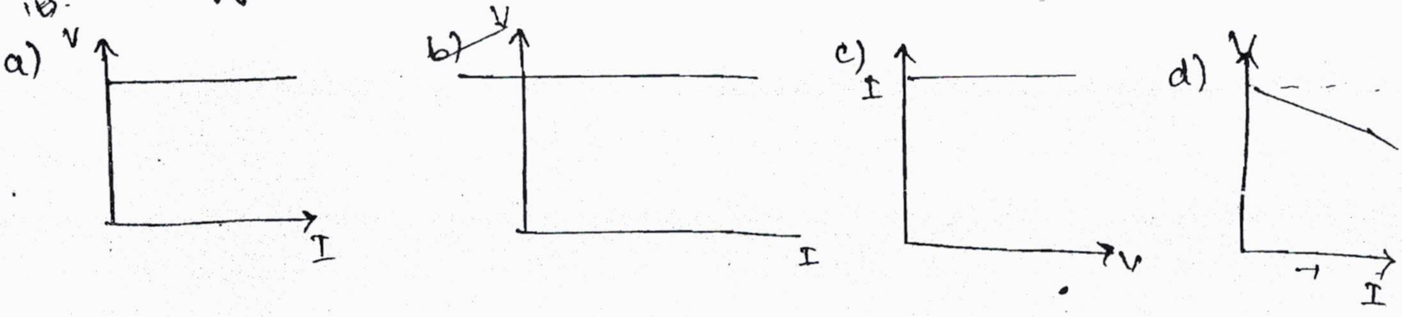
→ Practical voltage source delivers energy at specified voltage (V) which depends on current delivered by the source.

→ Internal Resistance of practical voltage source = R_s

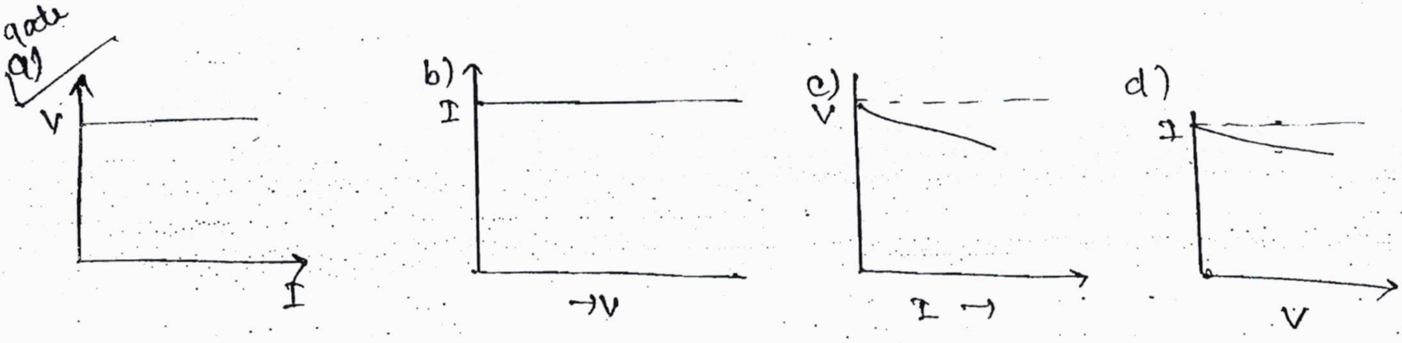
$R_s \neq 0$.

Independent voltage source does <u>not</u> satisfy <u>ohm's law</u> since VI characteristics is <u>not linear</u>. (does not cross origin or not linearly ↑↓)

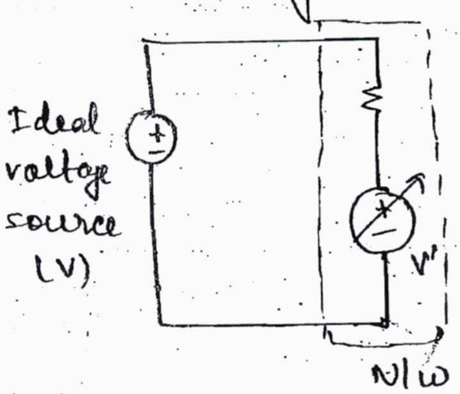
Q. Identify VI characteristics of ideal voltage source is.



Q. Same - Identify VI charact of ideal volt source.



:→ Considering a simple example:-

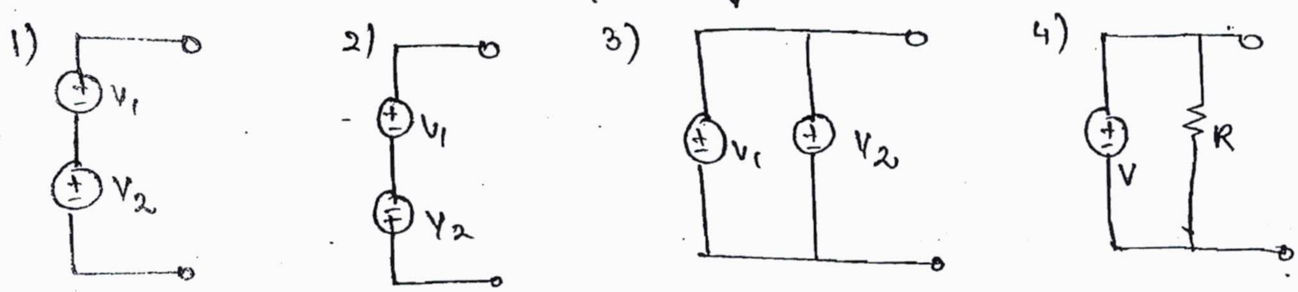


if $V' > V \Rightarrow I =$ (clockwise)
$V' < V \Rightarrow I =$ (anticlockwise)
$V' = V \Rightarrow I = 0$

** for both directions of I, V is constant, hence I considered in both +ve & -ve direction **

If both options Q_1(a, b) → select b → most appropriate
one option Q_2(a) → select a.

Q. Find equivalent ckt corresponding to them:-



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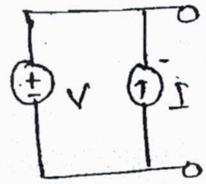
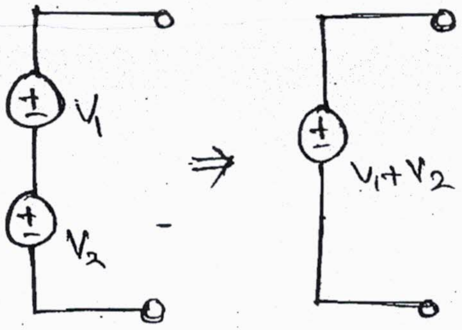
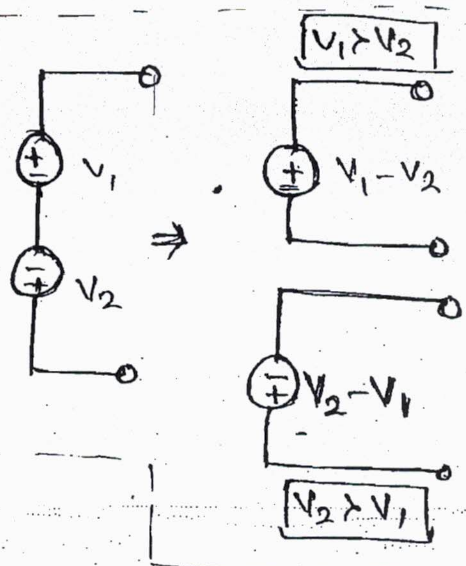
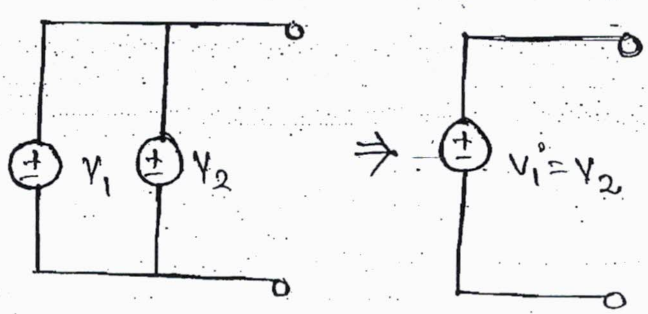
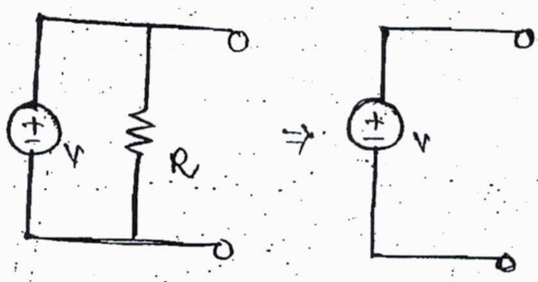
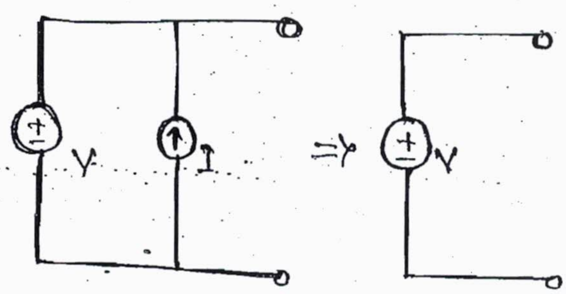




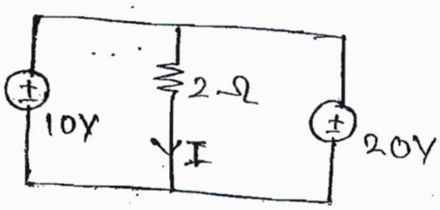








Q: Find current in the 2Ω resistance



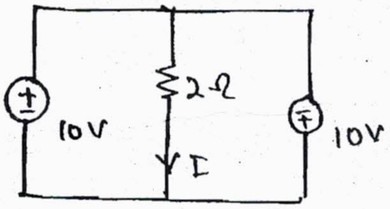
a) 5A b) 10A

c) 15A d) None or

(NOT satisfying KVL) or

(0)

NOTE:- With respect to KVL, voltage across all the parallel branches should be equal.

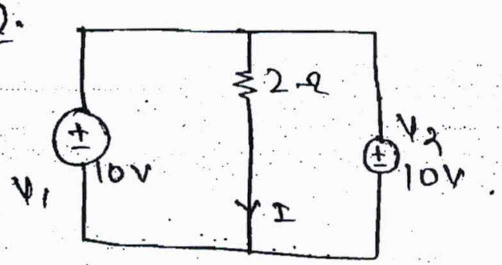


⇒ polarity as well as magnitude of voltages in parallel branches should be equal. Hence,

NOT satisfying KVL, I = 0

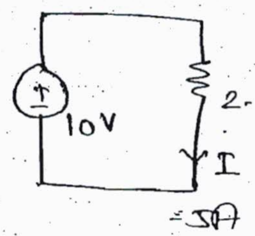
$10V \neq -10V$

Q.



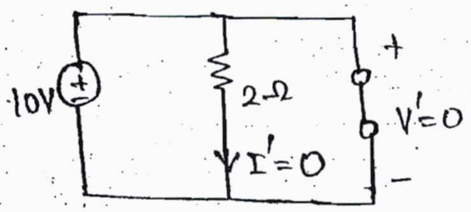
$10V = IR$

or $I = \frac{10V}{2} = \boxed{5A}$ ⇒

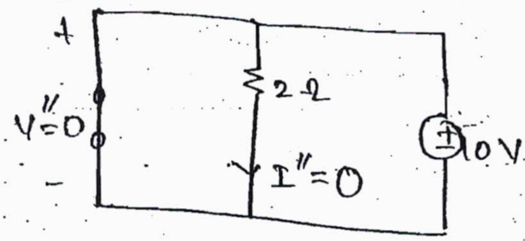


• Verifying by using superposition Theorem:-

Case 1 due to V_1;



Case 2 due to V_2.



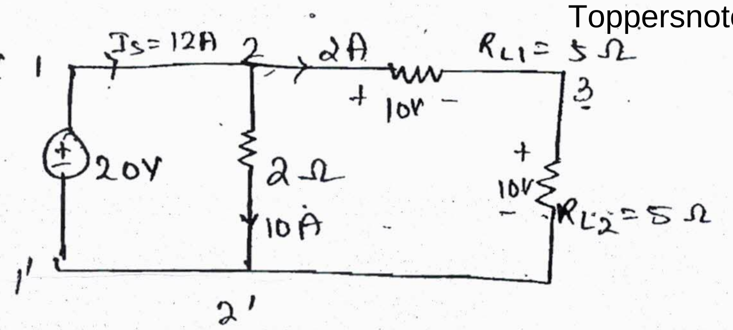
$I = I' + I'' = 0$

10V ≠ 0V → not satisfying KVL

$10V \neq V'$ ∴ KVL not satisfied ← ∴ The superposition does not apply.

NOTE:- For the above N/w superposition theorem cannot be applied since Case 1 & Case 2 circuits are not satisfying KVL.

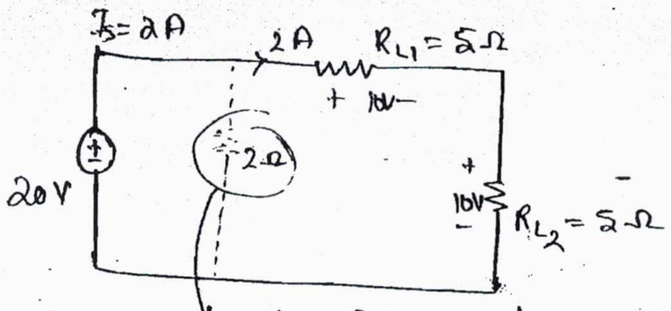
Q.

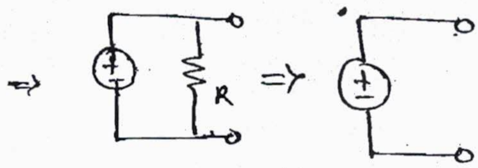


$V_{11'} = V_{22'} = V_{232'}$

↓

parallel branches





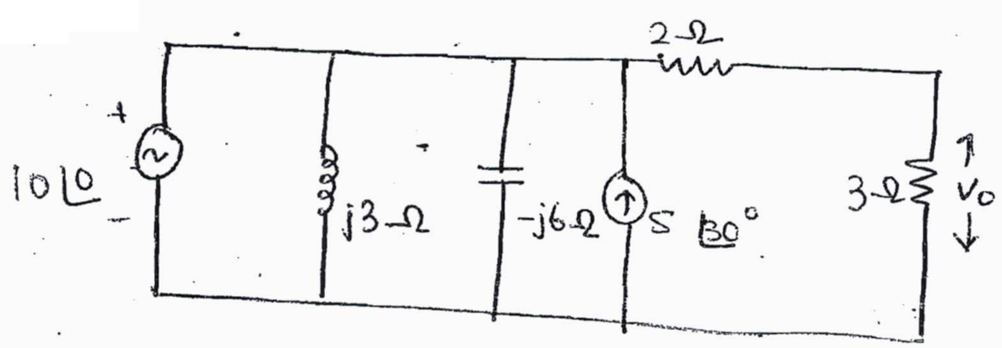
R not important/justifying ckt (4) from previous.

In 1st ckt: $P_s = 20 \times 12 = 240W$
In 2nd ckt: $P_s = 20 \times 2 = 40W$ } → not justifying ckt(4)

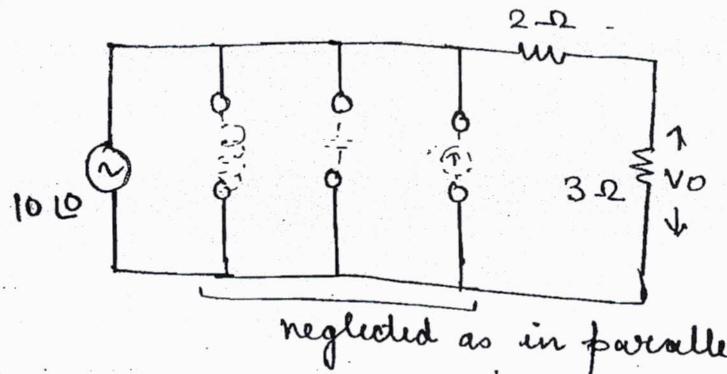
∴ Conclusion:→ R can be neglected wrt load calculations (V_L, I_L)
R cannot be neglected wrt source current & source power

NOTE:- In above N/w, 2Ω resistance (10A current) can be neglected to calculate as a load current or load voltage.
However, in above N/w, 2Ω resistance (10A current) cannot be neglected to calculate either source current or source power.

Q. Find V_o on the n/w shown.



⇒ Equivalent ckt for solving can be reduced to

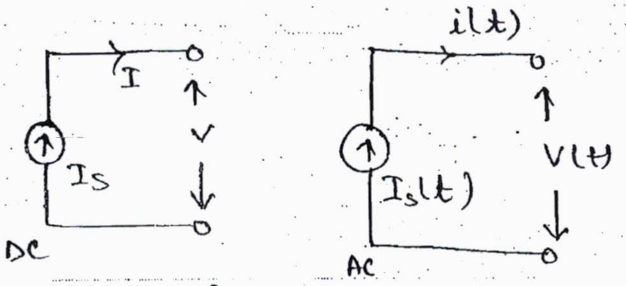


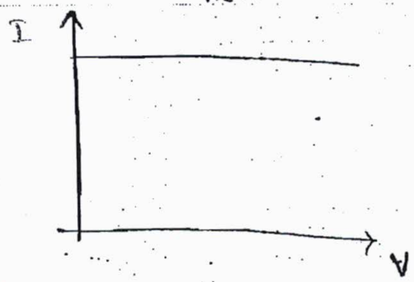
$I = \frac{10}{5} = 2\,A$

$V_0 = I \times 3\,\Omega$

$V_0 = 6\,V$ Ans

• Ideal Current Source –



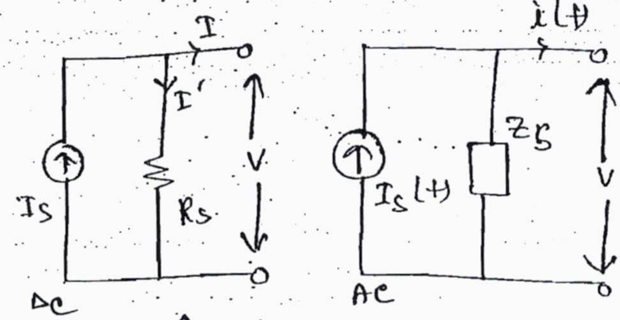


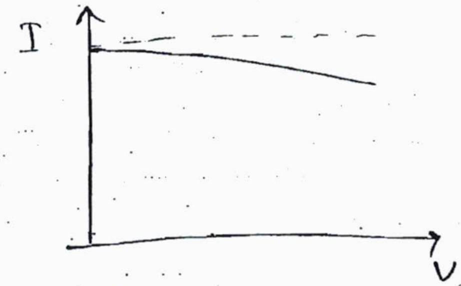
$R_s = \infty$

• Ideal current source delivers energy at specified current (I) which is independent of voltage across the source.

• Internal resistance of ideal current source = ∞

• Practical Current Source –





• $I_s = I' + I$

⇒ $I = I_s - I'$ or $I = I_s - \frac{V}{R_s}$

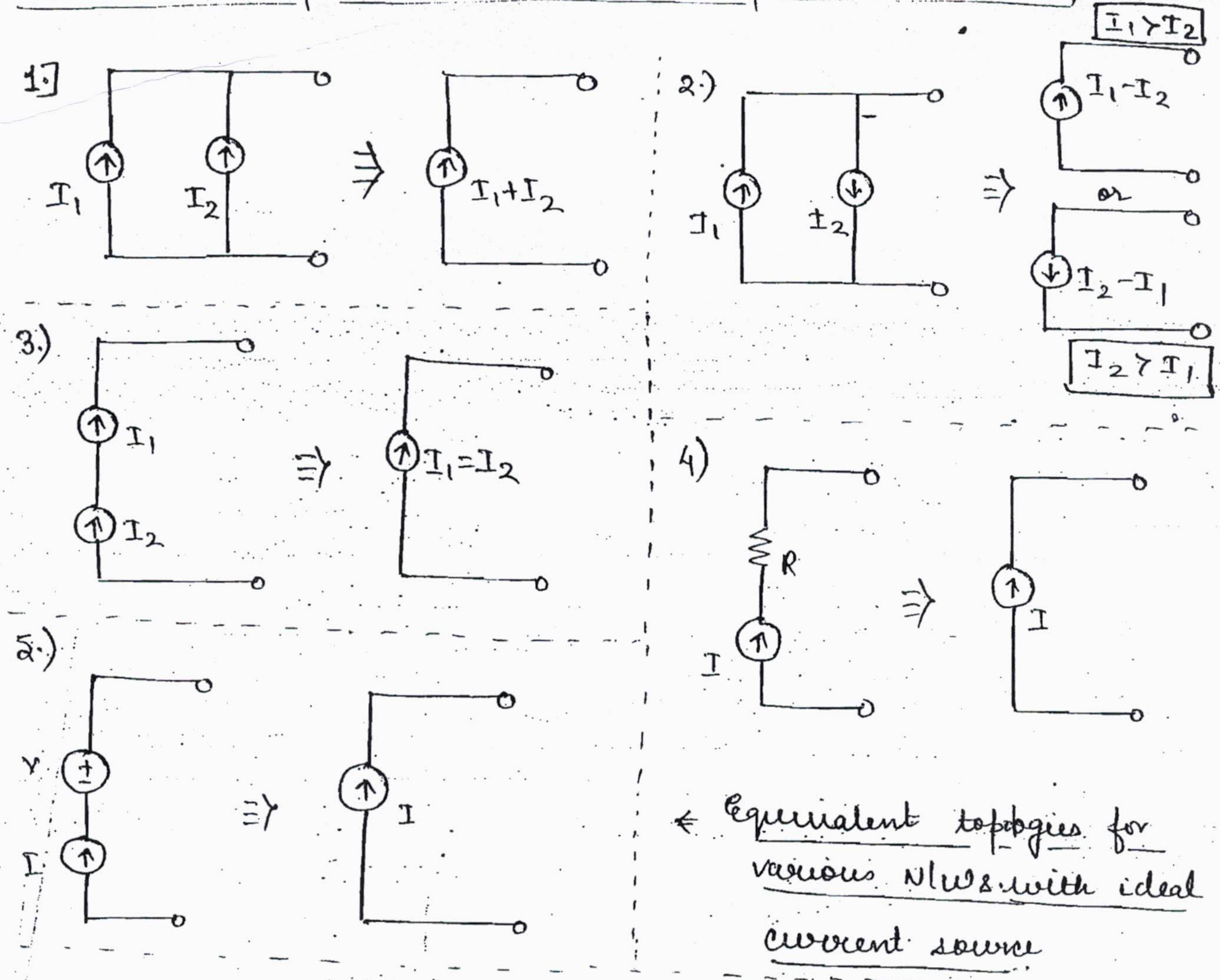
$I \propto V$

• Practical current source delivers energy at specified current (I) which depends on voltage across the source.

Conclusion:- Independent current source does not obey Ohm's law, since VI characteristics is non-linear.

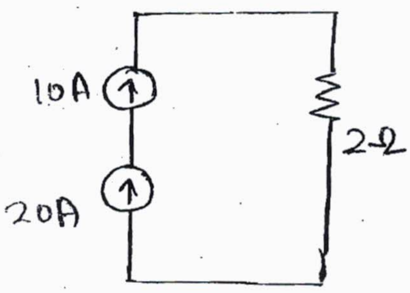
- Internal resistance of ideal voltmeter = ∞
- " " " ideal ammeter = 0 → Rs (ideal)
- In the practical system independent current source does not exist but dependent current source exists.

eg:- Transistor ↘ theoretical concept for source transformation.



← Equivalent topologies for various N/Ws with ideal current source

Q. Find equivalent current in 2Ω resistor.



a) 10A

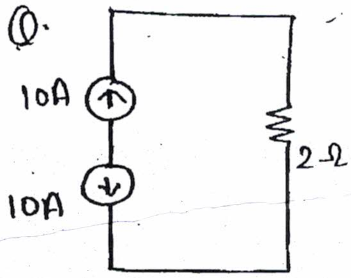
b) 20A

c) 30A

d) ✓ None or Not satisfying KCL

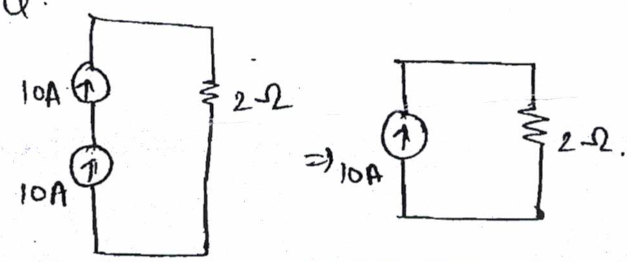
NOTE:- With respect to KCL, current flowing through all the series elements should be equal.

Q.



not satisfying KCL at
both direction + magnitude should be same.

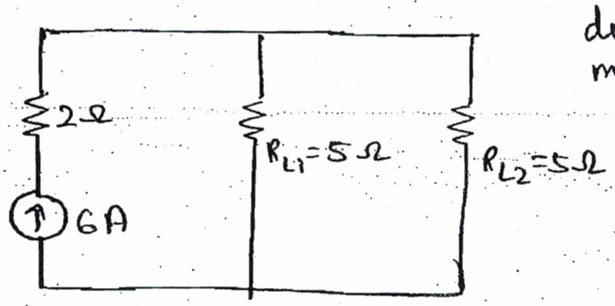
Q.

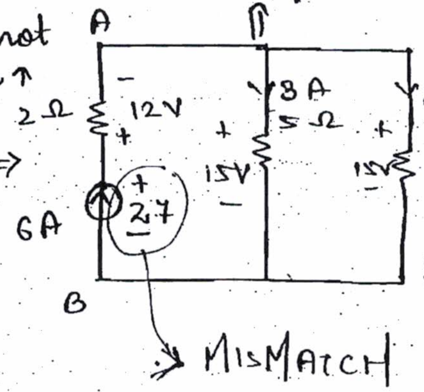


I = 10A.

Property (4) for load is verified (with/without 2Ω).

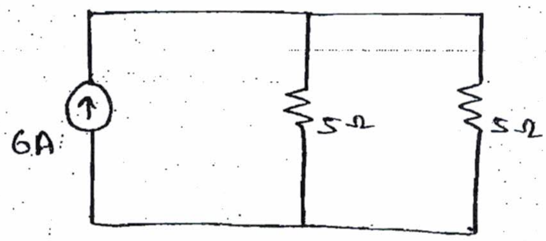
Q.

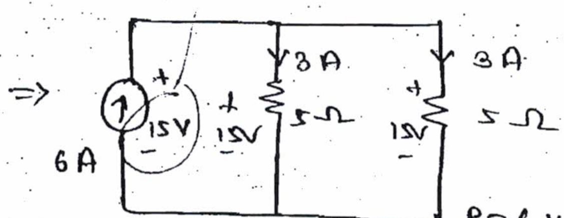




P = 6×27
= 142W

MISMATCH





P = 6×15
= 90W

Notations:- when current entering = +ve corresponding to arrow ↑ ±V

$V_{AB} = V_s - 12 \Rightarrow 15 = V_s - 12 \Rightarrow V_s = 27$ ($V_s > 12$) → Considered as source volt is greater.

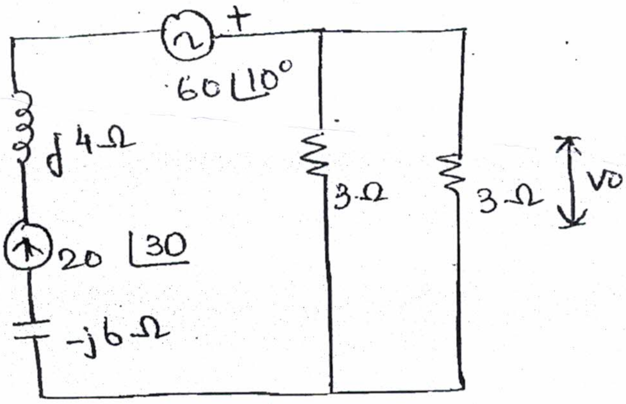
NOTE:- In above N/w:-

2Ω resistance (12V voltage) • can be neglected wrt load calculation $\|(V_L + I_L)\|$

• but it cannot be neglected wrt source calculations [current, source voltage or power of current source)

$\|(V_{IS}, P_{IS})\|$

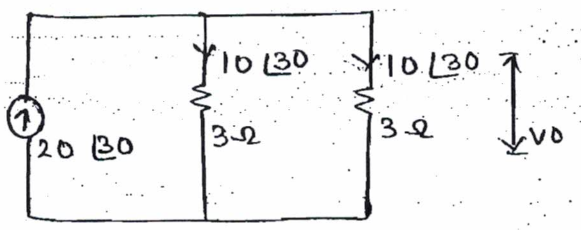
Q. *



Find V_0.

** All elements in series to current source are neglected *

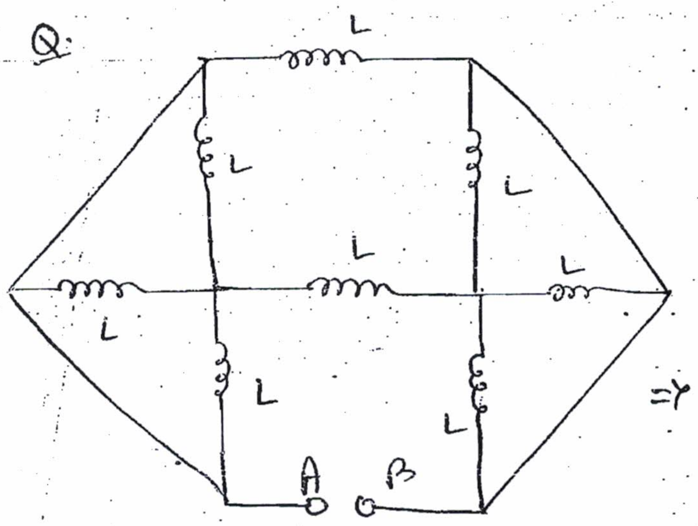
Equivalent ckt :→



$\therefore V_0 = 3 \times 10 \angle 30°$

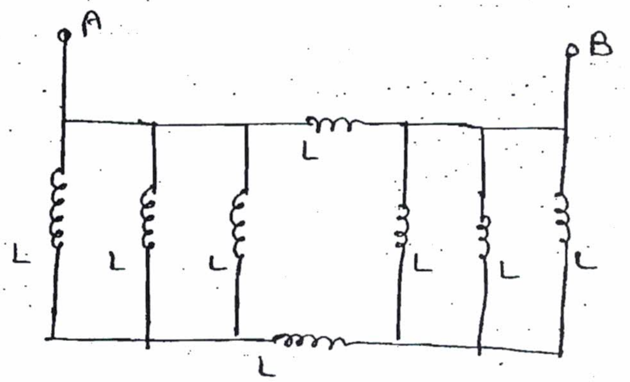
$$V_0 = 30 \angle 30° \text{ V}$$

Q.

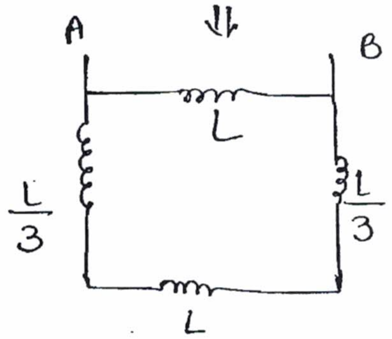


1) Find equivalent inductance w.r.t A + B.

⇒



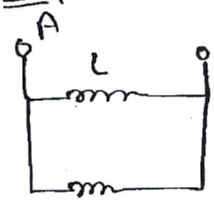
⇓



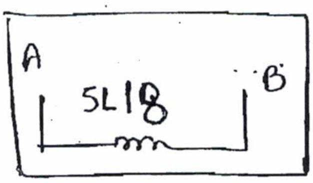
$\leftarrow \frac{L}{3}$

$\frac{5L}{3}$

$\left(\frac{L}{3} + L + \frac{L}{3}\right)$



⇐

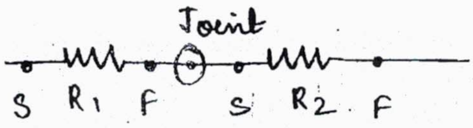


$L_{eq} = \frac{5L}{8}$ Ans

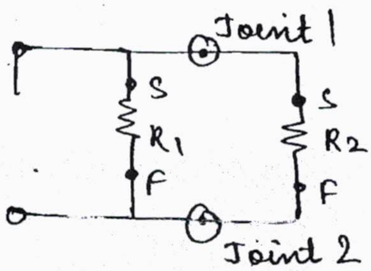
$L \parallel \frac{5L}{3}$

$$\Rightarrow \frac{L \times \frac{5L}{3}}{L + \frac{5L}{3}} = \frac{L^2}{4L} \cdot \frac{5L}{8}$$

Series & Parallel Connection

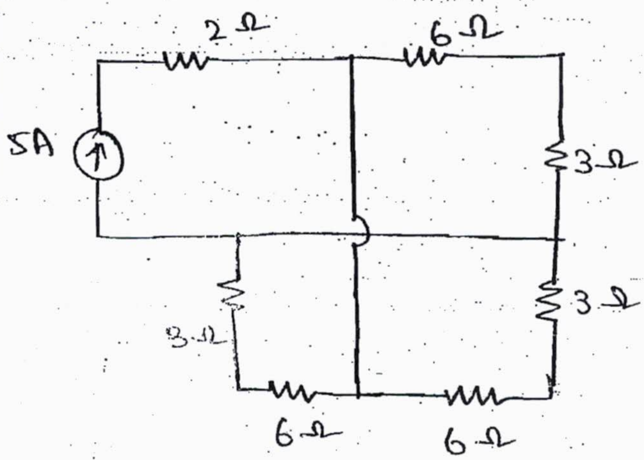


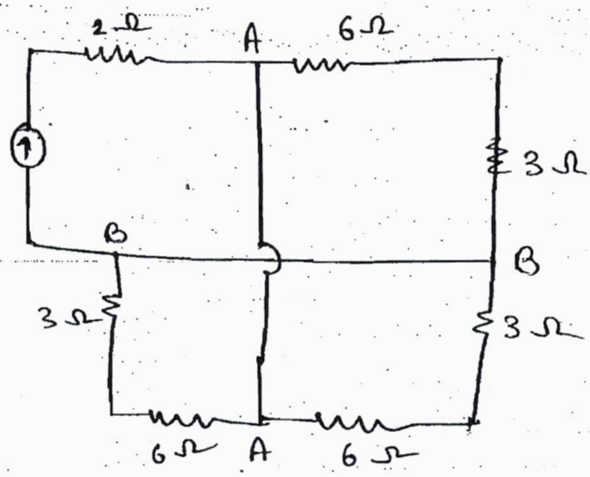
1) one joint (F – S)
2) Same current (I) flows through both



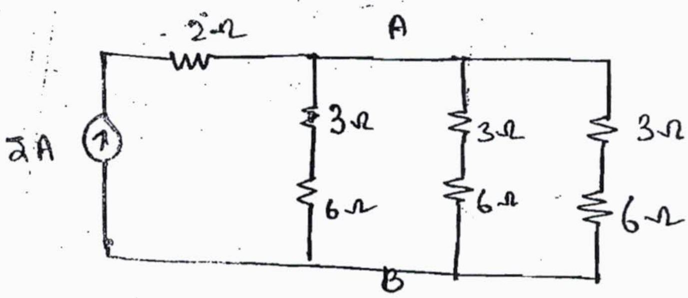
1) Two joints (S – S)
2) Same voltage through both

Q. Find power delivered by current source.

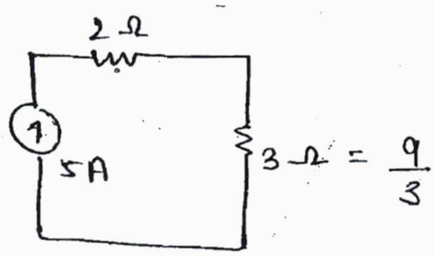




⇒ A to B → 3 branches ∴ all branches in parallel.



⇒



⇓

Power $= I^2R$

$= 25 \times 5$

$\boxed{P = 125W}$