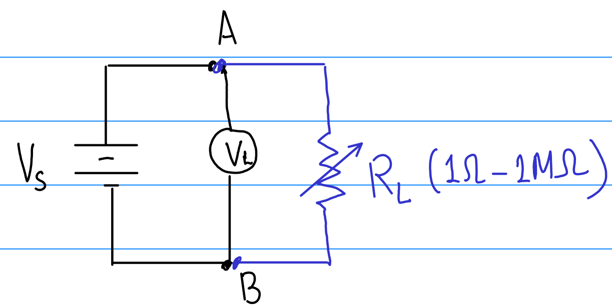
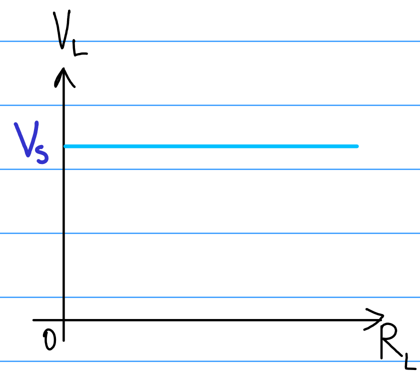
14.09.2023

Sources & Circuit Theorems

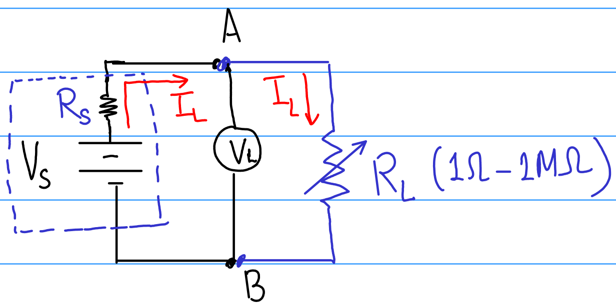
① Voltage Sources :

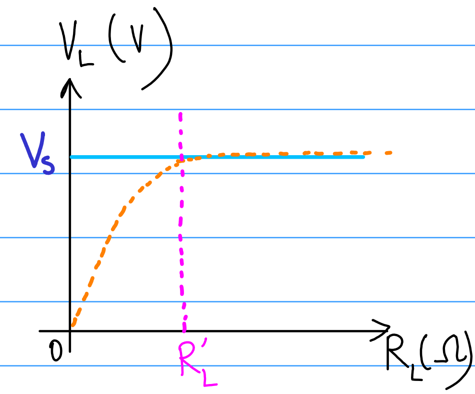




Ideal Voltage source

Real Voltage Source :





Real Voltage source

Load Current, $I_L = \dfrac{V_s}{R_s + R_L}$

$$V_L = I_L R_L = \left(\frac{R_L}{R_s + R_L}\right) V_s$$

$$\boxed{V_L = \left(\frac{R_L}{R_s + R_L}\right) V_s}$$

Load voltage we will measure across the load resistance R_L.

Special Case :

(i) $R_s = 0\ \Omega \Rightarrow V_L = V_s \Rightarrow$ Ideal Voltage Source

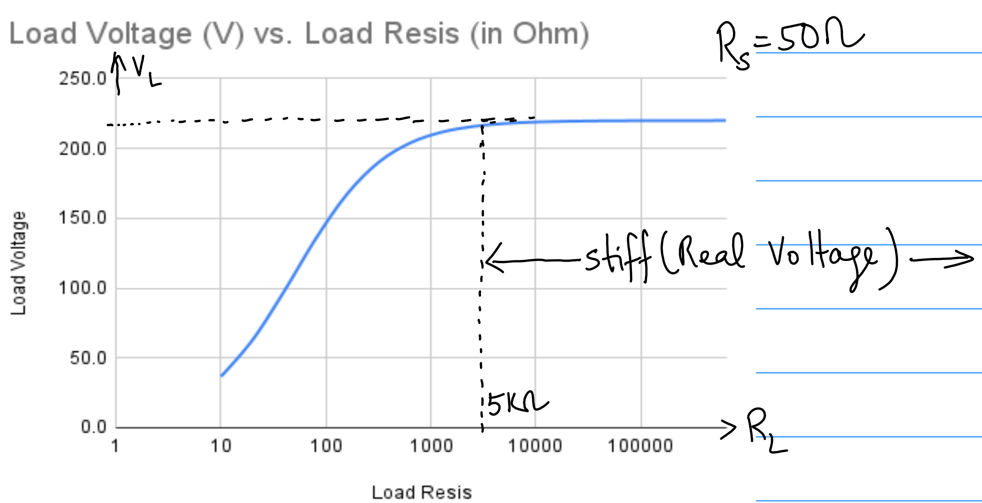
(ii) $R_s \neq 0$ (finite value) for example $R_s = 100\,\Omega$

$$V_L = \left(\frac{R_L}{100\,\Omega + R_L}\right) V_s$$

$R_L = 10\,\Omega \Rightarrow V_L = \frac{10}{110} \times V_s$

$\vdots$

$R_L = 500\,\Omega \Rightarrow V_L = \frac{500\,\Omega}{100\,\Omega + 500\,\Omega} \cdot V_s$

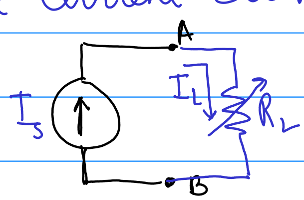


For real (stiff) voltage source,

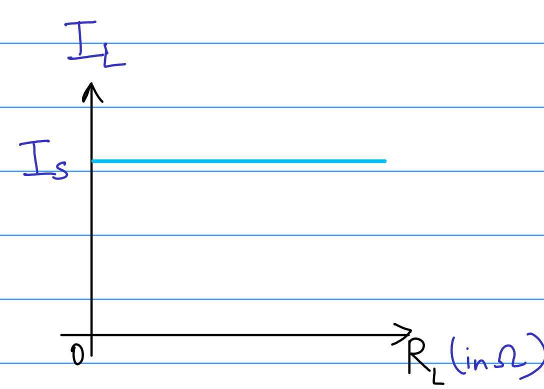
$$\boxed{R_L \geq 100\,R_s}$$

Current Sources :

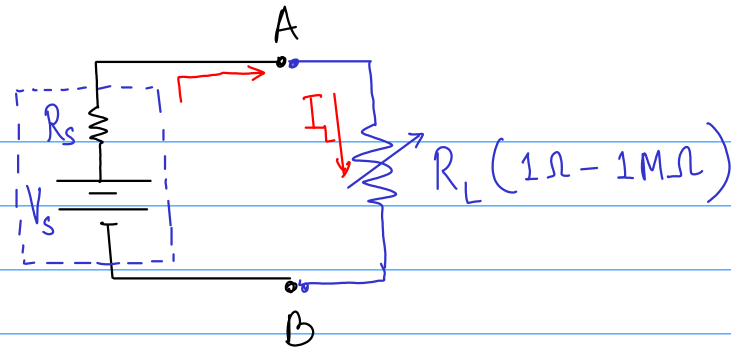
Ideal Current Source



$I_L = I_s$



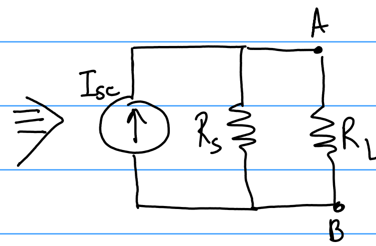
Real Voltage Source



$$\boxed{I_L = \frac{V_s}{R_s + R_L}}$$

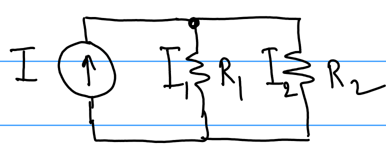
$$\Rightarrow \quad I_L = \frac{V_s/R_s}{(R_s+R_L)/R_s}$$

$$\boxed{I_L = \left(\frac{R_s}{R_s+R_L}\right) I_{sc}} \quad \Rightarrow$$



Recall;
(School level concept)

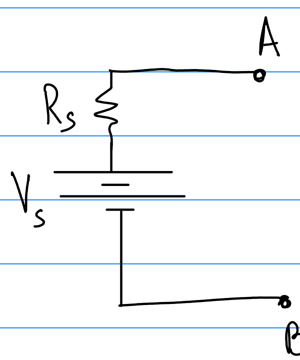
KCL



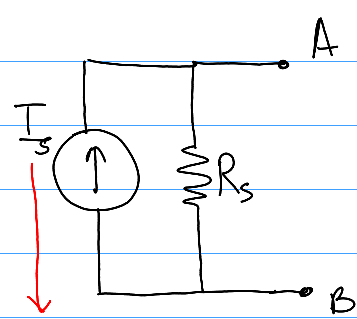
$$I = I_1 + I_2$$

$$I_2 = \left(\frac{R_1}{R_1+R_2}\right) I$$

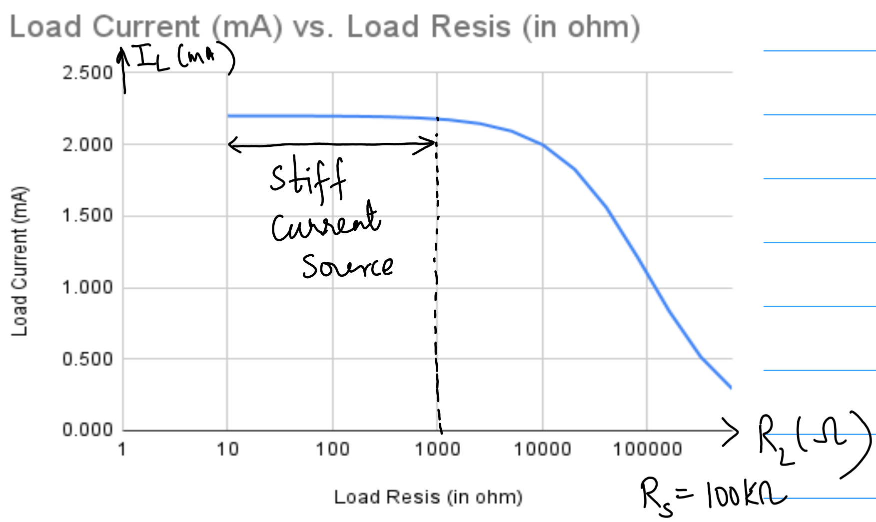
$$I_1 = \left(\frac{R_2}{R_1+R_2}\right) I$$



$\equiv$



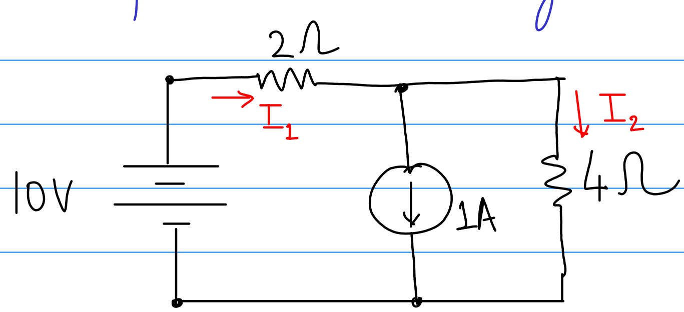
$$I_s = \left(\frac{V_s}{R_s}\right)$$



For a real (stiff) current source:

$$\boxed{R_L \le \frac{1}{100} R_s}$$

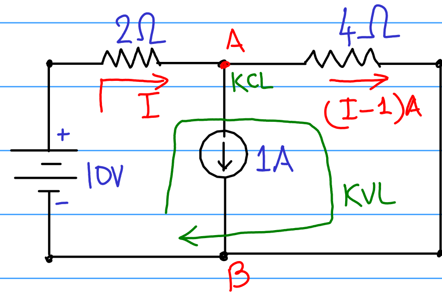
Simple example with voltage & current sources:



Use: KCL, KVL to determine I_1 & I_2

Circuit Theorems

Recap: A simple ckt. with both voltage and current sources.



KCL, KVL

$10V = 2I + 4(I-1)$

Solve to get I.

$I = \frac{7}{3}A \; ; \; \frac{4}{3}A$

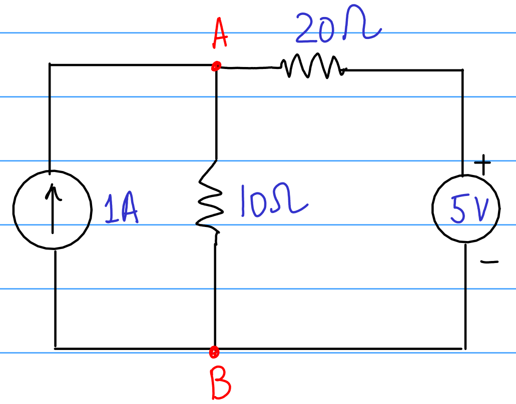
Suppose we have more number of sources in the ckt., and we would like to determine the effect of all the sources to a given ckt. element (eg. resistor).

Superposition Theorem: The voltage across (or the current through) an element in a given linear ckt. is the algebraic sum of the voltages across (or current through) that element due to each sources acting alone.

⇒ This means that while determining voltage (or current) due to one source, we need to zero the other sources

To make the sources zero, we need

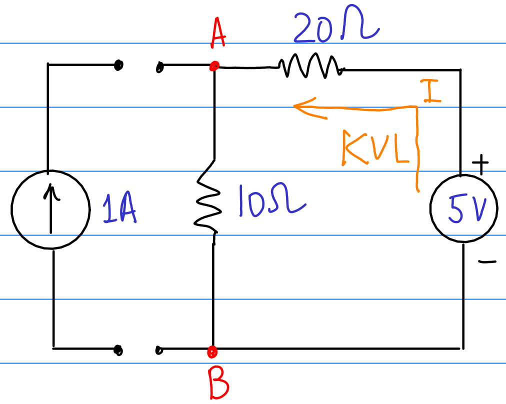
$$\boxed{\begin{array}{ll} \text{open} : & \text{all other current sources} \\ \text{short} : & \text{all other voltage sources} \end{array}}$$



Use superposition theorem to determine voltage across AB (ie, V_{AB})

(i) Effect of the voltage source acting alone.

⇒ we need to zero the current source



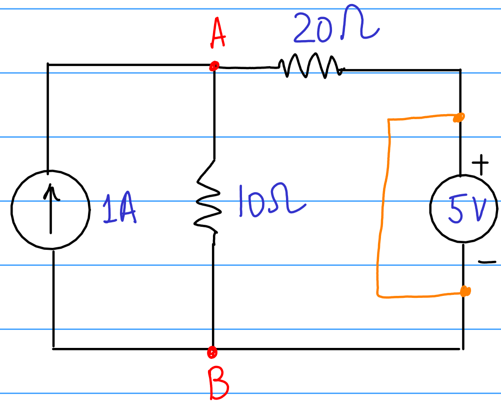
$$I = \frac{5V}{20\Omega + 10\Omega} = \frac{1}{6} A$$

$$V_{AB1} = \frac{10}{6} = \frac{5}{3} V$$

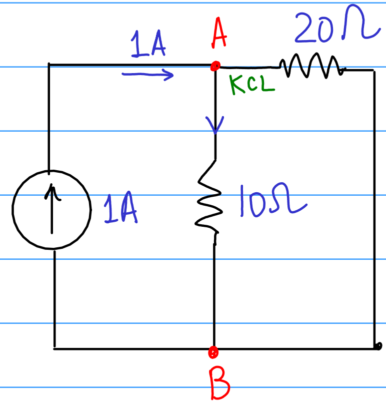
$$\boxed{V_{AB1} = \frac{5}{3} V}$$

(ii) effect of current source acting alone.

⇒ We need to zero the voltage source.



shorting the voltage source



$\Rightarrow$ Current divider ckt.

Current through 10Ω resistor

$$= \left(\frac{20\Omega}{10\Omega + 20\Omega}\right) 1A$$

$$= \frac{2}{3} A$$

$$V_{AB(2)} = \frac{2}{3} A \cdot 10\Omega$$

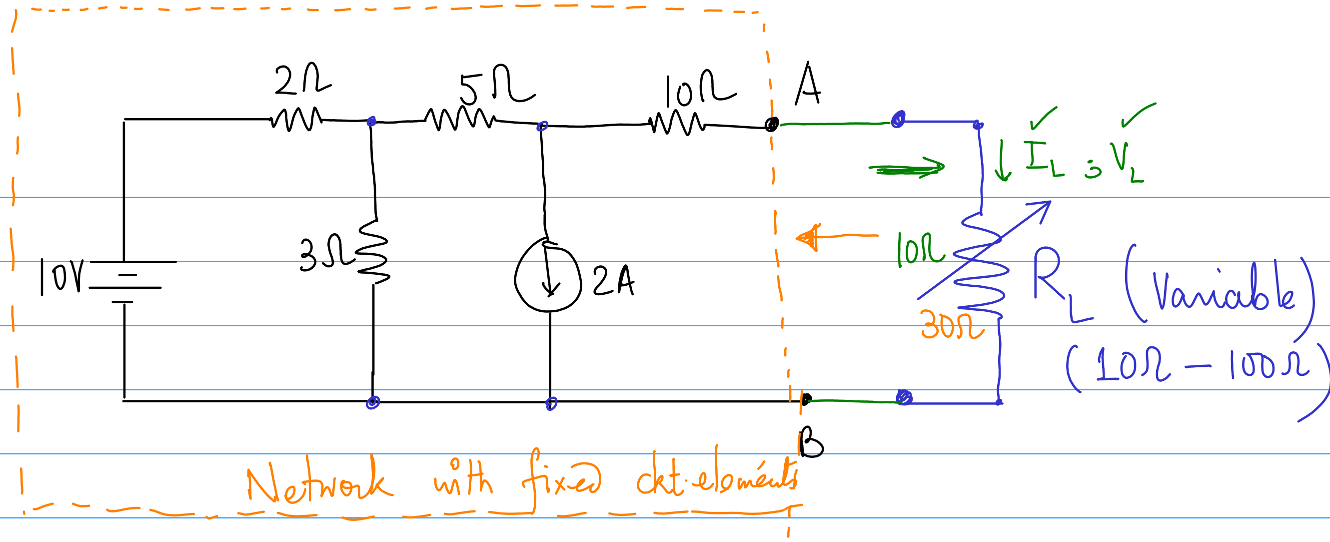
$$= \frac{20}{3} V$$

Therefore, according to superposition theorem:

$$V_{AB} = V_{AB(1)} + V_{AB(2)} = \frac{5}{3} V + \frac{20}{3} V$$

$$= \frac{25}{3} V$$

$$\boxed{V_{AB} = \frac{25}{3} V}$$



The value of load current (or load voltage) for a given network with fixed elements depends on the value of load resistance.

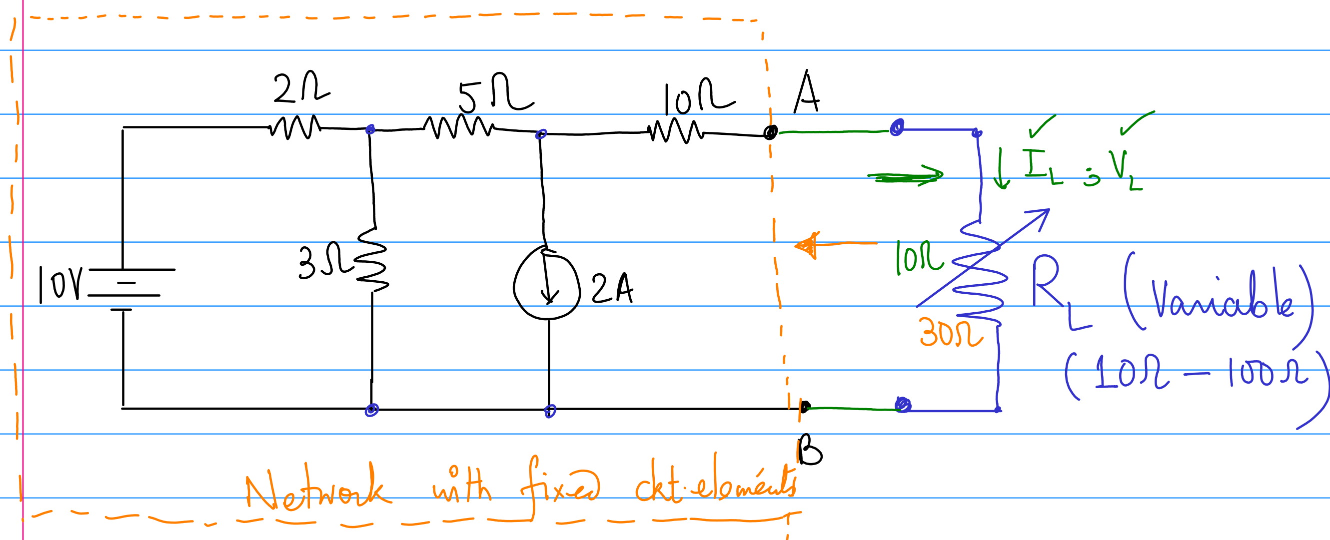
That is, each time value of R_L changes, you need re-calculate all the current/voltage to determine the value I_L & V_L.

To overcome this difficulty of ckt. analysis, we have a ckt. theorem.

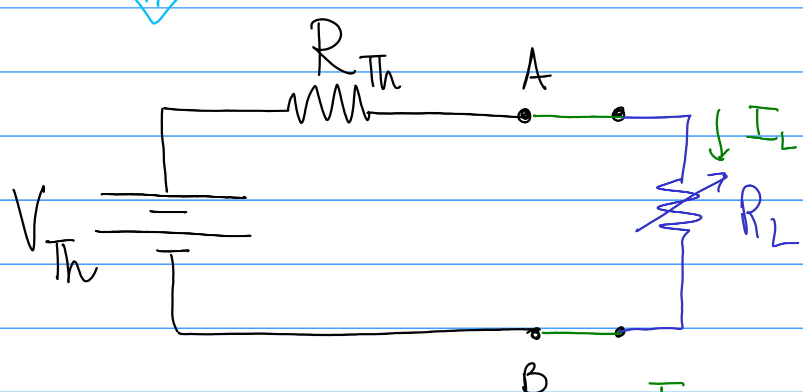
Ckt. theorem given by a French Engineer Leon Charles Thevenin.

Thevenin's Theorem :

A linear network with fixed values of ckt. elements can be replaced by an equivalent network consisting of a single voltage source and a series resistance.



⇓



$$I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

$$V_L = I_L R_L$$

Ques: How do we determine V_{Th} & R_{Th} for a given network.

V_{Th} = Open ckt. voltage across the load terminals (here AB)

$\Rightarrow$ Remove the load across AB & measure the open ckt. V_{AB} (open ckt.)

R_{Th} = Equivalent resistance of the given network across the load terminal (here AB) making all the sources zero.