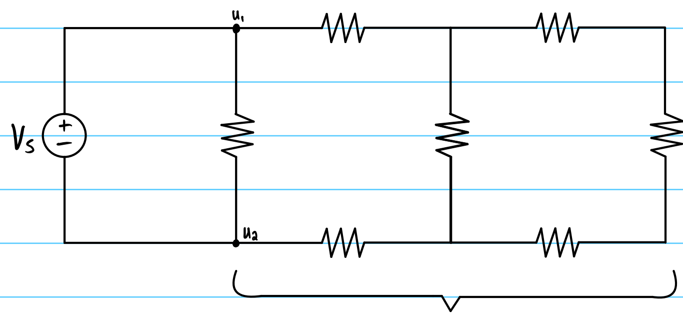
Discussion 8B :)

Anish's 16A Discussion
Office Hours: Tuesday 3-4
@Cory 144MA Friday 4-5

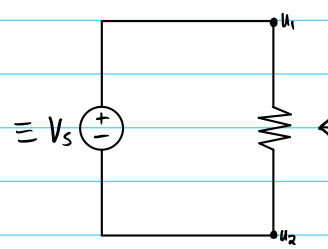
Resistor Equivalence:

Main Idea → Simplify circuits in order to ease circuit analysis and computations

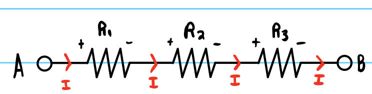
→ Example: complex resistor network → simple circuit



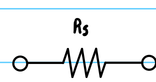
equivalent resistor



Resistor Equivalence

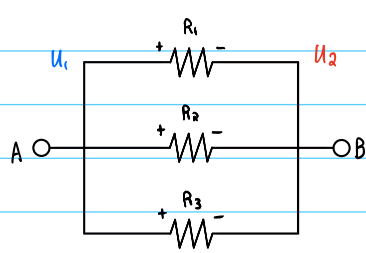


{Resistors in Series} $\equiv$



I → same current flowing through each resistor

$R_s = R_1 + R_2 + R_3$



{Resistors in Parallel} $\equiv$

$R_p = R_1 \parallel R_2 \parallel R_3$

↳ "parallel operator"

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

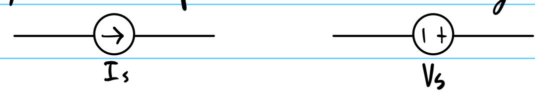
Same voltage drop across each resistor $(u_1 - u_2)$

Superposition:

Motivation: Break down circuits with multiple sources into several simpler circuits
↳ another tool for circuit analysis

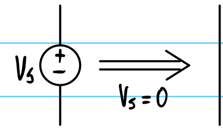
Steps:

① Identify each independent current/voltage source within the cicuit



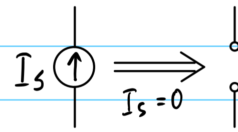
② For each source identified in step ①, draw an equivalent circuit by zeroing out all other independent sources.

Zeroing out a Voltage Source:



{Turns into a wire}

Zeroing out a Current Source:



{Turns into an open circuit}

③ Compute the circuit voltages and currents due to the independent source you are working with (This is the longest step and will be repeated several times).

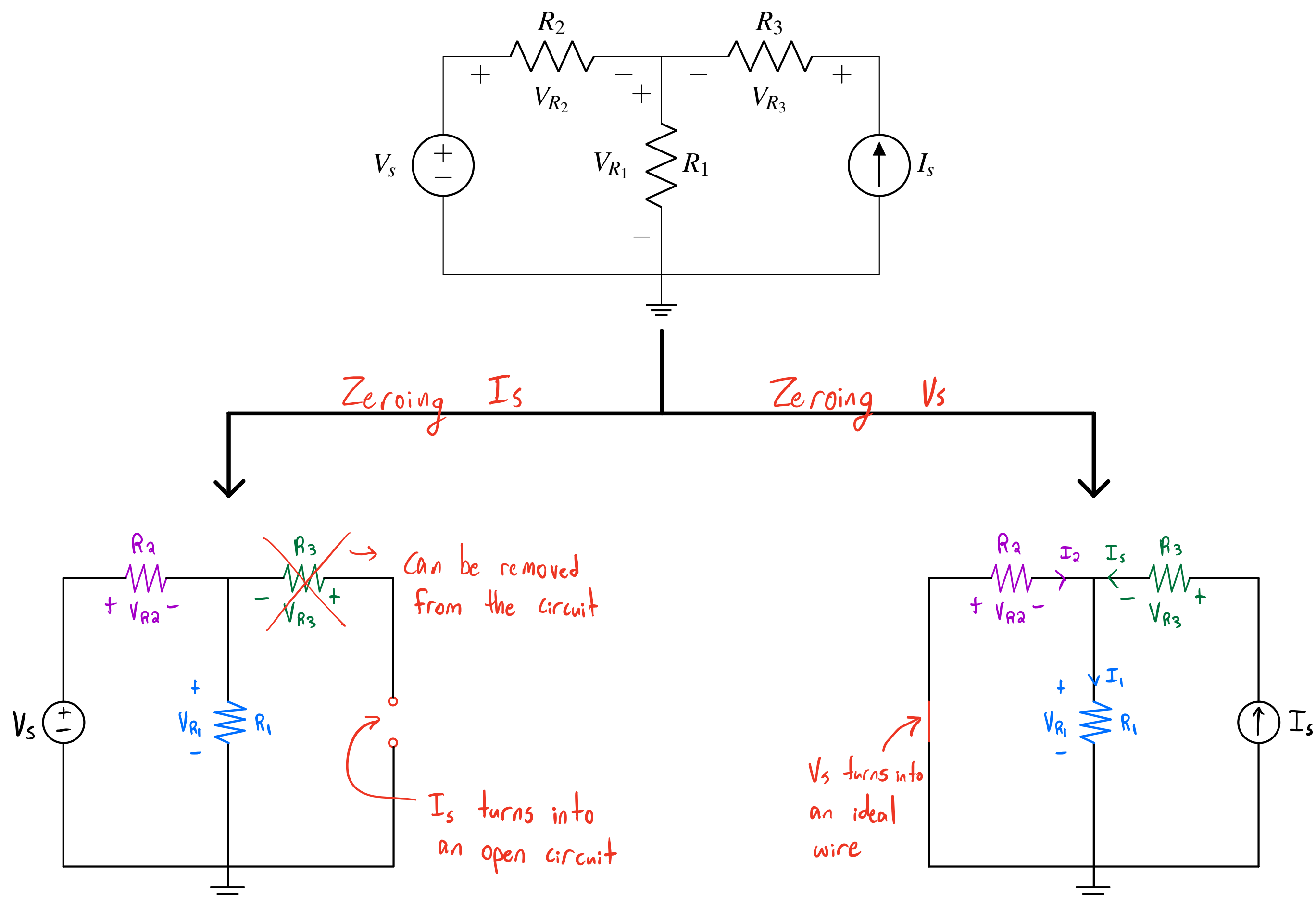
④ Finally, superimpose the individual circuits by adding up the currents and node potentials that directly correspond to each other.

EECS 16A Designing Information Devices and Systems I
Fall 2022 Discussion 8B

1. Superposition

For the following circuits, use the superposition theorem to solve for the voltages across the resistor(s).

(a)



The circuit reduces to a voltage divider!

$$V_{R_1} = \frac{R_1}{R_1 + R_2} V_s$$

$$V_{R_2} = \frac{R_2}{R_1 + R_2} V_s$$

$$V_{R_3} = 0$$

$V_{R_3} = I_s R_3$ (R_3 is in series with I_s)

$I_1 = \frac{R_2}{R_1 + R_2} I_s$ (Current Divider)

$V_{R_1} = -V_{R_2}$ (Parallel resistors with opposite polarity)

$I_2 = -\frac{R_1}{R_1 + R_2} I_s$

$V_{R_1} = I_1 R_1$
$V_{R_2} = I_2 R_2$ (By Ohm's Law)

$$V_{R_1} = \frac{R_1 R_2}{R_1 + R_2} I_s$$

$$V_{R_2} = -\frac{R_1 R_2}{R_1 + R_2} I_s$$

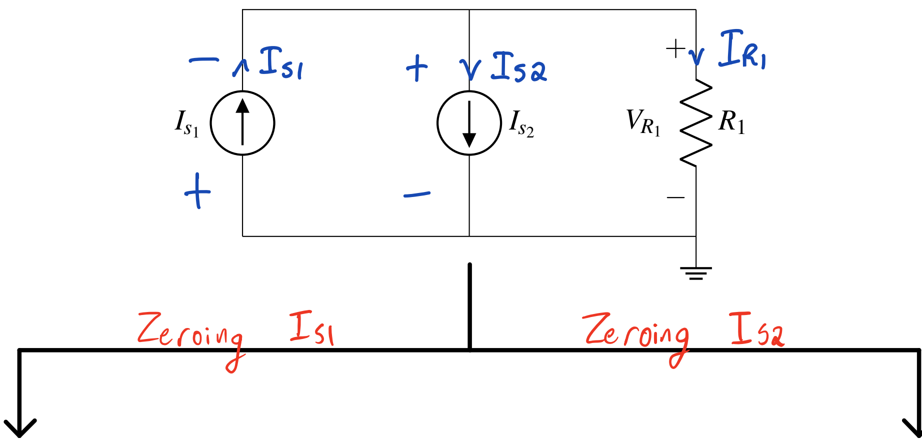
Finally, we superimpose the individual contributions from V_s and I_s to get:

$$V_{R_1} = \frac{R_1}{R_1 + R_2} V_s \quad + \quad V_{R_1} = \frac{R_1 R_2}{R_1 + R_2} I_s$$

$$V_{R_2} = \frac{R_2}{R_1 + R_2} V_s - \frac{R_1 R_2}{R_1 + R_2} I_s$$

$$V_{R_3} = 0 + I_s R_3 = I_s R_3$$

(b)



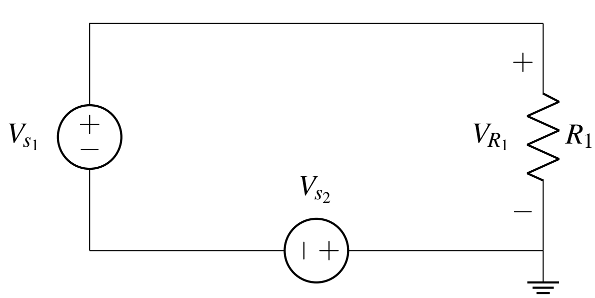
$V_{R1} = -I_{s2} R_1$

$V_{R1} = I_{s1} R_1$

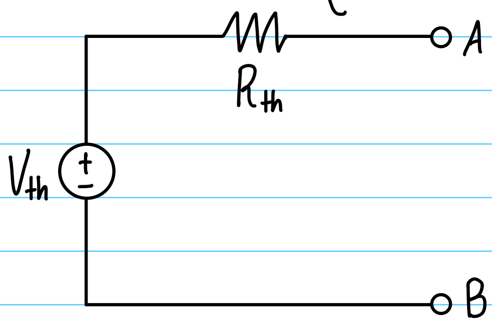
$$V_{R1} = -I_{s2} R_1 + I_{s1} R_1$$

$$V_{R1} = R_1 (I_{s1} - I_{s2})$$

(c) (**PRACTICE**)



Thevenin Equivalent:



To Solve:

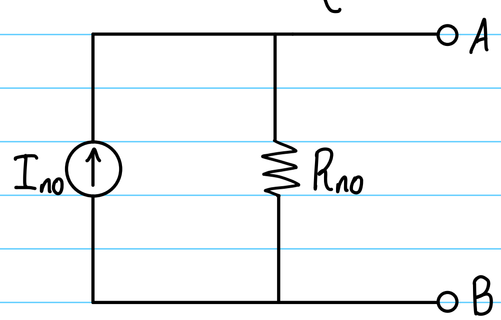
1. Find V_{th} by finding $\underbrace{V_{AB}}_{\text{open circuit voltage}}$ in given circuit

   $V_{th} = V_{ab}$

2. Zero out all independent sources and apply a test current I_{test} through the terminal or V_{test} across it

   $$R_{th} = \frac{V_{test}}{I_{test}}$$

Thevenin Equivalent:



To Solve:

1. Find I_{no} by finding $\underbrace{I_{AB}}_{\text{short circuit current}}$ in given circuit

   $I_{no} = I_{sc}$

2. Zero out all independent sources and apply a test current I_{test} through the terminal or V_{test} across it

   $$R_{th} = \frac{V_{test}}{I_{test}}$$

Note: $R_{th} = R_{no}$

Why do we care?

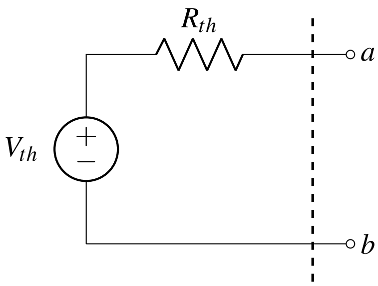
→ We can reduce large, complex circuits to their Thevenin and Norton equivalent with the same output behavior

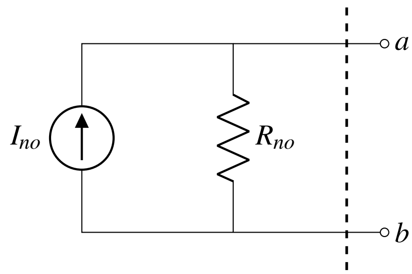
→ saves space, time, money, etc.

→ Drawback: you lose intermediate information

2. Thevenin and Norton Equivalence

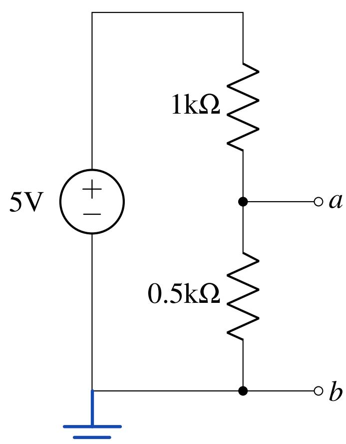
The general Thévenin and Norton equivalent circuits are shown below:





Find the Thévenin and Norton equivalents across terminals *a* and *b* for the circuits given below.

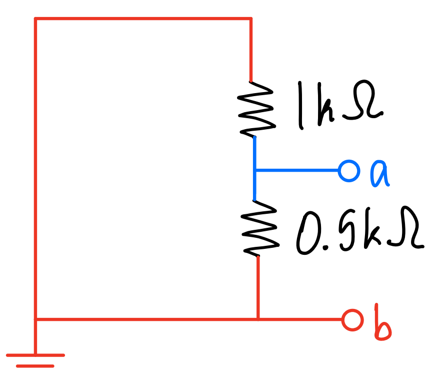
(a)



Voltage Divider!

$$V_{ab} = u_a - u_b = u_a - 0 = u_a = \frac{0.5k\Omega}{1k\Omega + 0.5k\Omega} \cdot 5V = 1.67V$$

To find R_{th}, we must zero out V_s:



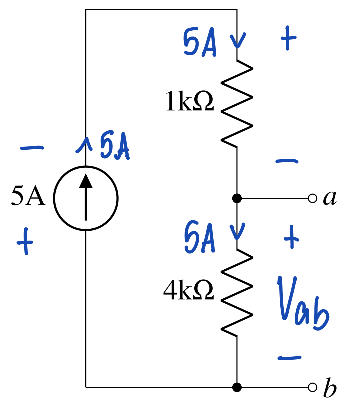
$$R_{th} = 1k\Omega \,||\, 0.5k\Omega$$

$$R_{th} = \frac{1k\Omega \cdot 0.5k\Omega}{1k\Omega + 0.5k\Omega} = 333\,\Omega$$

Since $R_{th} = R_{no}$,

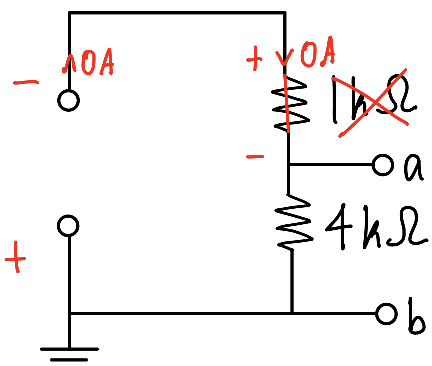
$$I_{no} = \frac{V_{th}}{R_{th}} = \frac{1.67V}{333\Omega} = 5A$$

(b)



All elements are in series
⇒ have the same current flowing through them

By Ohm's Law, $V_{th} = V_{ab} = 5A \cdot 4k\Omega = 20kV$

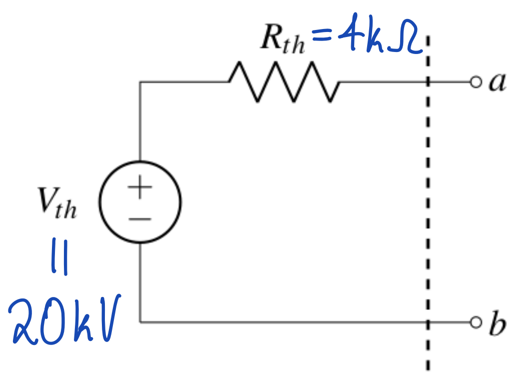


$R_{th} = 4k\Omega$

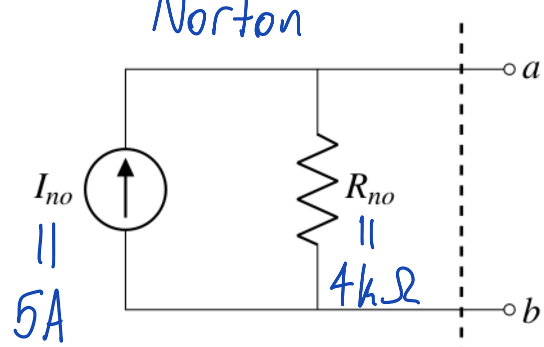
$$I_{no} = \frac{V_{th}}{R_{th}} = \frac{20\cancel{k}V}{4\cancel{k}\Omega} = 5A$$

Simplified Circuits:

Thevenin



Norton



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