# ECE 310 - Lecture 2

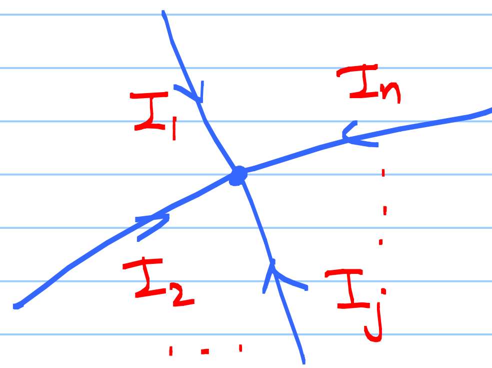
Note Title 8/23/2011

## Basic Circuit Theorems

① Kirchoff's Laws

Kirchoff's current law (KCL) states that the sum of currents flowing into a node is zero.

$$\sum_{j} I_j = 0$$

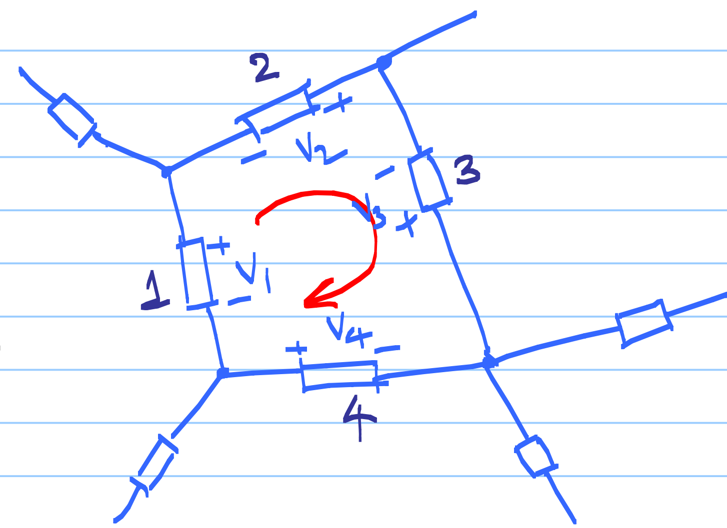


* Kirchoff's Voltage Law (KVL) states that the sum of voltage drops around any closed loop in a circuit is zero.

$$\sum_j V_j = 0$$

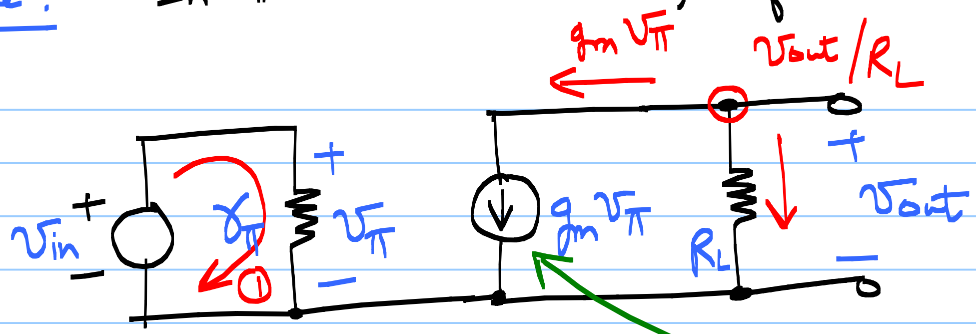
**Trick to apply KVL:**

* Traverse along the loop
* put down the sign you encounter first
* the sum of all voltages in the loop is zero.




$$-V_1 - V_2 - V_3 - V_4 = 0 \Rightarrow V_1 + V_2 + V_3 + V_4 = 0$$

**Example:** In the circuit below, find $\dfrac{v_{out}}{v_{in}}$




voltage controlled current source (VCCS)

* KVL in loop ① ⇒

$$-v_{in} - v_\pi = 0$$

$$\Rightarrow \boxed{v_{in} = v_\pi}$$

* KCL at the output node yields

$$\Rightarrow \quad -g_m v_\pi - \frac{v_{out}}{R_L} = 0$$

−ve sign as the currents are leaving the node

$$\Rightarrow \quad v_{out} = -g_m v_\pi \cdot R_L$$

$$= -g_m R_L \, v_{in} \qquad \because v_\pi = v_{in}$$

$$\Rightarrow \quad \boxed{\frac{v_{out}}{v_{in}} = -g_m R_L}$$

↳ an amplifier $|g_m R_L| > 1$.

↳ -ve sign means that the signal is inverted.

HW: Repeat Textbook examples 1.6 & 1.7

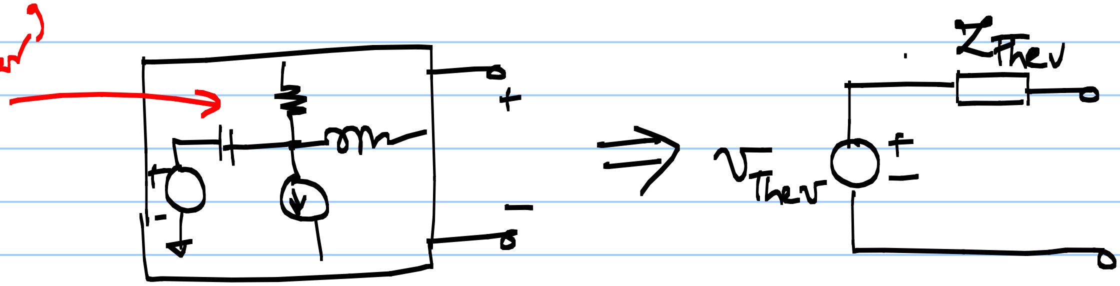
# Thevenin and Norton Equivalents

Thevenin and Norton theorems greatly simplify the algebra and provide insight into the circuit.

Thevenin's Theorem:

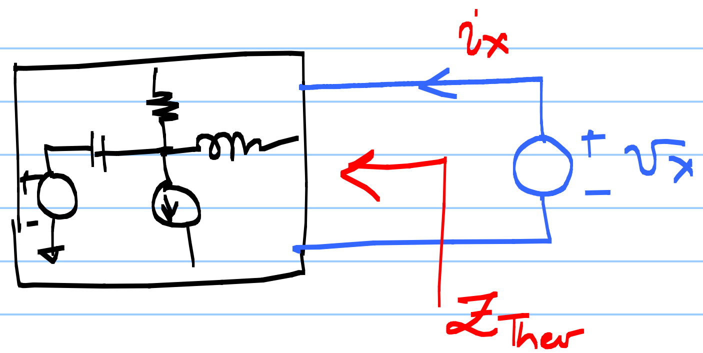
"A linear one-port network can be replaced with an equivalent circuit consisting of one voltage source in series with one impedance".

Any 'linear' 1-port circuit



* The equivalent voltage, $v_{Thev}$, is obtained by leaving the port "open" and computing the voltage created by the actual circuit at this port.

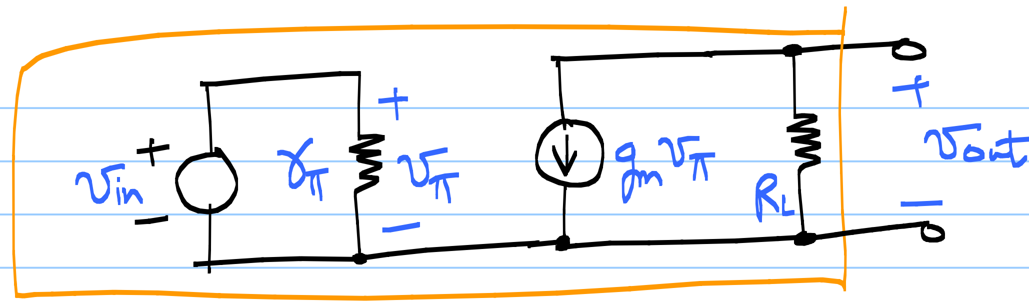
* The equivalent impedance $Z_{Thev}$ is determined by setting all independent voltage and current sources in the circuit to zero and then calculating the impedance between the two nodes

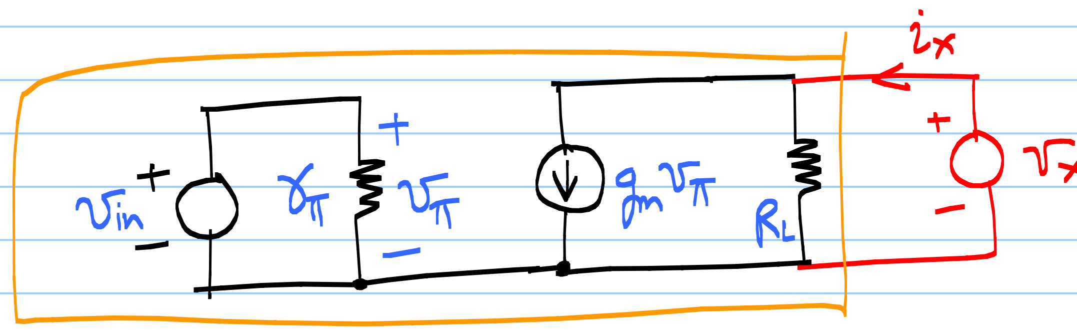



'short' the independent voltage sources
&
'open' the independent current sources

* Careful with dependent sources

Example :




Here, $v_{Thev} = v_{out} = -g_m R_L \cdot v_{in}$

* To calculate $Z_{Thev}$, set $\boxed{v_{in} = 0}$, and apply a test voltage source $v_x$ across the output port

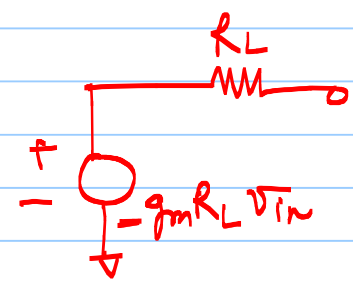
↳ determine the current drawn, $i_x$, at the output port

$\Rightarrow \boxed{v_\pi = 0}$

$\Rightarrow$ impedance at the output port $\Rightarrow R_L$

$$\Rightarrow \quad i_x = \frac{v_x}{R_L}$$

$$\Rightarrow \boxed{R_{Thev} = R_L}$$




← Thevenin Equivalent circuit

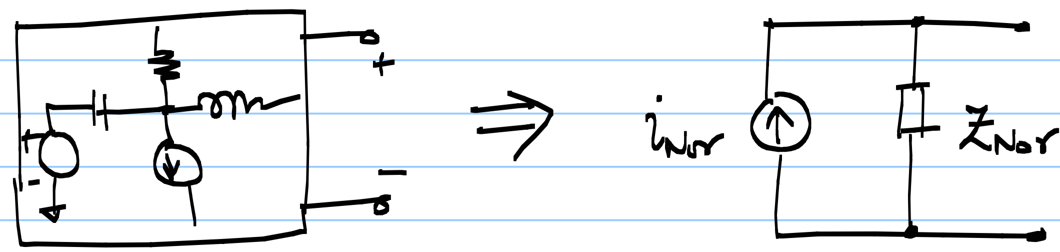
HW: Repeat Textbook Ex. 1.9 & 1.10

# Norton's Theorem :

" A linear one-port network can be represented by one current source in parallel with one impedance".

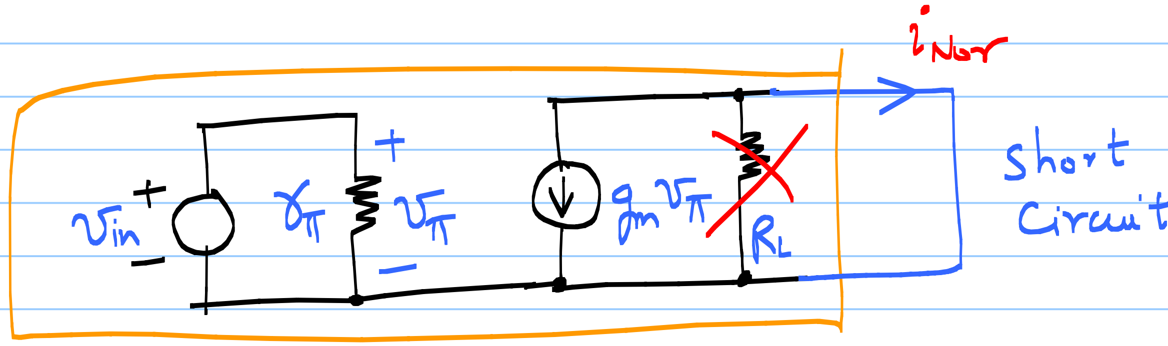
* The equivalent current, $i_{Nor}$, is obtained by shorting the port of interest and computing the current that flows through it.

* The equivalent impedance, $Z_{Nor}$, is found the same way as in Thevenin's theorem.
  ↳ set all independent sources to zero and calculate the impedance at the output port



+
−
$i_{Nor}$
$Z_{Nor}$

**Example** : short the output port and find the short-circuit current, $i_{Nor}$




$\Rightarrow$ due to the short the resistance has no effect

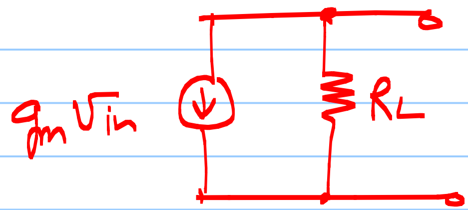
↳ remove it

$\Rightarrow$ KCL at the output node

$\Rightarrow$ $i_{Nor} = -g_m v_\pi = -g_m v_{in}$

* from previous example, $R_{Nor} = R_{Thev} = R_L$

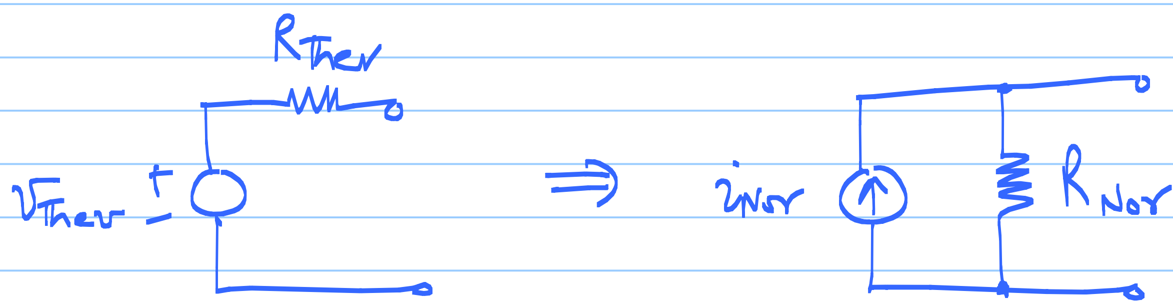
$\Rightarrow$




$\leftarrow$ Norton Equivalent circuit

HW: Repeat Textbook Example 1.12

# Conversion between Thevenin and Norton Circuits




$$i_{Nor} = \frac{v_{Thev}}{R_{Thev}}$$

$$R_{Nor} = R_{Thev}$$