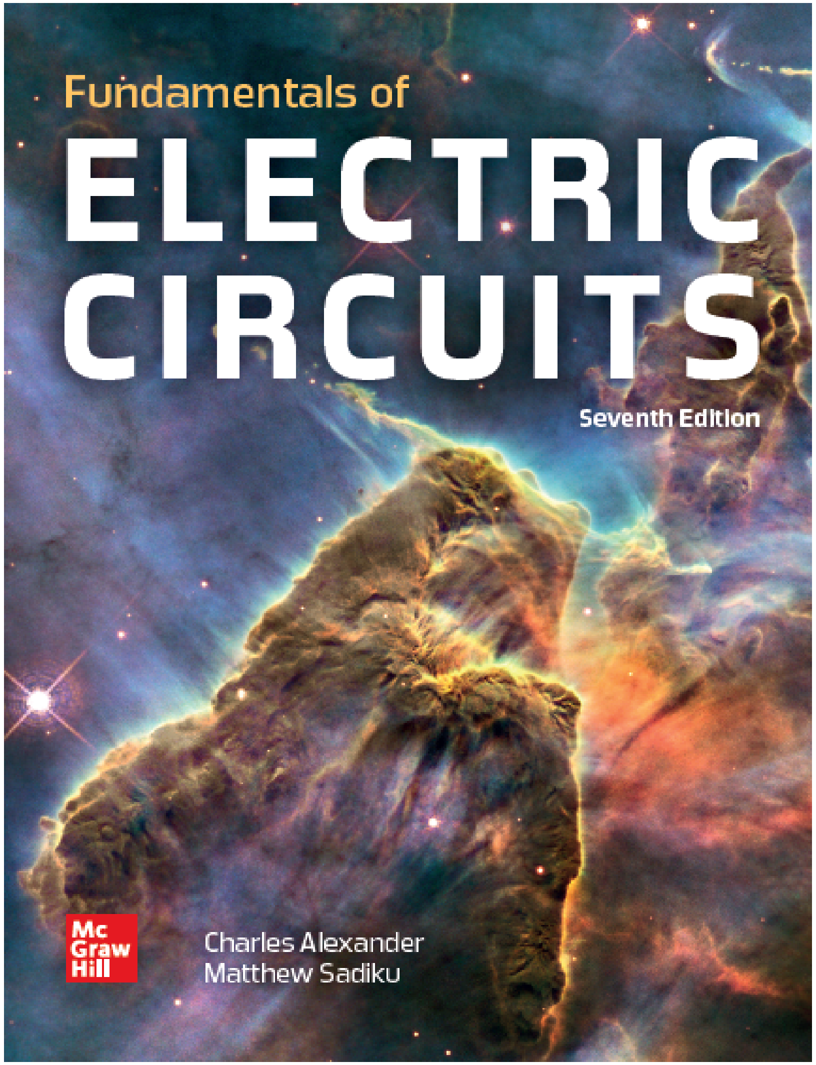
Because learning changes everything.®

Fundamentals of Electric Circuits

Chapter 4



Overview

- In this chapter, the concept of superposition will be introduced.
- Source transformation will also be covered.
- Thevenin and Norton’s theorems will be covered.
- Examples of applications for these concepts will be presented.

Linearity

- Linearity in a circuit means that as current is changed, the voltage changes proportionally.
- It also requires that the response of a circuit to a sum of sources will be the sum of the individual responses from each source separately.
- A resistor satisfies both of these criteria.

Superposition

If there are two or more independent sources there are two ways to solve for the circuit parameters:

- Nodal or mesh analysis.
- Use superposition.

The superposition principle states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone.

Applying Superposition

- Using superposition means applying one independent source at a time.
- Dependent sources are left alone.
- The steps are:

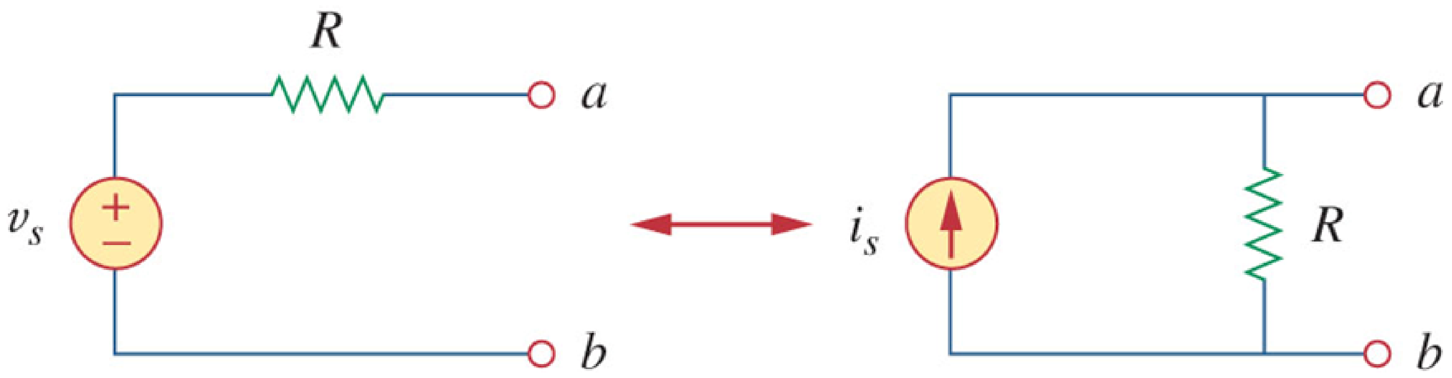
1. Turn off all independent sources except one source. Find the output (voltage or current) due to that active source using the techniques covered in Chapters 2 and 3.
2. Repeat step 1 for each of the other independent sources.
3. Find the total contribution by adding algebraically all the contributions due to the independent sources.

Source Transformation

- Much like the delta-wye transformation, it is possible to transform a source from one form to another.
- This can be useful for simplifying circuits.
- The principle behind all of these transformations is equivalence.

Source Transformation II

- A source transformation is the process of replacing a voltage source v_s in series with a resistor R by a current source i_s in parallel with a resistor R, or vice versa.



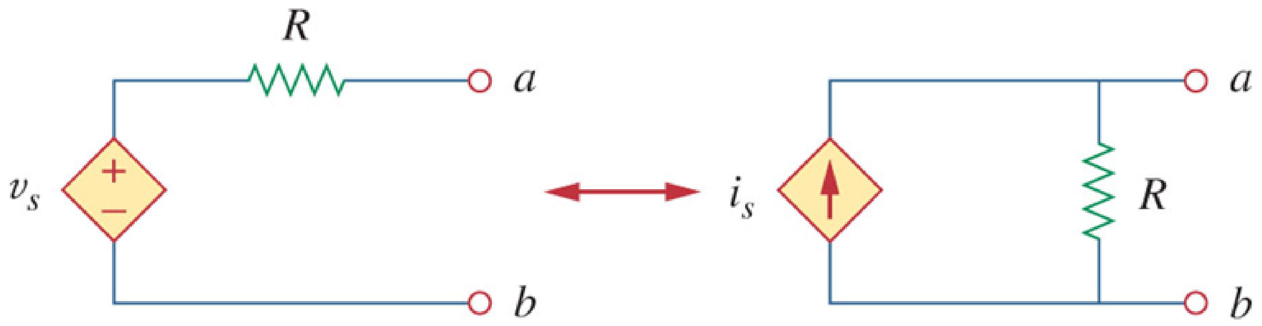
Terminal Equivalency

- These transformations work because the two sources have equivalent behavior at their terminals.
- If the sources are turned off the resistance at the terminals are both R.
- If the terminals are short circuited, the currents need to be the same.
- From this we get the following requirement:

$$v_s = i_s R \quad \text{or} \quad i_s = \frac{v_s}{R}$$

Dependent Sources

- Source transformation also applies to dependent sources.
- But, the dependent variable must be handled carefully.
- The same relationship between the voltage and current holds here:



Source transformation rules

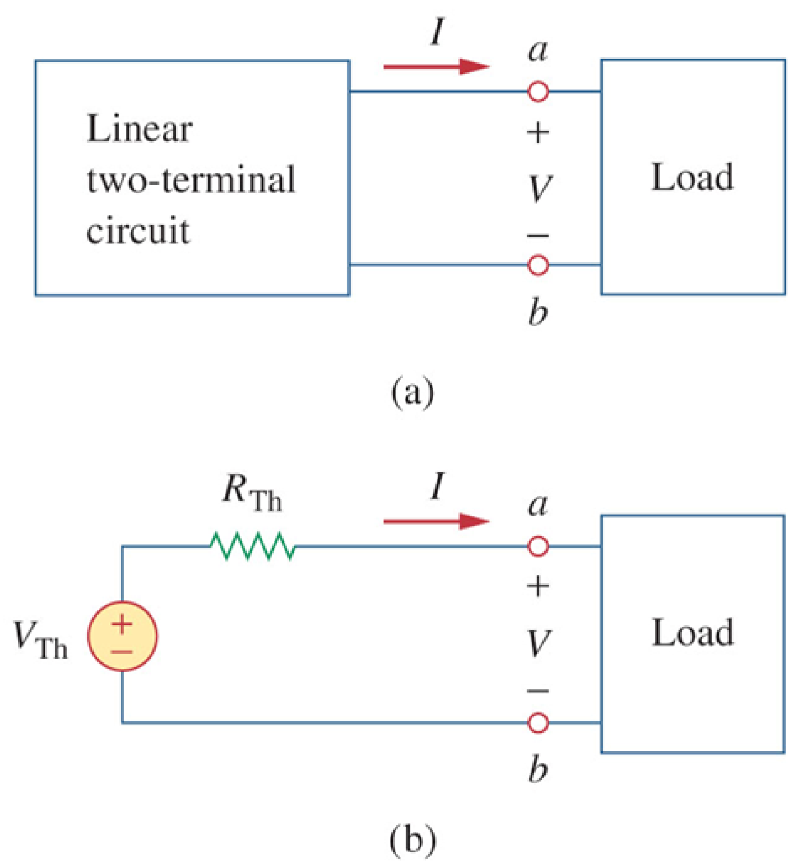
- Note that the arrow of the current source is directed towards the positive terminal of the voltage source.
- Source transformation is not possible when R = 0 for an ideal voltage source.
- For a realistic source, $R \neq 0$.
- For an ideal current source, $R = \infty$ also prevents the use of source transformation.

Thevenin’s Theorem

- In many circuits, one element will be variable.
- An example of this is mains power; many different appliances may be plugged into the outlet, each presenting a different resistance.
- This variable element is called the load.
- Ordinarily one would have to reanalyze the circuit for each change in the load.

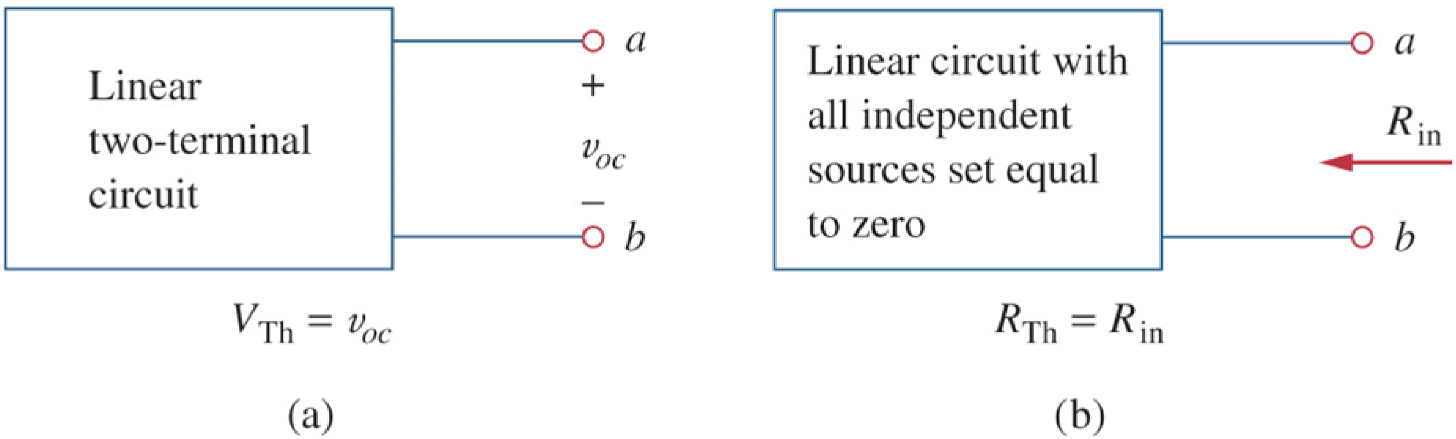
Thevenin's Theorem II

- Thevenin's theorem states that a linear two terminal circuit may be replaced with a voltage source and resistor.
- The voltage source's value is equal to the open circuit voltage at the terminals.
- The resistance is equal to the resistance measured at the terminals when the independent sources are turned off.



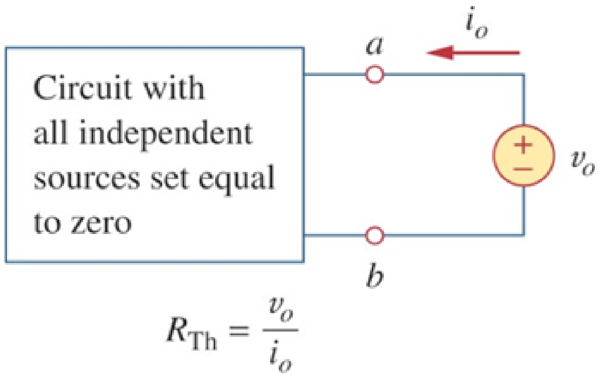
Thevenin's Theorem III

- There are two cases to consider when finding the equivalent resistance.
- Case 1: If there are no dependent sources, then the resistance may be found by simply turning off all the sources.

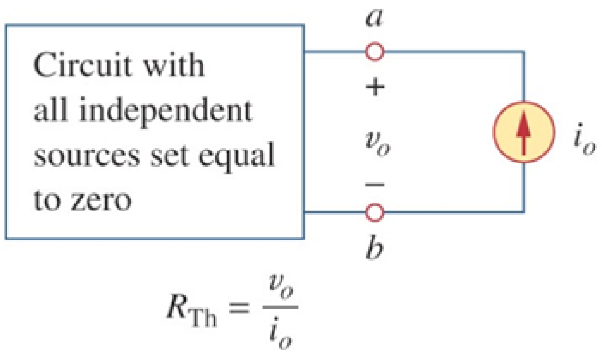


Thevenin's Theorem IV

- Case 2: If there are dependent sources, we still turn off all the independent sources.
- Now apply a voltage v_0 (or current i_0)to the terminals and determine the current i_0 (voltage v_0).



(a)



(b)

Thevenin’s Theorem V

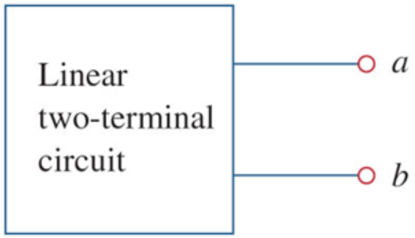
- Thevenin’s theorem is very powerful in circuit analysis.
- It allows one to simplify a circuit.
- A large circuit may be replaced by a single independent voltage source and a single resistor.
- The equivalent circuit behaves externally exactly the same as the original circuit.

Negative Resistance?

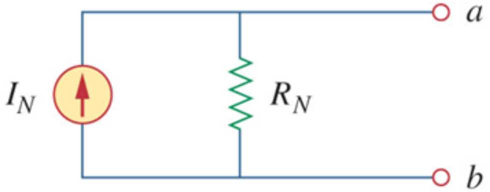
- It is possible for the result of this analysis to end up with a negative resistance.
- This implies the circuit is supplying power.
- This is reasonable with dependent sources.
- Note that in the end, the Thevenin equivalent makes working with variable loads much easier.
- Load current can be calculated with a voltage source and two series resistors.
- Load voltages use the voltage divider rule.

Norton’s Theorem

- Similar to Thevenin’s theorem, Norton’s theorem states that a linear two terminal circuit may be replaced with an equivalent circuit containing a resistor and a current source.
- The Norton resistance will be exactly the same as the Thevenin.



(a)

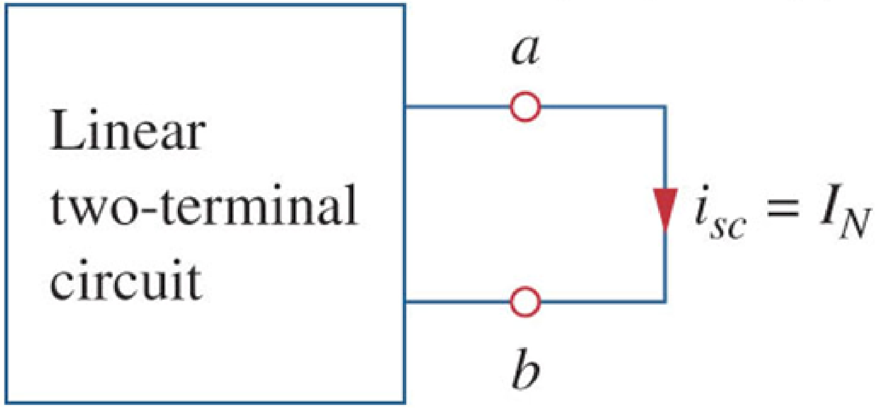


(b)

Norton's Theorem II

- The Norton current I_N is found by short circuiting the circuit's terminals and measuring the resulting current.

$$I_N = i_{sc}$$



Norton versus Thevenin

- These two equivalent circuits can be related to each other.
- One need only look at source transformation to understand this.
- The Norton current and Thevein voltage are related to each other as follows:

$$I_N = \frac{V_{Th}}{R_{Th}}$$

Norton versus Thevenin II

- With V_{TH}, I_N, and (R_{TH}=R_N) related, finding the Thevenin or Norton equivalent circuit requires that we find:
- The open-circuit voltage across terminals *a and b*.
- The short-circuit current at terminals *a and b*.
- The equivalent or input resistance at terminals *a and b when* all independent sources are turned off.

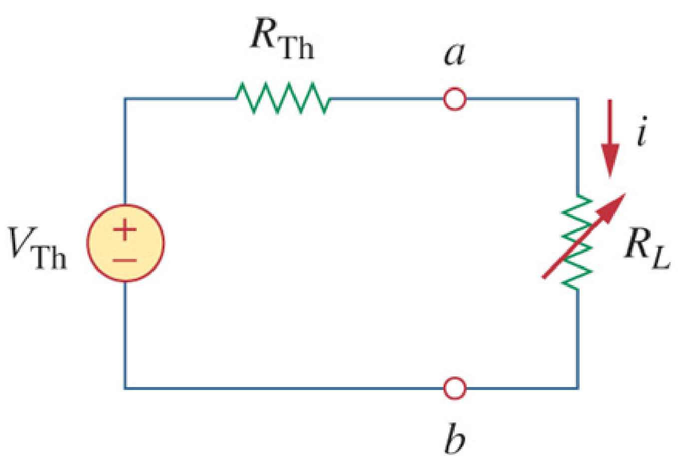
Maximum Power Transfer

- In many applications, a circuit is designed to power a load.
- Among those applications there are many cases where we wish to maximize the power transferred to the load.
- Unlike an ideal source, internal resistance will restrict the conditions where maximum power is transferred.

Maximum Power Transfer II

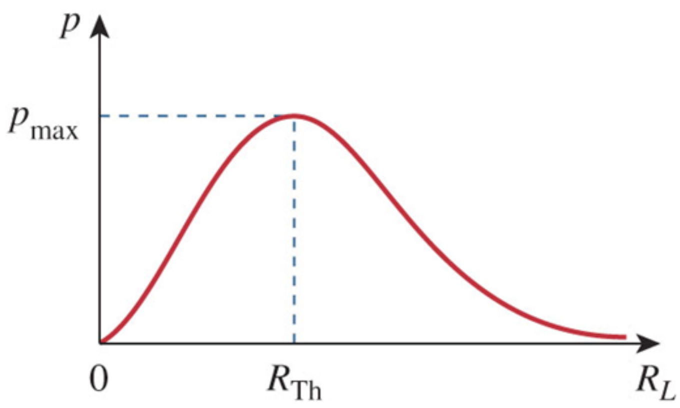
- We can use the Thevenin equivalent circuit for finding the maximum power in a linear circuit.
- We will assume that the load resistance can be varied
- Looking at the equivalent circuit with load included, the power transferred is:

$$p = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L$$



Maximum Power Transfer III

- For a given circuit, V_{TH} and R_{TH} are fixed. By varying the load resistance R_L, the power delivered to the load varies as shown.
- You can see that as R_L approaches 0 and ∞ the power transferred goes to zero.
- In fact the maximum power transferred is when $R_L = R_{TH}$.

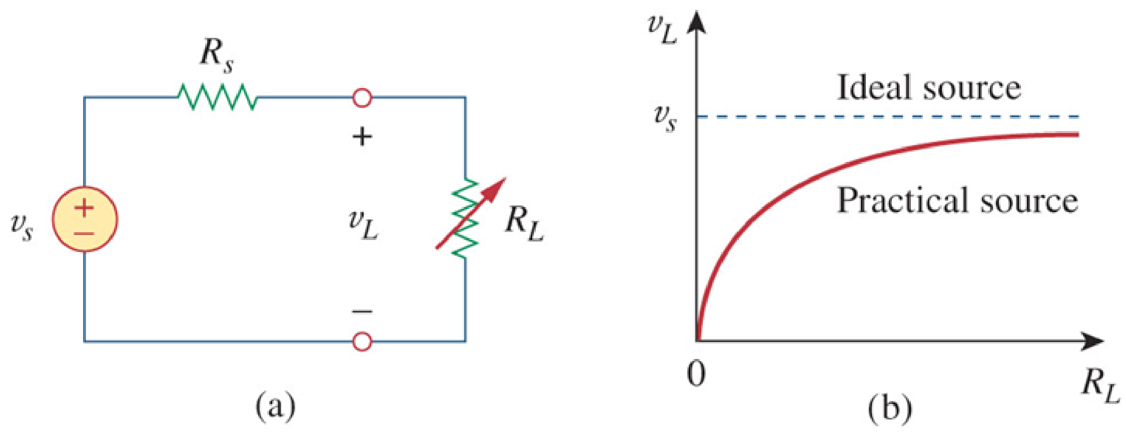


Pspice?

- The Thevenin and Norton equivalent circuits are useful in understanding the behavior of realistic sources.
- Ideal voltage sources have no internal resistance.
- Ideal current sources have infinite internal resistance.
- The Thevenin and Norton circuits introduce deviations from these ideals.

Source Modeling

- Take the Thevenin circuit with load resistor:
- The internal resistor and the load act a voltage divider.
- The lower the load resistance, the more voltage drop that occurs in the source.

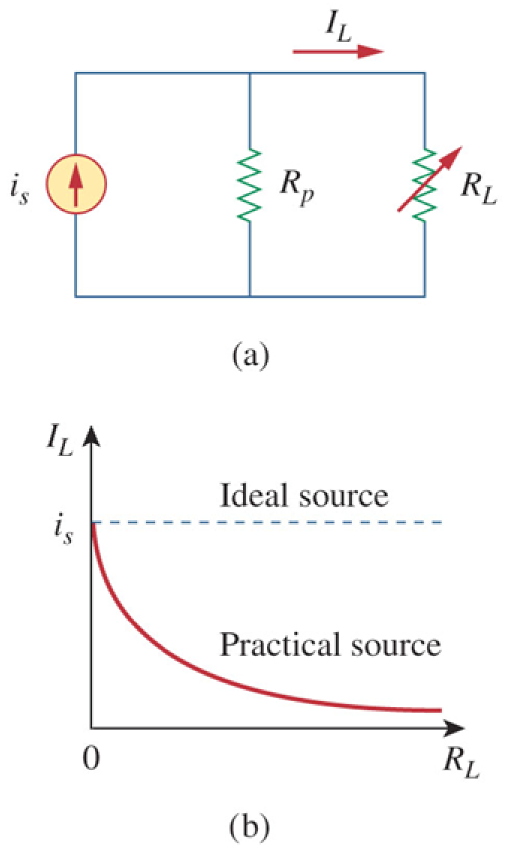


Source Modeling II

- This means that as the load resistance. increases, the voltage source comes closer to operating like the ideal source.
- Similarly, with a realistic current source, the internal resistor in parallel with the ideal source acts to siphon away current that would otherwise go to the load.

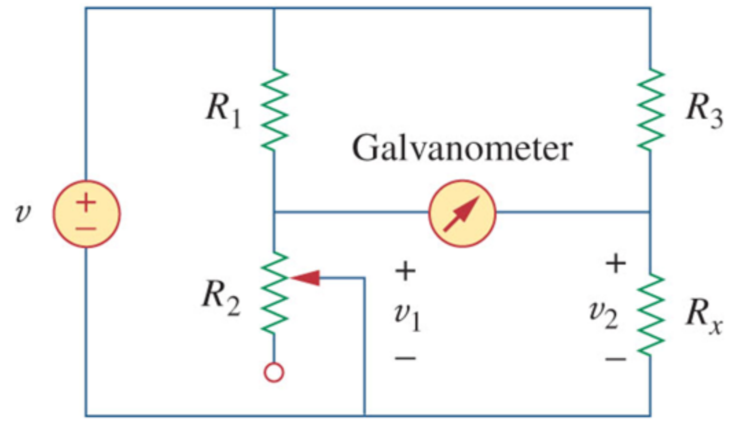
Source Modeling III

- Here, the load and the internal resistor act as a current divider.
- From that perspective, the lower the load resistance, the more current passes through it.
- Thus lower load resistance leads to behavior closer to the ideal source.



Resistance Measurement [1]

- Although the ohmmeter is the most common method for measuring resistance, there is a more accurate method.
- It is called the Wheatstone bridge.
- It is based on the principle of the voltage divider.



Resistance Measurement 2

- Using three known resistors and a galvanometer, an unknown resistor can be tested.
- The unknown resistor is placed at the position $R_{4.}$
- The variable resistor R_2 is adjusted until the galvanometer shows zero current.
- At this point, the bridge is “balanced” and the voltages from the two dividers are equal.

Balanced Bridge

- When balanced, the unknown resistor's value is.

$$R_x = \frac{R_3}{R_1} R_2$$

- The key to the high accuracy lies in the fact that any slight difference in the voltage dividers will lead to a current flow.

$$I = \frac{V_{Th}}{R_{Th} + R_m}$$

- Where the bridge, less the unknown resistor, is reduced to its Thevenin equivalent.

End of Main Content

Because learning changes everything.®

www.mheducation.com