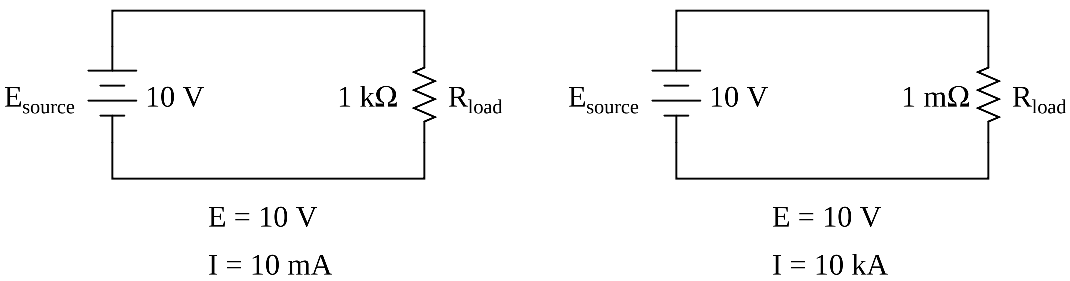
Question 2

A *voltage source* is a source of electricity that (ideally) outputs a constant voltage. That is, a perfect voltage source will hold its output voltage constant regardless of the load imposed upon it:

*Ideal voltage sources assumed*




In real life, there is no such thing as a perfect voltage source, but sources having extremely low internal resistance come close.

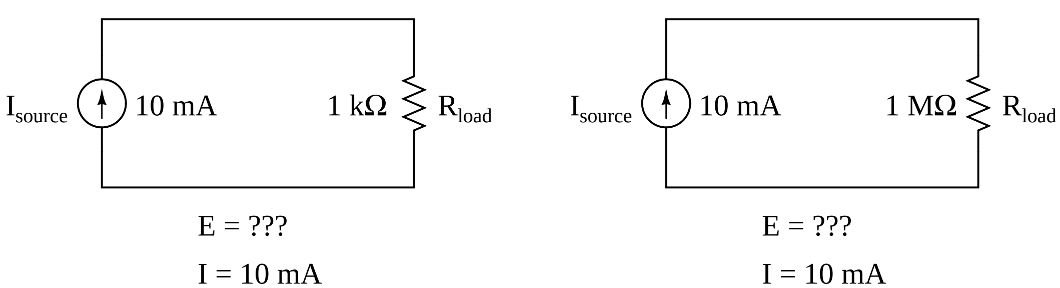
Another type of electricity source is the *current source*, which (ideally) outputs a constant current regardless of the load imposed upon it. A common symbol for a current source is a circle with an arrow inside (always pointing in the direction of conventional flow, not electron flow!). Another symbol is two intersecting circles, with an arrow nearby pointing in the direction of conventional flow:

*Current sources*



Predict how an ideal current source would behave for the following two load scenarios:

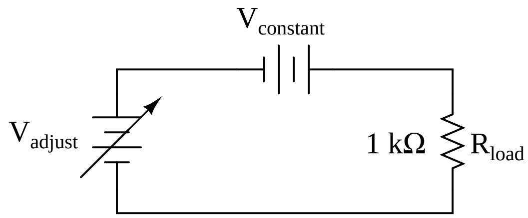
*Ideal current sources assumed*




file 01735

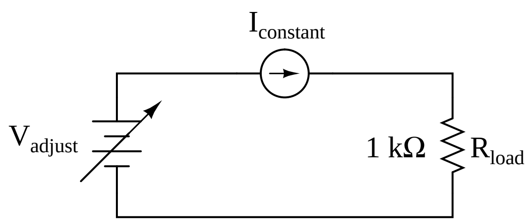
Question 7

In the following circuit, an adjustable voltage source is connected in series with a resistive load and another voltage source:




Determine what will happen to the current in this circuit if the adjustable voltage source is increased.

In this next circuit, an adjustable voltage source is connected in series with a resistive load and a *current* source:




Now determine what will happen to the current in this second circuit if the adjustable voltage source is increased.

One way to define electrical resistance is by comparing the *change* in applied voltage ($\Delta V$) to the *change* in resultant current ($\Delta I$). This is mathematically expressed by the following ratio:

$$R = \frac{\Delta V}{\Delta I}$$

From the perspective of the adjustable voltage source ($V_{adjust}$), and as defined by the above equation, which of these two circuits has the greatest resistance? What does this result suggest about the equivalent resistance of a constant-voltage source versus the equivalent resistance of a constant-current source?

file 03224

Question 10

Electrochemical batteries are supposed to act as constant voltage sources, outputting an unchanging voltage for a wide range of load currents. The output voltage of real batteries, though, always "sags" to some degree under the influence of a load.

Explain why this is so, in terms of modeling the battery as an ideal voltage source combined with a resistance. How do you suggest the internal resistance of a chemical battery be experimentally measured?

file 03223

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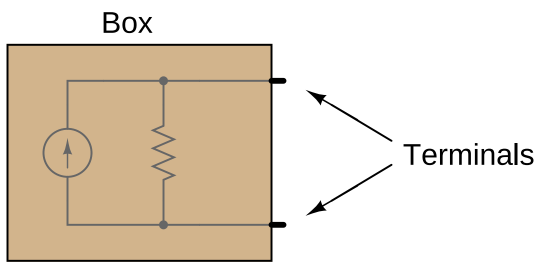
Question 11

Suppose you were handed a black box with two metal terminals on one side, for attaching electrical (wire) connections. Inside this box, you were told, was a current source (an ideal current source connected in parallel with a resistance):

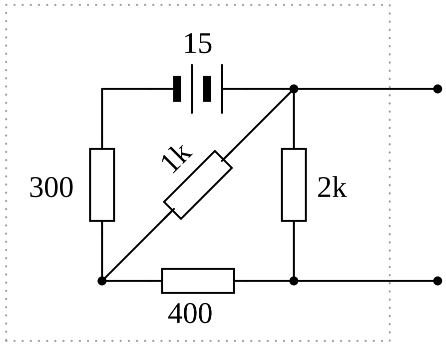



How would you experimentally determine the current of the ideal current source inside this box, and how would you experimentally determine the resistance of the parallel resistor? By "experimentally," I mean determine current and resistance using actual test equipment rather than assuming certain component values (remember, this "black box" is sealed, so you cannot look inside!).

file 01038

Question 28

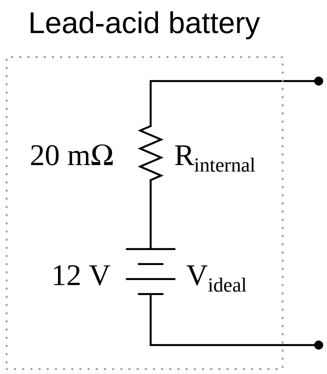
Thévenize this resistive network:




file 04047

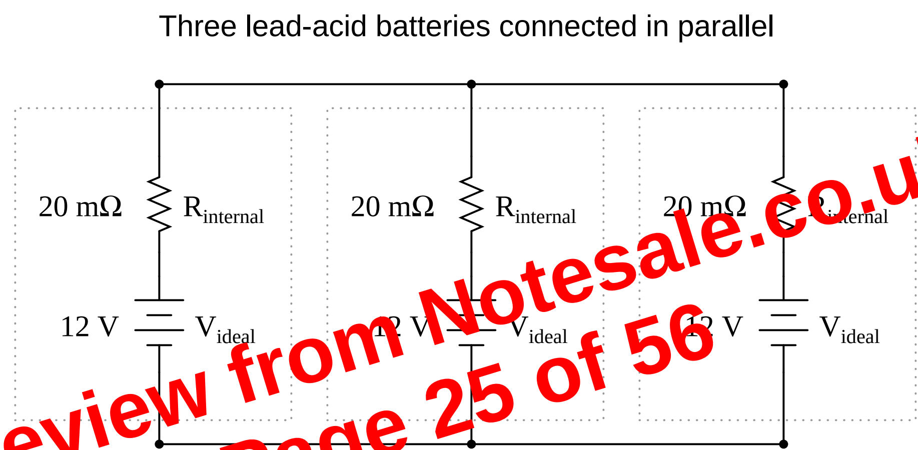
Question 29

Suppose a 12 volt lead-acid battery has an internal resistance of 20 milli-ohms (20 mΩ):




If a short-circuit were placed across the terminals of this large battery, the fault current would be quite large: 600 amps!

Now suppose three of these batteries were connected directly in parallel with one another:



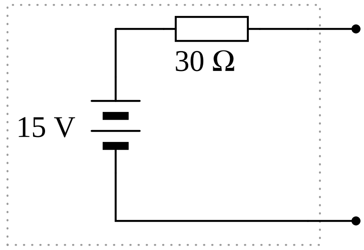



Reduce this network of parallel-connected batteries into either a Thévenin or a Norton equivalent circuit, and then re-calculate the fault current available at the terminals of the three-battery "bank" in the event of a direct short-circuit.

file 03243

Question 30

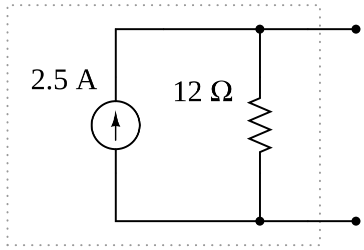
Convert the following Thévenin equivalent circuit into a Norton equivalent circuit:




file 03240

Question 31

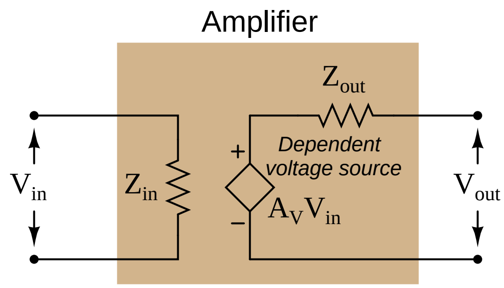
Convert the following Norton equivalent circuit into a Thévenin equivalent circuit:



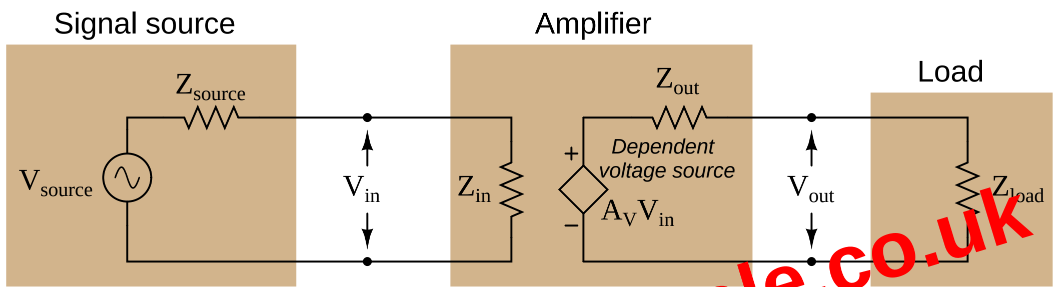

file 02030

Question 45

Sometimes you will see amplifier circuits expressed as collections of *impedances* and *dependent sources*:



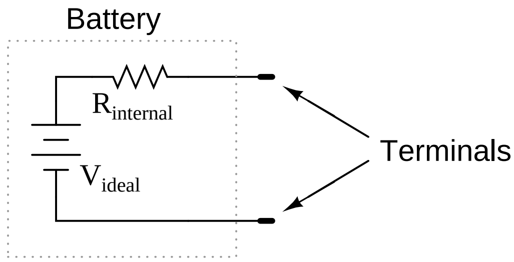

With this model, the amplifier appears as a load ($Z_{in}$) to whatever signal source its input is connected to, boosts that input voltage by the gain factor ($A_V$), then outputs the boosted signal through a series output impedance ($Z_{out}$) to whatever load is connected to the output terminals:




Explain why all these impedances (shown as resistors) are significant to us as we seek to apply amplifier circuits to practical applications. Which of these impedances do you suppose are typically easier for us to change, if they require changing at all?

file 02236

Answer 10




I'll let you figure out how to measure this internal resistance!

Answer 11

Measure the open-circuit voltage between the two terminals, and then measure the short-circuit current. The current source's value is measured, while the resistor's value is calculated using Ohm's Law.

Answer 12

With equal $V_{OC}$ and $I_{SC}$ figures and with linear componentry, the load lines must be identical. This means that *any* load resistance, when connected to each of the power sources, will experience the exact same voltage and current.

Answer 13

A good way to demonstrate the electrical equivalence of these circuits is to calculate their responses to identical load resistor values. The equivalence you see here is an application of *Thévenin's Theorem*.

Answer 14

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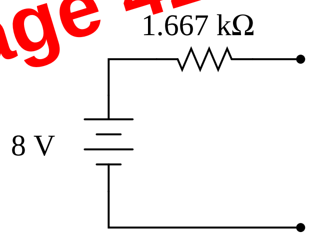
Answer 15






Follow-up question: is this circuit truly equivalent to the original shown in the question? Sure, it responds the same under extreme conditions (open-circuit and short-circuit), but will it respond the same as the original circuit under modest load conditions (say, with a 5 kΩ resistor connected across the load terminals)?

Notes 25

I really mean what I say here about looking this up in a textbook. Norton's Theorem is a very well-covered subject in many books, and so it is perfectly reasonable to expect students will do this research on their own and come back to class with a complete answer.

The follow-up question is very important, because some circuits (especially transistor amplifier circuits) contain *both* types of sources. Knowing how to consider each one in the process of calculating the Norton equivalent resistance for a circuit is very important. When performing this analysis on transistor amplifiers, the circuit often becomes much simpler than its original form with all the voltage sources shorted and current sources opened!

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Notes 26

Ask your students to show how (step-by-step) they arrived at the equivalent circuit, prior to calculating load voltage.

In case students are unfamiliar with the "double-chevron" symbols in the schematic diagram, let them know that these represent male/female connector pairs.

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Notes 27

Ask your students to show how (step-by-step) they arrived at the equivalent circuit, prior to calculating load voltage.

In case students are unfamiliar with the "double-chevron" symbols in the schematic diagram, let them know that these represent male/female connector pairs.

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Notes 28

Nothing but practice here. Have your students demonstrate how they did the Thévenin conversion, step-by-step.

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Notes 29

Ask your students whether they used Thévenin's Theorem or Norton's theorem to solve for the fault current. Have students demonstrate the analysis both ways to see which is easiest to understand.



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Notes 30

Nothing special here, just practice converting between Thevenin and Norton sources. Be sure to ask your students to explain all their steps and reasoning in arriving at the answer.

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Notes 31

Nothing special here, just practice converting between Thevenin and Norton sources. Be sure to ask your students to explain all their steps and reasoning in arriving at the answer.

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Notes 32

This question is not so much a practical one as it is designed to get students to think a little deeper about the differences between ideal voltage and current sources. In other words, it focuses on concepts rather than application.