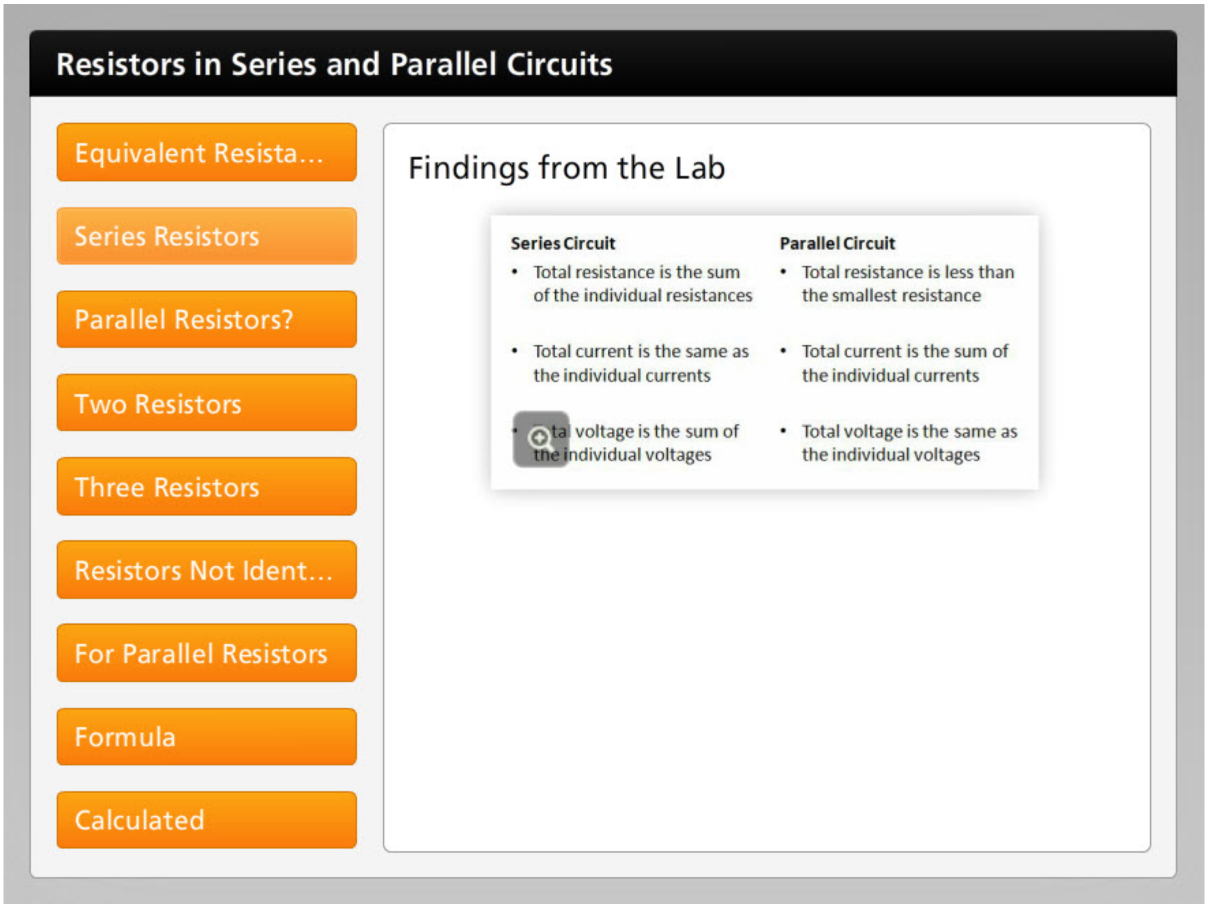
Module 7: Electricity- Electric Charge and Current

Topic 4 Content: Resistors in Series and Parallel Circuits Presentation Notes



In the lab you found the total resistance of each circuit experimentally by using Ohm's Law, R equals V over I. When you compared this total resistance to the individual values, you should have noted differences between the series and parallel circuits. Note that the word total is used to refer to the value for the entire circuit. Those differences are summarized here.

For a series circuit, the total resistance is the sum of the individual resistances. The total current is the same as the individual currents. The total voltage is the sum of the individual voltages.

For a parallel circuit, the relationship between the individual resistances and the total resistance is more complex. The total resistance calculated using Ohm's Law was less than the value of the smallest resistor in the group. The total resistance for parallel resistors is not the sum of the individual values. The total current is the sum of the individual currents. The total voltage is the same as the individual voltages.

Now that you have observed how these circuits function using the simulation you will learn how to analyze circuits mathematically. Your knowledge of how series and parallel circuits behave will help you understand your results.

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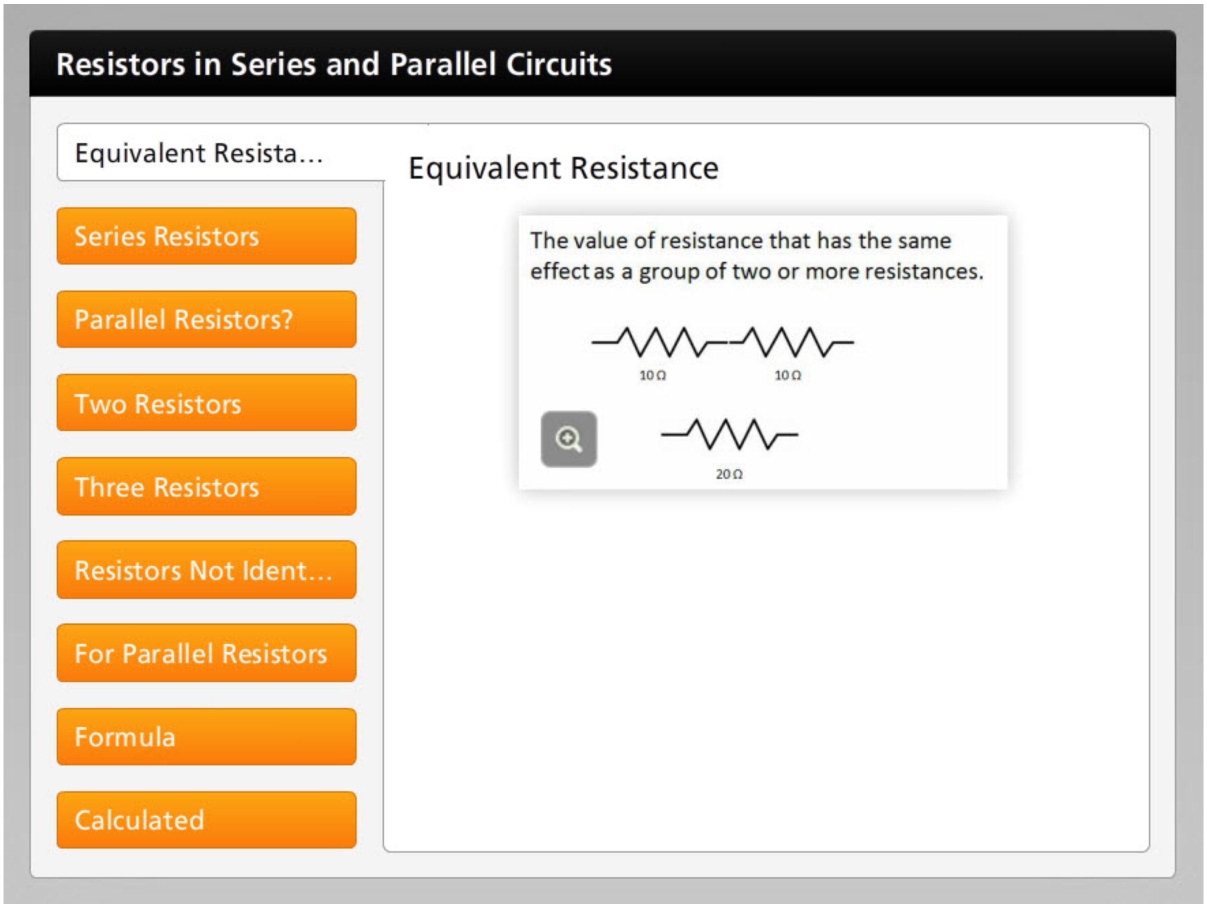
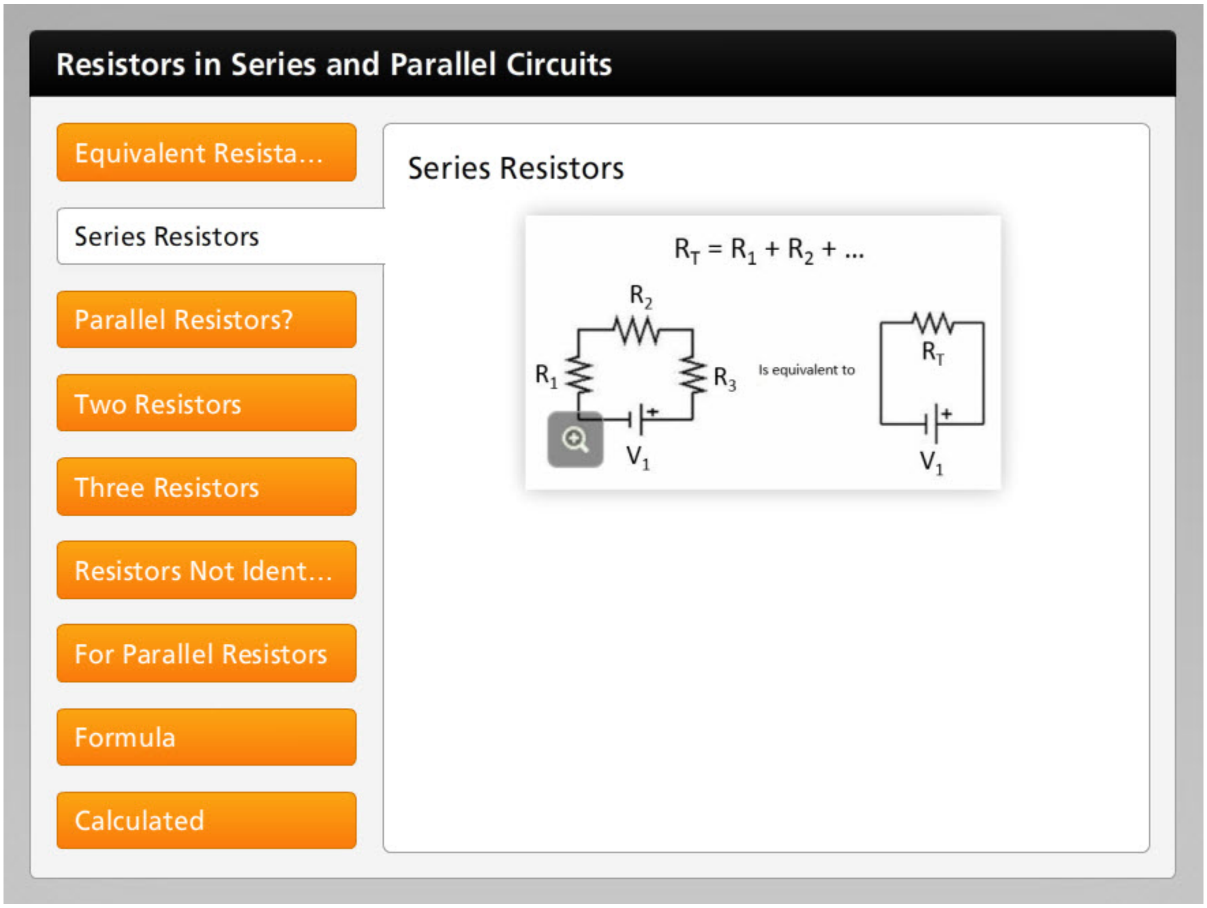


It will be easier to analyze circuits when you simplify complicate arrangements of resistors. To do this, you will use equivalent resistance. The equivalent resistance is a value of resistance that has the same effect as a group of two or more resistances.

For example, if two ten ohm resistors are put in series, this is equivalent to one twenty ohm resistor. Resistances in series are added to find the equivalent resistance.



You can replace two or more series resistors in a circuit with one resistor that has a resistance equal to the sum of the individual resistances. In the equation, the ellipses are uses to remind you that you can include as many terms as you have resistors in series.

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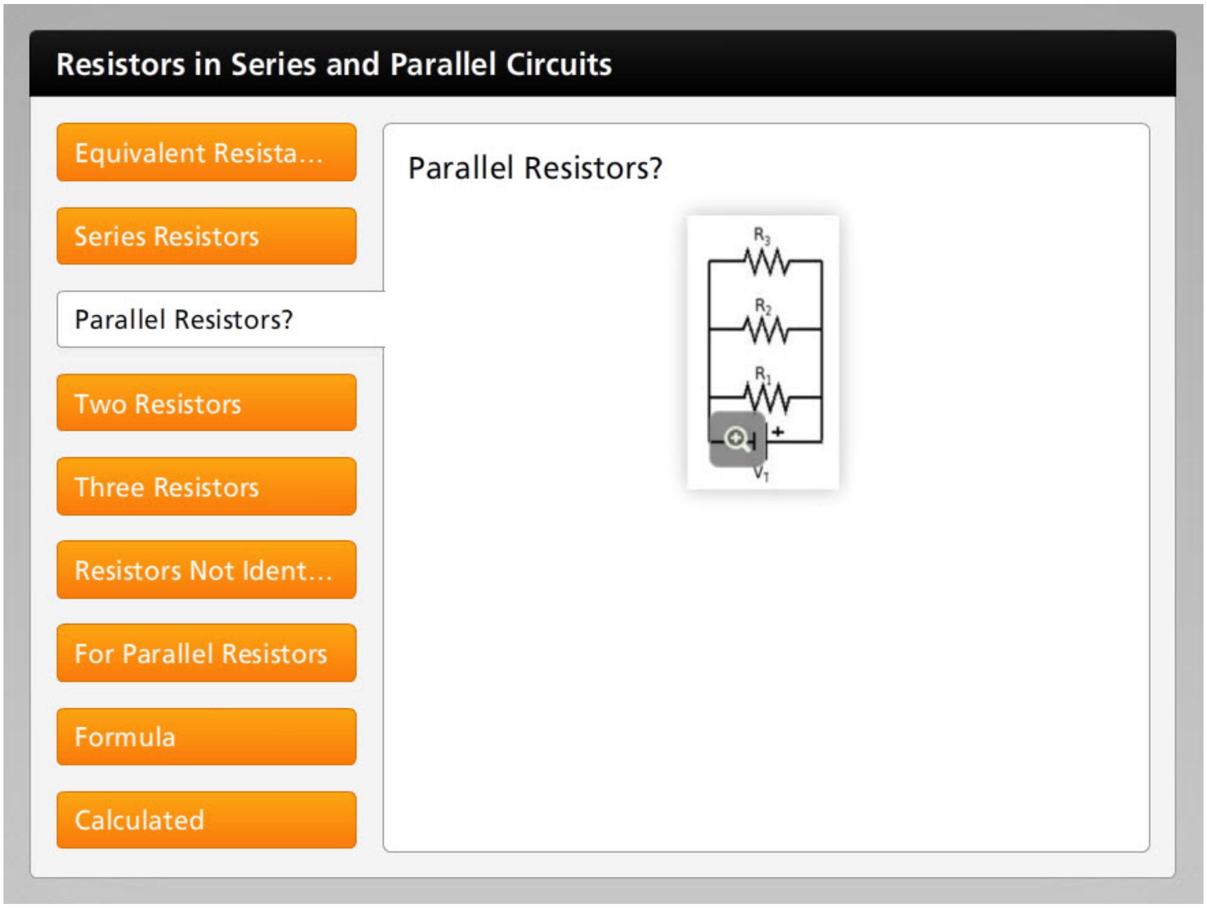
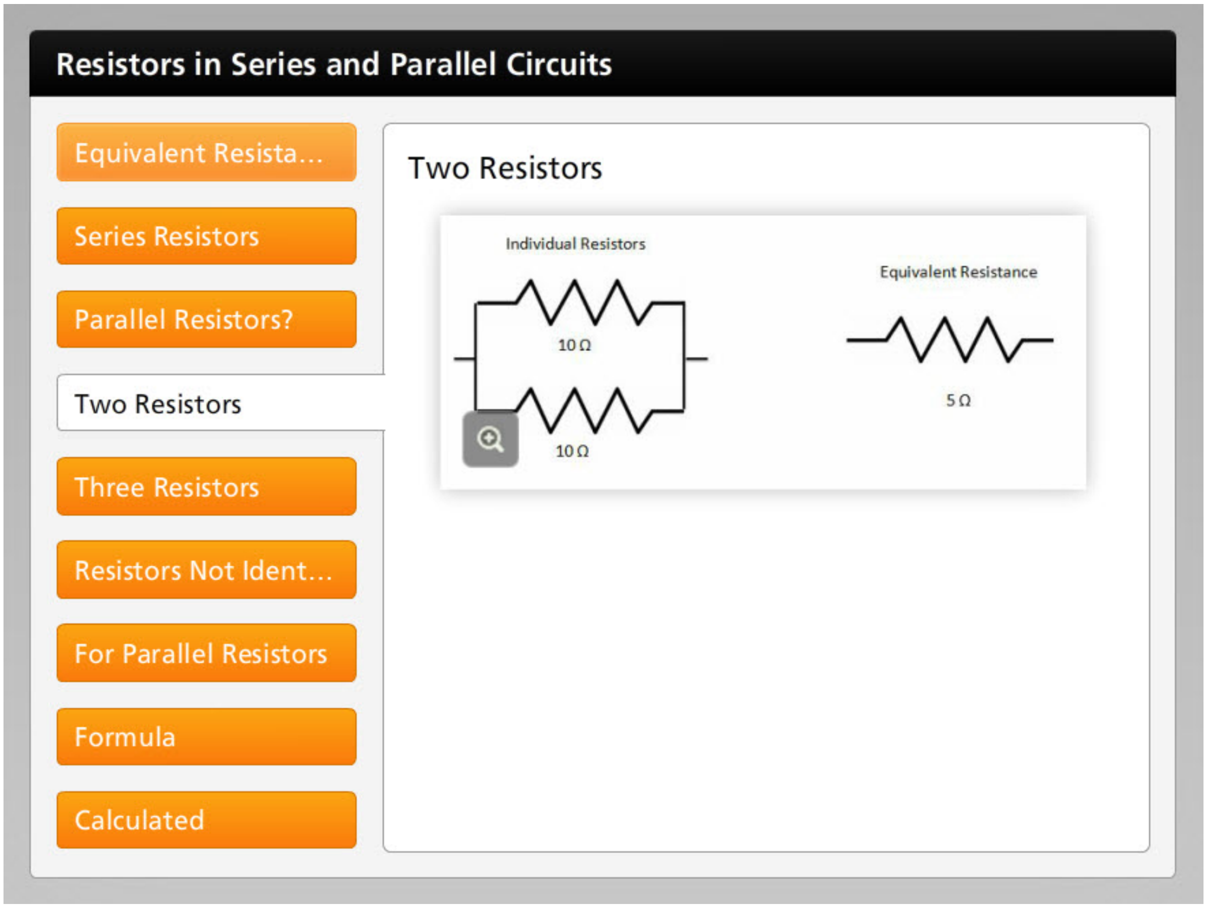


Series resistors are pretty simple, you can just add the resistance values. But what about parallel resistors? Let's look at some examples to see what happens when you add resistors in parallel.



If two ten ohm resistors in are put in parallel, this is equivalent to one five ohm resistor. The area for current flow has been doubled, which cuts the resistance in half.

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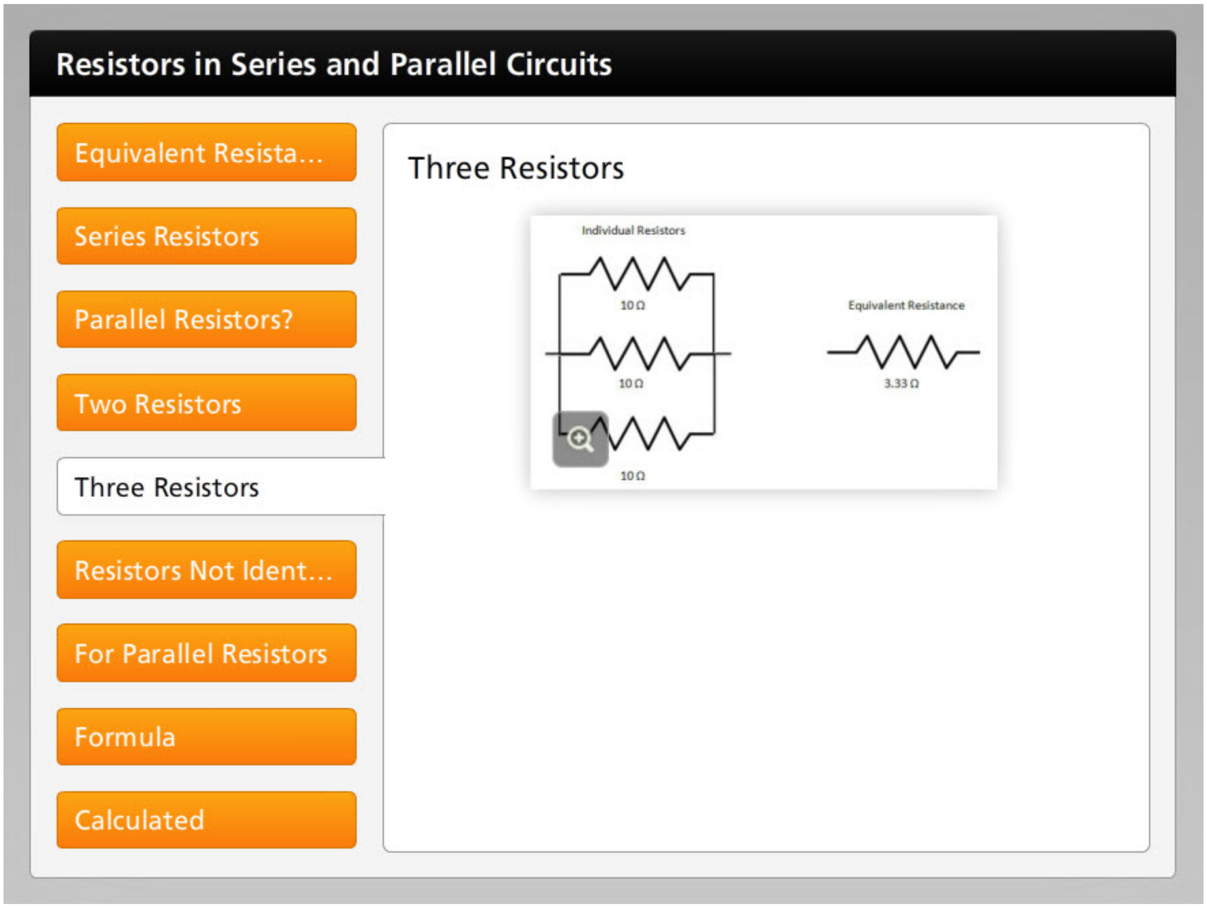
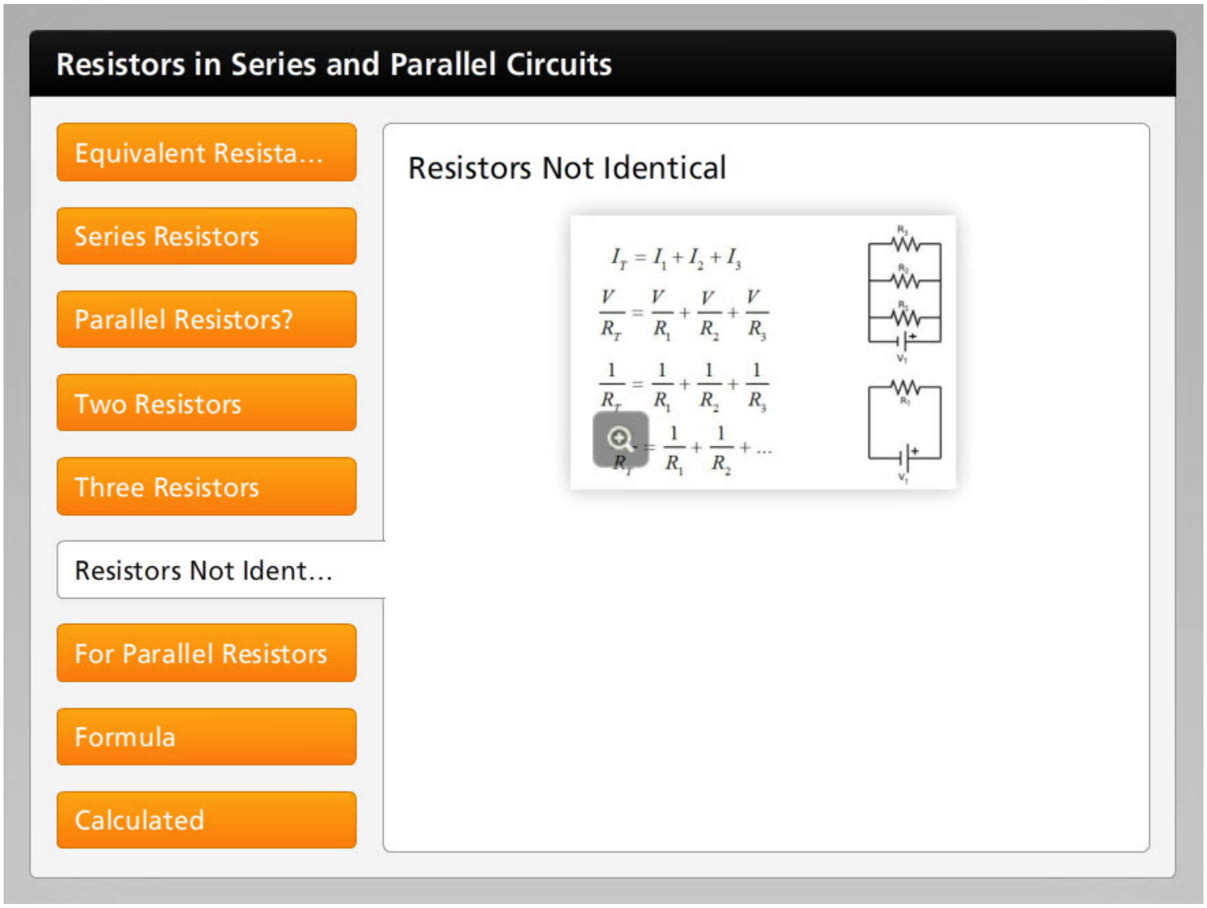


If the three ten ohm resistors in are put in parallel, this is equivalent to one three point three ohm resistor. The area for current flow has been tripled, which cuts the resistance to one-third of its original value.

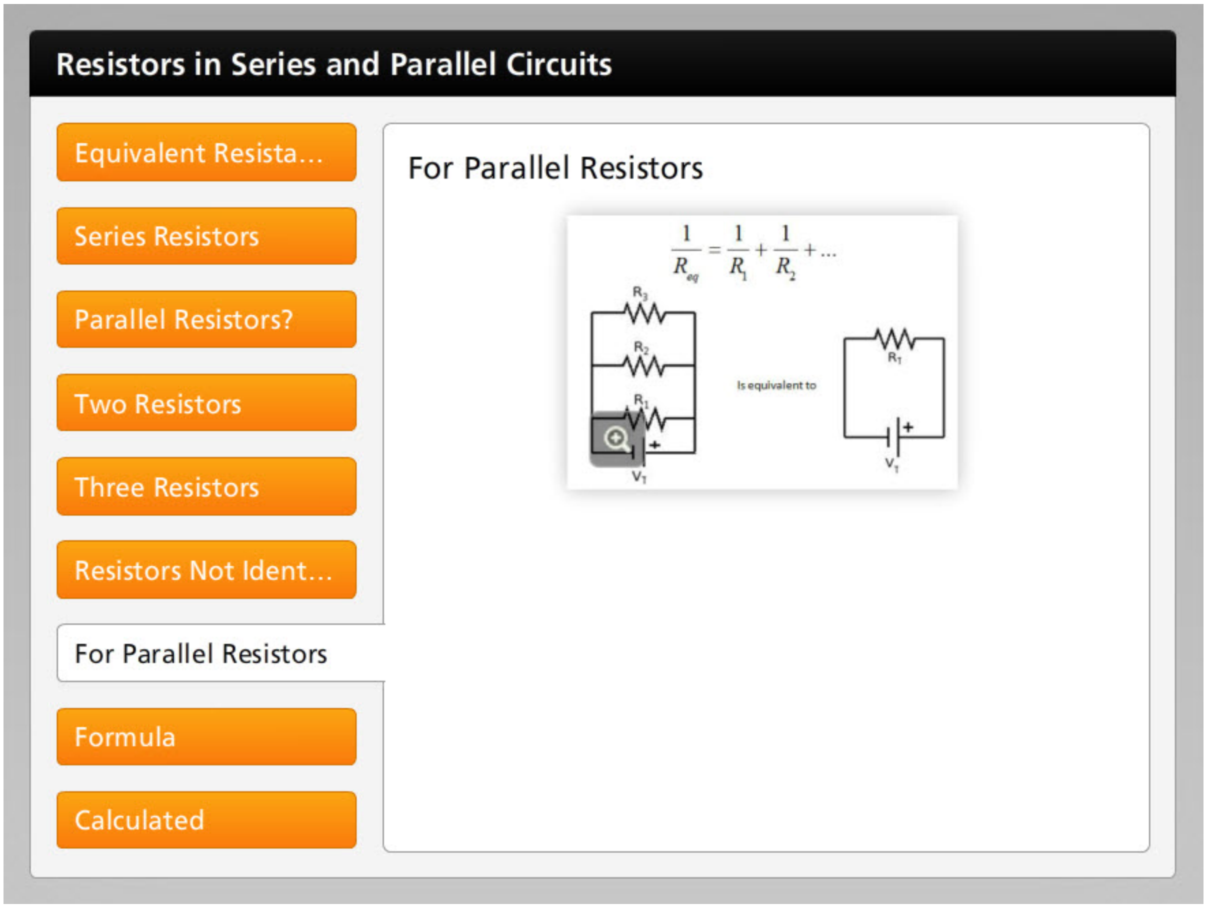
So if the resistors are identical, you can just divide the resistance of one resistor by the number of paths to get the equivalent resistance.



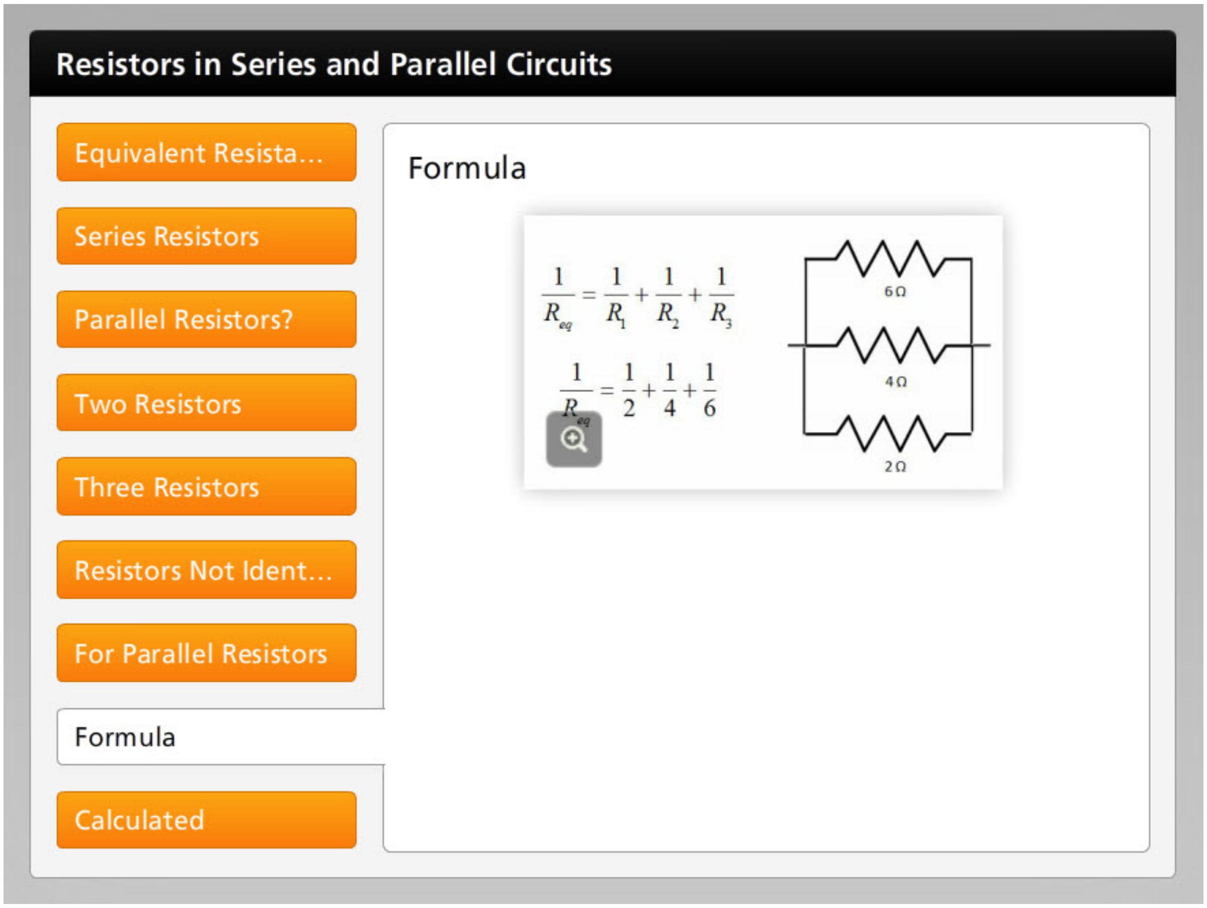
But what if the resistors are not identical? How can you find the equivalent resistance for parallel resistors that have different values? You need an equation to do this.

You can figure out this relationship by looking at a circuit and applying the relationships between current, voltage and resistance. In this parallel circuit, the three resistors have the same voltage, but different currents. The three currents must add up to be equal to the current from the battery, I total. To relate current to resistance, you will use Ohm's Law. The insect sees the vulture over the rabbit, or I equals V over R. This substitution seems make the equation more complicated, but remember that all the resistors have the same voltage as the battery so all the V's are the same. We can divide every term by V. This leaves you with the equation one over R total equals one over R one plus one over R two plus one over R three.

R total is the resistance that could replace the combination of all three resistors and draw the same current from the battery. This technique allows you to reduce the complex three branch circuit to a single resistor. You need one term on the right side for each parallel branch. If there are only two branches, you only have two terms. Because this equation applies for any number of branches, we write it with the ellipses at the end to indicate that you should use as many terms as you have branches in parallel.

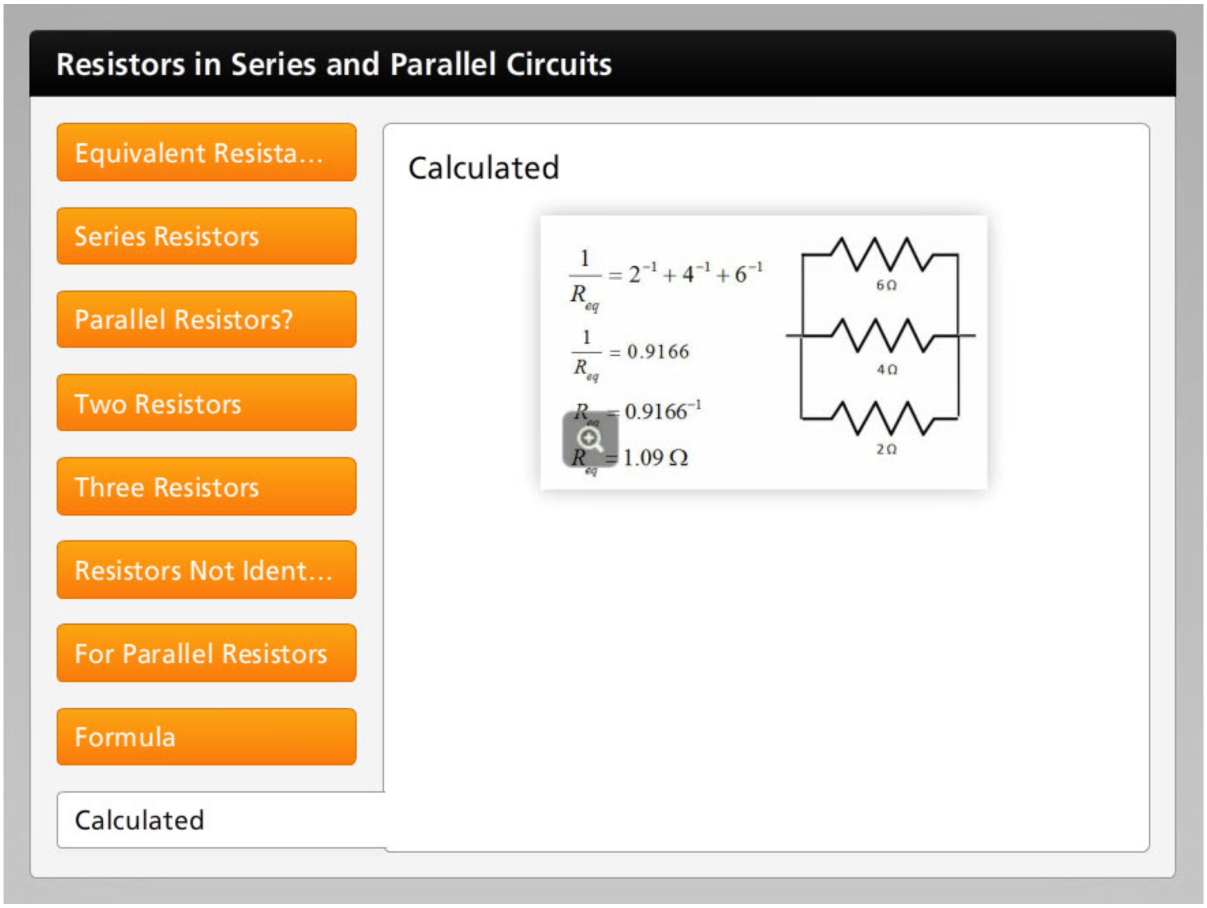


To find the equivalent resistance for parallel resistors you add the reciprocals of the resistances. This sum is the reciprocal of the equivalent resistance. Let's try an example to see how this works out.



Let's try an example to illustrate how this formula is used. If the three resistors are two ohms, four ohms and six ohms, let's find the equivalent resistance.

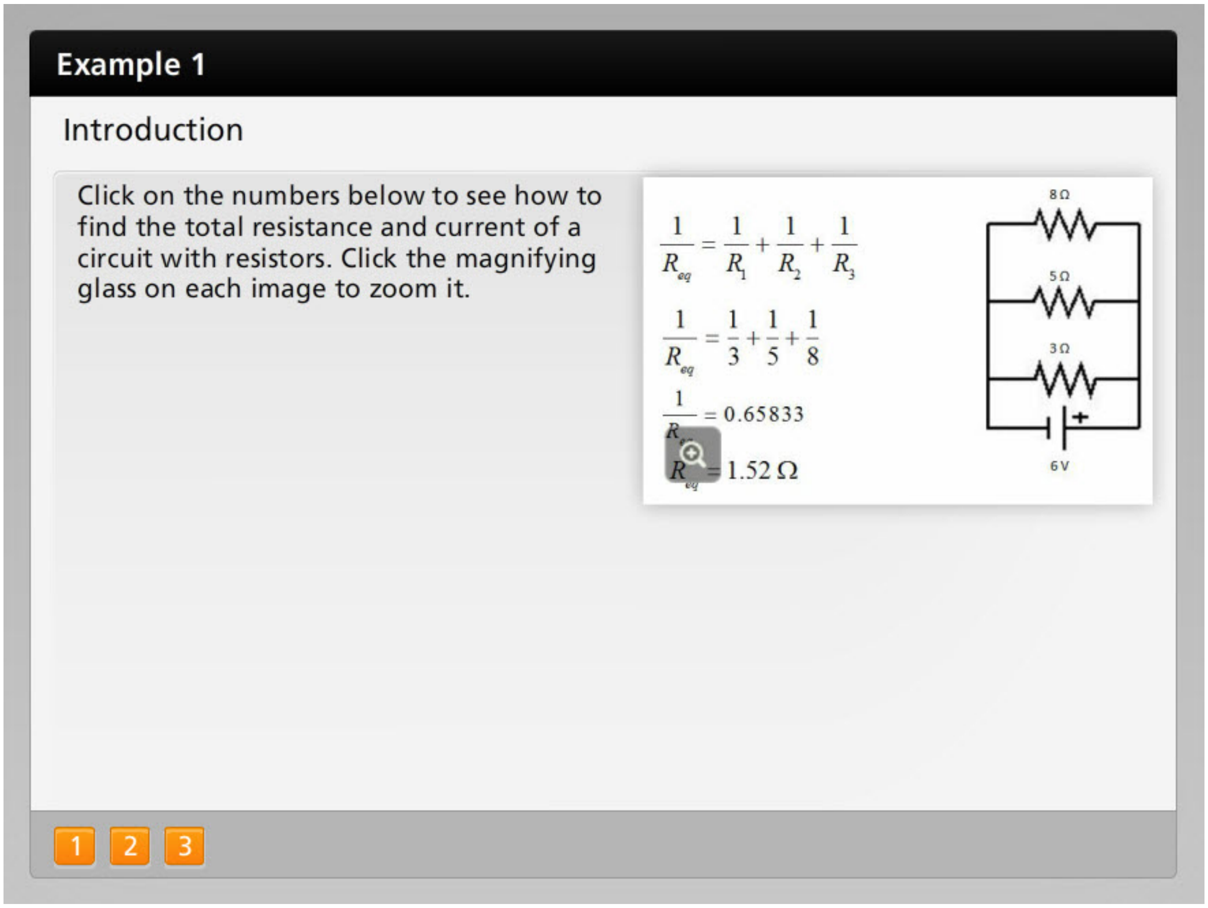
Although we could find a common denominator pretty easily for these numbers, often the resistances are not nice round numbers. So let's use a calculator. The x to the negative one button or the one over x button is very useful for this type of problem.



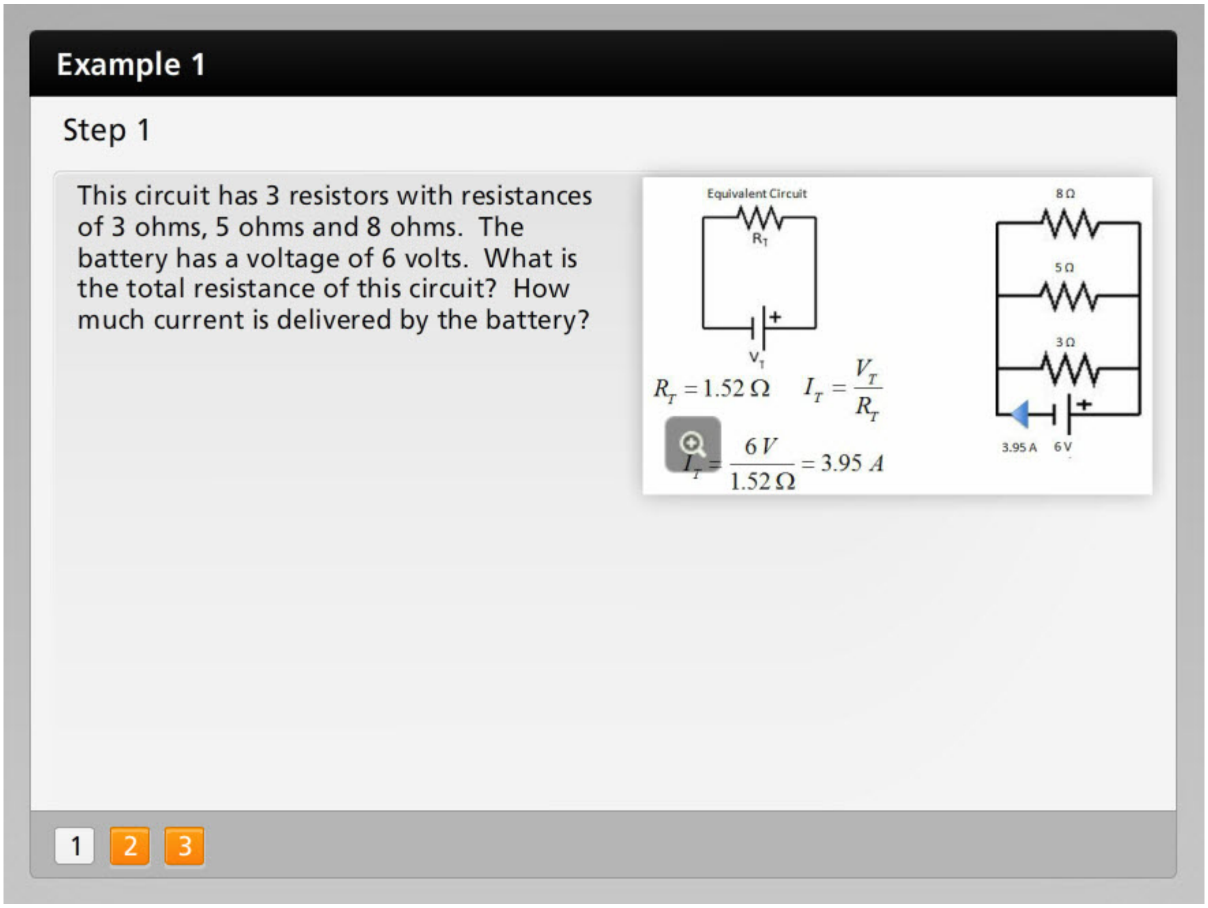
Enter in your calculator two to the negative one plus four to the negative one plus six to the negative one.

The result should be zero point nine one six six. This is one over R equivalent. Raise this answer to the negative one power, that will be R equivalent.

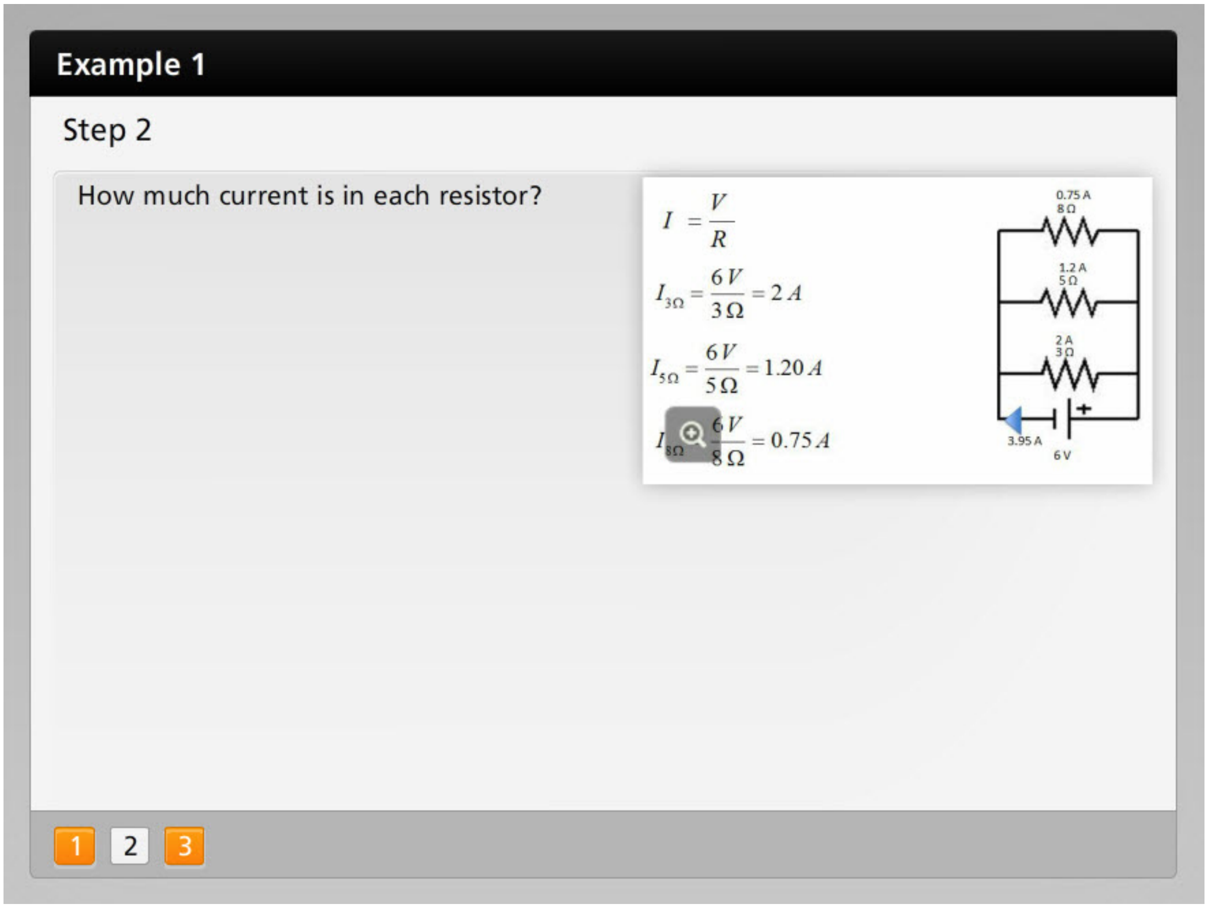
R equivalent is 1.09 ohms for this example. Notice that for parallel resistors, the equivalent resistance is always less than the smallest resistor in the group.



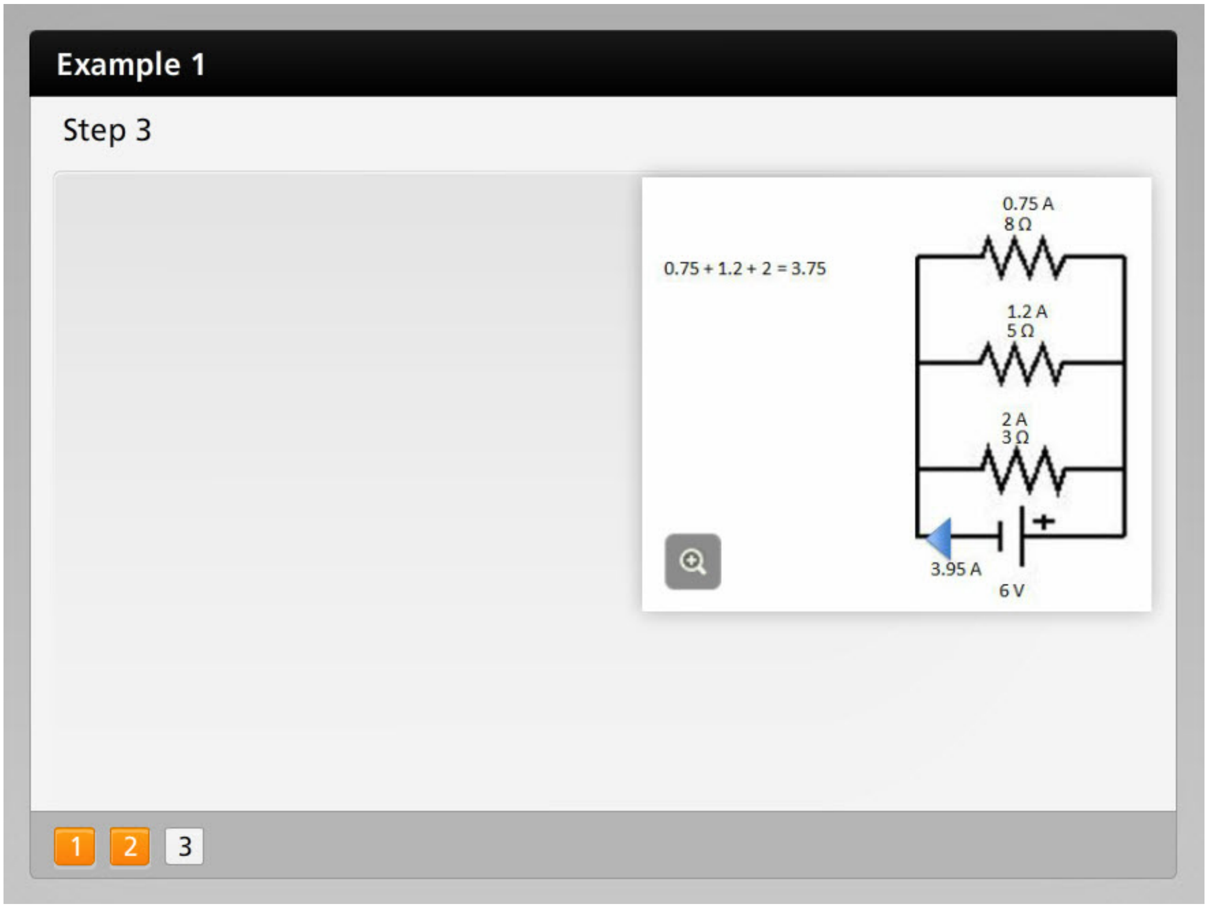
Click on the numbers below to see how to find the total resistance and current of a circuit with resistors. Click the magnifying glass on each image to zoom it.



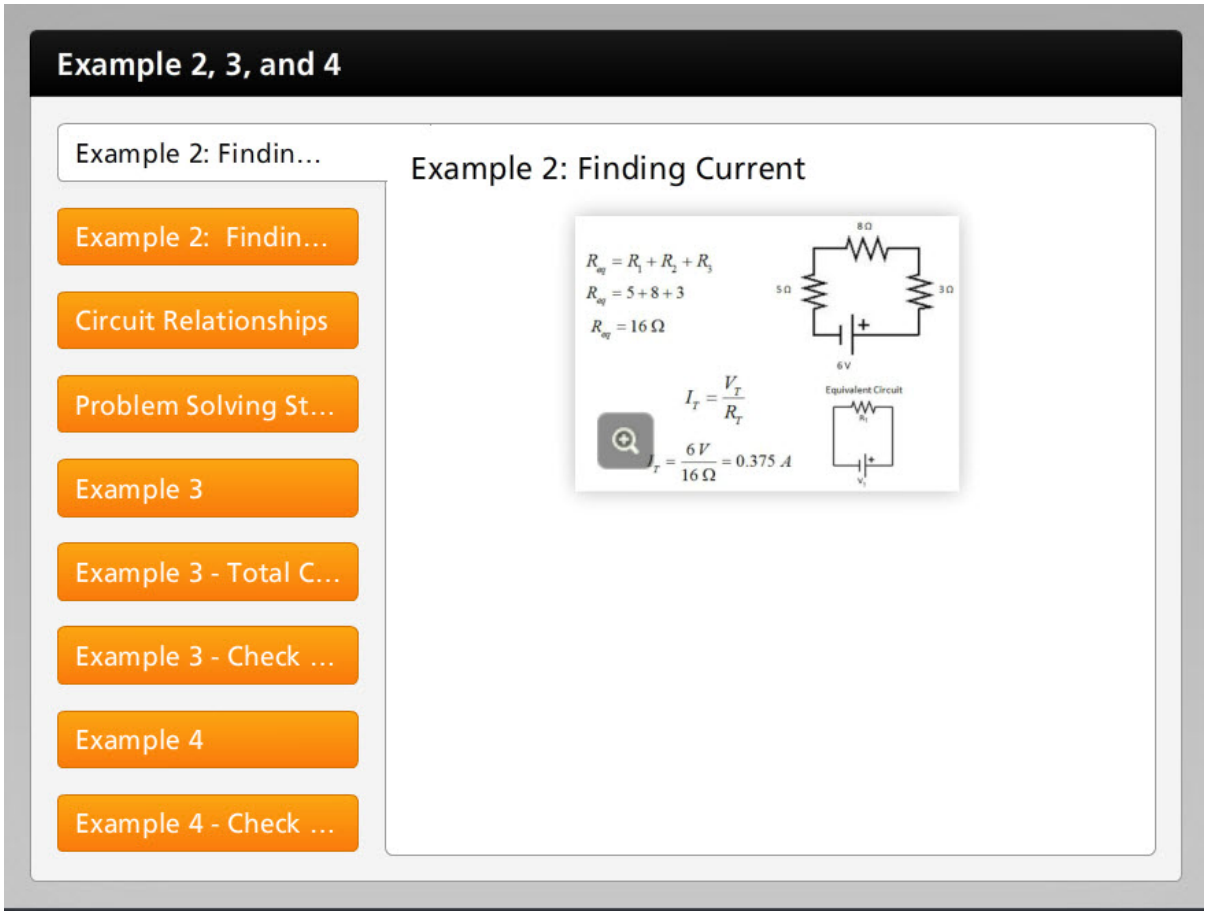
This circuit has three resistors with resistances of three ohms, five ohms and 8 ohms. The battery has a voltage of six volts. What is the total resistance of this circuit? How much current is delivered by the battery?



How much current is in each resistor? Each resistor has the same voltage, or six volts, since all three are connected across the battery. Apply Ohm's Law to each resistor. We can see that the current through the three ohm resistor is two amps, through the five ohm resistor is one point two amps and through the eight ohm resistor is zero point seven five amps.



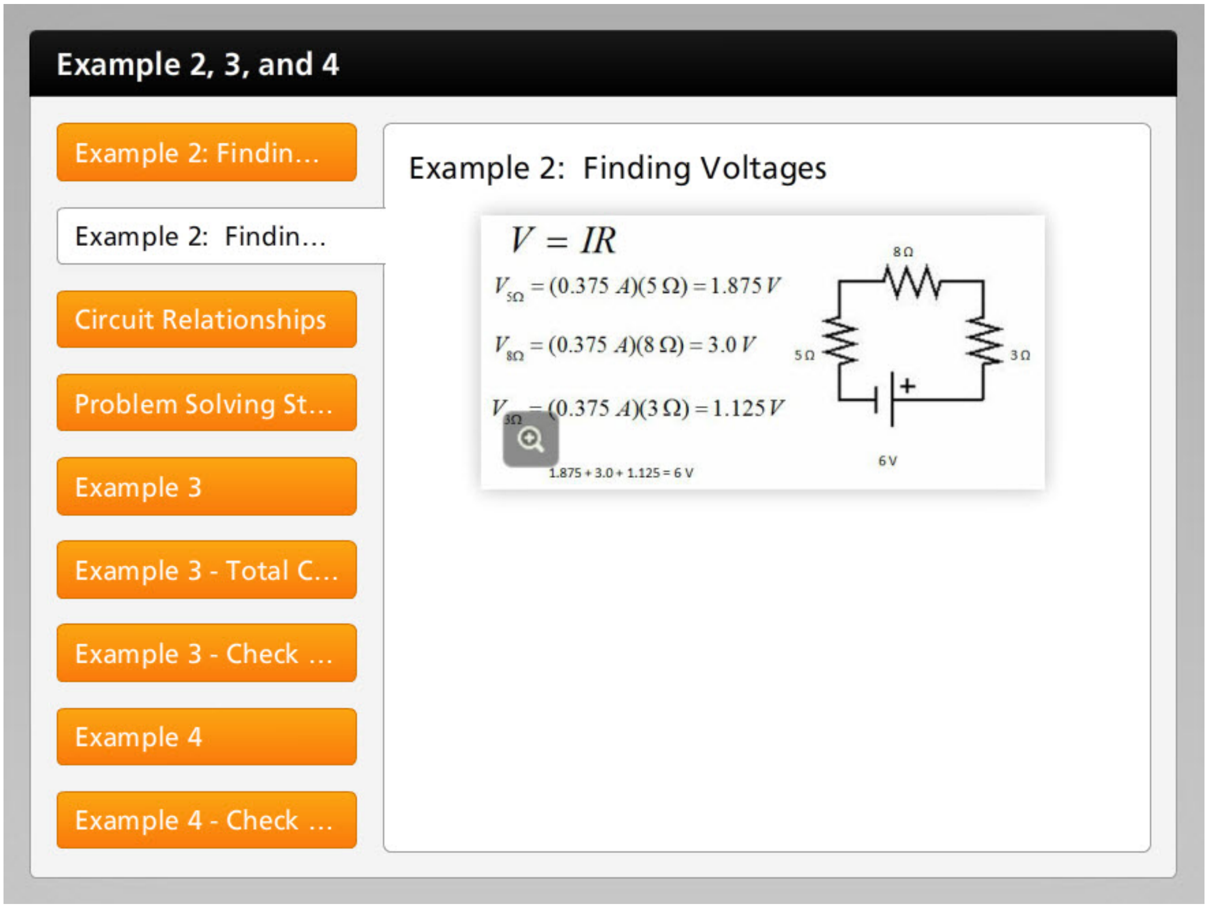
If we compare the sum of the three branch currents, we see that it is equal to the current that leaves the battery.



In this circuit, a six volt battery is used with a five ohm, eight ohm and 3 ohm resistors. What is the equivalent resistance? What is the current delivered by the battery?

In a series circuit, the equivalent resistance is found by adding the individual resistances. The equivalent resistance is sixteen ohms.

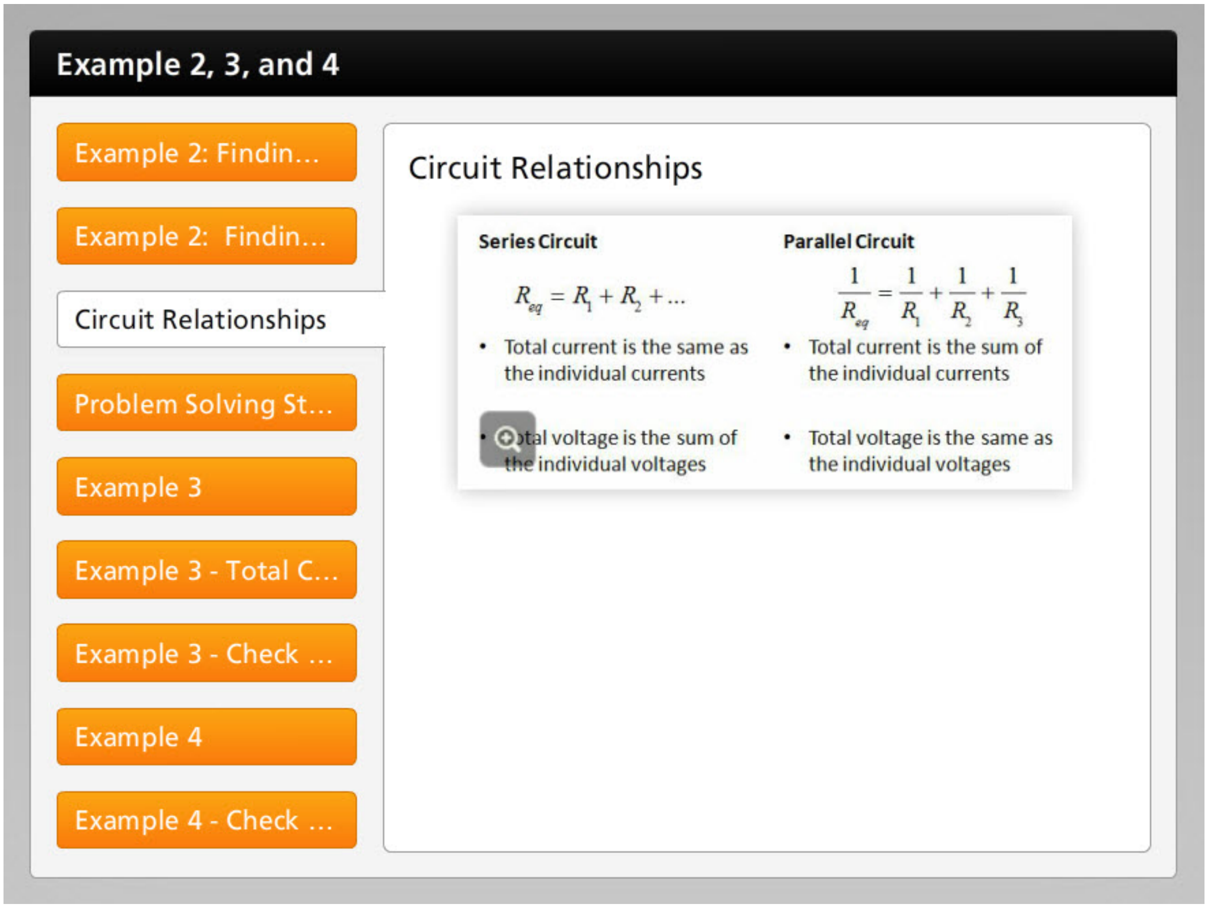
The current delivered by the battery is found from Ohm's Law. The insect sees the vulture over the rabbit, or I equals V over R. The current is zero point three seven five amps.



Since all the elements are in series, they all have the same current of zero point three seven five amps. What is the voltage drop across each resistor?

Apply Ohm’s Law to each resistor. Remember that the vulture sees the insect next to the rabbit, or V = IR.

We can see that the voltages across the three resistors are one point eight seven five volts, three point zero volts and one point one two five volts. Notice that these add up to six volts, the voltage gain of the battery.



In this lesson you learned how to determine the effect of connecting resistors in series or parallel on the total resistance of the circuit. Remember that total does not mean to add values, it refers to the combined effect of all of the resistors in a circuit. Equivalent resistance is the value of a single resistor that could replace a combination of resistors.

For a series circuit, the equivalent resistance is the sum of the individual resistances. The total current is the same as the individual currents. The total voltage is the sum of the individual voltages.

For a parallel circuit, the relationship between the individual resistances and the total resistance is more complex. The reciprocal of the equivalent resistance is equal to the sum of the reciprocals of the individual resistances. The total current is the sum of the individual currents. The total voltage is the same as the individual voltages.

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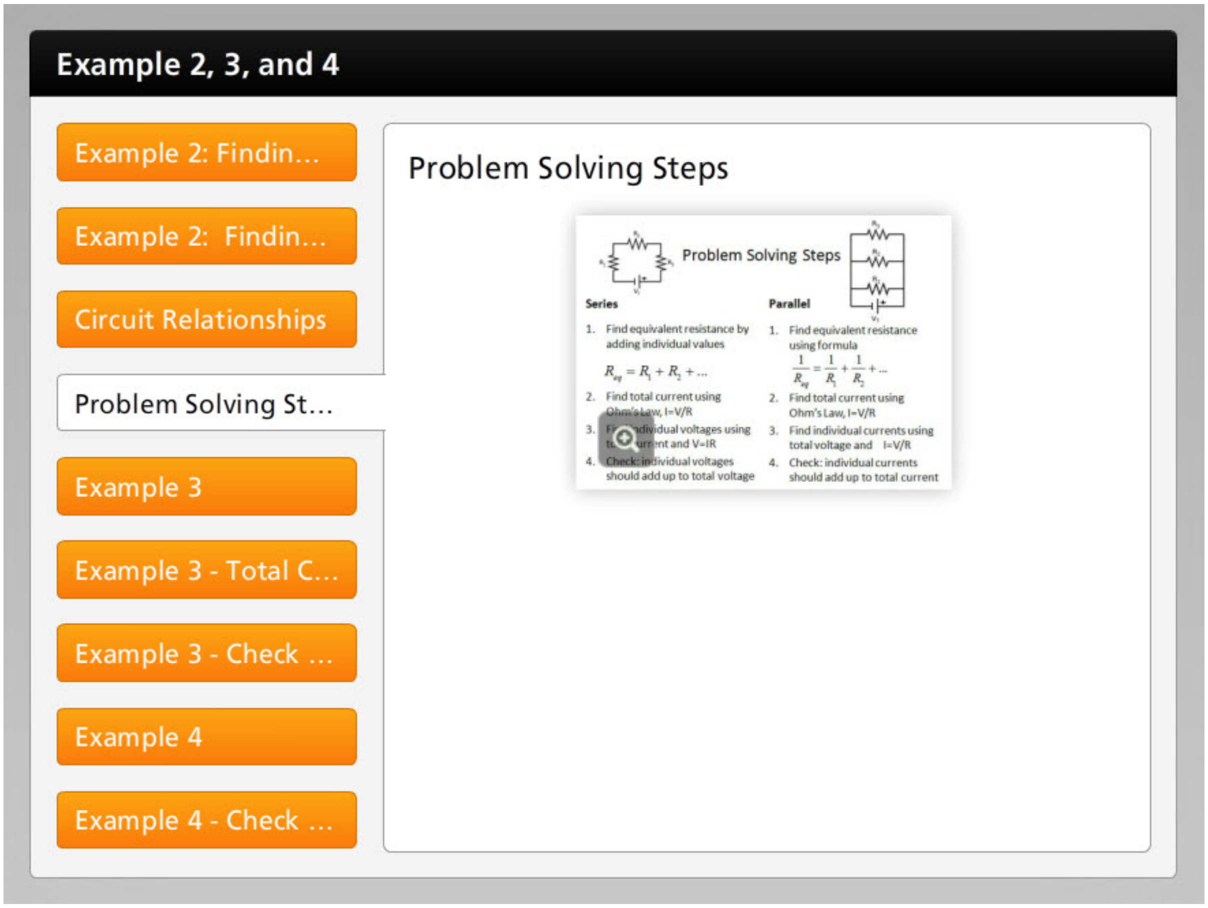


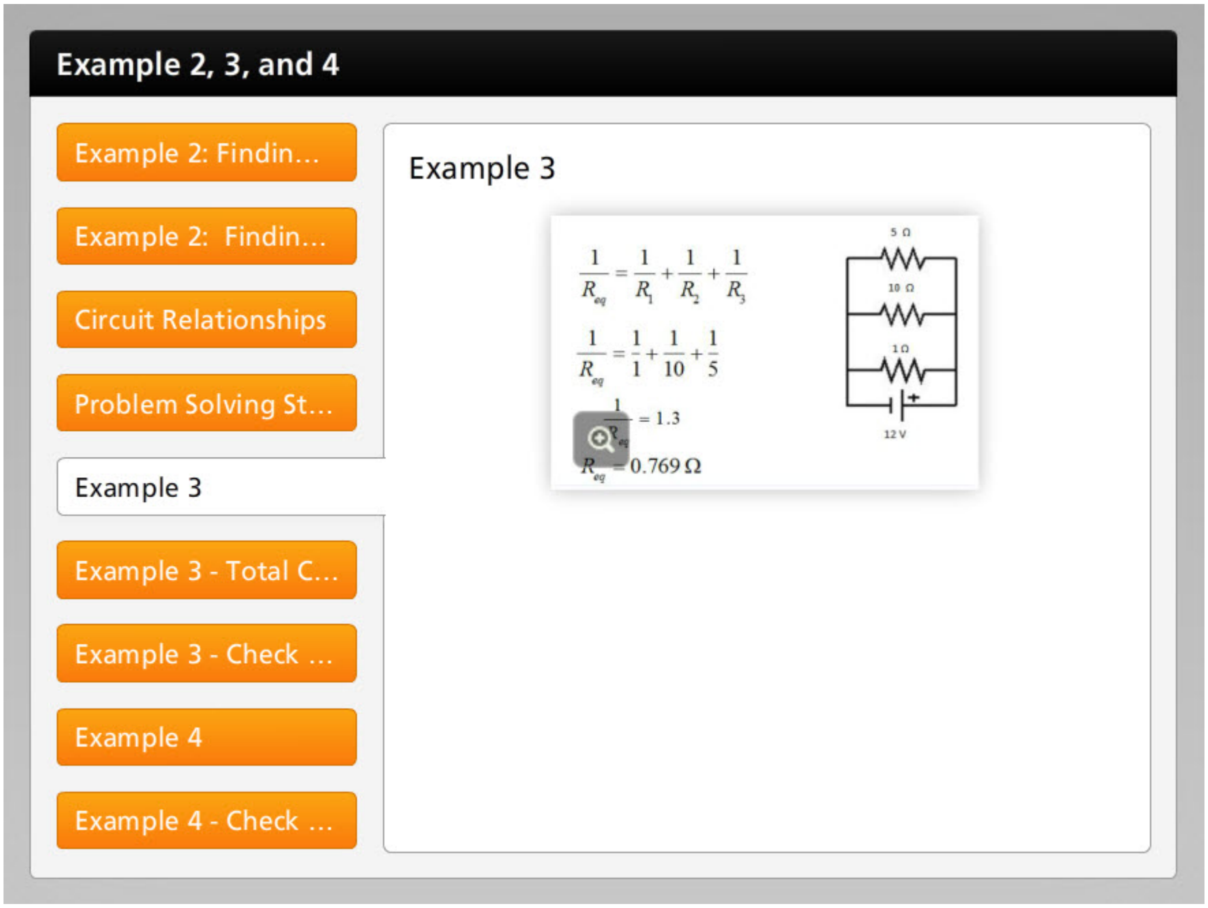
Knowing the relationships between voltage, current and resistance for series and parallel arrangements will help you in problem solving. There are two basic types of problems in this topic: series circuits and parallel circuits.

In a series circuits, the first step to solving is to find the equivalent resistance by adding the individual resistances. Once the total resistance is found, use Ohm's Law to find the total current delivered by the battery. This total current is the current through each resistor. Then you can find individual voltage drops using Ohm's Law. To check your work, the individual voltages should add up to the total voltage.

In a parallel circuit, the first step to solving is to find the equivalent resistance by using the formula. Similarly to the series circuit problem, once you have found the total resistance you can use Ohm's Law to find the total current delivered by the battery. For a parallel circuit, the voltages across each resistor are the same as the voltage of the battery. You can find the individual currents by using Ohm's Law. To check your work, the individual currents should add up to the total current.

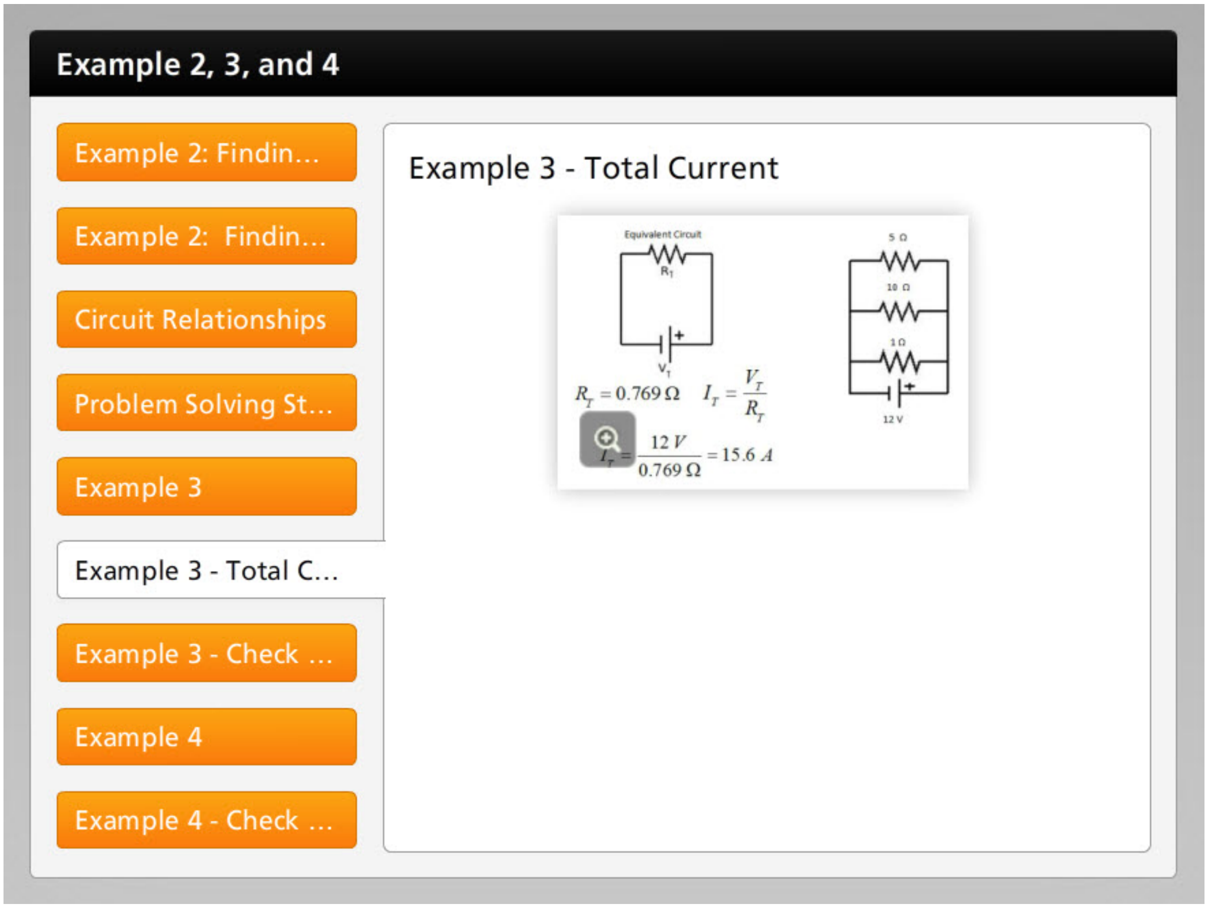
You will practice solving simple series or parallel circuit problems in this topic. In the next topic you will use these techniques to analyze circuits that are more complex. Remembering the series and parallel relationships will help you figure out what is going on in simple or complicated circuits.

Let's try another example together before you do the application on your own.

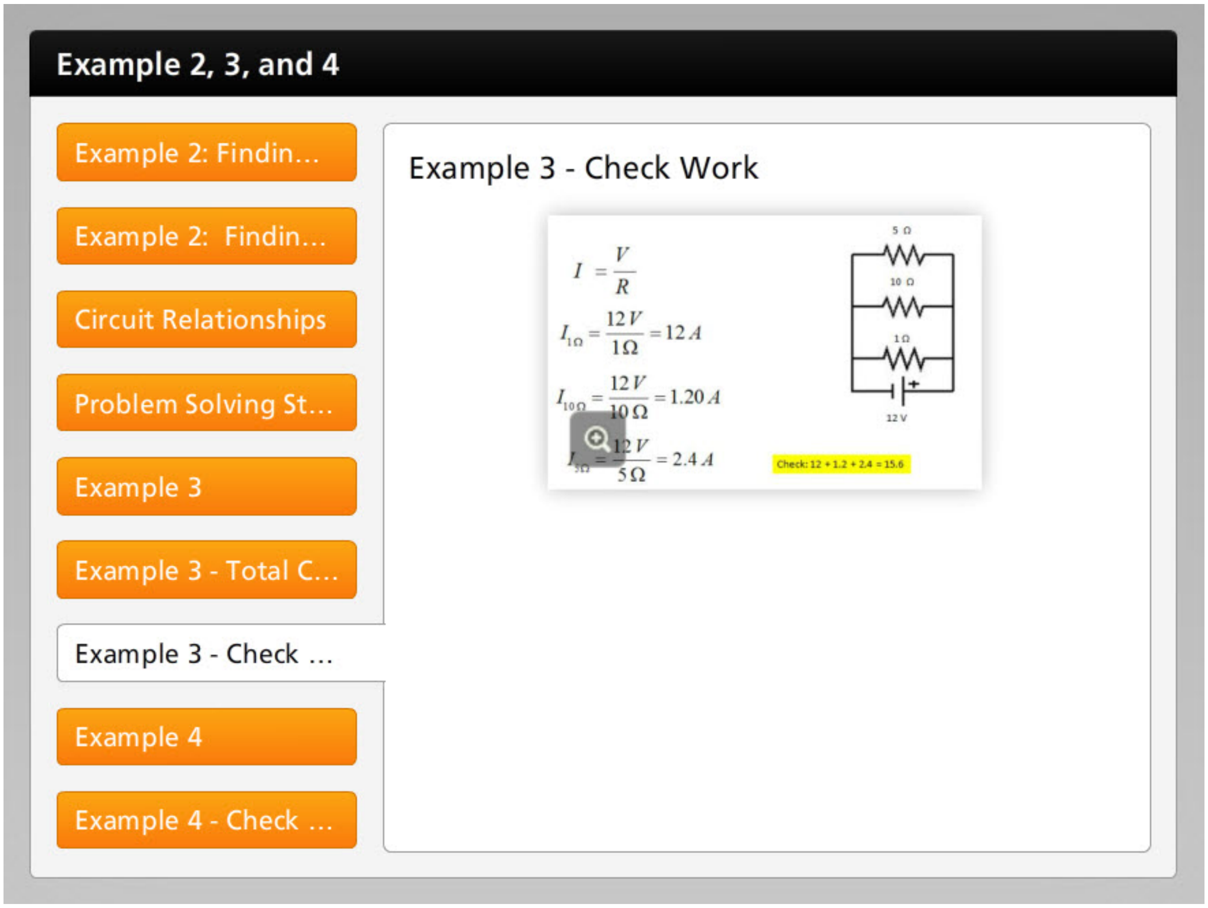


A circuit has three resistors, one ohm, ten ohms and five ohms. Find the current delivered by the battery and the current in each resistor.

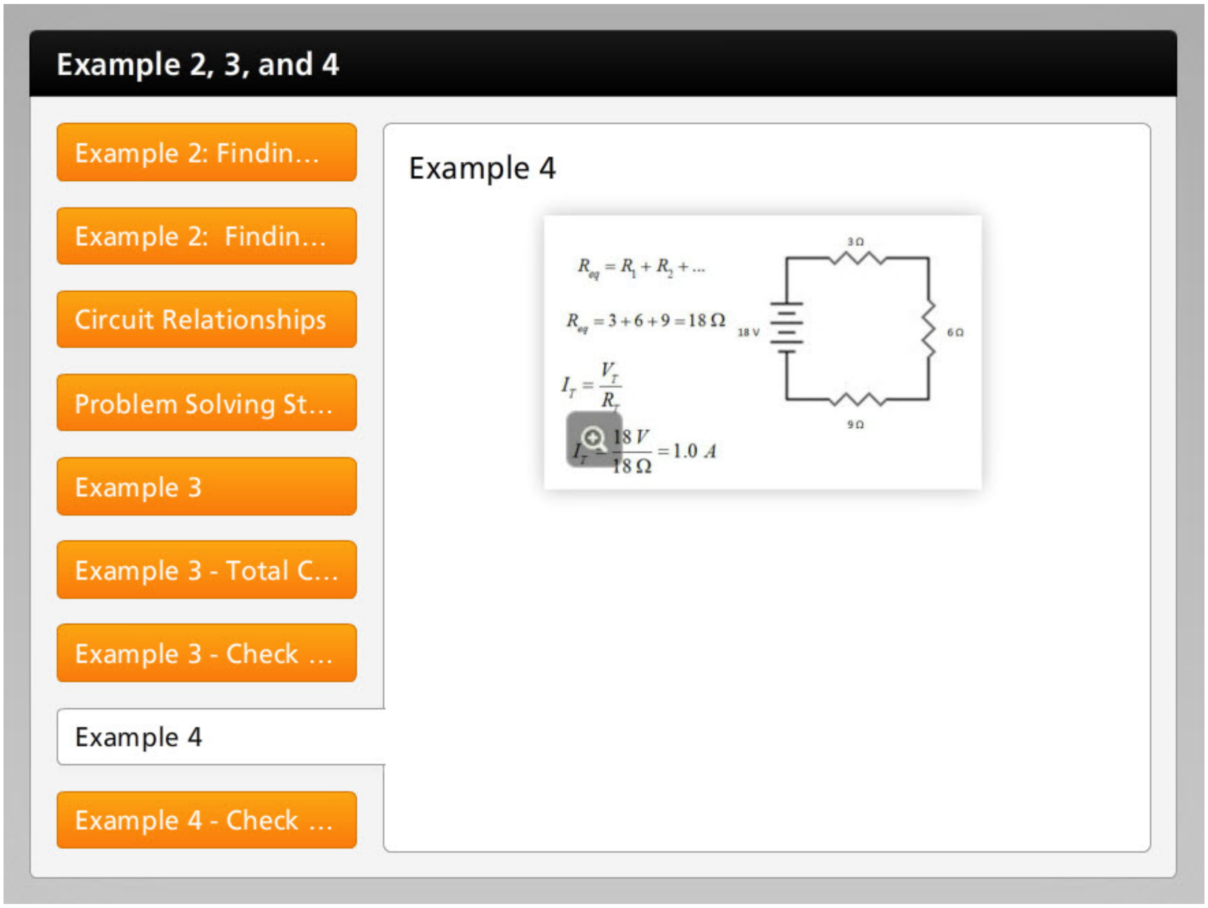
First, find the equivalent resistance using the appropriate formula. Substituting into the formula, we see that the equivalent resistance is zero point seven six nine ohms. This is the total resistance of this circuit.



Now that you have found the total resistance, use Ohm's Law to find the total current. The insect sees the vulture over the rabbit, so I equals V over R. Substituting the values for total resistance and total voltage, we see the total current is fifteen point six amps.



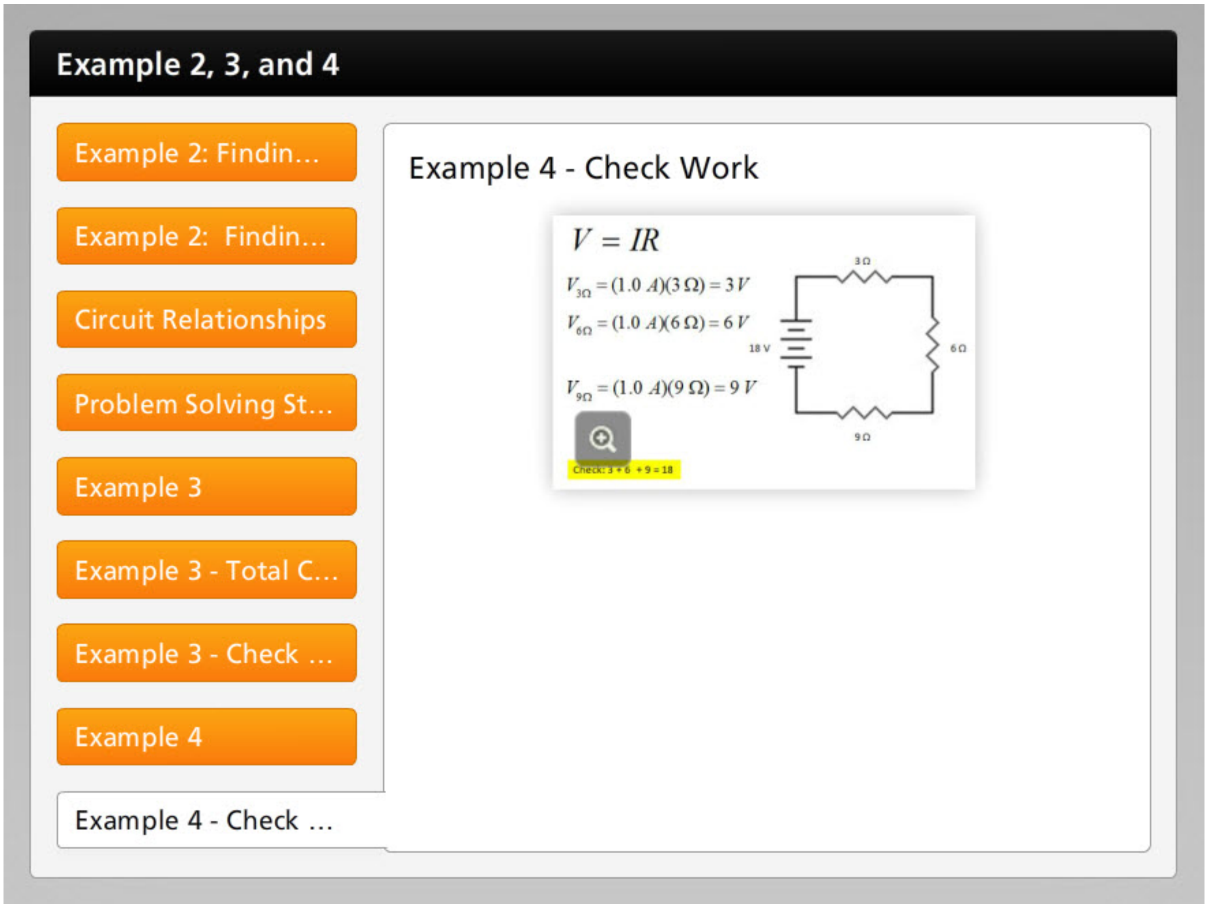
Now we need to remember the current and voltage relationships for parallel circuits. In parallel, resistors have the same voltage. We need to solve for the current using Ohm's Law. The vulture sees the insect next to the rabbit, so V equals I times R. Substituting values for each resistor, we can find the currents in each branch. The current in the one ohm branch is twelve amps, the current in the ten ohm branch is one point two ohms and the current in the five ohm branch is two point four amps. We check our work by verifying that the branch currents add up to the total current. Twelve plus one point two plus two point four equals fifteen point six. So, our work checks out.



Three resistors, with resistances of three ohms, six ohms, and eighteen ohms, are connected to an eighteen volt battery. Find the total current delivered by the battery and the current and voltage of each resistor.

First, find the equivalent resistance. The three resistors are in series with the battery. The equivalent resistance is found by adding the resistances. The total resistance for this circuit is eighteen ohms.

The total current delivered by the battery is found using Ohm's Law. Substituting the values for this circuit, the total current is one amp.



The total current is the same as the current through each resistor since they are in series.

Find the voltage drop across each resistor using Ohm's Law. The vulture sees the insect next to the rabbit or V equals I R. Substituting values for each resistor we get the voltage drop across the three ohm resistor to be three volts, across the six ohm resistor is six volts and across the nine ohm resistor is nine volts. To check your work, add the voltage drops across the resistors. Three plus six plus nine equals eighteen volts. This is equal to the battery voltage.