

Lecture 04: Circuit Elements and Ohm's Law

Ohm's law:

The voltage $v(t)$ and the current $i(t)$ in a resistor R are related by:

$$v = iR$$

The above relation is valid *only if* $i(t)$ enters the (+) terminal and leaves the (-) terminal.

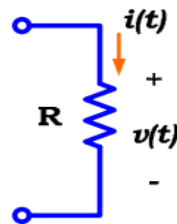


Figure 5

If $i(t)$ enters the (-) terminal and leaves the (+) terminal, then Ohm's law *must be* changed to:

$$v = -iR$$

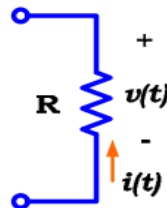


Figure 6

The passive sign convention:

The use of the \pm signs in Ohm's law and the power expression is known as the *passive sign convention*.

$$i(t) \text{ enters the (+) terminal} \Rightarrow p = +iv \quad \& \quad v = +iR$$

$$i(t) \text{ enters the (-) terminal} \Rightarrow p = -iv \quad \& \quad v = -iR$$

Example 3:

Calculate the unknown quantities in the following circuit.

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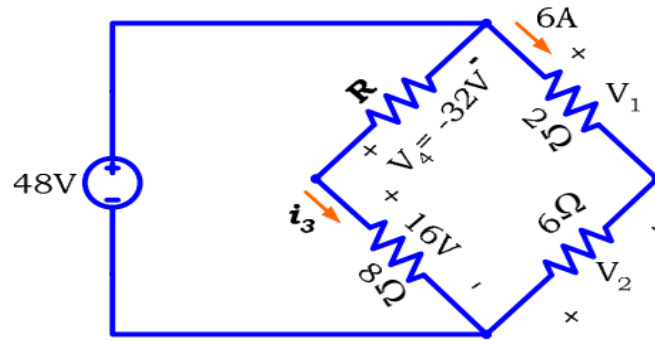


Figure 7

Solution:

$$v_1 = +(6)(2) = 12V$$

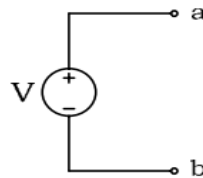
$$v_2 = -(6)(6) = -36V$$

$$i_3 = +(16)/(8) = 2A$$

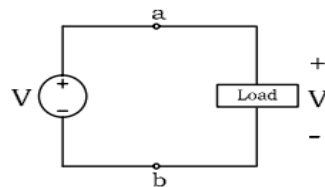
$$R = -(v_4)/i_3 = -(-32)/(2) = 16\Omega$$

Ideal Voltage Source:

The symbol of an ideal voltage source is shown below. The value of the voltage source is V volts and the terminals "a" and "b" are used to connect the ideal voltage source to other circuit elements.



When *any* load is connected across the terminals of an *ideal* voltage source of voltage V , the same voltage V appears *across* the load, *irrespective* of the load. Note that the (+) and (-) polarities of the voltage V are on the same side.



Example 1: Various *resistive* loads are connected to the 5 V ideal voltage source as shown in figure 3. In each case, the voltage across the load is also 5 V. Note that the equivalent resistance of the resistive load shown in circuit (c) and circuit (d) is considered to be the load.

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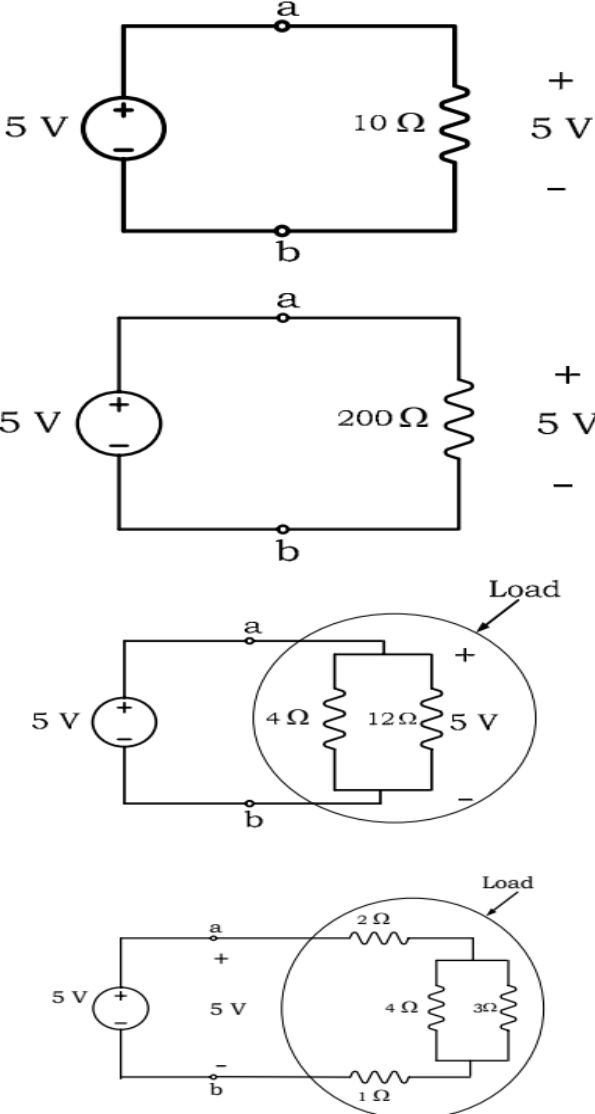


Figure 3 (a, b, c & d)

Example 2: Calculate the current I in the following circuit:

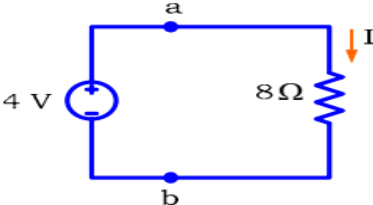


Figure 4

Solution: Using Ohm's law:

$$I = V / R = 4 / 8 = 0.5A$$

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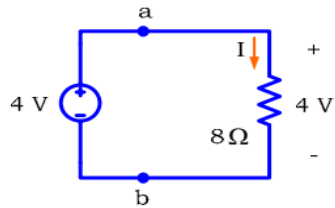


Figure 5

The following ideal voltage sources are *equivalent*. If you *invert* the algebraic sign of the voltage V , you *must* also *reverse* the voltage polarity. Otherwise, the sources are *not* equivalent.

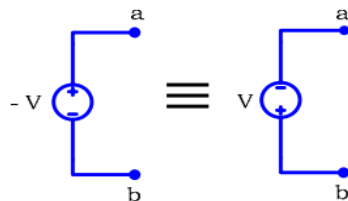


Figure 6

Example 3: Is the *actual* polarity of terminal “a” positive or negative?

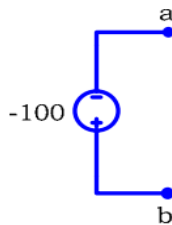


Figure 7

Solution: By inverting the sign of the ideal voltage source from -100 V to $+100\text{ V}$ and reversing the polarity of the voltage, we conclude that the actual polarity of terminal “a” is (+) or positive polarity. This means that terminal “a” is actually at a higher potential than terminal “b”.

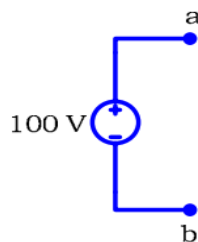


Figure 8

Ideal Current Source:

The symbol of an ideal current source is shown below. The value of the current source is I amperes and the terminals “a” and “b” are used to connect the ideal current source to other circuit elements.

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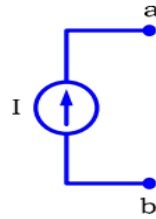


Figure 9

When *any* load is connected across the terminals of an *ideal* current source of current I , the same current I flows *through* the load, *irrespective* of the load.

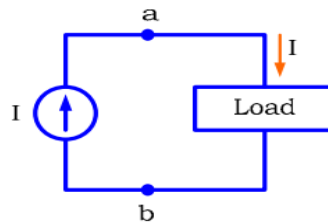


Figure 10

Example 3: The 3 A ideal current source shown below is connected to different resistive loads. In each case, the current that flows across the load is also 3 A. Note that in circuit (c), the current through the resistive load is 3 A, but the currents that flow into the individual resistances that make up the load are each less than 3 A.

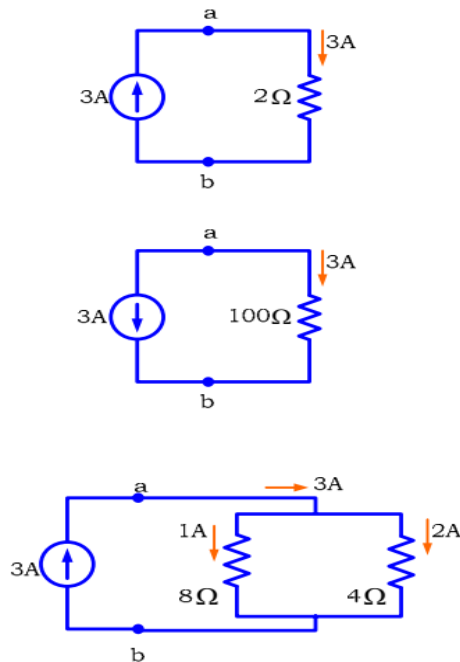


Figure 11

Example 4: In the following circuit, calculate the voltage V across the 20Ω resistance.

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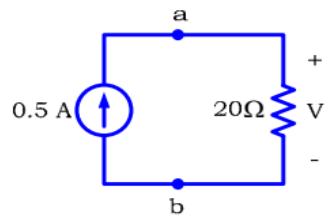


Figure 12

Solution: Using Ohm's law:

$$V = IR = 0.5 \times 20 = 10 \text{ V}$$

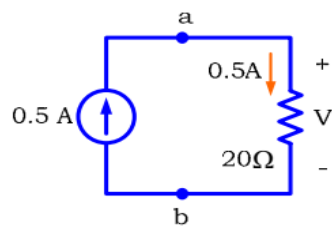


Figure 13

The following two current sources are equivalent. If you *invert* the algebraic sign of the current I , you *must* also *reverse* the direction of current flow. Otherwise the two sources are not equivalent.

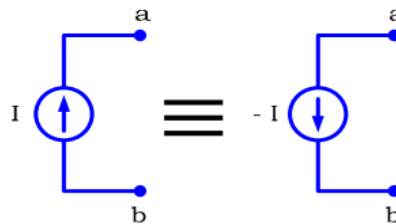


Figure 14

Example 5: What is the actual direction of the current in the 8Ω resistor?

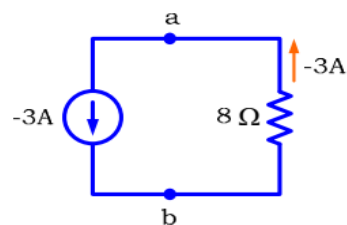


Figure 15

Solution: As shown in the diagram below, the actual current flow through the 8Ω resistance is from terminal "a" down to terminal "b".

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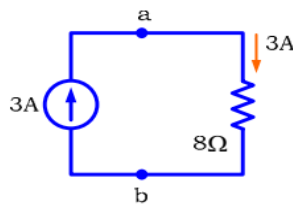


Figure 16

The short and the open circuits:

When a resistor has a zero resistance (i.e. $R = 0 \Omega$), we call it a *short circuit*.

When a resistor has an infinite resistance (i.e. $R = \infty$), we call it an *open circuit*.

The symbols of the short and the open circuits are respectively shown in figures (a) and (b) below:



Short Circuit

(a)



Open Circuit

(b)

Figure 17

The current *through* a short circuit is generally *not* equal to zero. However, the voltage across a short circuit is *always equal to zero*, because:

$$V = IR = 0R = 0$$

The voltage *across* an open circuit is generally *not* equal to zero. However, the current through an open circuit is *always equal to zero*, because:

$$I = V / R = V / \infty = 0$$

When the 10 V ideal voltage source is connected to a short circuit as shown below, we immediately face a problem. What is the voltage across the load in this case?

Is the voltage V across the load 10 V or 0 V?

In order to avoid this ambiguous question, which cannot be answered it *illegal* in this course to connect a short circuit across the terminals of an *ideal* voltage source. However, as we will see later in the course, we are allowed to connect a short circuit across the terminals of a *realistic* voltage source.

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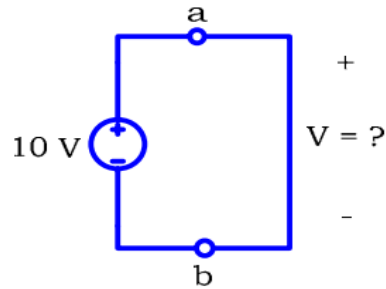


Figure 18

The same type of problem faces us, when we connect the 5 A current source to an open circuit load, as shown in the figure below.

What the current I through the load in this case? Is it 5 A or 0 A?

There is no answer to this question also. Thus, it is also illegal in this course to connect an open circuit to the terminals of an *ideal* current source.

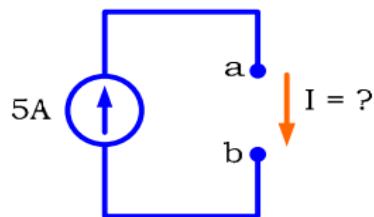


Figure 19

How many illegal circuits do we have in this class?