Unit 1: Ohm's Law

In this unit, we will examine the relationship between voltage and current in the simplest circuit element, the resistance. Fig. 1.1 shows two alternative circuit representations of a resistance, R, and Fig. 1.2 shows a real resistance.

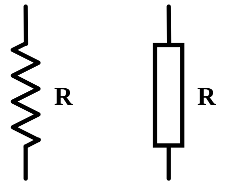


Fig. 1.1 Circuit diagram representation of a resistance

Fig. 1.2 Resistance for use in an electronic circuit
(The coloured bands define the value of the resistance)

When a resistance is connected into a circuit, a voltage is present across the resistance and current flows through it. The voltage and current are represented using the notation shown in Fig. 1.3. There are several important points to make about this voltage and current notation:

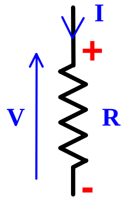


Fig. 1.3 Voltage and current applied to a resistance

a) a circuit convention is that constant quantities are denoted by capital letters. In this section of the module, we are dealing with circuits carrying dc (constant) voltages and currents, so the symbols V and I in the diagram are written with capital letters;

b) the arrow next to the current symbol (I) indicates the direction of *conventional* current flow: the flow of positive charge. Of course, in a conductor current is carried by negatively-charged electrons and this electron current flows in the opposite direction to the conventional current. From a circuit viewpoint, we will deal exclusively with conventional current;

c) the arrow next to the voltage symbol (V) points to the most positive end (highest potential) of the resistance. Some textbooks use the +/- notation shown in red in Fig. 1.3.

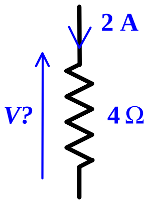
There is a well-known relationship, between the voltage, current and resistance defined in Fig. 1.3:

Ohm's Law: $V = R . I$

in which, using SI units, the voltage has units of Volts (V), the current has units of Amperes (A) and the resistance has units of Ohms (Ω).

Worked example 1.1

Calculate the voltage, *V*, across the 4 Ω resistance carrying a current of 2 A.



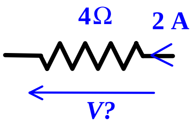
Solution

The voltage *V* can be calculated using Ohm's Law: $V = R.I = 4 \times 2$ V = <u>8 V</u>

Ohm's Law can be applied only when the voltage and current directions are as defined in Fig. 1.3, in which both the voltage and current arrows point at the same end of the resistance. Before applying Ohm's Law, as in the example above, it is essential to check that the voltage and current directions are defined in a way that is consistent with the Law. If the directions are inconsistent, then the problem needs to be approached carefully, as shown in the following example.

Worked example 1.2

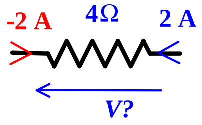
Calculate the voltage, *V*, across the 4 Ω resistance carrying a current of 2 A, as defined in the diagram.



Solution

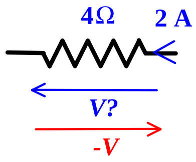
The directions of the voltage and current are not consistent with Ohm’s Law.

There are two possible strategies for dealing with this problem:



1. Define an equivalent current of -2 A flowing in the opposite direction. The arrows defining the directions of the unknown voltage V and the current -2 A are consistent, so the voltage can be calculated using Ohm’s Law:

$$V = \text{R.I} = 4 \times (-2)\ \text{V} = \underline{-8\ \text{V}}$$

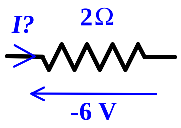


2. Define an equivalent voltage $-V$ in the opposite direction to the unknown voltage. The arrows defining the directions of $-V$ and the current of 2 A are consistent, so the voltage can be calculated using Ohm’s Law:

$-V = \text{R.I} = 4 \times (2)\ \text{V} = 8\ \text{V}$ and therefore: $\underline{V = -8\ \text{V}}$

The solution to the example above includes negative values of voltage and current. Negative values of variables will occur routinely during the analysis of circuits and need not cause any concern, as illustrated in the following examples.

Worked example 1.3



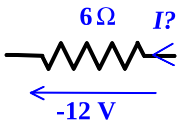
Calculate the current, I, flowing through the 2 Ω resistance with a voltage of -6 V, as defined in the diagram.

Solution

The voltage is negative, but its direction relative to the current *is* consistent with Ohm’s Law (both arrows point towards the same end of the resistance). So, the current can be calculated directly using Ohm’s Law:

$$V = \text{R.I} \quad \Rightarrow \quad I = V / R = (-6) / 2\ \text{A} = \underline{-3\ \text{A}}$$

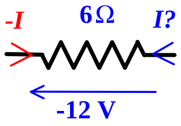
Worked example 1.4



Calculate the current, I, through the 6 Ω resistance with a voltage of -12 V, as defined in the diagram.

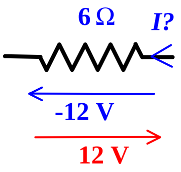
Solution

The voltage is negative, but more significant is that its direction relative to the current direction is not consistent with Ohm’s Law. There are two ways of dealing with the problem:



1. Define an equivalent current of $-I$ flowing in the opposite direction. The arrows defining the directions of the voltage and the current $-I$ are consistent, so the current can be calculated using Ohm’s Law:

$(-I) = V / R = (-12) / 6\ \text{A} = -2\ \text{A}$ and therefore: $\underline{I = 2\ \text{A}}$



2. Define an equivalent voltage +12 V in the opposite direction to the known voltage. The arrows defining the directions of voltage and current of 2 A are then consistent, so the current can be calculated using Ohm’s Law:

$$I = V / R = 12 / 6\ \text{A} = \underline{2\ \text{A}}$$