Explainer: Ohm's Law

In this explainer, we will learn how to use the formula $V = IR$ (Ohm's law) to work out the values of the potential difference, current, and resistance in simple circuits.

Ohm's law describes the relationship between current in and potential difference across conductors. The law was developed by physicist Georg Ohm, who found that for many types of conductors the current in them was directly proportional to the potential difference across them.

Ohm eventually identified a mathematical relationship between current, resistance, and potential difference for a conductor.

Formula: Ohm's Law

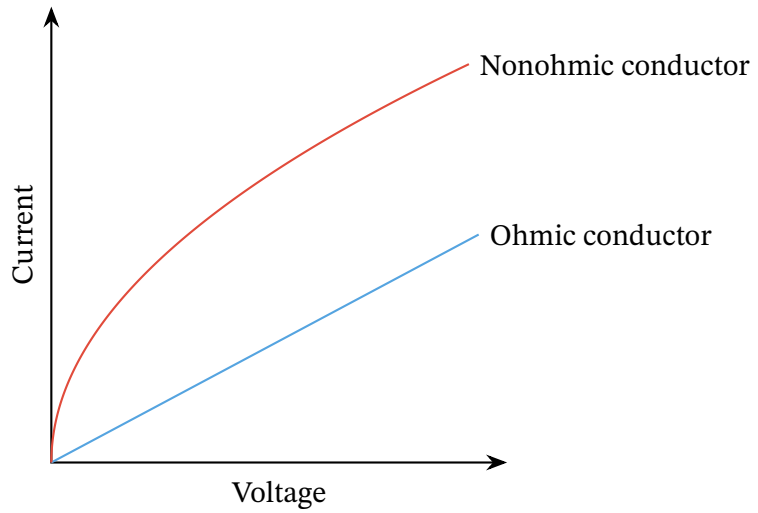
If I is the current in a conductor in an electrical circuit, V is the potential difference across the conductor, and R is the conductor's resistance to charge flow, then

$$V = I \times R.$$

In this expression, the standard unit of potential difference is volts (V), the unit of current is amperes (A), and the unit of resistance is ohms (Ω).

Ohm's law accurately describes many conductors. Materials that follow this law are called "ohmic." Any conductor, however, for which current and potential difference are not directly proportional is called "nonohmic."

On a plot of current versus potential difference, ohmic conductors appear as straight lines, while nonohmic conductors are represented by curves.



Example 1: Using Ohm's Law to Find the Current through a Resistor

A 10 Ω resistor in a circuit has a potential difference of 5 V across it. What is the current through the resistor?

Answer

Resistors with fixed values are ohmic, meaning they obey Ohm's law as follows:

$$V = I \times R.$$

Here, V is the potential difference across the resistor, I is the current through it, and R is its resistance.

Since we want to solve for the current, I, we can rearrange the equation by dividing both sides by R to read

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

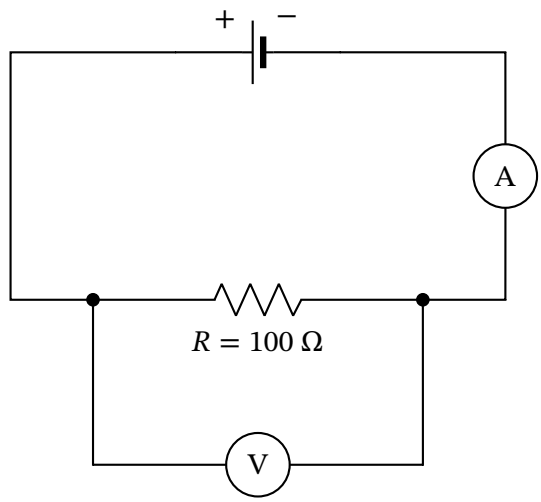
For this circuit, V is 5 V and R is 10 Ω, so

$$\begin{aligned} I &= \frac{5\ \text{V}}{10\ \Omega} \\ &= 0.5\ \text{A}. \end{aligned}$$

The current through the resistor is 0.5 amperes.

Example 2: Using Ohm's Law to Find the Potential Difference across a Resistor

A student sets up the circuit shown in the diagram. He sees that the ammeter reads 0.05 A. What value does the voltmeter read?



Answer

In this circuit, the ammeter is in series with the component being measured and the voltmeter is in parallel with it.

Set up this way, the current in the ammeter (and therefore through the resistor) is measured to be 0.05 amperes.

Knowing the resistor has a value of 100 ohms, we want to solve for the potential difference across it, which is what the voltmeter measures.

We can use Ohm's law to solve for this potential difference. Ohm's law states that

$$V = I \times R,$$

where V is the potential difference, I is the current, and R is the resistance.

Since the voltmeter measures the potential difference only across the resistor, we will apply Ohm's law to the resistor only.

Using the measured value of I and the known value of R,

$$\begin{aligned} V &= (0.05\ \text{A}) \times (100\ \Omega) \\ &= 5\ \text{V}. \end{aligned}$$

The voltmeter reads a value of 5 volts.

Example 3: Using Experimental Data to Find the Resistance of a Resistor

Fares wants to find out the resistance of a resistor. He connects the resistor to a power source of variable potential difference and uses an ammeter to find the current through the resistor. His results are shown in the table. What is the resistance of the resistor?

Potential Difference (V)	3	6	9	12	15
Current (mA)	50	100	150	200	250

Answer

The resistance of a resistor is equal to the ratio of the potential difference across the resistor to the current through it. Written as an equation,

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

The given table consists of five pairs of values, but we only need one such pair to compute the resistance of the unknown resistor. This is because the ratio of potential difference to current is the same for all five pairs.

Selecting the first pair of values, we see the potential difference is 3 V and the current is 50 mA.

If R is the resistance of the resistor, then

$$R = \frac{3\ \text{V}}{50\ \text{mA}}.$$

We convert the units of current from milliamperes to amperes using the fact that $1\ \text{mA} = 0.001\ \text{A}$ as follows:

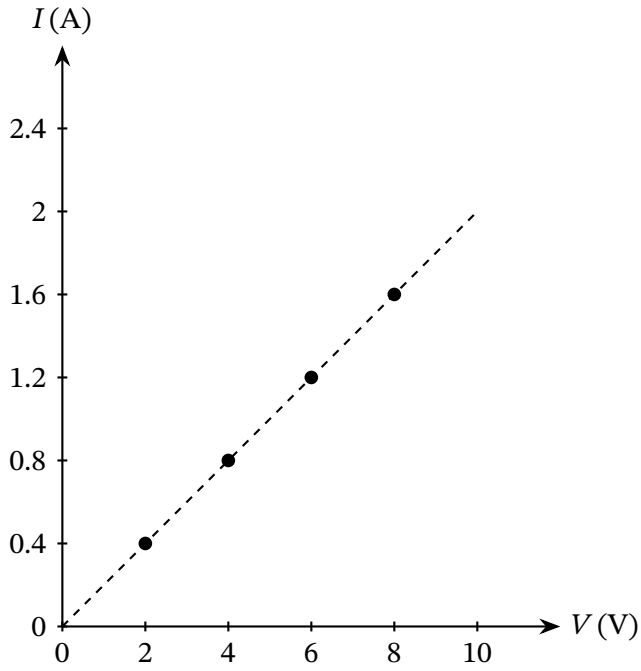
$$\begin{aligned} R &= \frac{3\ \text{V}}{50 \times 0.001\ \text{A}} \\ &= \frac{3\ \text{V}}{0.05\ \text{A}} \\ &= 60\ \Omega. \end{aligned}$$

The resistance of the resistor in this experiment is 60 ohms.

Example 4: Using Experimental Results to Find the Resistance of a Resistor

A student has a resistor of unknown resistance. She places the resistor in series with a source of variable potential difference. Using an ammeter, she measures the current through the resistor at

different potential differences and plots her results on the graph as shown in the diagram. What is the resistance of the resistor?



Answer

Here, we see a graph of current against voltage for a certain resistor.

Ohm's law states that the resistor's resistance (R) multiplied by the current through the resistor (I) equals the potential difference across it (V), as follows:

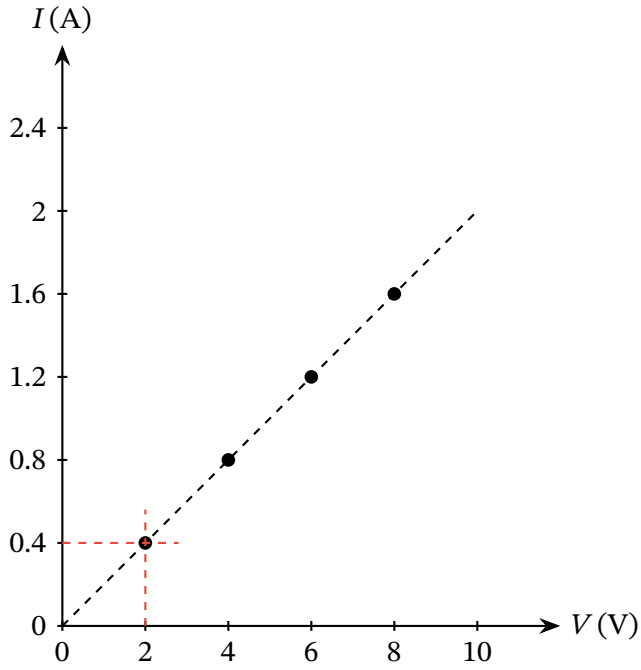
$$V = I \times R.$$

To solve for the resistance, we divide both sides of the equation by I and switch the left and right sides, yielding the following:

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

The graph shows four data points for the resistor: four measurements of corresponding values of current and potential difference.

We can use any of the four points to calculate R. Choosing the first point, we see that it corresponds to a current of 0.4 amperes and a potential difference of 2 volts, as shown below.



Using the equation $R = \frac{V}{I}$ and substituting 2 V for V and 0.4 A for I, we find

$$\begin{aligned} R &= \frac{2\text{ V}}{0.4\text{ A}} \\ &= 5\ \Omega. \end{aligned}$$

The resistance of the resistor is 5 ohms.

Key Points

- Ohm's law is the name of a relationship between current, I (in units of amperes); resistance, R (in units of ohms); and potential difference, V (in units of volts) in many conductors: $V = I \times R$.
- Ohm's law may be rearranged so that the current or the resistance is the subject: $I = \frac{V}{R}$ and $R = \frac{V}{I}$.
- Conductors for which current and voltage are not directly proportional are called nonohmic.