OHM'S LAW

This note explains Ohm's law connecting together current, voltage, and resistance. It also describes the concepts of work and power in this context.

Definitions

Electrical circuitry

The current (I for intensity) is the movement (flow) of electrons through an electrical circuit. It is measured in amperes A[1]. The force required to move the electrons is referred to as voltage (V) measured in volts V[2]. The third element of electrical circuitry is the resistance (R) against the flow of electrons, which is measured in ohms Ω[3].

Law

Ohm's law states that in a closed circuit current (I) is proportional to the voltage (V) and inversely proportional to the resistance (R).

$$I = \frac{V}{R} \longrightarrow V = I \times R \quad \text{and} \quad R = \frac{V}{I}$$

The law can also be expressed using the next figures.

[1] The ampere A is named after André Ampère, French physicist and mathematician, who in the late 18^{th} century worked with magnetism and current to develop some foundations for understanding the behavior of electricity. One ampere represents the movement of 6.25×10^{18} electrons (or one coulomb) past one point in a conductor in one second.

[2] The name comes from the Italian physicist and chemist Alessandro Volta. One volt is the amount of pressure (force) required to move one ampere of current through one ohm of resistance.

[3] Georg Ohm was a German physicist and mathematician around 1800 who discovered that all electrical quantities are proportional to each other and therefore have a mathematical relationship.

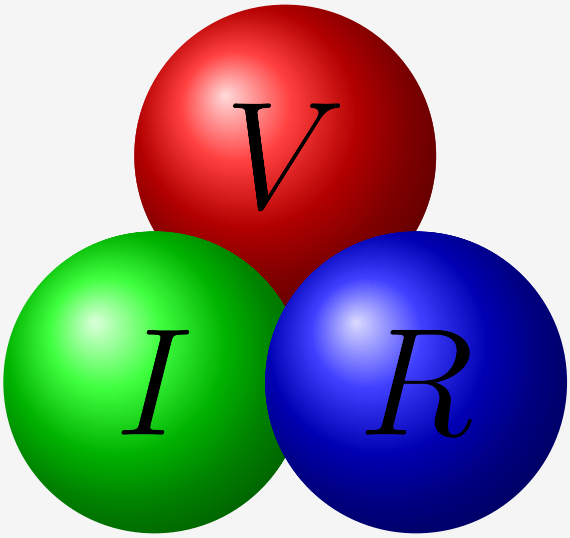

Figure 1: Ohm's law.

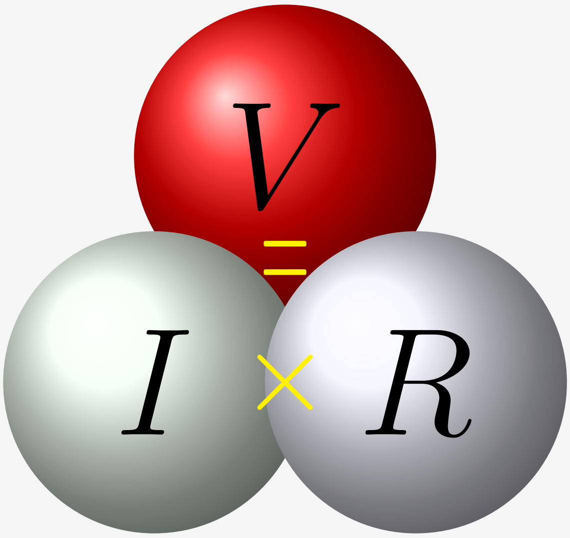

Figure 2: $V = I \times R$.

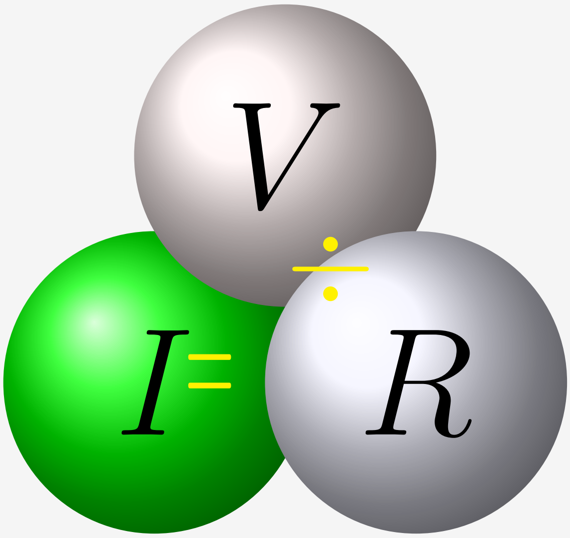

Figure 3: $I = \frac{V}{R}$.

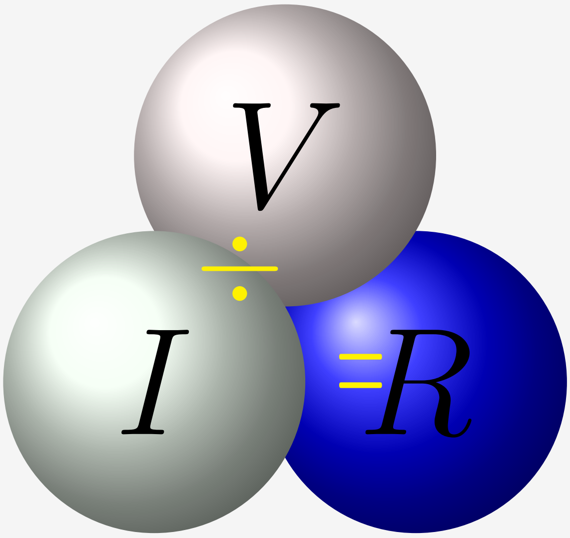

Figure 4: $R = \frac{V}{I}$.

Examples and intuition

Garden hose

First, using a garden hose. Replace the electrons with tap water pouring (current) through the hose (the conductor). How far you open the tap determines the force to push the water, which in turn controls the pressure (voltage). Then, if you kink the hose it produces a resistance, which slows down the current. Add a couple more kinks and it really slows down the current, unless you increase the force (voltage) with help of the tap.

Waterwheel

A second example uses a waterwheel, a large wheel turning with the help of water, used e.g. to grind wheat. The turning of the wheel represents the resistance. To fight this resistance you need enough water through the wheel (current) and enough pressure (voltage).

Explanation

Current and voltage

The movement of electrons is called a current. It flows through the wires. It is important to know the amount of electrons flowing, because this current does the work in your car. However, it is almost impractical to count electrons because the number needed to do a reasonable amount of work is extremely large.

The motive force which induces a current to flow is measured in volts. This voltage can be supplied from a battery or produced by a generator. In order for a flow to occur, the ends of a conductor must have a different voltage or, if you like, a voltage differential.

Voltage is often compared to water pressure. In the same way as applying two equal pressures of water to a pipe would result in no flow across the pipe, by connecting two $12V$ supplies together we produce no current, but by applying this combined potential to another conductor we may produce a flow with a pressure of $24V$.

Work

Electricity working gives us light, heat, or magnetic field. Any time work is done it produces one or more of these results. Most of the time, this work is desired or engineered into the circuit, but sometimes it is not. A bad connection, for example, might get warm as electrons flow through it.

All the devices in a car have some current flowing through them and do some work to produce light, heat, or magnetic field. Certain devices also give us motion. Starters, heater blowers, or windshield wipers give motion by setting up magnetic fields.

Work cannot be done by just voltage or just amperage. Both are needed. When the headlights are on overnight and run the battery down, the voltage is removed. When you try starting the car the next morning, you have electrons 'available in your headlights', but without voltage behind the electrons there is not any current and nothing happens when you turn the key.

Wattage (W) is the means of monitoring how much work is done. It is rated in watts W[4]. Therefore, a watt is the unit of electrical power, and equals $1A$ under the pressure of $1V$. It is also equal to 1 joule per second. Wattage is

[4] James Watt was an instrument maker and inventor whose steam engines contributed to the industrial revolutions

the result of multiplying the voltage applied to the current flowing.

$$\text{voltage} \times \text{amperage} = \text{wattage} \quad \text{or} \quad V \times A = W.$$

Two examples. A $60W$-bulb delivers one-half the light of a $120W$-bulb. This $60W$-bulb at home may draw $0.5A$ of current at $120V$ ($120 \times 0.5 = 60$). Another example. If $2000W$ are needed to crank over an engine, $200A$ are needed if the voltage is kept up to $10V$ ($200 \times 10 = 2000$). However, if the voltage drops down to $5V$, the amperage has to go up to $400A$ to crank the engine over at the same speed ($400 \times 5 = 2000$).

Resistance

Everything has some resistance to electrical flow, there are no perfect conductors. If you double the length of any cable you double its resistance to flow. If you double its cross-sectional size then resistance is halved.

Resistance is opposition. It is the force that opposes the flow of electrons. This back pressure, along with the voltage, dictate the number of electrons able to flow through a circuit. When current is moving through electrical components, such as bulbs and motors, the amount of current flowing is dependent on these two conditions: the voltage, or pressure on the electrons, and the resistance that the circuit puts up against the flow of electrons.

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Héritage automobile APPROVED