Ohm’s Law

OBJECTIVES

- Define Ohm’s Law
- Discuss Ohm’s Law with “Arrow Analysis”
- Calculate It, Rt, and Vt using Ohm’s Law

INTRODUCTION

In the 19th century, Georg Simon Ohm derived through experimentation one of the basic laws of electrical circuits. Ohm’s Law describes the relationship between Current, Voltage and Resistance. In this lesson we will cover this relationship with “Arrow Analysis” and with mathematical formulae.

Ohm’s Law

Ohm determined that if Voltage is increased across a resistance, more current will flow through the resistance, and likewise, if Voltage is decreased across a resistance, less current will flow through the resistance.

Ohm’s Law states that the current (in Amperes) is equal to the Voltage (in Volts) divided by the resistance (in Ohms).

This relationship can be shown in the following three equations:

1. Current = Voltage ÷ Resistance

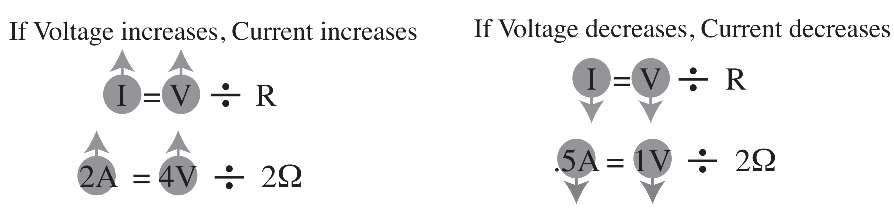
2. Resistance = Voltage ÷ Current

3. Voltage = Current X Resistance

It can be shown with Arrow Analysis the relationship between Voltage, Current, and Resistance. Understanding this relationship will help in understanding basic electrical circuit operations and later electrical circuit troubleshooting. Simple math will also be used to illustrate and validate the Arrow Analysis.

What happens to Current if Voltage changes but Resistance stays unchanged?

Math Proof 1 Amp = 2 Volts ÷ 2 Ohms
Start With



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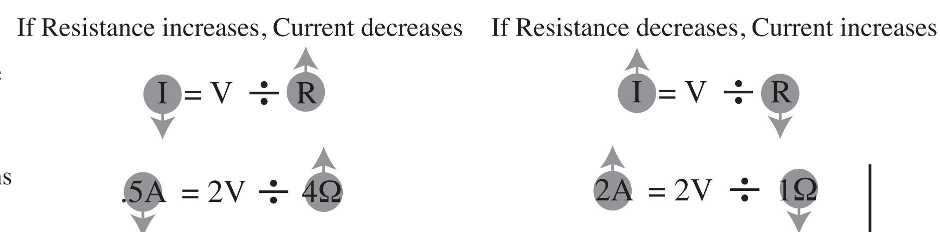


Arrow Analysis for Current

What happens to Voltage if Current changes but Resistance stays unchanged?

Math Proof 1 Volts = 1 Amp X 1 Ohms

Start With

If Current increases, Voltage increases

$$V\uparrow = I\uparrow \times R$$

$$2V\uparrow = 2A\uparrow \times 1\Omega$$

If Current decreases, Voltage decreases

$$V\downarrow = I\downarrow \times R$$

$$.5V\downarrow = .5A\downarrow \times 1\Omega$$

What happens to Voltage if Resistance changes but Current stays unchanged?

Math Proof 1 Volts = 1 Amp X 1 Ohms

Start With

If Resistance increases, Voltage increases

$$V\uparrow = I \times R\uparrow$$

$$2V\uparrow = 1A \times 2\Omega\uparrow$$

If Resistance decreases, Voltage decreases

$$V\downarrow = I \times R\downarrow$$

$$.5V\downarrow = 1A \times .5\Omega\downarrow$$

Arrow Analysis for Voltage

What happens to Resistance if Current changes but Voltage stays unchanged?

Math Proof 1 Ohm = 2 Volts ÷ 2 Amps

Start With

If Current increases, Resistance decreases

$$R\downarrow = V \div I\uparrow$$

$$.5\Omega\downarrow = 2V \div 4A\uparrow$$

If Current decreases, Resistance increases

$$R\uparrow = V \div I\downarrow$$

$$2\Omega\uparrow = 2V \div 1A\downarrow$$

What happens to Resistance if Voltage changes but Current stays unchanged?

Math Proof 1 Ohm = 2 Volts ÷ 2 Amps

Start With

If Voltage increases, Resistance increases

$$R\uparrow = V\uparrow \div I$$

$$2\Omega\uparrow = 4V\uparrow \div 2A$$

If Voltage decreases, Resistance decreases

$$R\downarrow = V\downarrow \div I$$

$$.5\Omega\downarrow = 1V\downarrow \div 2A$$

Arrow Analysis for Resistance

Arrow Analysis is useful for basic Ohm's Law understanding, but it can also be used during troubleshooting of an electrical circuit. An example of the usefulness of Arrow Analysis for troubleshooting would be if a circuit you are working on keeps "blowing a fuse". (A fuse is an electrical component that is used to open a circuit and stop current from flowing if too much current flows.) By replacing the fuse and measuring the voltage before the fuse blows again you can tell if the Voltage is what is expected for the circuit. With these two pieces of information, 1) Current increases and 2) Voltage stays the same, it is determined that resistance is decreasing. (The problem.) Now a multimeter can be used to find the reason for the lowered resistance, i.e. a short.

$$I\uparrow = V \div R\downarrow$$

If the Voltage had increased before the fuse blow, then the resistance can be checked and if it is what is expected for the circuit the source of the Voltage is the problem. (i.e. Power Supply, Alternator, Generator ...)

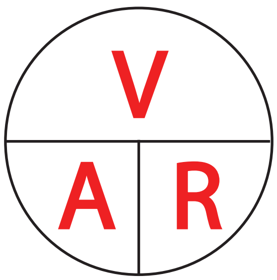
$$I\uparrow = V\uparrow \div R$$

Notice both problems cause the same issue, an increase in Current. Understanding Ohm's Law and Arrow Analysis can help lead you to the true reason for the failure.

Should someone memorize Arrow Analysis? This is up to the person taking this course. But, knowing that it exists and can be looked up when needed is important. Experience troubleshooting will help in learning Arrow Analysis. When in doubt doing the math for the equations of Ohm's Law will give you the Arrow Analysis charts above.

Ohm's Law Chart

Remembering the three equations stated on the first page of this lesson, they can be made easier to remember with a simple chart. (See Figure 1) With this chart simply cover the electrical property you want to calculate for and what is left is the equation for the covered property.



Remember: Voltage is symbolized by V or E
Current is symbolized by A or I
Resistance is symbolized by R or Ω

It is hard to pick just one symbol for any electrical property because all are used with equal regularity in electronic text books. But I tend to use V for Voltage, I for Current, and R for Resistance in equations. But label circuit values with V for Voltage, A for Current, and Ω for resistance. I will use E very rarely.

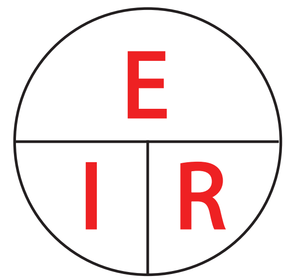


Figure 1

Finding the Equation for Voltage using the Ohm's Law chart

To find the equation for Voltage, place your finger over the V on the chart and you will have I R together left. Remember back to your High School Math classes, Two variables placed together get multiplied together and can be rewritten as I X R. So, by covering up the V you get the equation V = I X R. (See Figure 2)

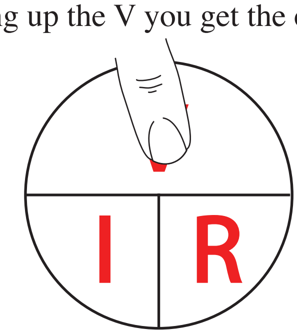


Figure 2

Finding the Equation for Current using the Ohm's Law chart

To find the equation for Current, place your finger over the I on the chart and you will have a V above an R separated by a line, this represents a fraction or a division equation. So, by covering up the I you get the equation I = V ÷ R. (See Figure 3)

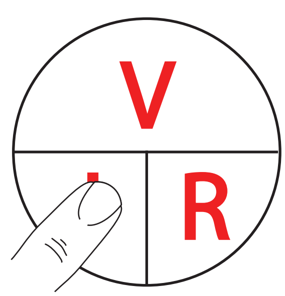


Figure 3

Finding the Equation for Resistance using the Ohm's Law chart

To find the equation for Resistance, place your finger over the R on the chart and you will have a V above an I separated by a line, this represents a fraction or a division equation. So, by covering up the R you get the equation R = V ÷ I. (See Figure 4)

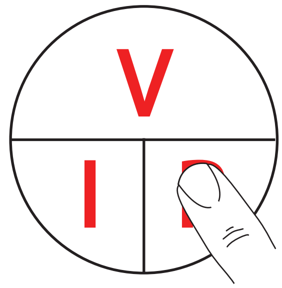


Figure 4

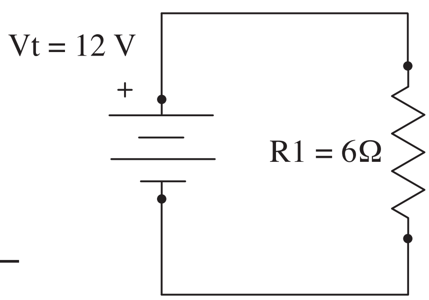
Calculating with Ohm's Law Equations

When calculating using Ohm's Law equations it is important to insure that you use common terms, such as Resistance Total (Rt), Voltage Total (Vt), or Current Total (It). In later lessons, single electrical components can use Ohm's Law, such as Voltage across Resistor 1 (V_{R1}), Current through Resistor 1 (I_{R1}), or the Resistance of Resistor 1 (R1).

Ohm's Law equations FAIL if you mix terms, such as Vt = I_{r1} X R3. So be careful.

Practice Problems:

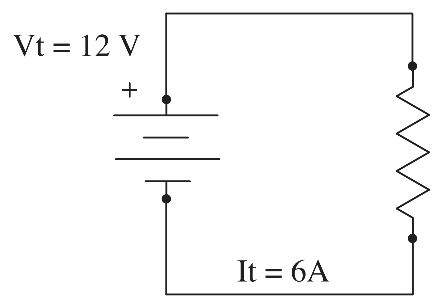
1.



It = ______

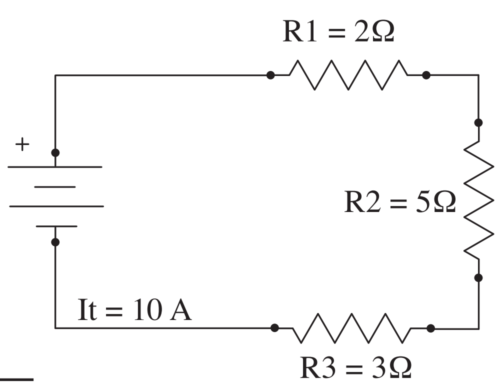
If there is only one resistor you can think of that as Rt.

2.



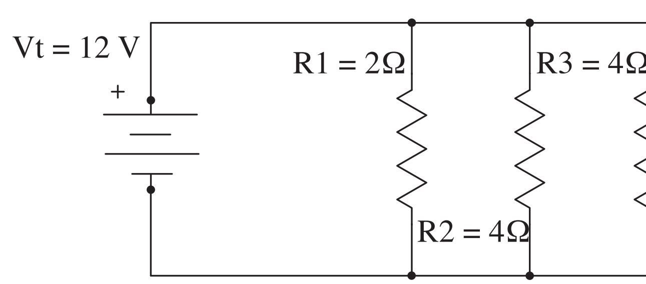
Rt = ______

3.



Vt = ______

4.



It = ______

Remember how to calculate Rt?