11.5.3: Series Circuits

Figure 17.3.1

Resistors, including electrical appliances, have a particular current at which they operate most effectively and safely, and excessive current can cause irreparable damage. Therefore, it is important to limit the amount of current that may pass through a particular electrical circuit. There are a number of safety devices used in electrical circuits to limit the current: fuses, circuit breakers, and surge suppressors. When fuses, such as those shown above, are placed in an electrical circuit, all the current must pass through the wire in the fuse.

Series Circuits

Electrical circuits are often modeled by using water in a river. The potential energy of the water is the highest at the source of the river and decreases as the water flows down the river toward the end. When the water reaches the ocean, its potential energy has become zero. The circuit shown below has a similar situation. The current in this circuit is drawn in the direction of the electron flow. It starts at the battery on the left, where electrons leave the negative terminal and travel around the circuit. Since all of the current travels across each resistor, these resistors are said to be in **series**. A series circuit is one in which all of the current must pass through every resistor in the circuit. Returning to the water analogy, there is only one riverbed from the top of the mountain to the ocean.

Three resistors in series

Figure 17.3.2

Consider the series circuit sketched above. This circuit has a voltage drop for the entire circuit of 120 V and has three resistors connected in series. The current in this circuit is drawn in terms of electron flow. The electrons leave the potential difference source at the negative terminal and flow through the three resistors, starting with R3. Though they have a small amount of resistance, the resistance of the connecting wires is so small in relation to the resistors that we ignore it. Therefore, we say that there is no voltage drop when the current passes through the connecting wires. The voltage drops occur when the current passes through each of the resistors and the total voltage drop for the entire circuit is equal to the sum of the voltage drops through the three resistors.

$$V_T=V_1+V_2+V_3$$

The current through each of the resistors must be exactly the same because the current in a series circuit is the same everywhere. The current is moving in the entire circuit at the same time.

$$I_T=I_1=I_2=I_3$$

Since the current passes through each resistor, the total resistance in the circuit is equal to the sum of the resistors. In the circuit above, the total resistance is:

$$R_T=R_1+R_2+R_3=30\ \Omega+15\ \Omega+15\ \Omega=60\ \Omega$$

Therefore, the total current and the current through each resistor is

$$I=V/R=120\ V/60\ \Omega=2.0\ A.$$

The individual voltage drops can be calculated using the current through each resistor and each resistor's individual resistance.

$$V_1=I_1R_1=(2.0\ A)(30\ \Omega)=60\ V$$

$$V_2=I_2R_2=(2.0\ A)(15\ \Omega)=30\ V$$

$$V_3=I_3R_3=(2.0\ A)(15\ \Omega)=30\ V$$

Example 17.3.1

Four 15 Ω resistors are connected in series with a 45 V battery. What is the current in the circuit?

Solution

$$RT=15\ \Omega+15\ \Omega+15\ \Omega+15\ \Omega=60\ \Omega$$

$$I=VR=45\ V60\ \Omega=0.75\ A$$

Adjust the the resistance provided by each light bulb in the circuit and observe what happens to the total resistance in the PLIX Interactive below:

Adjust the total voltage of the circuit and observe what happens to the individual voltage drops in the PLIX Interactive below:

Summary

- A series circuit is one in which all of the current must pass through every resistor in the circuit.
- $V_T=V_1+V_2+V_3$
- $I_T=I_1=I_2=I_3$
- $R_T=R_1+R_2+R_3$

Review

1. There are three 20.0 Ω resistors connected in series across a 120 V generator.
    1. What is the total resistance of the circuit?
    2. What is the current in the circuit?
    3. What is the voltage drop across one of the resistors?
2. A 5.00 Ω, a 10.0 Ω, and a 15.0 Ω resistor are connected in series across a 90.0 V battery.
    1. What is the equivalent resistance of the circuit?
    2. What is the current in the circuit?
    3. What is the voltage drop across the 5.00 Ω resistor?
3. A 5.00 Ω and a 10.0 Ω resistor are connected in series across an unknown voltage. The total current in the circuit is 3.00 A.
    1. What is the equivalent resistance of the circuit?
    2. What is the current through the 5.00 Ω resistor?
    3. What is the total voltage drop for the entire circuit?

Explore More

Use this resource to answer the questions that follow.

1. How do the voltage drops across the two light bulbs in the video relate to the total voltage drop for the entire circuit?
2. In the video, what was the assumed voltage drop for the connecting wires and the switch?
3. What was the current through the second light bulb as compared to the current through the first light bulb?

Additional Resources

Study Guide: Electrical Systems Study Guide

Real World Application: Lights in Series

Interactive: Dollhouse, Marquee Lights

Video: