

## Series Circuits (Resistance Only)

**Unit:** DC Circuits

**NGSS Standards/MA Curriculum Frameworks (2016):** HS-PS2-9(MA)

**AP<sup>®</sup> Physics 2 Learning Objectives/Essential Knowledge (2024):** 11.5.A, 11.5.A.1, 11.5.A.1.i, 11.5.A.2, 11.5.A.2.i, 11.5.B, 11.5.B.1, 11.5.B.1.i, 11.5.B.1.ii

**Mastery Objective(s):** (Students will be able to...)

- Calculate voltage, current, resistance and power in series circuits.

**Success Criteria:**

- Correct relationships are applied for voltage, current, resistance and power in series circuits.
- Variables are correctly identified and substituted correctly into the correct equations.
- Algebra is correct and rounding to appropriate number of significant figures is reasonable.

**Language Objectives:**

- Explain the relationships for voltages, current, resistance and power in series circuits.

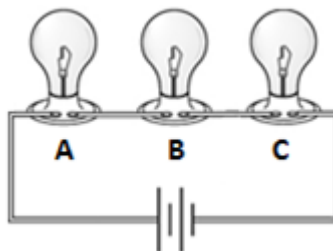
**Tier 2 Vocabulary:** series, circuit

**Labs, Activities & Demonstrations:**

- Circuit with light bulbs wired in series.

**Notes:**

series: Components in series lie along the same path, one after the other.



In a series circuit, all of the current flows through every component, one after another. If the current is interrupted anywhere in the circuit, no current will flow. For example, in the following series circuit, if any of the light bulbs A, B, or C is removed, no current can flow and none of the light bulbs will be illuminated.

Because some of the electric potential energy (voltage) is “used up” by each bulb in the circuit, each additional bulb means the voltage is divided among more bulbs and is therefore less for each bulb. This is why light bulbs get dimmer as you add more bulbs in series.

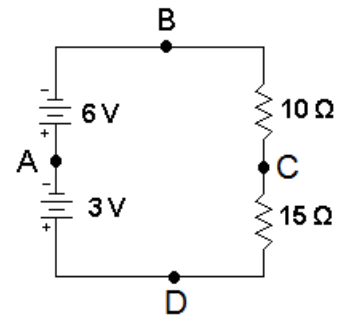
Christmas tree lights used to be wired in series. This caused a lot of frustration, because if one bulb burned out, the entire string went out, and it could take several tries to find which bulb was burned out.

The diagram to the right shows two batteries and two resistors in series.

### Current

Because there is only one path, all of the current flows through every component. This means the current is the same through every component in the circuit:

$$I_{total} = I_1 = I_2 = I_3 = \dots$$



### Voltage

In a series circuit, if there are multiple voltage sources (*e.g.*, batteries), the voltages add:

$$\Delta V_{total} = \Delta V_1 + \Delta V_2 + \Delta V_3 + \dots$$

In the above circuit, there are two batteries, one that supplies 6 V and one that supplies 3 V. The voltage from A to B is +6 V, the voltage from A to D is -3 V (note that A to D means measuring from negative to positive), and the voltage from D to B is (+3 V) + (+6 V) = +9 V.

### Resistance

If there are multiple resistors, each one contributes to the total resistance and the resistances add:

$$R_{total} = R_1 + R_2 + R_3 + \dots$$

In the above circuit, the resistance between points B and D is  $10\Omega + 15\Omega = 25\Omega$ .

### Power

In all circuits (series and parallel), any component that has resistance dissipates power whenever current passes through it. The total power consumed by the circuit is the sum of the power dissipated by each component:

$$P_{total} = P_1 + P_2 + P_3 + \dots$$

**Calculations**

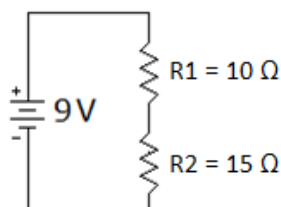
You can calculate the voltage, current, resistance, and power of each component separately, any subset of the circuit, or entire circuit, using the equations:

$$\Delta V = IR \qquad P = I\Delta V = I^2R = \frac{(\Delta V)^2}{R}$$

“Solving” the circuit for these quantities is much like solving a Sudoku puzzle. You systematically decide which variables (for each component and/or the entire circuit) you have enough information to solve for. Each result enables you to determine more and more of the, until you have found all of the quantities you need.

**Sample Problem:**

Suppose we are given the following series circuit:



and we are asked to fill in the following table:

	R <sub>1</sub>	R <sub>2</sub>	Total
Voltage ( $\Delta V$ )			9 V
Current ( $I$ )			
Resistance ( $R$ )	10 $\Omega$	15 $\Omega$	
Power ( $P$ )			

First, we recognize that resistances in series add, which gives us:

	R <sub>1</sub>	R <sub>2</sub>	Total
Voltage ( $\Delta V$ )			9 V
Current ( $I$ )			
Resistance ( $R$ )	10 $\Omega$	15 $\Omega$	<b>25 <math>\Omega</math></b>
Power ( $P$ )			

Now, we know two variables in the “Total” column, so we use  $\Delta V = IR$  to find the current.

$$\Delta V = IR$$

$$9 = (I)(25)$$

$$I = \frac{9}{25} = 0.36 \text{ A}$$

## Series Circuits (Resistance Only)

Because this is a series circuit, the total current is also the current through  $R_1$  and  $R_2$ .

	$R_1$	$R_2$	Total
Voltage ( $\Delta V$ )			9 V
Current ( $I$ )	<b>0.36 A</b>	<b>0.36 A</b>	<b>0.36 A</b>
Resistance ( $R$ )	10 $\Omega$	15 $\Omega$	25 $\Omega$
Power ( $P$ )			

As soon as we know the current, we can find the voltage across  $R_1$  and  $R_2$ , again using  $\Delta V = IR$ .

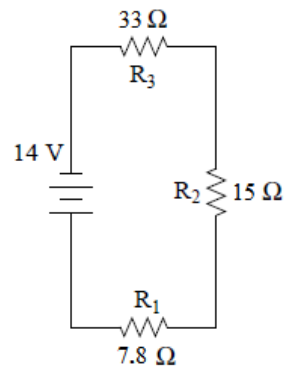
	$R_1$	$R_2$	Total
Voltage ( $\Delta V$ )	<b>3.6 V</b>	<b>5.4 V</b>	9 V
Current ( $I$ )	0.36 A	0.36 A	0.36 A
Resistance ( $R$ )	10 $\Omega$	15 $\Omega$	25 $\Omega$
Power ( $P$ )			

Finally, we can fill in the power, using  $P = I \Delta V$ :

	$R_1$	$R_2$	Total
Voltage ( $\Delta V$ )	3.6 V	5.4 V	9 V
Current ( $I$ )	0.36 A	0.36 A	0.36 A
Resistance ( $R$ )	10 $\Omega$	15 $\Omega$	25 $\Omega$
Power ( $P$ )	<b>1.30 W</b>	<b>1.94 W</b>	<b>3.24 W</b>

### Homework Problems

1. **(M)** Fill in the table for the following circuit:

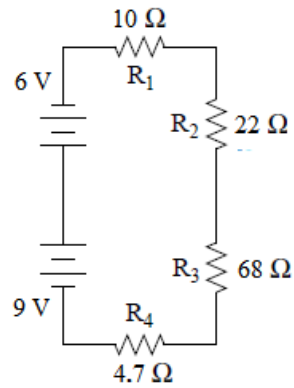


	$R_1$	$R_2$	$R_3$	Total
Voltage ( $\Delta V$ )				14 V
Current ( $I$ )				
Resist. ( $R$ )	$7.8 \Omega$	$15 \Omega$	$33 \Omega$	
Power ( $P$ )				

*(The space below is intentionally left blank for calculations.)*

2. **(M)** Fill in the table for the following circuit.

*(Hint: Notice that the batteries are oriented in opposite directions.)*



	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	Total
Voltage ( $\Delta V$ )					
Current ( $I$ )					
Resist. ( $R$ )	10 $\Omega$	22 $\Omega$	68 $\Omega$	4.7 $\Omega$	
Power ( $P$ )					

*(The space below is intentionally left blank for calculations.)*