Photo Courtesy: GrigoriosMoraitis/Getty Images When it comes to electrical circuits, there are two basic varieties: series circuits and parallel circuits. The major difference between the two is the number of paths that the electrical current can flow through. Here, we'll zero in on series circuits, exploring both how they work and which common electronic devices utilize them.In a series circuit, there's only one pathway the electricity can flow through. While a series circuit may power multiple devices, every part of the circuit, including all of the devices, wires, and the power source, are connected along the same path. Photo Courtesy: Emilija Manevska/Getty Images Need a visual of how it works? Think of a group of people standing in a circle, each holding a candle. One person in the circle lights their candle — and then they light the candle of the person to their left. That second person will then use their newly lit candle to light that of the person to their left, and so on. That pattern would continue until everyone's candle was lit. In essence, that's how a series circuit works. The power source sends electricity to the first device; the electricity flows through that first device and into the second, and so on until, eventually, all of the devices are connected, one right after the other.As efficient as a series circuit can be, it isn't without its downsides. Since electricity travels through each device along a single path, all it takes is one device to burn out to put the rest in jeopardy. Going back to our candle example, if the second person in the circle has a candle that just won't light, they can't pass the flame on to the third person. Photo Courtesy: gmcoop/Getty Images With electricity, things are even worse. All it takes is for one device to malfunction and the entire operation is a mess. Back in the old days, this was a common problem with Christmas lights. All it took was one bulb burning out to render an entire strand of lights incapable of producing their signature seasonal glow. Another downside? Because all of the devices share the same power source, they all get an equal amount of energy. This isn't inherently a bad thing in and of itself — well, unless you want to add a large number of devices. With each new device you add, there's less energy to go around, so in the case of lights, each of the lights in the circuit would grow dimmer with each new addition.Series circuits tend to be popular because they are definitely not without their advantages. One of the more obvious perks of the series circuit is that it tends to be much easier and efficient to set up. Photo Courtesy: svetkid/Getty Images Consider the case of string lights, for instance. Because they utilize a series circuit, it's not necessary to connect every single light to a power source with its own wire. Instead, a single strand of wires simply connects one light to the next so that they all form a handy line. Another advantage? Each light in a strand gets its equal share of electricity. Otherwise, you might have two or three lights that shine like rockstars while the others produce a weak glow. It's also easier to read a series circuit with an ammeter or a voltmeter, should you desire to do so. Since the current flows evenly throughout the entire circuit, you'll get the same readings no matter what part of the circuit you measure.In order to better understand the additional advantages of series circuits, let's take a look at some common household items that tend to use them. Water heaters, for example, illustrate how useful series circuits can be when one needs to cut off the flow of electricity. Photo Courtesy: Nattawat Chakreyanan / EyeEm/Getty Images That is, power flows to a water heater through a thermostat, which is rigged to be able to tell the temperature of the water. The power is able to flow through the thermostat and into the heating element, which in turn heats the water. But when the thermostat can tell that the water has reached its target temperature, it's able to switch off. This breaks the series circuit and keeps the water from getting any hotter than intended. Lamps are another example of why a series circuit can come in handy. In basic terms, the series circuit is made up of a power source that travels through a path connected to the switch, then up to the bulb and back again. When you turn off a lamp, you're really just breaking the series circuit. A circuit diagram uses symbols that represent different parts of said circuit. Engineers use these series diagrams to map out a potential circuit much like an architect uses blueprints. Some diagrams are pretty straightforward, while others can be incredibly complex. Photo Courtesy: mets501/Wikipedia The two you'll see above are examples of very basic series circuit diagrams and show some of the basic symbols used to represent different parts of the circuit. In the first diagram, you'll see two parallel lines over on the left-hand side which represent an energy cell. The straight lines on each diagram represent wires that the electric current flows through. The squiggly lines in the diagram on the left represent resistors. At the bottom of the second diagram, you'll see a different set of parallel lines that together make up the symbol for a battery. As you follow the wires around the series circuit, you'll see three circles, each of which has an x in the middle. This is the symbol used to indicate a light bulb. If you're interested in learning more about circuit diagrams, and how to read them, check out this great breakdown from Teach Engineering. MORE FROM REFERENCE.COM In a parallel circuit, there is more than one way for the current to flow while in a series circuit, there is a single path for the current flow. The circuits in which components are connected in series are called series circuits. In a series circuit, the current flowing in each component is the same but the voltage is different. It is easy to design and easy to understand but susceptible to total circuit failure if one component fails. In the article, we'll explore what series circuits are, and how they work, and dive into examples to calculate their current, voltage, and equivalent resistance. When learning electronic circuits, it's essential to learn different combinations of circuits. One of the fundamental circuit configurations is the series circuit. Let's discuss the series circuit in detail. A series circuit is defined as, A series circuit is an electrical circuit in which electronic components are connected end-to-end in a single path, so the same current flows through each component. The components are connected in line and there is only one path for current to flow. The whole current flows through each component. You can see in the above circuit, that the components which are resistors are connected in line and there is only one path for current to flow. The series circuit is simple to design and very easy to understand as it has straightforward connections. There are also some limitations of a series circuit such as if one component fails in the series circuit the entire circuit becomes non-functional. In a series circuit, components are connected in a single pathway so that the current has only one route to follow. This arrangement creates a sequential flow of electricity through each component. Here are some characteristics of series circuits. In a series circuit the current flows in sequential form. There is no branching or division of the current; it passes through one component after another along the same path. The current is the same throughout the circuit and the same current is flowing in each component. So if there are 'n' number of components in the circuit the current is I_T = I_1 = I_2 = ...= I_n Where I_T is the total current flowing in the circuit. The voltage in the series circuit is different across each component. The total voltage provided by the power source is distributed across all the components in the circuit. Each component utilizes a portion of the total voltage. As the current flows in each component, the voltage drop is according to the resistance of the component. So the total voltage in the circuit is equal to V_T = V_1 + V_2 + ... + V_n By adding voltage drop across each component you can find the total voltage in the circuit. The equivalent resistance in a series circuit is the sum of all the individual resistances. This total resistance impacts the overall current flow. If there are "n" number of resistors then the equivalent resistance will be equal to R_eq = R_1 + R_2 + ... + R_n Let's consider examples to understand how to analyze a series circuit. Example no. 1 In the given circuit we have three resistors connected in a series across a 120V battery. In a series circuit, the equivalent resistance is equal to the sum of the individual resistance in the circuit. As in the above circuit, we have three resistors so R_eq = R1+R2+R3 R_eq = 15+5+20 R_eq = 40Ω As the circuit has only one path, the same current will flow in each resistor. So I_T = I_1 = I_2 = I_3 Using Ohm's law we can find the total current. The total current is given by I_T = V_T/R_eq As we know V_T = 120 and R_eq = 40Ω I_T = 120/40 I_T = 3A Now we can find the voltage drop for each component and the total voltage is equal to the sum of all the voltage drops in the circuit. Using Ohm's law V_1 = I_T*R_1 V_1 = (3A)(15Ω) V_1 = 45V For resistor two V_2 = I_T*R_2 V_2 = (3A)(5Ω) V_2 = 15V Voltage across resistor three V_3 = I_T*R_3 V_3 = (3A)(20Ω) V_3=60V The total source voltage is equal V_T = V_1 + V_2 + V_3 V_T = 45V+15V+60V V_T = 120V As you can see the applied voltage is distributed across all resistors. Example no. 2 Let's consider another example of a series connection. In this example, we have three resistors and they are connected in series with a 12V voltage source. First, we have to find the current in the circuit so the equivalent resistance is equal to the sum of all resistors. R_eq = R1 + R2 + R3 R_eq= 10 + 20 + 30 R_eq= 60 Ω Now the current across the circuit is I_T = V_S/R_T I_T = 12/60 I_T = 0.2A As the current across each resistors it same so it will be 0.2A. The voltage will be divided, and the voltage drop across each resistor can be found by V_1 = I_T*R_1 V_1 = (0.2)(10) V_1 = 2V In the same way, we can find the voltage drop across each resistor. Find the voltage drop in the other two resistors and verify if the calculated voltage is equal to the applied voltage. The following are a few benefits of series circuits: Series circuits are simple to design and require few wires to construct them. All components are connected end-to-end, making it easy to calculate the circuit's total current. They consume less power when compared to parallel circuits. In a series circuit, the current remains the same across components. Series circuits also have some drawbacks. If one component in a series circuit fails, the entire circuit stops working. The voltage is divided among components, meaning each component gets less voltage as more are added, which may reduce performance. If one component gets short it will cause an increase in current in all components and will damage it. Series circuits are not suitable for complex or high-power applications due to their limited voltage and current distribution. Understanding series circuits provides a foundation for comprehending more complex electronic systems. It offers a base for understanding complex electronic circuits. In a series circuit, the components are connected in line and provide only one path for the current to flow. The same current passes sequentially through each component, as opposed to branching out. The voltage is not the same across each component and the voltage drop depends upon the resistance of the component. The total voltage is equal to the sum of all individual voltage drops in the circuit and the equivalent resistance of the circuit is equal to the sum of individual resistance in the circuit. The main disadvantage of the series circuit is if one component stops working it will affect the entire circuit functionality. So this was all about the series circuits, I hope it will be helpful. Thank you... Other useful posts: Kirchhoff's voltage law Parallel circuits Fundamental electronic components The article explores the principles and analysis of series circuits, discussing their configuration, characteristics, and applications. It covers key topics like equivalent resistance, current and voltage behavior, Kirchhoff's Voltage Law, power dissipation, and special cases such as open and short circuits, providing equations, examples, and practical insights for understanding and designing series circuits. Series Circuit Definition Resistors are stated to be in series configuration once they are linked in such a way that there is ONLY one path for current flow which means that the current stays the same in all parts of the series circuit. Series Circuit Characteristics The voltage drop across each element of a series circuit depend on the resistance of the element, and the current is the same at the series level. Two or more series connected resistors can be used as a voltage divider. The potentiometer is an adjustable resistor used as a variable voltage divider. The total power supplied to a series circuit is the sum of the power dissipated in the individual resistances. Resistors may be employed in series with an electronic component for the purpose of voltage dropping or current limiting. How to Calculate Equivalent Resistance in a Series Circuit The circuit diagram for three series-connected resistors and a voltage source is shown in Figure 1. Figure 1. Circuit Diagram of Battery and Series-Connected Resistors The total resistance connected across the voltage source is: $R=\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}$ This is also called the equivalent resistance of the series circuit. For any series circuit with n resistors, the equivalent resistance is $\begin{matrix} R=\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\cdots +\{\{R\}_{n}\} & \cdots & (1) \end{matrix}$ For a circuit consisting of n equal value resistors $R=n^*R$ The equivalent circuit for the series resistance circuit is illustrated in Figure 2. The equivalent circuit simply consists of the voltage source and the equivalent resistance. Figure 2. Equivalent Resistance Circuit An ammeter connected anywhere in the series circuit reads the same current. Current Level is the Same in All Parts of the Circuit You May Also Read: Parallel Circuit Definition & Parallel Circuit Examples Because the resistors are connected end-to-end, there is only one path for current flow. Current flows from the positive terminal of the voltage source through the ammeter, through the top terminal of resistor R1. Clearly, all of the current that flows into the one end of R1 must flow out of the other end. So, the current flows out of the bottom terminal of R1 into the top terminal of R2, and from R2 it moves through R3 to the negative terminal of the voltage source. Thus it is seen that The current is the same in all parts of a series circuit. Using ohm's law, the current through the series circuit is calculated as \[\begin{matrix} I=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\cdots +\{\{R\}_{n}\}} & \cdots & (2) \end{matrix}\] How to Calculate Voltage Drop in a Series Circuit The three-resistor series circuit is reproduced again in Figure 4 with the addition of a voltmeter connected across R1. Figure 4. Sum of the Voltage Drops Equal the Supply Voltage The Sum of Series Voltage Drops It is seen that the current flow through each resistor causes a voltage drop, or potential difference, across each resistor. There is a voltage drop between the terminals of each resistor, otherwise there would be no current flow. Using Ohm's law, the voltage drops across each resistor are, \[\{\{V\}_{1}\}=I\{\{R\}_{1}\},\text{ }\{\{V\}_{2}\}=I\{\{R\}_{2}\}\text{ }and\text{ }\{\{V\}_{3}\}=I\{\{R\}_{3}\}\] Note that the polarity of the resistor voltage drops is always such that the (conventional) current direction is from positive to negative. That is, from the top of each resistor to the bottom. As the circuit shows, the sum of the voltage drops is V1+V2+V3, and, as shown in figure 4, this must be equal to the applied emf E. For any series circuit, $E=\{\{V\}_{1}\}+\{\{V\}_{2}\}+\{\{V\}_{3}\}+\cdots +\{\{V\}_{n}\}$ Or $\begin{matrix} E=I\{\{R\}_{1}\}+I\{\{R\}_{2}\}+I\{\{R\}_{3}\}+\cdots +I\{\{R\}_{n}\} & \cdots & (3) \end{matrix}$ Therefore the total voltage drop will be, $\begin{matrix} E=I(\{\{R\}_{1}\}+\{\{R\}_{2}\}+\cdots +\{\{R\}_{n}\}) & \cdots & (4) \end{matrix}$ Kirchhoff's Voltage Law The relationship between the applied emf and the resistor voltage drops in a series circuit is defined by Kirchhoff's Voltage Law: [stextbox id='info' caption='KVL Definition ']In any closed electric circuit, the algebraic sum of the voltage drops must equal the algebraic sum of the applied EMFs.[/stextbox] Using the following values, determine the voltage drops across each resistor in the circuit shown in Figure 4. $\begin{matrix} \begin{matrix} \{\{R\}_{1}\}\text{=5 }\!\!\Omega\!\!\text{ } & \{\{R\}_{2}\}\text{=15 }\!\!\Omega\!\!\text{ } & \{\{R\}_{3}\}\text{=25 }\!\!\Omega\!\!\text{ } \end{matrix} & \text{E=9V} & \text{I=0.2A} \end{matrix}$ Solution Voltage drop across each resistor would be; $\begin{align} & \{\{V\}_{1}\}=I\{\{R\}_{1}\}=0.2A*5\Omega =1V \\ & \{\{V\}_{2}\}=I\{\{R\}_{2}\}=0.2A*15\Omega =3V \\ & \{\{V\}_{3}\}=I\{\{R\}_{3}\}=0.2A*25\Omega =5V \\ & finally, \\ & E=\{\{V\}_{1}\}+\{\{V\}_{2}\}+\{\{V\}_{3}\}=9V \\ \end{align}$ Series-Connected Voltage Sources The three-series connected voltage cells in Figure 5 are arranged so that they all produce current in the same direction when applied to a circuit. Figure 5. Voltage Sources Connected Series-Aiding The terminal voltages add together to give $E=\{\{E\}_{1}\}+\{\{E\}_{2}\}+\{\{E\}_{3}\}$ Because the voltage sources assist one another to produce current, they are said to be connected series-aiding. In figure 6, the bottom cell of the three has its opposite terminal connected to the negative terminal of the middle cell. Figure 6. Voltage Sources Connected Series-Aiding and Series-Opposing Thus, as illustrated by the circuit diagram for the cells, the total voltage is $E=\{\{E\}_{1}\}+\{\{E\}_{2}\}-\{\{E\}_{3}\}$ Because of its terminal polarity, the bottom cell will attempt to produce the current in the opposite direction to that from the other two. Consequently, the bottom cell is connected series-opposing with the top two cells. When more than one battery or another source of emf is involved, Kirchhoff's voltage law still applies. Consequently, for the circuit shown in figure 7, $\{\{E\}_{1}\}+\{\{E\}_{2}\}=I\{\{R\}_{1}\}+I\{\{R\}_{2}\}+I\{\{R\}_{3}\}$ Figure 7. Circuit Diagram of Resistors with Series-Aiding Voltage Sources The voltage equation for the circuit in Figure 8 is $\{\{E\}_{1}\}-\{\{E\}_{2}\}=I\{\{R\}_{1}\}+I\{\{R\}_{2}\}+I\{\{R\}_{3}\}+I\{\{R\}_{4}\}$ Figure 8. Circuit Diagram of Resistors with Series-Opposing Voltage Sources How to Solve a Series Circuit Determine the total applied voltage E=E1+E2+... Calculate the total series resistance, Equation (1) Calculate the circuit current, Equation (2) Determine the voltage drop across each component. \[\{\{V\}_{1}\}=I\{\{R\}_{1}\},\text{ }\{\{V\}_{2}\}=I\{\{R\}_{2}\},\text{ etc}\] Series Circuit Example for Series-Aiding Case The four resistors in figure 7 have the following values: R1=5Ω, R2=13Ω, R3=25Ω, and R4=17Ω. The emf are E1=4.5V and E2=1.5V. Determine the circuit current and the resistor voltage drops. Solution Step 1: Determine the total applied voltage $\{\{E\}_{1}\}+\{\{E\}_{2}\}=4.5V+1.5V=6V$ Step 2: Calculate the total series resistance $\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\{\{R\}_{4}\}=5\Omega +13\Omega +25\Omega +17\Omega =60\Omega$ Step 3: Calculate the circuit current I=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\{\{R\}_{4}\}}=\frac{6}{60}=0.1A\] Step 4: Determine the voltage drop across each component: $\begin{align} & \{\{V\}_{1}\}=I\{\{R\}_{1}\}=0.1A*5\Omega =0.5V \\ & \{\{V\}_{2}\}=I\{\{R\}_{2}\}=0.1A*13\Omega =1.3V \\ & \{\{V\}_{3}\}=I\{\{R\}_{3}\}=0.1A*25\Omega =2.5V \\ & \{\{V\}_{4}\}=I\{\{R\}_{4}\}=0.1A*17\Omega =1.7V \\ & finally, \\ & E=\{\{V\}_{1}\}+\{\{V\}_{2}\}+\{\{V\}_{3}\}+\{\{V\}_{4}\}=6V \\ \end{align}$ Voltage Divider Circuit and Equations It has been shown that the voltage drops across a string of resistors add up to the value of the supply emf E. Another way of looking at this is that the applied emf is divided up between the series resistors. Figure 9 shows two series connected resistors used as a voltage divider or potential divider. Figure 9. Voltage Divider Circuit From previous results, $I=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}}$ Also, \{\{V\}_{1}\}=I\{\{R\}_{1}\}\] Therefore, \[\{\{V\}_{1}\}=\left(\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}} \right)^*\{\{R\}_{1}\}\] Or we can simply write \[\begin{matrix} \{\{V\}_{1}\}=\left(\frac{\{\{R\}_{1}\}}\{\{\{R\}_{1}\}+\{\{R\}_{2}\}} \right)^*E & \cdots & (5) \end{matrix}\] Also, $\{\{V\}_{2}\}=\frac{E}{\{\{R\}_{2}\}}$ Then, \[\{\{V\}_{2}\}=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}}*\{\{R\}_{2}\}\] When more than two resistors are involved, the voltage drop across any one resistor Rn is: $\begin{matrix} \{\{V\}_{n}\}=\left(\frac{\{\{R\}_{n}\}}{\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\cdots } \right)^*E & \cdots & (6) \end{matrix}$ When there are n equal value resistors in series \[\{\{V\}_{1}\}=\{\{V\}_{2}\}=\cdots =\{\{V\}_{n}\}=\frac{E}{n}\] Voltage Divider Theorem In a series circuit, the voltage drop across a particular resistor is the source voltage time ratios of that resistor value to the total series resistance. The voltage-divider theorem in equation 5 and 6 is important because it is applied over and over again in electronic circuits. A surprisingly large amount of electronic circuit designs is merely a selection of appropriate resistor values for voltage-divider networks. How to Find Power in a Series Circuit In a series circuit, it is possible to calculate the power dissipated in a resistor from a knowledge of any two of the three quantities: current, voltage, and resistance. Thus, in Figure 10, the power dissipated in R1 is: \[\begin{matrix} {} & \{\{P\}_{1}\}=\{\{V\}_{1}\}I & \\ {} & \{\{P\}_{1}\}=\frac{\{\{V\}_{1}\}^{2}}{\{\{R\}_{1}\}} & \\ {} & \{\{P\}_{1}\}=\{\{I\}^{2}\}\{\{R\}_{1}\} & \\ \end{matrix}\] Figure 10. Power Dissipation in Series Connected Resistors The power dissipated in R2 is calculated in exactly the same way. The total power dissipated in the circuit is the sum of the individual resistor power dissipations. For any series circuit, the total power dissipated is \[\begin{matrix} \{\{P\}_{T}\}=\{\{P\}_{1}\}+\{\{P\}_{2}\}+\{\{P\}_{3}\}+\cdots +\{\{P\}_{n}\} & \cdots & (7) \end{matrix}\] And \[\begin{align} & P=\{\{V\}_{1}\}I+\{\{V\}_{2}\}I+\{\{V\}_{3}\}I+\cdots \\ & P=(\{\{V\}_{1}\}+\{\{V\}_{2}\}+\{\{V\}_{3}\}+\cdots +\{\{V\}_{n}\})I \\ & P=IE=Supply\text{ }Power \end{align}\] The total power can also be calculated as \[\begin{matrix} P=\frac{\{\{E\}^{2}\}}{\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\cdots +\{\{R\}_{n}\}} & \cdots & (8) \\ \end{matrix}\] Where E is the supply voltage. Also, \[\begin{matrix} P=\{\{I\}^{2}\}(\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\cdots +\{\{R\}_{n}\}) & \cdots & (9) \\ \end{matrix}\] Power Dissipation in Series Circuit Example Determine the total power dissipated and the power dissipation in each resistor in figure 10 when V1=44V and V2=56V. Solution \[\begin{align} & \{\{P\}_{1}\}=\frac{V_\{1\}^{2}}{\{\{R\}_{1}\}}=\frac{\{\{(44)\}^{2}\}}{22}=88W \\ & Similarly, \\ & \{\{P\}_{2}\}=\frac{V_\{2\}^{2}}{\{\{R\}_{2}\}}=\frac{\{\{(56)\}^{2}\}}{28}=112W \end{align}\] For total power, \[\begin{align} & P=\{\{P\}_{1}\}+\{\{P\}_{2}\}=88+112=200W \\ & or \\ & P=\frac{\{\{E\}^{2}\}}{\{\{R\}_{1}\}+\{\{R\}_{2}\}}=\frac{\{\{(100)\}^{2}\}}{(22+28)}=200W \end{align}\] Power Rating of Resistors The physical size and type of construction of a resistor determine the maximum power that it may dissipate. The maximum power that may be dissipated safely in any component is specified by the manufacturer and it is referred to as its power rating. A wide range of resistors is available with various power ratings. Typical ratings for resistors employed in electronic circuits are: 1/8 W, ¼ W, ½ W, and 1 W. the power ratings for small potentiometers and variable resistors typically ranges from ½ W to 5W. Every time the value of a resistor is calculated for a particular application, its power dissipation should also be determined. Where a component power dissipation exceeds its rating, the component is likely to burn out. Voltage Dropping and Current Limiting Sometimes a resistor is included in series with an electronic device to drop the supply voltage down to a required level. In other circumstances, this kind of arrangement can be thought of as a current limiting resistor. In the circuit shown in Figure 11, series resistor Rs limits the current to an electronic device that operates at a voltage level lower than the source voltage. In Figure 12, Rs provides a voltage drop to three series-connected lamps. It can also be shown that Rs limits the current to the level required by the three lamps. Figure 11. Use of a Current Limiting Resistor Figure 12. Use of a Voltage Dropping Resistor Open Circuit and Short Circuit in a Series Circuit An open-circuit occurs in a series resistance circuit when one of the resistors becomes disconnected from an adjacent resistor as shown in Figure 13. An open-circuit can also occur when one of the resistors has been destroyed by excessive power dissipation. Figure 13. Circuit Diagram of Series Circuit with an Open-Circuited Connection In the circuit of figure 13, the open-circuit can be thought of as another resistance in series with R1, R2, and R3. Thus instead of the current being \[I=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}}\] It becomes \[I=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}+\{\{R\}_{oc}\}}\] Suppose that Roc=100,000 MΩ and E=100V; then, with Roc>> (R1+R2+R3), \[I=\frac{100V}{100,000M\Omega }=1nA\] This small amount causes an insignificant voltage drop along R1, R2, and R3. With virtually zero voltage drop across the resistors, the voltage at the open circuit is $\{\{V\}_{oc}\}=E$ Figure 14 shows a series resistance circuit with resistor R3 short-circuited. In this case, the resistance between the terminals of R3 is effectively zero. Consequently, instead of the current being \[I=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}+\{\{R\}_{3}\}}\] It becomes \[I=\frac{E}{\{\{R\}_{1}\}+\{\{R\}_{2}\}}\] Figure 14. Circuit Diagram of Series Circuit with a Short-Circuited Connection It is obvious that open-circuit and short-circuit seriously affect the current flow through a series resistance circuit. You May Also Read: Series-Parallel Circuit with Examples Series Circuit Key Takeaways In a series circuit components like resistors and loads are connected in a single path. Current must go through every component in order starting from the positive terminal of the battery through everything in order and back to the negative battery terminal. Practice and Series Circuit Virtual Lab Sheet Series Circuits only have one path while parallel circuits we will see in a later unit have branches. Compare the pictures below each with three resistors. When lights are connected in a series circuit and one goes out the circuit becomes open and no other light works. This is because there is no path to the negative terminal of the battery when a circuit is open. When lights are connected in parallel circuit and one light goes out the remaining ones stay on. No current will flow down the branch with the disconnected light bulb since that branch is open. Current will follow the other paths to the negative terminal of the battery leaving the other lights on. To keep the models simple we will only places a battery and resistors in the circuits of our diagrams on this page. Remember that the longer line in the battery symbol is the positive terminal and the shorter line is the negative terminal. The convention is to have current run from the positive terminal to the negative terminal. Due to this convention the resistors are numbered in order. Here the resistors get their number resistor 1, resistor 2, and resistor 3 based on the flow of current starting from the positive terminal of the battery. In a series circuit voltage drops across each resistor until the entire amount provided by the battery has dropped. If you add all the individual voltage drops of a series circuit together you can determine the voltage of the entire circuit (VT) found at the power source. There is only one path in a series circuit for current to travel on. All current must run from the positive terminal to the negative terminal of the power source. Observe the animation of how the same current has to flow through every component of the circuit in series. Any resistor or load (device with a resistance) in a series acts like a speed bump in a series slowing current down. Since there is only one conductive path in series every device adds to total resistance. Note that a wire itself has resistance and the less conductive a wire is the more resistance it would add to a circuit. We will ignore this in our examples below for simplicity and pretend the wire was 100% conductive. Ohm's Law (V=IR), Voltage equals current times resistance, can be used anywhere in the circuit but only at a single location. See all the squares in red above, if you are using Ohm's law you can only use information in that location, the V,I, and R within a single square. The location can be an individual resistor, for example resistor one with the variables Voltage (V1), Current (I1), Resistance (R1). The location can also be at the battery, which is a measure that represents the overall circuits voltage (VT), current (IT), and Resistance (RT). At the battery the subscript T (ex. VT) stands for total or of the circuit. Some equations sheets may use emf (ex. Vemf) or another notation, if there is any subscript other than a number it will likely be of the circuit. When you are using information between different red blocks you must use the series circuit rules. Start any problem by drawing out the circuit and have every resistor labeled as you see in the picture above. Then write in all your givens. Next, follow the basic steps to a series circuit problem. IT = I1 = I2 = I3 = … VT = V1 + V2 + V3 + … RT = R1 + R2 + R3 + … You will continue to follow these steps over and over until everything in the circuit is complete. Follow our examples below until you feel comfortable to follow the steps solving series circuit problems on your own. Note: While our example stick to whole numbers for simplicity, this would be very uncommon and you would normally have decimals. Do not be shocked if you have decimals, just make sure all the rules are followed and do a final check as presented in the examples below. Some problems as the one seen below are drawn showing multimeters taking the reading of the current as seen below. This is not part of the circuit and is just taking a reading. You would rewrite the problem above taking out the multimeters and placing the readings into the problem and start the problem as seen in example 4 below. Try example 4 on your own and click "See Solution" to check your answers. Be aware that current can also be drawn into a problem in the wire and not at a single resistor. This is not an additional resistor but seeing the current drawn as a circle over the wire shows you the current in that wire. Since there is only one wire going from the previous resistor to the new resistor, you know in series both of those must have that current as well. See the picture to see a visual of this. The following PhET circuit construction kit can help you understand the workings of circuits more. Go to the following website is the embedded version is not working Electronics is a fascinating subject. We use countless electronic devices, appliances and gadgets in our everyday life. If you want to understand electronics, either to design a product yourself or to install or repair them, you have to start with the basics of electric system, circuits energy and power. One such basic concept is Series Circuit (the other being a Parallel Circuit). If you learn the basics of Series and Parallel Circuits, you can easily work on large complex circuit. In this guide, we will explore more about Series Circuits, Kirchhoff's Voltage Law (KVL) and Voltage Divider concepts. We already made a dedicated guide on Parallel Circuits and also a comparison of Series vs Parallel Circuits. Check the above links for more information. What is Series Circuit? We already know from the previous tutorials that an electric circuit is combination of an energy source (voltage or current source), some components (resistors, capacitors, etc.) and metal conductors to connect them all. Electric Current flows from the energy source (such as a battery) to the load (such as a light bulb, which is essentially a resistor) through the conductors and the bulb glows. What if we have two or more bulbs? How can we connect them to a single battery? There are a couple of basic ways you can connect two or more electronic components to an energy source. They are: Series and Parallel. You can also combine these two types into making a complex circuit but these two are the main. In a Series Circuit, we connect all the components back-to-back in a 'series' fashion. Let us take the light bulb and battery example here as well. As the light bulb has two legs (or terminals or contacts), we connect the second leg of the first bulb to the first leg of the second bulb. Then, we continue this i.e., the second leg of the second bulb to the first leg of the third bulb and so on. Finally, we connect the first leg of the first bulb and the second leg of the last bulb to the battery. This is the simplest explanation of a Series Circuit. You can easily understand clearly with the help of the following circuit diagram. In this we have a battery and four light bulbs and all the light bulbs are "in series" with the battery. Characteristics of a Series Circuit Let us understand the rules associated with a Series Circuit. For this, we shall use resistors as the circuit components as they the simplest of all. Assume there is a voltage source with three resistors in series. There is only one path for the current to flow in the circuit. As there is only one current path, same current flows through all the components of a series Circuit. For example, if I is the current in the circuit, then the current through all the resistors R1, R2 and R3 is also I. So, if IR1 is the current through R1, IR2 is the current through R2 and IR3 is the current through R3, then I = IR1 = IR2 = IR3 Next, the sum of voltage drops across all the components in a series circuit is equal to the source voltage. If VR1, VR2 and VR3 are the voltage drops across R1, R2 and R3 respectively and V is the Supply Voltage (or Source Voltage), then V = VR1 + VR2 + VR3 From Ohm's Law, we know that the voltage drop across a component is equal to the product of current flowing through the component and its resistance. V = I × R We can apply this law to the above circuit. V = VR1 + VR2 + VR3 But according to Ohm's Law, VR1 = IR1 × R1, VR2 = IR2 × R2 and VR3 = IR3 × R3 Substituting these in the above equation, we get V = IR1 × R1 + IR2 × R2 + IR3 × R3 But the current in a series circuit is same. So, IR1 = IR2 = IR3 = I V = I × R1 + I × R2 + I × R3 V = I × (R1 + R2 + R3) For the sake of convenience, let us assume V is the supply Voltage, I is the total current in the circuit and R is the total resistance of the circuit. Then, V = I × R = I × (R1 + R2 + R3) Therefore, R = R1 + R2 + R3 The total resistance of resistors in series is equal to the sum of individual resistances. Different Components in Series Combination Let us now see the equivalent values of different components in series. Resistors in Series We already saw the result of resistors in series connection. The equivalent resistance is equal to the sum of individual resistances. REQ = R1 + R2 + R3 Capacitors in Series It is slightly different for capacitors in series. If CEQ is the equivalent capacitance of three capacitors C1, C2 and C3 in series, then 1/CEQ = 1/C1 + 1/C2 + 1/C3 Inductors in Series Finally, we have inductors. This is again same as the resistors i.e.; the total inductance is equal to the sum of individual inductances. LEQ = L1 + L2 + L3 Voltage Divider An important concept in electrical and electronic circuits is Voltage Divider. We know that the voltage drop across the circuit components that are connected in series is equal to the product of its respective resistance and the current flowing through it. Assume we have two resistors R1 and R2 that are connected in series as shown in the following image. Here, V is the supply voltage, VR1 and VR2 are the voltage drops across R1 and R2 respectively. From the combination of Ohm's Law and characteristics of Series Circuit, we get V = I × R = VR1 + VR2 = I×R1 + I×R2 Now, if we calculate the voltage across the second resistor R2, VR2 = V × R2 / (R1 + R2) Here, from the above equation, we can understand that the voltage across the second resistor R2 is a part of the input supply voltage. As the circuit essentially divides the input voltage between the two resistors, this circuit is known as Voltage Divider or Potential Divider Circuit. This is an important technique to provide a low voltage that the supply voltage. For example, if we want to connect 5V and 3.3V devices (such as Arduino and a Bluetooth Module), we use such voltage dividers to reduce the 5V from Arduino down to 3.3V. Kirchhoff's Voltage Law Consider the previous example of three resistors in series with a power supply. The sum of voltage drops across these three resistors is equal to the supply voltage. VS = VR1 + VR2 + VR3 By re-arranging the above equation, we get, VS – VR1 – VR2 – VR3 = 0 This is known as Kirchhoff's Voltage Law or simply KVL. According to KVL, the algebraic sum of all the voltages in a closed loop is equal to zero. Applications of Series Circuits An important application of Series Circuits is the holiday lights that we use in our homes for decoration. It consists of several light bulbs that are connected in series to the mains power supply. Since each bulbs have some voltage drop, we have to carefully design the series light bulbs so that all the bulbs have sufficient voltage. From the previous explanation, we know there is only one path for the current to flow in a series connection and same current flows through all the bulbs. So, the problem with these series light bulbs is if any one bulb fails, the entire set doesn't light up. Another useful application of series connection is series battery connection. We know in a series circuit; the total voltage is the sum of individual voltages. So, of we connect two batteries in series, then we get the output as the sum of the battery voltages. For example, you have two 12V batteries. If you connect them in series, then you have a 24V source at your disposal. Conclusion A Series Circuit is one of the fundamental electric circuits. It is simply a back-to-back connection of all the components so that there is only one path for the current to flow. We saw the basic series circuit using light bulbs and resistors and also the characteristics of series circuits. After that, we take a look at two important concepts associated with series connection: Voltage Divider and Kirchhoff's Voltage Law (KVL). Finally, we saw couple of important applications of Series Circuits. Electricity powers much of the world around us, from the smartphone in your pocket to the lights in your classroom. Moreover, at the heart of these technologies lies a fundamental concept: electrical circuits. These circuits are the pathways that allow electricity to flow, powering various devices and systems. In the following post, we'll explore series circuits, one of the two main types of circuits used in electronics. But what is a series circuit? A series circuit is a simple setup where components like bulbs, resistors, or batteries are connected end-to-end, forming a single pathway for electric current to flow. Understanding series circuits is essential for anyone interested in electronics or physics, as they are the building blocks for more complex designs. Interested in an Albert school license? Picture a string of old-fashioned Christmas lights: when one bulb goes out, they all go out. This is a classic example of a series circuit. In a series circuit, electrical components are connected in a single, continuous loop. This means that the current (the flow of electric charge) has only one path to take. If any part of the circuit is broken or a component fails, the entire circuit stops working, just like those Christmas lights. In contrast, a parallel circuit is one where components are connected across multiple pathways. If you've ever used a strip of modern LED lights, you've seen a parallel circuit in action. In these circuits, each component has its own direct path to the power source. If one LED burns out, the others keep shining because they have separate paths for the current to flow. Accordingly, understanding the differences between series and parallel circuits is crucial for understanding electronics. Series circuits are simpler and have their unique characteristics and applications, which we'll explore in more detail. When we talk about visualizing a series circuit, think of it as a straightforward, no-detour path. For example, consider all of the components in a series circuit like dominoes in a line; the current flows through one after the other with no branches or alternative routes. This simplicity makes series circuits an excellent starting point for understanding the basics of electrical circuits. To demonstrate this concept, let us look at a basic series circuit diagram. In this example, the diagram shows a battery, two resistors, and a light bulb, all connected in a single line. The battery, positioned on the left, acts as the power source. Following the battery are the two resistors, and finally, on the right is the light bulb. You'll see straight lines connecting these components, representing wires. These illustrate the clear, linear path that the electric current follows. Explore Series Circuits on Albert First, the primary advantage of series circuits is their simplicity in design and function. This simplicity makes them easy to construct and understand, ideal for educational purposes and basic electronic projects. In a series circuit, the current that flows through each component is the same, so diagnosing problems or calculating values like voltage and resistance becomes straightforward. However, it's important to note that the simplicity of series circuits also brings a limitation: if one component fails, the entire circuit stops working. This characteristic is both a pro and a con, depending on the application. Series circuits may seem basic, but they find practical applications in everyday life. One of the most common examples is the string of old-fashioned lights. When one bulb burns out, the whole string goes dark, indicating a series circuit configuration. Another example is certain types of flashlights, where multiple batteries are connected in series to provide the necessary voltage. In these flashlights, each battery adds to the total voltage, allowing the light bulb to receive enough power to shine brightly. As you saw, in a series circuit, the flow of electric current is like traffic moving along a single-lane road; it has to follow one path. This means that the current (measured in amperes, or 'amps') is the same at every point in a series circuit. Moreover, if you measure the current flowing through each component, you'll find it remains constant throughout. Contrast this with a parallel circuit, where the current can take multiple paths. Think of it like a multi-lane highway; the total traffic (current) splits across different lanes (paths). In parallel circuits, the total current is divided among the different paths. This means the current through each component can vary. This uniform current in series circuits makes them predictable and highlights their vulnerability. If one component fails, it's like a roadblock on that single-lane road, halting the flow of current throughout the entire circuit. Interested in an Albert school license? One of the fundamental concepts in series circuits is calculating the total resistance. This is crucial because it affects how much current flows through the circuit. The effective resistance of a series circuit is the sum of the resistance values of the individual components. Effective Resistance in a Series CircuitR_{total} = R_1 + R_2 + R_3... Here's a simple step-by-step guide: Identify Individual Resistances: First, note the resistance of each component in the circuit, measured in ohms (Ω). Add Them Up: In a series circuit, the total resistance (R_{total}) is the sum of individual resistances. So, if you have resistors R_1, R_2, and R_3 in series, the total resistance is R_{total} = R_1 + R_2 + R_3. Suppose you have three resistors in a series circuit: R_1 = 2\ \Omega, R_2 = 3\ \Omega, and R_3 = 5\ \Omega. The total resistance would be R_{total} = 2\ \Omega + 3\ \Omega + 5\ \Omega = 10 \ \Omega. This simple addition is all it takes to find the total resistance in a series circuit, making it easy to predict and calculate circuit behavior. Ohm's Law is a fundamental principle in electronics and physics. It states that the current flowing through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance between them. Simply put, Ohm's Law is expressed by the formula: Where V is the voltage measured in volts, I is the current measured in amperes, and R is the resistance measured in ohms. This formula allows us to understand better and predict how electrical circuits behave. Let's apply Ohm's Law to series circuits with two step-by-step examples. Suppose you have a series circuit with a 12\text{-volt} battery and two resistors. The resistors have resistances of 2\ \Omega and 3\ \Omega respectively. Step 1: Find Total Resistance Firstly, calculate the total resistance using the effective resistance of a series circuit. Total Resistance (R_{total}) = R_1 + R_2 = 2\ \Omega + 3\ \Omega = 5\ \Omega. Step 2: Apply Ohm's Law to Find the Current Secondly, rearrange (if needed) and apply Ohm's Law. Using Ohm's Law, Current (I) = Voltage (V) / Resistance (R). Here, I = 12\text{ V} / 5 \ \Omega = 2.4\text{ Amps}. So, the current flowing through the circuit is 2.4\text{ Amps}. In the same circuit, let's find the voltage drop across the first resistor (2\ \Omega). Step 1: Use the Current from Example 1 Firstly, identify the current in the circuit. We already know the current flowing through the circuit is 2.4\text{ Amps}. Step 2: Apply Ohm's Law to Find Voltage Drop Secondly, apply Ohm's Law using the given values. Voltage (V) = Current (I) × Resistance (R). For the first resistor, V = 2.4\text{ A} \times 2\ \Omega = 4.8\text{ Volts}. This means there's a voltage drop of 4.8\text{ volts} across the first resistor. As you can see, these examples show how Ohm's Law is applied in series circuits to calculate current and voltage across individual components. Specifically, understanding this relationship is key in designing and troubleshooting electronic circuits, making Ohm's Law a vital tool for anyone interested in electronics and physics. Explore Series Circuits on Albert In conclusion, with their simple design and predictable current flow, series circuits serve as a fundamental concept in the study of electricity and electronics. They offer a straightforward method to understand how electric circuits work, making them an excellent starting point for budding scientists and engineers. The constant current and additive nature of resistance in series circuits highlights their simplicity and limitations. As you continue exploring the fascinating world of electrical circuits, remember that series circuits are just the beginning. Parallel circuits and, later, combinations of both open up a world of possibilities in designing and understanding complex electronic systems. The journey through the electrifying world of circuits is just beginning! A series circuit is one of the most important concepts of electrical and electronics courses. In a series circuit, all the components are sequentially arranged and connected with each other to form a single current path. The installed total resistance is the sum of all individual resistors' resistances. Hence, the total voltage drop is also the sum of the individual voltage drops across the respective resistors. This article will cover the equations, simplifications, and uses of series circuit systems. What is Series Circuit?Series circuit is an electrical circuit configuration where components are linked to each other end-to-end, creating a single path for the current flow. Thus, the current in the circuit will flow through every component successively. In a series circuit, the total resistance, which is the sum of the individual resistances of the components in the circuit, is increased as the number of resistors connected in the circuit increases. This is because the current goes on through each resistor, one after the other, then the resistance it will face is the sum of the resistances of each resistor. This is because the voltage drop in each element on which current is flowing is constant and proportional to the element's resistance. A key characteristic of the series circuit is that if one part or component fails or is removed, the circuit would be broken so that no current will flow through it. Series Circuit FormulaIn a series circuit, all the current moves through each individual component because there is only one unidirectional path for the current movement. In a series circuit, the total resistance (Rs) is the sum of the individual resistance of the resistors (R1, R2, R3,...Rn): Rs = R1 + R2 + R3 + ... + Rn The total voltage drop (Vs) in a series circuit is equal to the sum of the individual voltage drops (V1, V2, V3,...Vn): Vs = V1 + V2 + V3 + ... + Vn Derivation of Series Circuit formulaIn a series circuit, the current is the same at every point because there is only one path for the current to flow. We can use this fact to derive the formula for the total resistance in a series circuit. Let's assume we have a series circuit with n resistors, each with R1, R2, R3, ..., Rn resistance. The total resistance of the circuit, which we will denote as RT, is the sum of the individual resistances: RT = R1 + R2 + R3 + ... + Rn We can derive this formula by considering the voltage drop across each resistor. The formula gives the voltage drop across a resistor: V = IR Where V is the voltage drop, I is the current, and R is the resistance. Since the current is the same at every point in the circuit, we can use the same current I in each voltage drop formula. Therefore, the voltage drop across each resistor is: V1 = I * R1 V2 = I * R2 V3 = I * R3 ... Vn = I * Rn The total voltage drop across the entire circuit is the sum of the voltage drops across each resistor: VT = V1 + V2 + V3 + ... + Vn Substituting the voltage drop formulas for each resistor, we get: VT = I × R1 + I × R2 + I × R3 + ... + I × Rn We can factor out the current I from each term to get: VT = I × (R1 + R2 + R3 + ... + Rn) The total resistance RT is defined as the ratio of the total voltage drop VT to the current I: RT = VT / I Substituting the expression for VT, we get: RT = I × (R1 + R2 + R3 + ... + Rn) / I The current I cancels out, leaving us with the formula for the total resistance in a series circuit: RT = R1 + R2 + R3 + ... + Rn This equation shows that the total resistance of a series circuit is straightforward addition of the individual resistances. This is an important property of series circuits because it allows us to obtain the total resistance of a circuit by adding the individual resistances of its elements. Three Rules of Series CircuitThe Three rules of the series circuit are as follows: Current in Series CircuitsThe current (I) in a series circuit is the same at every point. Ohm's law can be applied to determine the current through a resistor when the voltage and resistance are known: I = V / R For example, if a resistor has a voltage of 9V across it and a resistance of 3kΩ, the current through the resistor can be calculated as follows: I = 9V / 3kΩ = 0.003A or 3mA Voltage in Series CircuitsThe voltage drop across each resistor in a series circuit is directly proportional to the size of the resistor. The voltage drop (VR) across a resistor in a series circuit can be calculated using Ohm's law: VR = I × R For example, if the current through a resistor is 3mA and the resistance is 3kΩ, the voltage drop across the resistor can be calculated as follows: VR = 0.003A × 3kΩ = 9V Resistance in Series Circuits The total resistance in a series circuit equals the sum of the individual resistors. This is because the current flowing through each resistor is the same. The formula for calculating the total resistance in a series circuit is: Rs = R1 + R2 + R3 + ... + Rn For example, if a circuit has three resistors in series with resistances of 4 ohms, 8 ohms, and 2 ohms, the total resistance can be calculated as follows: Rs = R1 + R2 + R3 Rs = 4 ohms + 8 ohms + 2 ohms Rs = 14 ohms Applications of Series CircuitSeries circuits have various applications, including: Lighting Circuits: The series circuit is present in the lighting boards, where the bulbs are connected in series. An event such as the burning out of one bulb will result in the electrical circuit, which will, in turn, interrupt the connection, and all bulbs will be turned off. This feature is often seen in older holiday light strings.Voltage Dividers: A series circuit is common where a voltage divider circuit is used, where the divider output voltage is a fraction of the input voltage. This technique is accomplished by building a series circuit with a couple of resistors, resulting in the voltage across one resistor.Temperature Sensors: A concrete example of a series circuit is temperature sensors, where the change in resistance of a resistor that changes with temperature (thermistor) is measured to determine the true value of temperature. There are two thermistors in the circuit. The thermistor is placed both in series with the fixed resistor and in the voltage divider circuit.Battery Packs: Series circuits are a tool to increase the battery's total output voltage. The voltage gets steadily higher as you connect the batteries in series. This way, a high output voltage is achieved, resulting in many applications, including electric cars and mobile electronics.Electrical Safety Devices: Series circuits include fuses and circuit breakers. The latter are devices placed in the circuit that break it whenever a short circuit or overload is detected to protect the components.Difference between Series circuit and Parallel circuitsThe difference between series circuit and parallel circuits are as follows: Series Circuit Parallel Circuit Components are connected end-to-end in a line Components are connected parallel to each other All components have the same current flowing through them The current through each component is different If one component breaks down, the whole circuit burns out Other components will function even if one component breaks down Components share one electrical node with their nearest neighbor Components share two common nodes Total resistance is equal to the sum of individual resistors Total resistance is less than the smallest individual resistor Also, Check Solved Examples on Series Circuit FormulaExample 1: A series circuit consists of a 12V battery, a 4Ω resistor, and a 6Ω resistor. Find the total resistance, current, and voltage drop across each resistor. Solution: 1. Total resistance in a series circuit is equal to the sum of the individual resistances: Total resistance, RT = R1 + R2 = 4Ω + 6Ω = 10Ω 2. Using Ohm's law, the current in the circuit is: Current, I = V / RT = 12V / 10Ω = 1.2A 3. The voltage drop across each resistor can be calculated using Ohm's law: Voltage drop across 4Ω resistor, V1 = I × R1 = 1.2A × 4Ω = 4.8V Voltage drop across 6Ω resistor, V2 = I × R2 = 1.2A × 6Ω = 7.2V The total voltage drop across the circuit is the sum of the individual voltage drops: VT = V1 + V2 = 4.8V + 7.2V = 12V Example 2. A series circuit has a 120V power source, a 10Ω resistor, and a 15Ω resistor. Calculate the current flowing in the circuit and the voltage drop across each of the resistor. Solution: Total resistance in the series circuit: RT = R1 + R2 = 10Ω + 15Ω = 25Ω Using Ohm's law, the current in the circuit is: I = V / RT = 120V / 25Ω = 4.8A The voltage drop across each resistor can be calculated using Ohm's law: Voltage drop across 10Ω resistor, V1 = I × R1 = 4.8A × 10Ω = 48V Voltage drop across 15Ω resistor, V2 = I × R2 = 4.8A × 15Ω = 72V The total voltage drop across the circuit is the sum of the individual voltage drops: VT = V1 + V2 = 48V + 72V = 120V Example 3. A series circuit has a 220V power source, a 100Ω resistor, and a light bulb with an unknown resistance. If the current in the circuit is 2A, find the resistance of the light bulb. Solution: Total resistance in the series circuit: RT = V / I = 220V / 2A = 110Ω The resistance of the light bulb can be found by subtracting the known resistor from the total resistance: Rlight bulb = RT - R1 = 110Ω - 100Ω = 10Ω Practice Questions on Series Circuit FormulaQ1. A series circuit has a 9V battery, a 3Ω resistor, and a 6Ω resistor. Find the total resistance, current, and voltage drop across each resistor. (RT = 9Ω, I = 1A, V1 = 3V, V2 = 6V) Q2. A series circuit consists of a 15V power source, a 20Ω resistor, and a 30Ω resistor. Calculate the total resistance, current, and voltage drop across each resistor. (RT = 50Ω, I = 0.3A, V1 = 6V, V2 = 9V) Q3. In a series circuit, the total resistance is 50Ω, and the current is 0.4A. If there are two resistors in the circuit, one with a resistance of 30Ω, find the value of the other resistor. (R2 = 20Ω) Let's start with a series circuit consisting of three resistors and a single battery: The first principle to understand about series circuits is that the amount of current is the same through any component in the circuit. This is because there is only one path for electrons to flow in a series circuit, and because free electrons flow through conductors like marbles in a tube, the rate of flow (marble speed) at any point in the circuit (tube) at any specific point in time must be equal. From the way that the 9 volt battery is arranged, we can tell that the electrons in this circuit will flow in a counter-clockwise direction, from point 4 to 3 to 2 to 1 and back to 4. However, we have one source of voltage and three resistances. How do we use Ohm's Law here? An important caveat to Ohm's Law is that all quantities (voltage, current, resistance, and power) must relate to each other in terms of the same two points in a circuit. For instance, with a single-battery, single-resistor circuit, we could easily calculate any quantity because they all applied to the same two points in the circuit: Since points 1 and 2 are connected together with wire of negligible resistance, as are points 3 and 4, we can say that point 1 is electrically common to point 2, and that point 3 is electrically common to point 4. Since we know we have 9 volts of electromotive force between points 1 and 4 (directly across the battery), and since point 2 is common to point 1 and point 3 common to point 4, we must also have 9 volts between points 2 and 3 (directly across the resistor). Therefore, we can apply Ohm's Law (I = E/R) to the current through the resistor, because we know the voltage (E) across the resistor and the resistance (R) of that resistor. All terms (E, I, R) apply to the same two points in the circuit, to that same resistor, so we can use the Ohm's Law formula with no reservation. However, in circuits containing more than one resistor, we must be careful in how we apply Ohm's Law. In the three-resistor example circuit below, we know that we have 9 volts between points 1 and 4, which is the amount of electromotive force trying to push electrons through the series combination of R1, R2, and R3. However, we cannot take the value of 9 volts and divide it by 3k, 10k or 5k Ω to try to find a current value, because we don't know how much voltage is across any one of those resistors, individually. The figure of 9 volts is a total quantity for the whole circuit, whereas the figures of 3k, 10k, and 5k Ω are individual quantities for individual resistors. If we were to plug a figure for total voltage into an Ohm's Law equation with a figure for individual resistance, the result would not relate accurately to any quantity in the real circuit. For R1, Ohm's Law will relate the amount of voltage across R1 with the current through R1, given R1's resistance, 3kΩ: But, since we don't know the voltage across R1 (only the total voltage supplied by the battery across the three-resistor series combination) and we don't know the current through R1, we can't do any calculations with either formula. The same goes for R2 and R3: we can apply the Ohm's Law equations if and only if all terms are representative of their respective quantities between the same two points in the circuit. So what can we do? We know the voltage of the source (9 volts) applied across the series combination of R1, R2, and R3, and we know the resistances of each resistor, but since those quantities aren't in the same context, we can't use Ohm's Law to determine the circuit current. If only we knew what the total resistance was for the circuit: then we could calculate total current with our figure for total voltage (I=E/R). This brings us to the second principle of series circuits: the total resistance of any series circuit is equal to the sum of the individual resistances. This should make intuitive sense: the more resistors in series that the electrons must flow through, the more difficult it will be for those electrons to flow. In the example problem, we had a 3 kΩ, 10 kΩ, and 5 kΩ resistor in series, giving us a total resistance of 18 kΩ: In essence, we've calculated the equivalent resistance of R1, R2, and R3 combined. Knowing this, we could re-draw the circuit with a single equivalent resistor representing the series combination of R1, R2, and R3: Now we have all the necessary information to calculate circuit current, because we have the voltage between points 1 and 4 (9 volts) and the resistance between points 1 and 4 (18 kΩ): Knowing that current is equal through all components of a series circuit (and we just determined the current through the battery), we can go back to our original circuit schematic and note the current through each component: Now that we know the amount of current through each resistor, we can use Ohm's Law to determine the voltage drop across each one (applying Ohm's Law in its proper context): Notice the voltage drops across each resistor, and how the sum of the voltage drops (1.5 + 5 + 2.5) is equal to the battery (supply) voltage: 9 volts. This is the third principle of series circuits: that the supply voltage is equal to the sum of the individual voltage drops. However, the method we just used to analyze this simple series circuit can be streamlined for better understanding. By using a table to list all voltages, currents, and resistances in the circuit, it becomes very easy to see which of those quantities can be properly related in any Ohm's Law equation: The rule with such a table is to apply Ohm's Law only to the values within each vertical column. For instance, ER1 only with IR1 and R1; ER2 only with IR2 and R2; etc. You begin your analysis by filling in those elements of the table that are given to you from the beginning: As you can see from the arrangement of the data, we can't apply the 9 volts of ET (total voltage) to any of the resistances (R1, R2, or R3) in any Ohm's Law formula because they're in different columns. The 9 volts of battery voltage is not applied directly across R1, R2, or R3. However, we can use our "rules" of series circuits to fill in blank spots on a horizontal row. In this case, we can use the series rule of resistances to determine a total resistance from the sum of individual resistances: Now, with a value for total resistance inserted into the rightmost ("Total") column, we can apply Ohm's Law of I=E/R to total voltage and total resistance to arrive at a total current of 500 ï¿½A: Then, knowing that the current is shared equally by all components of a series circuit (another "rule" of series circuits), we can fill in the currents for each resistor from the current figure just calculated: Finally, we can use Ohm's Law to determine the voltage drop across each resistor, one column at a time: Just for fun, we can use a computer to analyze this very same circuit automatically. It will be a good way to verify our calculations and also become more familiar with computer analysis. First, we have to describe the circuit to the computer in a format recognizable by the software. The SPICE program we'll be using requires that all electrically unique points in a circuit be numbered, and component placement is understood by which of those numbered points, or "nodes," they share. For clarity, I numbered the four corners of our example circuit 1 through 4. SPICE, however, demands that there be a node zero somewhere in the circuit, so I'll re-draw the circuit, changing the numbering scheme slightly: All I've done here is re-numbered the lower-left corner of the circuit 0 instead of 4. Now, I can enter several lines of text into a computer file describing the circuit in terms SPICE will understand, complete with a couple of extra lines of code directing the program to display voltage and current data for our viewing pleasure. This computer file is known as the netlist in SPICE terminology: series circuit v1 1 0 r1 1 2 3k r2 2 3 10k r3 3 0 5k .dc v1 9 9 1 .print dc v(1,2) v(2,3) v(3,0) .end Now, all I have to do is run the SPICE program to process the netlist and output the results: v1 v(1,2) v(2,3) v(3) i(v1) 9.000E+00 1.500E+00 5.000E+00 2.500E+00 -5.000E-04 This printout is telling us the battery voltage is 9 volts, and the voltage drops across R1, R2, and R3 are 1.5 volts, 5 volts, and 2.5 volts, respectively. Voltage drops across any component in SPICE are referenced by the node numbers the component lies between, so v(1,2) is referencing the voltage between nodes 1 and 2 in the circuit, which are the points between which R1 is located. The order of node numbers is important: when SPICE outputs a figure for v(1,2), it regards the polarity the same way as if we were holding a voltmeter with the red test lead on node 1 and the black test lead on node 2. We also have a display showing current (albeit with a negative value) at 0.5 milliamps, or 500 microamps. So our mathematical analysis has been vindicated by the computer. This figure appears as a negative number in the SPICE analysis, due to a quirk in the way SPICE handles current calculations. In summary, a series circuit is defined as having only one path for electrons to flow. From this definition, three rules of series circuits follow: all components share the same current; resistances add to equal a larger, total resistance; and voltage drops add to equal a larger, total voltage. All of these rules find root in the definition of a series circuit. If you understand that definition fully, then the rules are nothing more than footnotes to the definition. REVIEW: Components in a series circuit share the same current: ITotal = I1 = I2 = . . . In Total resistance in a series circuit is equal to the sum of the individual resistances: RTotal = R1 + R2 + . . . Rn Total voltage in a series circuit is equal to the sum of the individual voltage drops: ETotal = E1 + E2 + . . . En