DC Circuits

Introduction

As we have learned in "Introduction to Electricity", there are two forms of electricity used for commercial use to the public, AC current and DC current. AC is the major source of power used by most all customers, residential, commercial and industrial. It seems logical that circuit theory and analysis should begin with AC, but AC contains complex elements (units) that may confuse the first time learner. So, DC is the choice to where we will begin to learn about electrical circuits. But first, we must complete a short review of some electrical concepts.

Voltage EMF

Voltage is a property (some prefer to call it a phenomenon) of electricity that is the driving force of a charge. That is the movement of coulombs of electrons is accomplished from the presence of a voltage. This form of voltage exists when a circuit is present. Another form that voltage exists is when the charge has no means to move, (open circuit) voltage will exist as a potential difference. That is, there is a difference in magnitude of charge between two points (voltage). If there were a means to move charge (a conductor or circuit) to connect the two points, the potential voltage would become the Electromotive force which moves the charge so the two points connected, will become the same magnitude of charge. A volt is the amount of force necessary to cause one coulomb of charge to produce one joule of work (joules per coulomb; ${}^{j}\!/_{C}$).

Current

Current is a measurement of the magnitude of charge over time which exists as the charge is in motion. You should remember that a coulomb of charge is a quantity of electrons (or electron holes) which equals an amount of 6.28×10^{18}. One ampere of current equals the flow of charge, at a rate which it passes a point, as one coulomb of charge per second. Current exists only when charge is moving. (coulomb per second; ${}^{C}\!/_{s}$).

Resistance

Resistance is the opposition to the flow of current. The ohm, **Ω**, is the unit of resistance and is defined as, one ohm of resistance will limit the flow of current to one amp when one volt of EMF is applied. Resistance is a property in which materials possess. These materials are formed into components which are then inserted into a circuit in order to change the characteristic of that circuit. The effect of resistance will affect the current, the voltage or both. That is, resistance will limit current flow of current, but if more current is needed through the existing resistor, more voltage is needed.

Power (watts)

Power in an electric circuit is measured in watts. Watts is defined as an amount of work being done over a given amount of time. The joule is a measurement of work and the standard of time is measured in seconds therefore one watt is equal to one joule of work done over a time frame of one second. (one joule per second; ${}^{j}\!/\!_{s}$) Let's look at the watt as a relationship of voltage and current. Watts are derived from the product of current and voltage. Voltage has a relationship to a unit of work and current has a relationship to time. So let's do the math.

One volt multiplied by one ampere equals one watt.

$$1_V \times 1_A = 1_{VA} \ \ or \ 1_W$$

Let's look at voltage as $\boldsymbol{{}^{j}\!/\!_{C} \ \ or \ \left({}^{joules}\!/\!_{coulomb}\right)}$ and current as $\boldsymbol{{}^{C}\!/\!_{s} \ \ or \ \left({}^{coulomb}\!/\!_{\sec ond}\right)}$; now let's do the math again.

$$\boldsymbol{\frac{j}{\color{red}{C}} \times \frac{\color{red}{C}}{s} = \frac{j}{s} = watts} \qquad \text{The Coulombs cancel.}$$

Ohm's Law

This may be a good time to review the steps in deriving the 12 equations from Ohm's law. This lesson was completed in a previous course, "Introduction to Electricity". The two basic equations are;

$$E=I\times R \ \text{ and } \ P=I\times E$$

E=voltage

I=current

R=resistance

P=power (watts)

These are the first two equations, derive the other ten. No cheating as you will be using these formulas throughout your career.

The DC Source

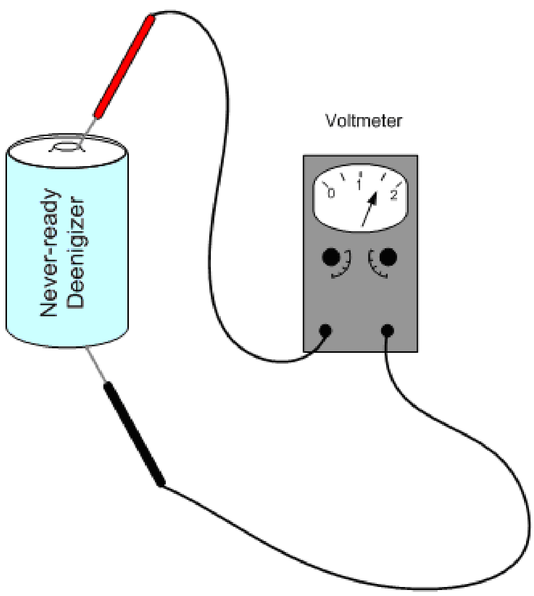
In the early discoveries of electricity the voltic pile was used as a current source for the experimentation of electricity. Also, layden jars were used to store trapped charge in static form. Later, after Faraday's inventions, the use of the electric dynamo was used to produce a DC current source. Today we have the DC generator, storage batteries, and rectified DC from an AC source. When performing experiments, a controlled DC source is needed so that experimentation can be made in a safe accurate manner.

Most DC electronic test supplies have current-limiting devices built within them. The danger when performing lab experiments is the possibility of short circuits or circuits that can not handle a large current. It is quite embarrassing to see your project go up in smoke as well as being very dangerous to yourself.

The ideal sources for experiments are the newer DC power supplies. Apprentices may find these devices in their meter/relay department. These devices have the current-limiting circuits within them and are safer to use. The storage battery is also a good source for a DC current. Care must be taken and proper fusing used because there is no current limiting here. If you short out a battery (not good) you may find out why batteries are rated in amp hours. Don't use your car's battery for experiments. Their current ratings are way too high and you might need to use your car in the morning. You can weld with a car battery.

The DC Circuit

In order to build a circuit we must begin with a DC source. Most all operational (non-electronic) DC circuits, if not powered by a battery, they are backed up by one. In the utility industry, substation yard equipment is controlled by a DC battery bank. In case of a complete loss of power within a substation, the DC battery will enable the equipment in the yard to continue to operate.

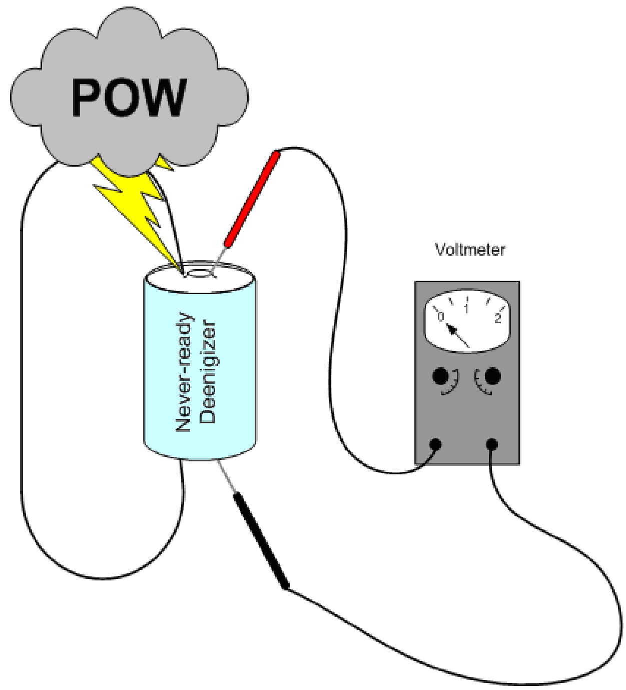


This illustration shows a typical flashlight battery. With the use of a voltmeter, the battery indicates that there is a difference in charge between the battery posts. The charge has a potential EMF of 1.5 volts.

This will be the first component to build a circuit.

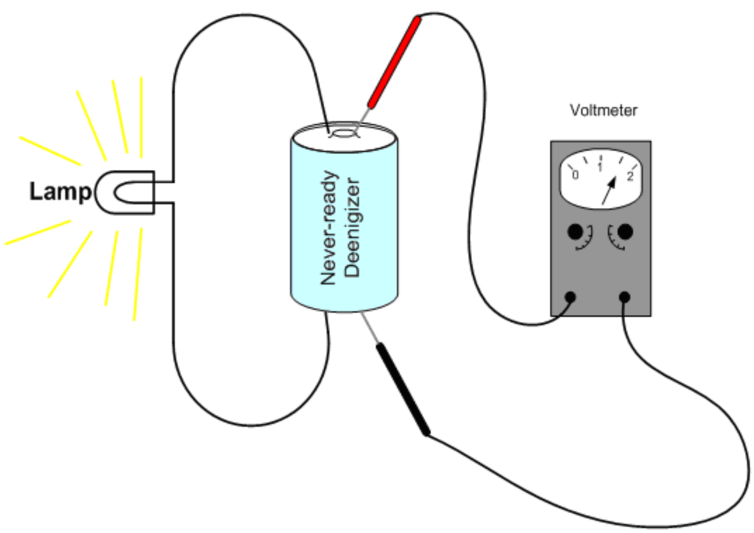
In order to build a circuit a conductor must be connected between the two posts of the battery. But wait…. Oh oh too late.

If a conductor is directly connected between the two posts of a battery, the resultant circuit will be a short circuit.



The short circuit creates a rapid discharge of the battery. The charge difference stored in the battery will, at once, seek to balance the charge between the two posts. A great amount of current will flow to achieve the balance. Remember that current is a bunch of electrons moving past a point per second. The number of electrons will be so great that we count the electrons as coulombs, (6.28×10^{18}). Notice the reading on the voltmeter. With the short circuit installed there is no difference in charge and only the resistance of the conductor is limiting the current flow.

The movement of these electrons will create heat throughout the conductor. If the storage battery contains a large amount of charge, i.e. an auto battery; the conductor will become so hot it will vaporize. Using the small flashlight battery, as we did, it will limit the effects of the event. If the conductor used is very small, you will burn it in two. Never less, you will be creating a lot of heat **so don't do this**.



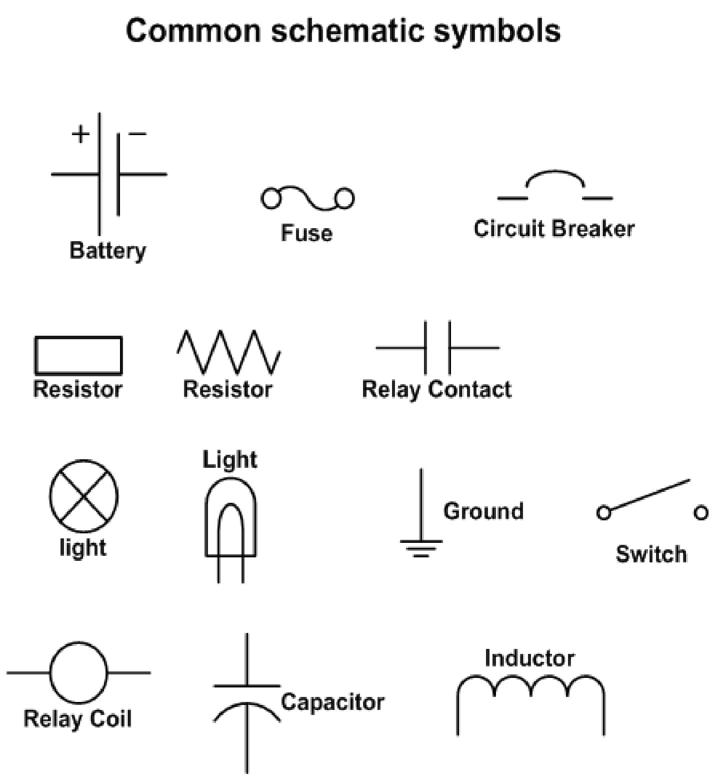
A device that limits the flow of current must be installed. This device will contain the electrical properties of resistance. As shown in the illustration, a lamp can be installed to add enough resistance to the circuit to limit the current. This is a simple series circuit which contains only one device, the lamp.

Schematics and Symbols

The preceding illustrations showing the battery and lamp is a drawing of a simple circuit. As illustrated the drawings gave you the idea of what a circuit is and the hazards involving the circuit. This was simple, yet the world of electricity is quite complex. You can't draw complex circuits by using picture art. It wouldn't make sense and would be too busy to use as a tool.

Schematics are drawings used for the purpose of illustrating electric circuits and their components, and are used as a diagnostic tool for troubleshooting. The schematic drawing illustrates the correct electrical connections by lines, and the components, shown as symbols, are laid out so that an analysis of the circuit can be easily made. Connection diagrams or wiring diagrams are other types of drawings that will show the exact locations for components and all of the point to point connections of the wiring for the circuit. These wiring diagrams are used for the construction of such circuits and may be needed to assist in troubleshooting so one can determine the actual points to be tested or repaired.

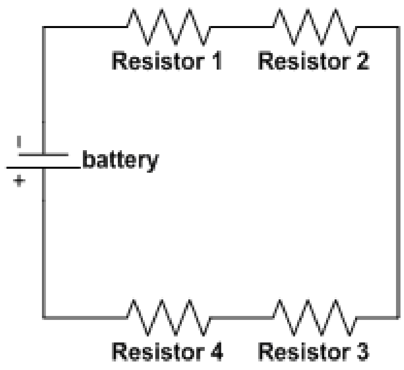
The schematic diagram is the backbone for circuit analysis. To better understand electrical schematics, standard symbols are used to represent circuit components. This list is quite long so I made "the short list" of schematics in which we will use throughout our course. Here is the list;



We will begin by building some simple circuits including the series, parallel and combination circuits.

Types of Circuits

Shown below are some common circuits drawn as schematics. The first schematic is a series circuit. Notice that all of the components are connected one after the other in a series.



From the source battery, a current will flow from negative to positive through resistors 1, 2, 3 and 4. It will be the same current through all components. For this reason, the circuit is called a series circuit.

Fig.1

The second illustration shows a schematic of a parallel circuit. As you can see, each resistor is located on its own branch circuit so that one side of all the resistors are connected to one post of the battery and all of the other sides of the resistors are connected to the other post of the battery. Any current which leaves the battery will have to divide itself among the parallel branches according to the values of resistance and Ohm's law.

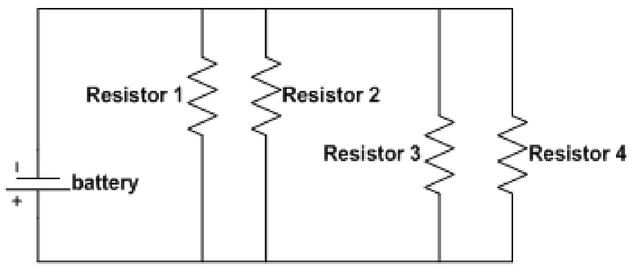
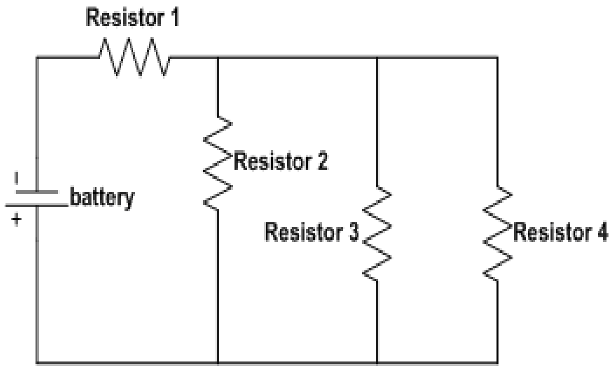


Fig. 2



The third illustration is of a combination circuit. In this type of circuit some components are in series and others are in parallel. In this circuit resistor 1 is in series and all of the current will flow through it. The remaining three resistors are in parallel branches, the current must divide itself through the parallel branches according to the values of resistance.

Fig. 3

These schematics are simple and most other schemes are far more complex. In each schematic, I have only illustrated the source and resistors. Most operational circuits will also contain fusing for protection, switches as means to operate the circuit and finally components, such as lamps, contacts and coils. We will be working with these and similar schematics throughout this course.

Please complete the exercises contained in Practice 1 - Circuit Recognition --

Safety

Earlier we discussed the hazards of an electrical short circuit. The hazards are: (1) extreme heat; (2) a flash that may damage eyes; (3) vaporized materials that are blown away when the connection occurs which may contact and burn surrounding materials as well as you.

Once I entered a substation control house to find it completely full of smoke. For sure, I thought the whole place must be on fire. After evacuation of the smoke and inspecting for the source of the problem, we found that a small relay, similar to the one illustrated, burned up from a short circuit. It was hard to believe that the plastic from that size relay could produce that much smoke.

When a short circuit occurs, we must be aware of the rapid response of the person, or people within the working distance of the event. One does not want to engage in the art of, “pull out all of the wires”, tactics to eliminate the danger. This action usually puts the participant in lethal danger of electrocution or physical burns from molten material. The first thing to do is the unnatural act of, “don’t panic”. Always be aware and prepare, so in case of an unfortunate event you have a plan, a way to safely disable the electric circuit.

Be aware of your surroundings. In the real world of working around control circuitry, the opening of one circuit does not protect you from other energized circuits or sources. Know what is behind you and plan escape routes if needed. Your first reaction is to usually jump back. Don’t jump back into something energized.

Before you begin your work scan your environment, make a plan and discuss this if you are working with a partner or crew.

- ✓ Do you know where the proper fire extinguishers are located?
- ✓ Where is the main power source cutouts located?
- ✓ How do you communicate to get outside help i.e. telephone intercom, radio, 911 etc?
- ✓ Where is the first-aid kit?
- ✓ If needed, where are the exits?
- ✓ What other hazards are present surrounding my work environment?

We are discussing the work involved on low voltage circuits which is defined as circuits at or below 500 volts. When you work in an industrial or power utility environment, you may be working in close proximity to high voltage equipment. If possible use barriers or guards in this situation so you can avoid accidental contact with the high voltage circuits.

Lets talk about jewelry; nice stuff, expensive and most of all dangerous around electrical circuitry. We learned how a conductor will support the flow of current and a good conductor has an atomic structure with few electrons within their valence shells. So where does silver and gold fit in to the category of conductors. Gold has an atomic number of 79 and has one electron in its valence shell. Silver's atomic number is 47, also with one electron in its valence shell. Both of these elements are very good conductors and will support current quite well. Remember, the flow of current will produce heat, and a lot of it. If a gold ring comes across a 120volt AC source (household) the metal can become white hot. White hot is quite hot and will sometimes stop burning when the ring hits the bone.

True story:

> *While working, as an apprentice power system electrician, I was taught as you are now, about the dangers of jewelry around electrical equipment. While performing a routine maintenance on the control circuits of a power circuit breaker, I noticed my journeyman, Bob J., was wearing a fancy watch with a big silver band inlayed with turquoise. I mentioned the hazard present if he continued to wear the watch. He shrugged it off by saying, "I've been wearing this watch for years and nothing has happened yet". Notice that he used the qualifier "yet". A few years later I ran across Bob at the most opportune time. He said, "Hey, remember about the watch? Well I should have listened". He then showed the most awful burn scar around his wrist. He said that he got his watch hung up on a 220 volt heater circuit. Blew those pretty little turquoise stones to bits and the silver seared his wrist with 3rd degree burns.*

Just think what a necklace or neck chain would do in such a circuit. Take your jewelry off! If you must wear a ring such as a wedding band, put some "88" tape over it. This, you should do even for the low volt experiments which we will be making in this course.

We have discussed large currents and drastic burns, but there are still more hazards we must talk about, **electrocution**. In order for current to flow to do any damage to our body, we must become part of the circuit. The idea is not to become a part of an electric circuit therefore this should become your personal working habit. The greatest risk of contact comes with your hands when you are working on or around electric circuits. The object is that if you make contact with an energized electric circuit, we must limit the length of the path in which a current will pass through the body. The worst case scenario is to have an electric current enter the trunk of your body. This area is where your internal organs are and especially susceptible to electric shock is your heart. So we don't want to make up an electric circuit across our arm span. This makes the shortest path for current go across our chest through our heart. Don't be hanging on to anything conductive while you are working on a circuit with the other hand. A good habit is to rest your wrist or forearm of your working hand on the chassis of the equipment you are working on. Better yet, work while standing on insulated mats. The Navy practices using only one hand to work on or around electric circuits. Your company will usually have a safety program for electrical safety in which to follow. These safety rules will meet or exceed the OSHA safety rules. If your company doesn't have a program, then follow the OSHA rules.

Well how much current can the body withstand? We will begin with your first line of protection, your skin. Skin has the resistance of about 500Ω-600Ω. It will take about 250 volts to puncture it. If wearing jewelry, the heat from the current through the jewelry will burn through the skin into the flesh so currents supported with lesser voltages can then enter your body. The internal body has an average resistance of less than 500Ω. Your body reacts to current not in the range of amps, but in milliamps. Check out the chart below.

Amount (mA)	Effect
5	Slight sensation
10	Can’t let go
35	Muscular paralysis
45	Sever shock pain
60-90	Breathing difficulties
100-300	Ventricular fibrillation
500	Heart stops
600	Breathing stops
900	Severe burning

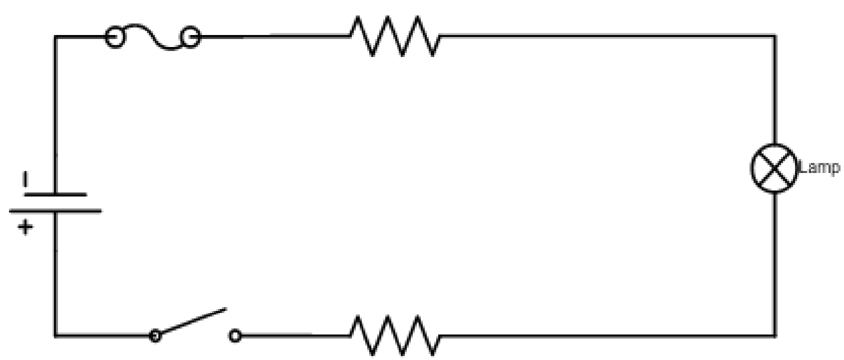
As you see, it doesn’t take much so again, take care of **yourself; follow your safety rules.**

This is just a reminder about “Lockout-Tagout” LOTO. The LOTO is means to secure circuits which, when energized, can harm personnel when performing tasks on are around such circuits. This not only protects personnel from electrical hazards, it protects from all types of energy storage systems such as mechanical spring, pneumatic systems, and hydraulic systems.

This is a good time to review your company’s accident prevention manual.

The Series Circuit

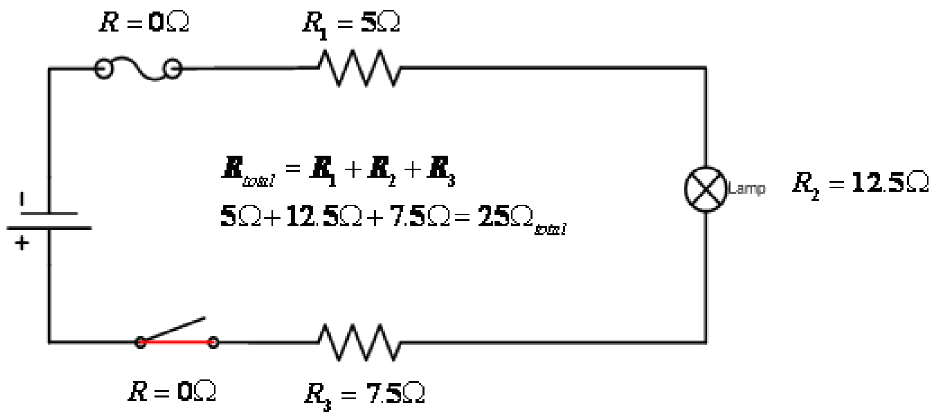
We have defined a series circuit as a circuit which has all its components connected to each other in a string, one after another. The circuit below is an example of a series circuit. This circuit contains a fuse, two resistors, a lamp and a switch connected to a DC battery source. Let’s look at the units of resistance, current, voltage and power as they relate to this series circuit.



of

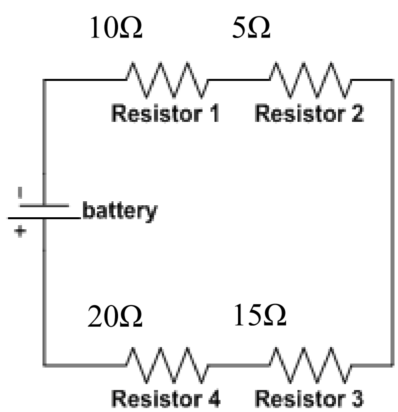
Resistance

The resistance’s of a series circuit are additive. That means that the total resistance equals the additive sums of all of the resistive components in the series circuit. Components such as fuses and switches contain negligible amounts of resistance; therefore we consider them for all purposes as part of the conductors or zero resistance. In the circuit below, the total resistance will be the sum of the resistance of the two resistors and the resistance of the lamp.



The two resistors have a resistance of 5Ω and 7.5Ω. The lamp has a resistance of 12.5Ω. The total resistance will be the sum of the three resistances or 25Ω. Let's look at a couple of examples and solve them.

1. A series circuit has four resistors connected to it. The resistances of the four resistors are 10Ω, 5Ω, 15Ω and 20Ω. Find the total resistance of the circuit. Let's first look at a schematic of the circuit to visualize what we are doing.



The total resistance is the sums of the components resistance.

10Ω + 5Ω + 15Ω + 20Ω = 50Ω

This is just simple addition.

2. A circuit has six resistors connected in series. Find the total resistance if ;

$$
\begin{aligned}
R_1 &= 12\Omega \\
R_2 &= 28\Omega \\
R_3 &= 32\Omega \\
R_4 &= 25\Omega \\
R_5 &= 13\Omega \\
R_6 &= 27\Omega \\
\hline
R_{total} &= 137\Omega
\end{aligned}
$$

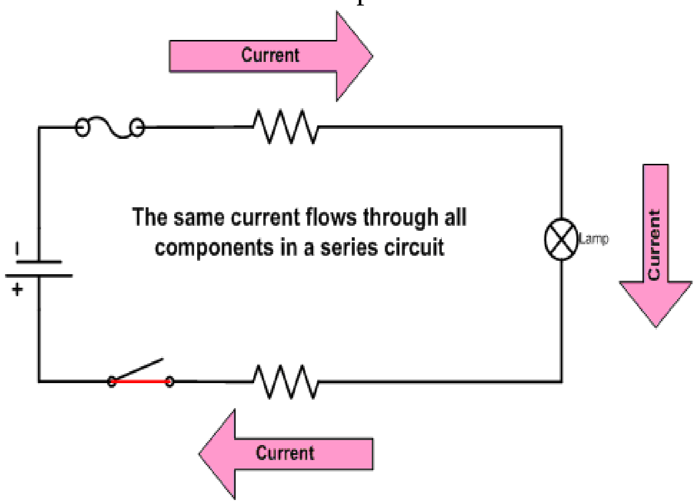
The individual resistances are summed to determine the total resistance.

If a resistance of a component is unknown, the resistances of the other components can be summed and the difference of the sum and the total resistance will equal the unknown resistance. For instance, a series circuit containing three resistors has a total of 50Ω. Two of the resistors have resistances of 12Ω and 28Ω. To find the resistance across the third resistor the sum of the two resistors (30Ω) subtracted from the total resistance (50Ω). The difference will be the resistance of the third resistor or 20Ω.

Please complete the exercises contained in Practice 2 - Series Resistance –

Current

The total current in a series circuit is the same current that travels through all of the components within the circuit. If a series circuit containing two components has two amps of total current, then the current through component one will be two amps and the current through component two is also the same two amps.



The schematic shows a current, which flows from a battery through a fuse into a resistor, a lamp, another resistor then through a switch. This current is flowing at the same magnitude through all components of the series circuit

Current through a series circuit is calculated by using the Ohm's formula;

$$I_{series} = E_{source} / R_{total}$$

To establish a current, the total resistance of the series circuit must be calculated then the source voltage is divided by that total. For example, a series circuit in which the voltage source is 10 volts has a total resistance of 20 ohms. The current of this circuit is;

$$10V/_{20\Omega} = 0.5A$$

Let's now combine our knowledge of resistance and current by solving a few examples

1. A series circuit has three resistors connected to a source of 35 volts. Resistor one has 35Ω, resistor two has 40Ω and resistor three has 25Ω. Find the total current of this circuit and find the current which flows through resistor two. We must first determine the total resistance by adding the three component resistances.

   $$\begin{array}{l} 35\Omega \\ 40\Omega \\ \underline{25\Omega} \\ 100\Omega_{total} \end{array}$$

   The total current can now be calculated by Ohm's Law;

   $$I = \frac{E}{R} = \frac{35_{volts}}{100_{ohms}}$$

   That is a current of 350 milliamps.

   $$I = 0.35A \text{ or } 350mA$$

   The current which runs through resistor two is the same as the total current which is 350 *mA*.

2. A circuit has five resistors in series connected to a source containing 50 volts. Find the total current if the resistance, across the five resistors are 20Ω, 15Ω, 49Ω, 35Ω and 21Ω respectively. First step is to sum the resistances, which then gives a total resistance of 140Ω. The source voltage is then divided by the total resistance.

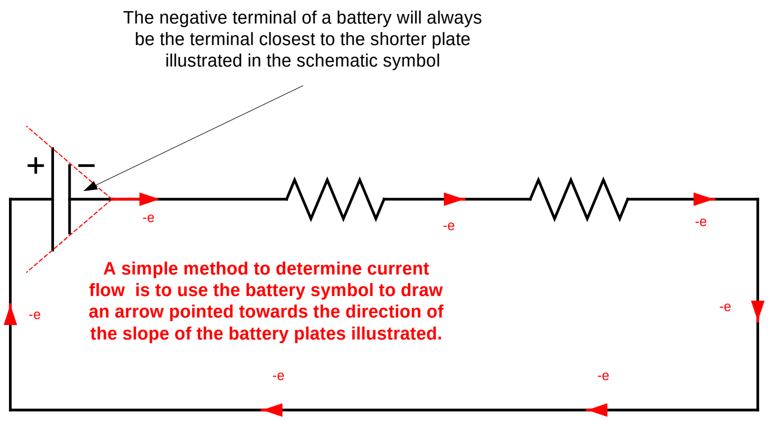
   $$I = E_{source}/_{R_{total}} = 50V/_{140\Omega} = 0.357A \text{ or } 357mA$$

Please complete the exercises contained in Practice 3 - Series current –

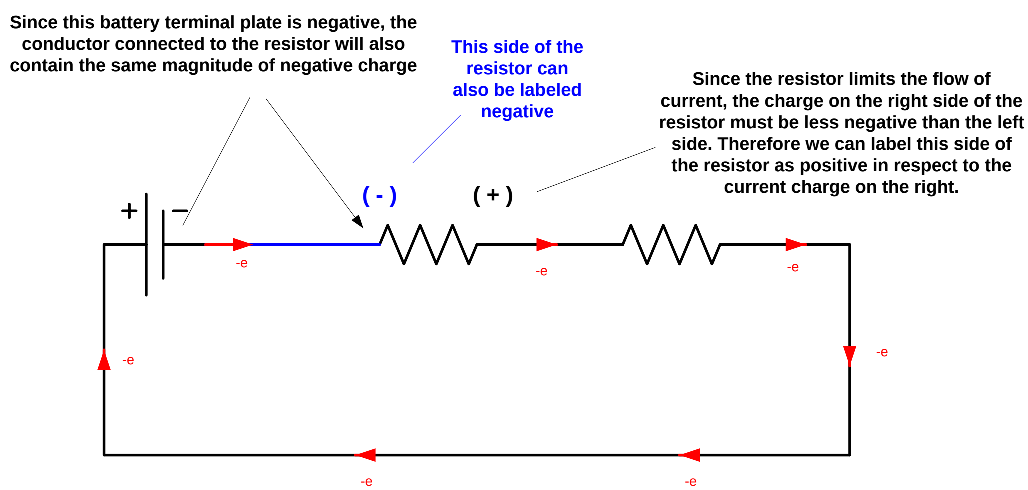
Current Flow and Voltage Polarity

As stated in our earlier lessons, we defined the direction of current flow to be the same as the electron flow. Do you remember the state of charge of an electron?.....(-e). A Current can be described as a flow of negative charged electrons. Let's look at a simple schematic to understand this concept.

Again I will stress that the convention I use for my text and lessons refer to the current in the sense of electron flow and not conventional current flow. If you use other text as references, you may come upon this conflict. In either case Ohm's Law and Kirchhoff's remain the same.

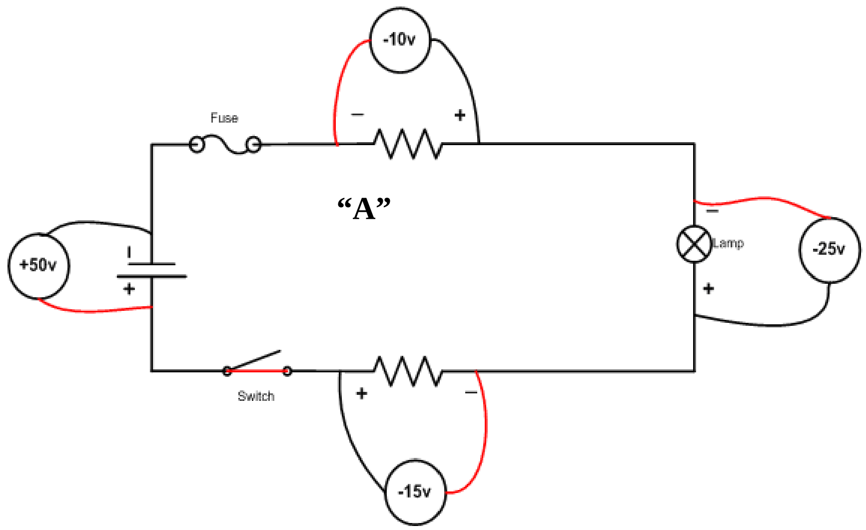


Let's look at voltage in this circuit. We determined current flow in this circuit as clockwise confirmed by drawing an arrow on the battery schematic symbol. The battery symbol is also labeled negative at that terminal. (Note: some battery symbols do not always label the terminals with polarity markings. You must then rely upon the arrow method to determine polarity) Since there is an abundance of negative charged electrons at the batteries negative terminal, the conductor that leads from the batteries negative terminal to the first resistor should be of that same charge. Therefore the left side of the resistor, the side connected to the battery, will have more charge than the right side because of the nature of a resistor is to limit current flow. Let's look at the schematic again to clarify this.

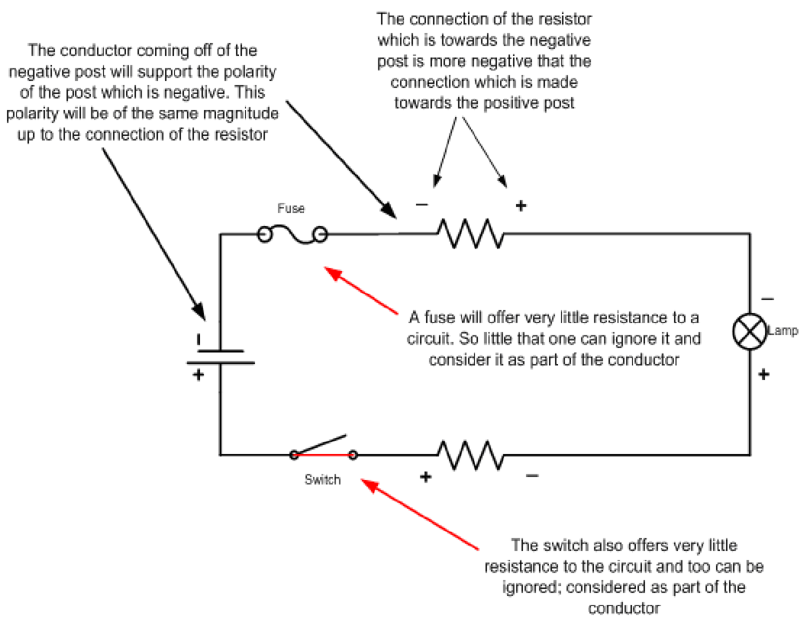


Voltage

The total voltage (source voltage) across a series circuit is equal to the sum of the individual voltage drops across the components of that circuit.



The schematic above shows a source at 50 volts. As the current flows, resultant voltage drops occurs across every resistive component. If a current flows through resistor "A" the product of that current through the resistor will equal a voltage drop of 10 volts as indicated by the voltmeter. In fact every resistance will have a voltage drop across it. If we add up all of the voltage drops in the schematic we will find that the sum of the drops equals 50 volts, the same as the source voltage. Did you notice that the source voltage is labeled as positive and the voltage drops across the resistances is negative? In reality if all of the voltages were summed, that is the source as well as the total drops, that sum would be zero.



If you notice the polarities of the leads of the voltmeters they are all referencing each component, as well as the source, so that the red polarity is on the same side in respect to the source as you traverse the circuit with the meter. This will give you a positive reading for the source voltage and negative readings for the component voltages.

This concurs with Kirchhoff's law for voltage.

Kirchhoff's Voltage Law

Kirchhoff’s Voltage Law states; *“the algebraic sum of all of the voltages within a circuit equals zero”*

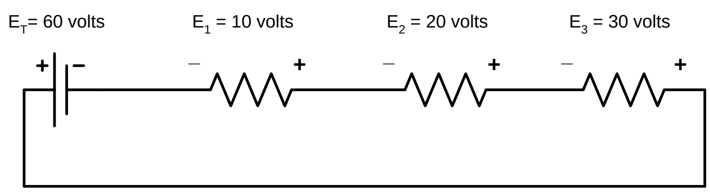
When you sum the voltages the sum must include all of the voltage sources and all of the voltage drops. Also important is the polarities of the voltages to be summed. The wrong polarity will not give you a net zero sum. Let's look at a typical equation that will describe Kirchhoff’s voltage law.

$$+\left(\pm\ \boldsymbol{E_t}\right)+\left(\pm\ \boldsymbol{E_1}\right)+\left(\pm\ \boldsymbol{E_2}\right)+\left(\pm\ \boldsymbol{E_3}\right)=\mathbf{0}$$

Algebraic sum   polarity

magnitude

Let’s look at an example and perform the summation.



We can add the components by using the polarities all on the left sides of the components. The equation will then be;

$$+\left(+\mathbf{60}\right)+\left(-\mathbf{10}\right)+\left(-\mathbf{20}\right)+\left(-\mathbf{30}\right)=\mathbf{0}$$

$$\mathbf{60 - 10 - 20 - 30 = 0}$$

$$\mathbf{0 = 0}$$

Remember how to add the signs (+ + = +) and (+ - = -).

We can also add the voltages of the components from the polarities on the right side of the components. That equation will then be;

$$+\left(-\mathbf{60}\right)+\left(+\mathbf{10}\right)+\left(+\mathbf{20}\right)+\left(+\mathbf{30}\right)=\mathbf{0}$$

The readings of the polarities must be consistent; read all from the left or all from the right.

Let's look at an example of a series circuit with two resistors, one with a resistance of 45Ω, the other of 20Ω. If a current of 1.5 A is flowing through this circuit the voltage drops can be calculated by Ohm's law.

$$\begin{aligned} & \boldsymbol{E = IR} \\ \textbf{Resistor 1:}\ & \boldsymbol{E = 1.5 \times 45} \\ & \boldsymbol{E = 67.5\ Volts} \end{aligned}$$

$$\begin{aligned} & \boldsymbol{E = IR} \\ \textbf{Resistor 2:}\ & \boldsymbol{E = 1.5 \times 20} \\ & \boldsymbol{E = 30\ Volts} \end{aligned}$$

So from Kirchhoff's law we can derive the source voltage, understanding that the two drops across the resistors are negative.

$$\begin{aligned} & \boldsymbol{-E_{r1} + -E_{r2} + E_{source} = 0} \\ & \boldsymbol{-67.5V + -30V + E_{source} = 0} \\ & \boldsymbol{(-67.5) + 67.5 + (-30) + 30 + E_{source} = 67.5 + 30} \\ & \boldsymbol{cancel\ out} \\ & \boldsymbol{E_{source} = 67.5 + 30} \\ & \boldsymbol{E_{source} = 97.5\ Volts} \end{aligned}$$

We can then derive the total resistance from the total current and the source voltage.

$$R = E/I = 97.5/1.5 = 65\Omega_{total}$$

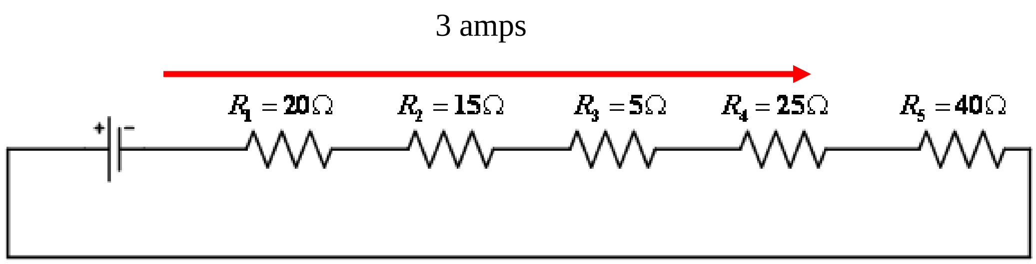
Proof:

$$\begin{aligned} & R_1 + R_2 = R_{total} \\ & 45\Omega + 20\Omega = 65\Omega_{total} \end{aligned}$$

Ohm's law can be used to solve for every unit value as long as you know two values.

Let's look at another example.

A series circuit having five resistors has a current of 3 amps flowing through the components. Find the voltage drop across each resistor and the total voltage of the source if;



The voltage drops are derived using Ohm's law

Resistor 1

$$E = IR$$
$$E = 3A \times 20\Omega$$
$$E = 60 \ Volts$$

Resistor 2

$$E = IR$$
$$E = 3A \times 15\Omega$$
$$E = 45 \ Volts$$

Resistor 3

$$E = IR$$
$$E = 3A \times 5\Omega$$
$$E = 15 \ Volts$$

Resistor 4

$$E = IR$$
$$E = 3A \times 25\Omega$$
$$E = 75 \ Volts$$

Resistor 5

$$E = IR$$
$$E = 3A \times 40\Omega$$
$$E = 120 \ Volts$$

The source voltage equals the sum of the voltage drops

$$E_1 + E_2 + E_3 + E_4 + E_5 = E_{total}$$
$$60V + 45V + 15V + 75V + 120V = 315 \ Volts$$

That's a lot of voltage, let's prove this equation.

Find the total resistance

$$R_{total} = 20\Omega + 15\Omega + 5\Omega + 25\Omega + 40\Omega$$
$$R_{total} = 105\Omega$$

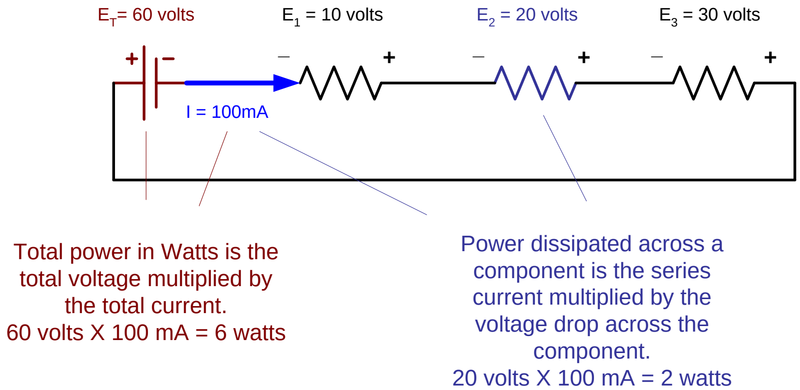
Ohm's Law for the totals

$$E = IR$$
$$E = 3A \times 105\Omega$$
$$E = 315 \ Volts$$

Please complete the exercises contained in Practice 4 - Series voltage –

Power

Power is a measurement of work over time, which is "joules per second". Electrical power is defined in the unit of the watt. Watts are derived from the product of voltage and current. Total power across a series circuit is derived from the total voltage of the source multiplied by the total current through the circuit. Power dissipated across a circuit component is the current through the component multiplied by the voltage drop across the component. Let's look at an example.



The total power can also be derived by the sum of all of the power dissipated across all of the components in the circuit. Let's complete the power dissipations across the remaining two resistors in the illustration above.

$$P_1 = I_t E_1$$
$$P_1 = 100\text{mA} \times 10 \text{ volts}$$
$$P_1 = 1 \text{ watt}$$

and

$$P_3 = I_t E_3$$
$$P_3 = 100\text{mA} \times 30 \text{ volts}$$
$$P_3 = 3 \text{ watts}$$

The sum of the powers dissipated across all of the components equals;

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

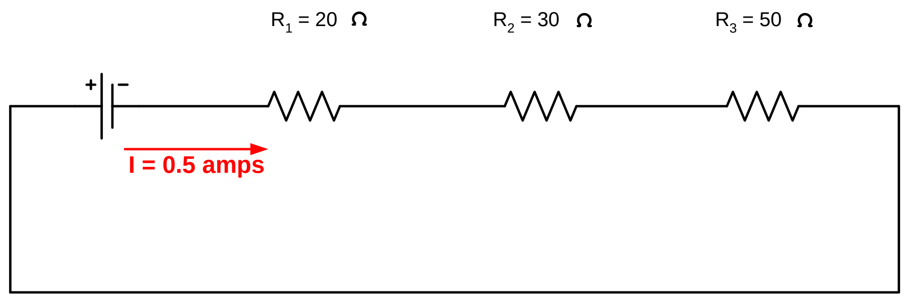
1 watt + 2 watts + 3 watts = 6 watts

This sum is equal to the product of the total current times the source voltage as shown above

Let's look at an example to derive the power dissipation of a series circuit.

A series circuit has three resistors rated at 20Ω, 30Ω and 50Ω respectively. A current of 500mA flows through this circuit. Find the power dissipated across each resistor and find the total power dissipated in the total circuit.

We will first draw out a simple schematic.



Step 1: Find the voltages across each resistor.

R1:

$$V_{R_1} = I_{series} \times R_1$$
$$V_{R_1} = 0.5_{amps} \times 20\Omega$$
$$V_{R_1} = 10_{volts}$$

R2:

$$V_{R_2} = I_{series} \times R_2$$
$$V_{R2} = 0.5_{amps} \times 30\Omega$$
$$V_{R_2} = 15_{volts}$$

R3:

$$V_{R_3} = I_{series} \times R_3$$
$$V_{R_3} = 0.5_{amps} \times 50\Omega$$
$$V_{R_3} = 25_{volts}$$

The total voltage of the circuit can now be derived.

$$V_1 + V_2 + V_3 = V_{total}$$
$$10_{Volts} + 15_{Volts} + 25_{Volts} = 50\ volts$$

Step 2: Find the power dissipated across each resistor.

R1:

$$P_1 = I_{series} \times E_1$$
$$P_1 = 0.5_{amps} \times 10_{volts}$$
$$P_1 = 5_{watts}$$

$$\begin{aligned} &P_2 = I_{series} \times E_2 \\ \textbf{R}_2\textbf{:} \quad &P_2 = 0.5_{amps} \times 15_{volts} \\ &P_2 = 7.5_{watts} \end{aligned}$$

$$\begin{aligned} &P_3 = I_{series} \times E_3 \\ \textbf{R}_3\textbf{:} \quad &P_3 = 0.5_{amps} \times 25_{volts} \\ &P_3 = 12.5_{watts} \end{aligned}$$

Step 3: Find the total power dissipated in the series circuit.

$$\begin{aligned} P_{total} &= P_1 + P_2 + P_3 \\ P_{total} &= 5_{watts} + 7.5_{watts} + 12.5_{watts} \\ P_{total} &= 25_{watts} \end{aligned}$$

Proof:

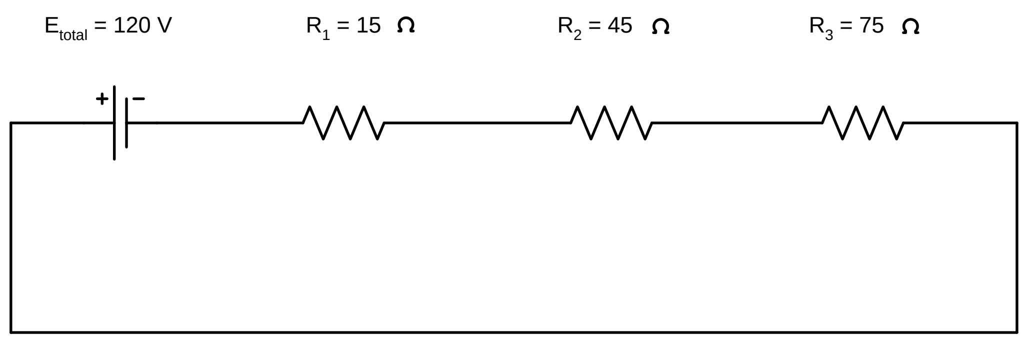
Remember that when we derived the voltages, we found the total voltage too. By then using the circuit totals we can derive the total power dissipated by this formula.

$$\begin{aligned} P_{total} &= I_{source} \times E_{total} \\ P_{total} &= 0.5_{amps} \times 50_{volts} \\ P_{total} &= 25_{watts} \end{aligned}$$

When working with equations, always determine a proof equation to check yourself. The proof does not have to be a part of the lessons answers, but rather a habit to develop when you are working in the field. This habit is part of being a professional technician.

Let's work another example:

A series circuit contains three resistors with values of 15Ω, 45Ω and 75Ω respectively. The source voltage is 120 volts. Find the power dissipation of the total circuit and across each resistor. First we draw the schematic.



Step 1: Find the total resistance so we can then derive the series current.

$$R_{total} = R_1 + R_2 + R_3$$
$$R_{total} = 15\Omega + 45\Omega + 75\Omega$$
$$R_{total} = 135\Omega_{total}$$

Step 2: Find the total current.

$$I_{series} = E_{source} / R_{total}$$
$$I_{series} = 120_{volts} / 135\Omega$$

Take care when you round off answers.

$$I_{series} = 0.889_{amps} \text{ or } 889mA$$

Step 3: Find the voltage drops across each resistor.

R₁:

$$E_1 = I_{series} \times R_1$$
$$E_1 = 0.889_{amps} \times 15\Omega$$
$$E_1 = 13.34_{volts}$$

R₂:

$$E_2 = I_{series} \times R_2$$
$$E_2 = 0.889_{amps} \times 45\Omega$$
$$E_2 = 40_{volts}$$

$$\mathbf{R_3:}\quad \begin{aligned} E_3 &= I_{series} \times R_3 \\ E_3 &= 0.889_{amps} \times 75\Omega \\ E_3 &= 66.68_{volts} \end{aligned}$$

We can then proof the voltage solutions by Kirchhoff's voltage law. We must remember that the voltage drops across the resistors have a negative polarity and the source voltage is positive.

$$V_{source} + V_1 + V_2 + V_3 = 0$$
$$+120_{volts} + (-13.34_{volts}) + (-40_{volts}) + (-66.68_{volts}) = 0$$
$$0.02_v \neq 0$$

The reason for the slight difference is the rounding of the current and voltages when we solved for those values. With that in mind, the proof validated the answers as correct.

Step 4: Find the total power across the series circuit.

$$P = I_{series} \times E_{source}$$
$$P = 0.889_{amps} \times 120_{volts}$$
$$P = 106.68_{watts}$$

This is the answer to "part 1" of the question.

Step 5: Find the power dissipated across the three resistors.

$$\mathbf{R_1:}\quad \begin{aligned} P_1 &= I_{source} \times E_1 \\ P_1 &= 0.889_{amps} \times 13.34_{volts} \\ P_1 &= 11.86_{watts} \end{aligned}$$

$$\mathbf{R_2:}\quad \begin{aligned} P_2 &= I_{source} \times E_2 \\ P_2 &= 0.889_{amps} \times 40_{volts} \\ P_2 &= 35.56_{watts} \end{aligned}$$

$$\mathbf{R_3:}\quad \begin{aligned} P_3 &= I_{source} \times E_3 \\ P_3 &= 0.889_{amps} \times 66.68_{volts} \\ P_3 &= 59.28_{watts} \end{aligned}$$

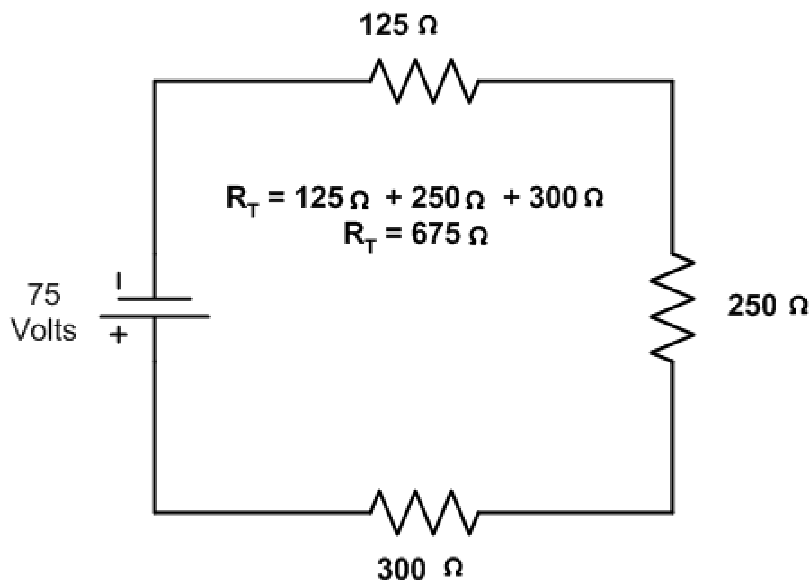
Let's proof our answers again by summing the power dissipated in the three resistors and compare it to the total power of the circuit, which we solved above.

$$P_{total} = P_1 + P_2 + P_3$$
$$P_{total} = 11.86_{watts} + 35.56_{watts} + 59.28_{watts}$$
$$P_{total} = 106.7_{watts}$$

Again if we look at how we rounded off, the proof concludes that our answers are correct.

A second method for calculating power (refer back to the PIER wheel, Ohm's Law) is the use of the equation $P = I^2R$. Therefore to calculate a total power you must use the total (equivalent) current squared times the total resistance.
To find the power dissipated across a resistor component in a series circuit, the equation will use the total current squared times the resistance of the component evaluated. Let's do an example to define the use of this equation.

A series circuit contains three resistors and is connected to a DC voltage source of 75 volts. The three values of the resistors are 125Ω, 250Ω, and 300Ω respectively. What is the total power across the circuit as well as the power dissipated across each resistor?



The total resistance has been calculated by the addition of the three resistors. We must then define the total current which is the same current throughout the entire circuit. Using Ohm's Law we can define the current as;

$$I_t = \frac{E_t}{R_t}$$

$$I_t = \frac{75_{volts}}{675\Omega}$$

$$I_t = 0.111 \text{ or } 111 \text{ mA}$$

The total power can now be derived by the formula;

$$P = I^2R \qquad\qquad P = I \bullet E$$
$$P = 0.111^2 \times 675 \qquad \text{let's prove this} \qquad P = 0.111 \times 75$$
$$P = 0.012321 \times 675 \qquad\qquad P = 8.325 \text{ watts}$$
$$P = 8.32 \text{ watts}$$

Either equation will work just as well.

The power dissipated across each resistor can also be found using $P = I^2R$.

Resistor 1
$$P = I^2R$$
$$P = (0.111)^2 \times 125$$
$$P = 0.012321 \times 125$$
$$P = 1.54 \text{ watts}$$

Resistor 2
$$P = I^2R$$
$$P = (0.111)^2 \times 250$$
$$P = 0.012321 \times 250$$
$$P = 3.08 \text{ watts}$$

Resistor 3
$$P = I^2R$$
$$P = (0.111)^2 \times 300$$
$$P = 0.012321 \times 300$$
$$P = 3.70 \text{ watts}$$

The total power is the sum of the powers dissipated across all of the resistors in a series circuit.

$$P_t = P_1 + P_2 + P_3$$
$$P_t = 1.54 + 3.08 + 3.70$$
$$P_t = 8.32 \text{ watts}$$

The sum of the power equals the same power in the equation for the total power proving the answers are correct.

Please complete the exercises contained in Practice 5 - Series power –

Law of Proportionality

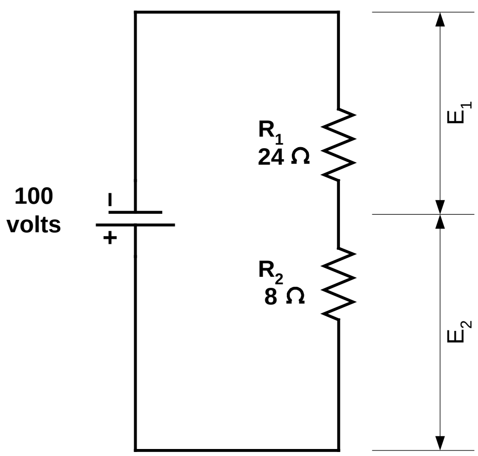
Let's look at another means to solve circuit variables other than the use of Ohm's Law. We will use the law of proportionality. We know that in a series circuit the current is constant throughout all of the components of that circuit. The voltage drops across the resistors in a series circuit will have a directly proportional relationship to the resistances of the same resistors.

If the voltage across a resistor is twice the magnitude as another resistor of the series circuit, the resistance of that resistor will also be twice as high.

Example:

> If resistor 1 has a voltage drop of 10 volts and has a resistance of 50Ω and resistor 2 has a 20 volt drop then resistor 2 must have 100Ω of resistance.

Let's look at another example and determine the voltages across the resistors using the Law of proportionality.



To find the voltage drop across R_1, the relation $\frac{R_1}{R_1 + R_2}$ is used.
If you multiply this relation by the total voltage you will find the voltage drop across R_1.

To find R_2, use the following relation and then multiply it by the total voltage just as you did above.

$$\frac{R_2}{R_2 + R_1}$$

Let's solve for these voltage drops.

$$E_1 = E_{source}\left(\frac{R_1}{R_1 + R_2}\right)$$

E_1:

$$E_1 = 100_{volts}\left(\frac{24\Omega}{24\Omega + 8\Omega}\right)$$

$$E_1 = 100 \times \frac{24}{32}$$

$$E_1 = 75_{volts}$$

$$E_2 = E_{source}\left(\frac{R_2}{R_2 + R_1}\right)$$

E$_2$:

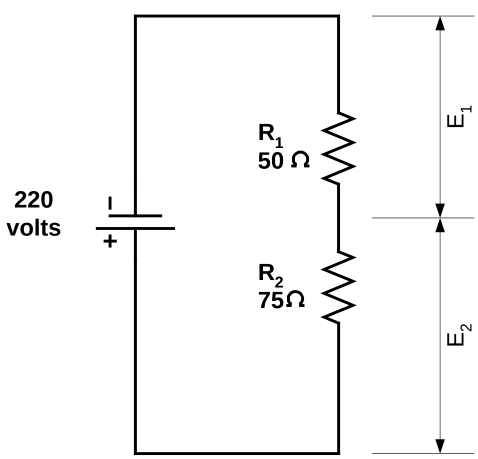
$$E_2 = 100_{volts}\left(\frac{8\Omega}{8\Omega + 24\Omega}\right)$$

$$E_2 = 100 \times \frac{8}{32}$$

$$E_2 = 25_{volts}$$

If you noticed, you can simplify the ratios of the equation from $\frac{24}{32}$ **and** $\frac{8}{32}$ to $\frac{3}{4}$ **and** $\frac{1}{4}$ respectively to simplify the math.

Another way to look at this is to just use ratios and cross multiply to solve for the unknowns. Again remember that the current is a constant throughout the circuit and can be ignored when using these ratios. We will use the following values.



By just looking at the resistive values, since R$_2$ is greater than R$_1$, the voltage drop across R$_2$ should be greater.

Let's sum the two resistances to obtain the total resistance.

50Ω + 75Ω = 125Ω total resistance.

We can then make a ratio using the total resistance and total voltage (source).

The ratio relationships should look like the equations below.

$$\frac{V_{total}}{R_{total}} = \frac{V_1}{R_1} = \frac{V_2}{R_2} \text{ and the ratio for the totals is } \frac{220}{125}$$

This ratio can the be used as is or simplified to $\frac{44}{25}$

$$\frac{44}{25}=\frac{E_1}{50}$$

Solve for E_1:

$$\frac{44\times 50}{25}=E_1$$

$$E_1 = 88_{volts}$$

$$\frac{44}{25}=\frac{E_2}{75}$$

Solve for E_2:

$$\frac{44\times 75}{25}=E_2$$

$$E_2 = 132_{volts}$$

Again we will prove that the solutions are correct by summing the drops.

$$V_1 + V_2 = V_{total}$$

$$88_{volts} + 132_{volts} = 220_{volts}$$

This proves our answers are correct because the voltage drop sums equals the total voltage.

The use of ratios is better than the" law of proportion" equation because the ratios are all equal and you do not need to know the total voltage for finding a variable from one resistor ratio to the other.

Example: A resistor with a resistance of 100Ω has a voltage drop of 20 volts. What is the voltage drop across a second resistor of 75Ω and what is the total voltage if these resistors were in a series circuit?

$$\frac{R_1}{E_1}=\frac{R_2}{E_2}$$

$$\frac{100\Omega}{20V}=\frac{75\Omega}{E_2}$$

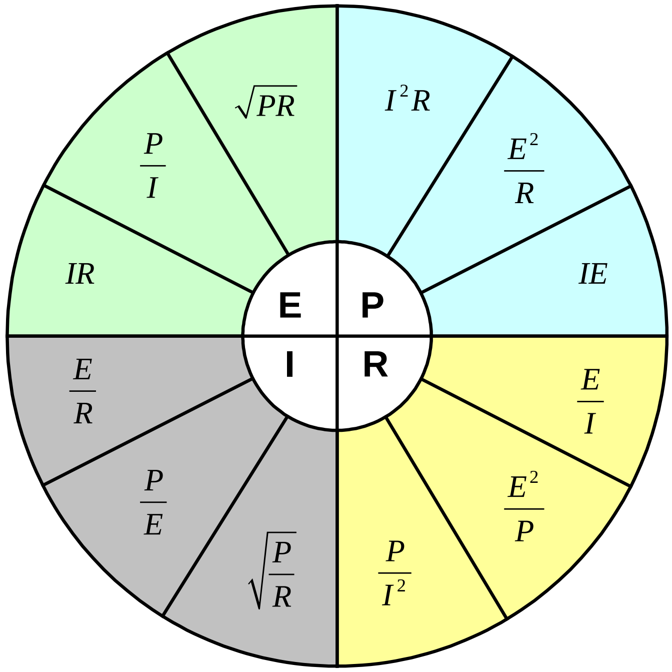
and the total voltage equals; $20_{volts} + 15_{volts} = 35V_{total}$

$$\frac{75\times 20}{100}=E_2$$

$$E_2 = 15V$$

Please complete the exercises contained in Practice 6 - Series proportion –

Series Circuit Parameters



The following paragraphs represent the parameters for series circuits. These parameters are the rules in which we have just covered in the previous paragraphs concerning series circuits. They can be considered a recap of what we have learned about series circuits. There are six parameters as listed below;

1. The same current flows through each part of a series circuit.

2. The total resistance of a series circuit is equal to the sum of the individual resistances.

3. The total voltage across a series circuit is equal to the sum of the individual voltage drops.

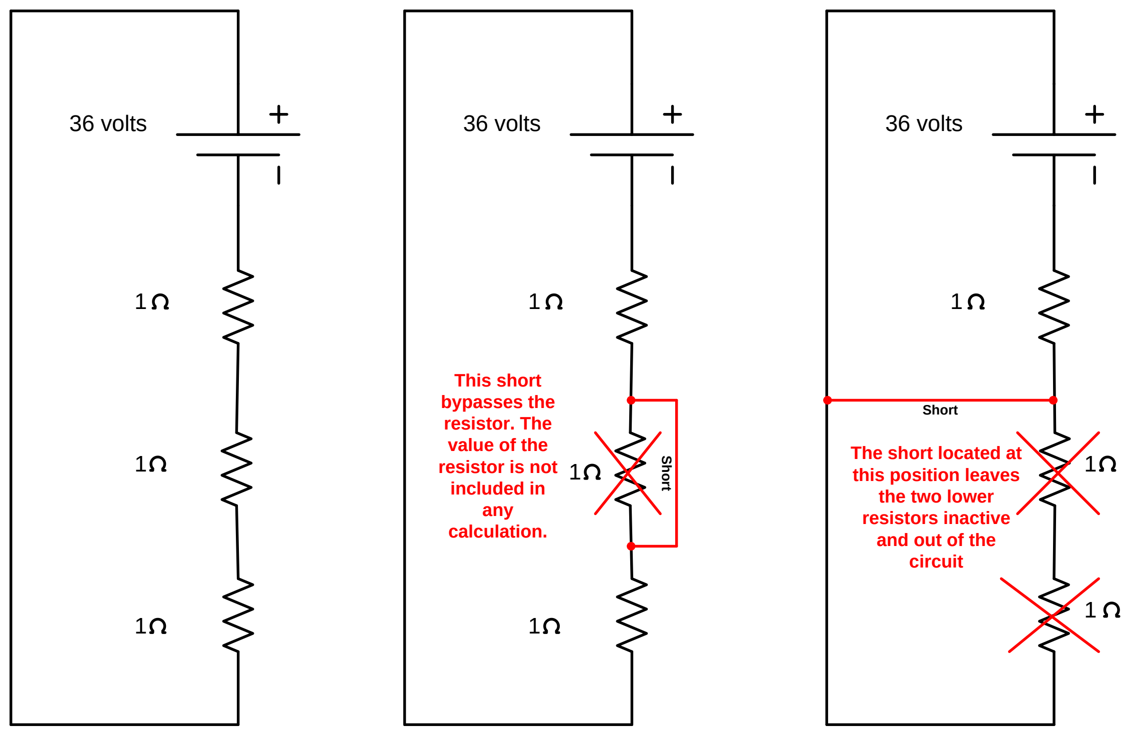
4. The voltage drop across a resistor in a series circuit is directly proportional to the size of the resistor.

5. The total power dissipated in a series circuit is equal to the sum of the individual power dissipations.

6. Ohm's Law applies to each component and to the entire circuit.

Opens and Shorts

Shorts in a series circuit can become quite a problem altering the function of the circuit. The resistances are additive in a series circuit so if a portion or component is shorted, a dangerous current then may exist. On the other hand, open circuits in a series circuit will terminate any current flow and all of the components will fail to operate. A good example of this is Christmas tree lights. When one bulb fails, all of the bulbs go out. You must check each bulb till the failed bulb is found. Let's look at the affects a short circuit has on a series circuit. We will use the following illustration for discussion.



Normal (A)

One Resistor Shorted (B)

Two resistors Shorted (C)

We will first calculate the current and power dissipated across circuit (A), the normal circuit.

$$R_t = R_1 + R_2 + R_3$$
$$R_t = 1\Omega + 1\Omega + 1\Omega$$
$$R_t = 3\Omega$$

Next we will define the series current in (A) the normal circuit.

$$I = \frac{E_t}{R_t}$$
$$I = \frac{36V}{3\Omega}$$
$$I = 12\ amps$$

The power dissipated can then be calculated across the entire circuit.

$$P = IE$$
$$P = 12A \times 36V$$ in a real circuit, this is *cook'in*.
$$P = 432\ Watts$$

In the illustration, (B) represents a short across one resistor. The short effectively eliminates the resistor from the circuit. The new total resistance of the circuit can now be found as;

$$R_t = R_1 + R_3$$
$$R_t = 1\Omega + 1\Omega$$
$$R_t = 2\Omega$$

The total new current can then be found

$$I = \frac{E_t}{R_t}$$
$$I = \frac{36V}{2\Omega}$$
$$I = 18 \ amps$$

And the total power dissipated is calculated as;

$$P = IE$$
$$P = 18A \times 36V$$
$$P = 648 \ Watts$$

Did you notice that the resistance of the circuit went down by 33%, and the power dissipated across the circuit increased by 33%? A change in total resistance of a series circuit is inversely proportional to the power dissipated across the same circuit.

In the illustration, part (C) shows that two resistors are shorted and effectively out of the circuit. Since two thirds of the resistance is now removed (the three resistors are equal in resistance), the resistance is lower by two thirds; therefore the power should be greater by two thirds. Let's solve for the variables.

The circuit has only one resistor so the resistance of the circuit is equal to the resistance of the resistor, 1 ohm. The current can now be determined as;

$$I = \frac{E_t}{R_t}$$
$$I = \frac{36V}{1\Omega}$$
$$I = 36 \ amps$$

And the power dissipated in this circuit is;

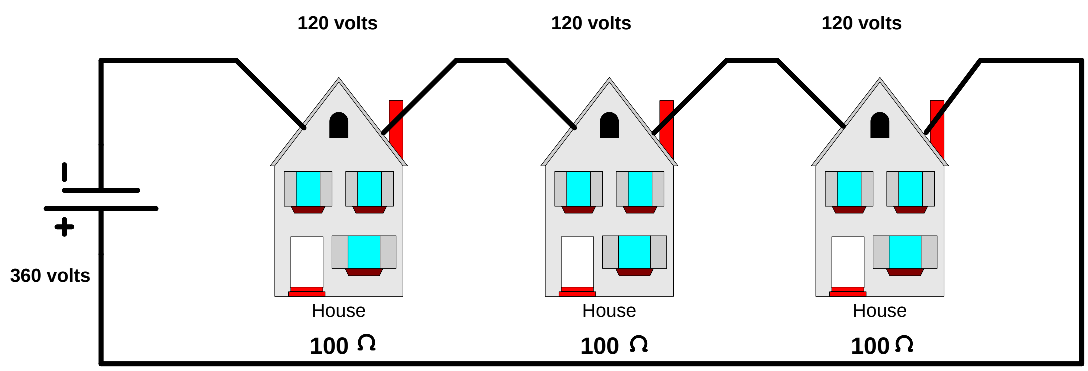
$$P = IE$$
$$P = 36A \times 36V$$
$$P = 1296\ Watts$$

The original 432 watts is only 33% of the final 1296 watts therefore the power dissipated across the circuit is 66% or $^{2}/_{3^{rds}}$ greater.

An open in the circuit is equal to inserting a resistance of infinite value therefore no current will flow through a series circuit. An open circuit can be established by opening a switch that is installed in the series circuit or a wire (conductor) becomes loose or broken thus causing an open.

Loading

We have just discussed how a short can affect a series circuit. A shorted resistor acts as if it is non-existent within the circuit. A series circuit with minimal resistance may lead to an overload within the circuit. Remember that it is the resistance that limits the flow of current within a series circuit. Therefore a lower resistance will have an increase in current and a higher resistance will have a decrease in current. Current through components in an electric circuit will cause the components to heat. Too much current will cause the components to overheat. This condition is called an overloaded circuit. Let's make a power system so that we may supply electrical power to some houses. We will construct this system so that the houses are connected in series. Remember that the supply for our houses will be 120 volts.



The system voltage must be the sum of the three houses, or 360 volts.

The total resistance for our power system is the total resistance of the three houses, 300Ω.

The current of this circuit is;

$$I = \frac{E}{R}$$

$$I = \frac{360_{volts}}{300\Omega}$$

$$I = 1.2_{Amps}$$

The power dissipated across our power system is:

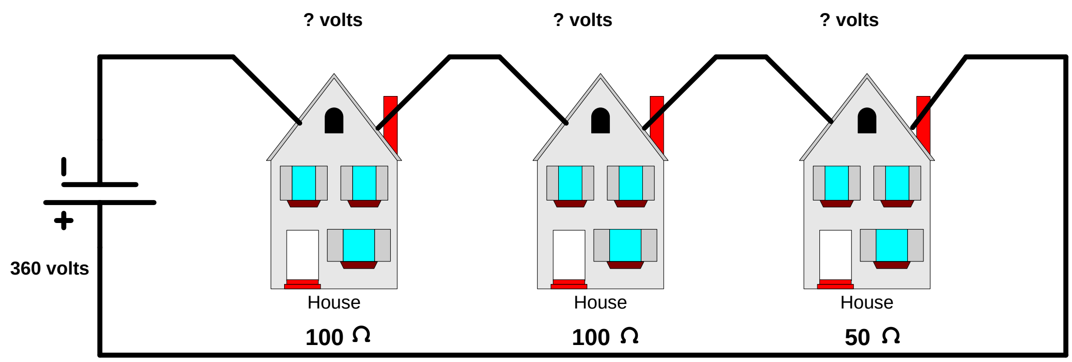
$$P = IE$$

$$P = 1.2_{Amps} \times 360_{volts}$$

$$P = 432 \ watts$$

Again this will give a supply voltage to each house at 120 volts.

The third house has gotten tired of its electric bill and he decided to put in gas heat. This cut his total resistance in his house in half or to 50Ω. Let's see what happens to our system now.



We can no longer insure that each house has a supply of 120 volts each. The total resistance to the power system is now 250Ω and the current is calculated at;

$$I = \frac{E}{R}$$

$$I = \frac{360_{volts}}{250\Omega}$$

$$I = 1.44_{Amps}$$

We now have 1.44 amps running through each house in our system. Remember that our system was built with an original supply of 360 volts. Let's look at the voltages in each house.

House #1 and #2

$$E = IR$$
$$E = 1.44_{amps} \times 100\Omega$$
$$E = 144 \ volts$$

each house has 144 volts across them.

House #3

$$E = IR$$
$$E = 1.44_{amps} \times 50\Omega$$
$$E = 72 \ volts$$

Two of the houses now have an over-voltage problem and the third house has an under-voltage problem.

A power system connected in series is not very efficient and a steady voltage supply cannot be guaranteed. As you can imagine the dynamics of change in resistance in each house as lights within each house come on and off at different times, the heating systems may be set differently and kick on or off at different times. There can't be any guarantees to a steady voltage supply unless the resistances, of the houses, remain equal and the same at all times.

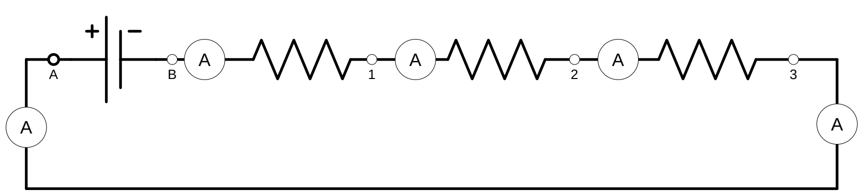
It is not a good plan to design a power system as a series circuit.

What is Really Consumed in a Circuit

We must start off with the question "what is consumed in a circuit"? Is it the voltage, current or power? We can automatically eliminate the resistance because once the circuit is built the resistance is constant and unchanging.

Let's look at a circuit and explore the units as we step through all of the components within the circuit.

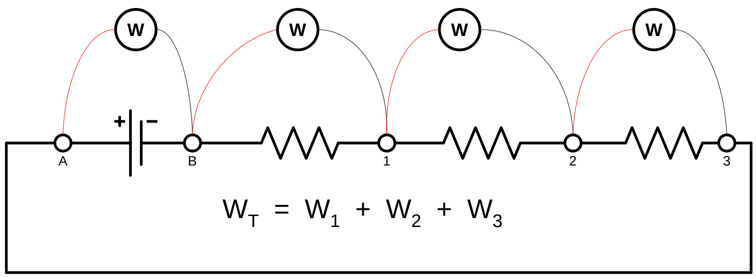
Current;



We have learned that the current in a series circuit remains constant throughout the circuit. All of the ammeters will read the same current magnitude throughout the circuit. It seems that no current is consumed.

Power,

Power is proportional to the resistance of the components. A resistor of high ohmic value will have a higher power dissipated across it than of a resistor with a lower ohmic value.

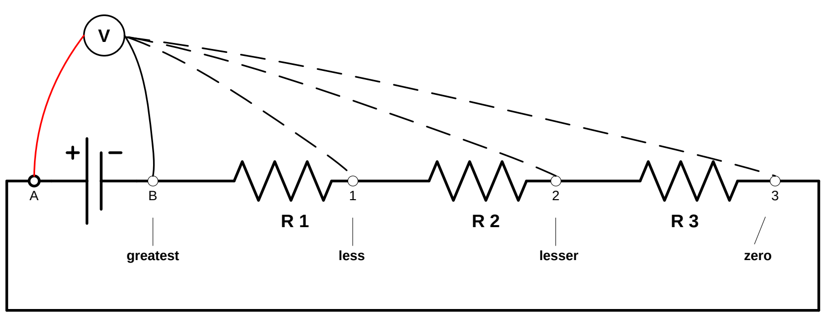


The watts dissipated across the three resistors are proportional to their resistances. A higher resistance will have a greater power dissipated across it since the series current is the same throughout the circuit. If R_3 is greater than R_1, the power dissipated across R_3 will be greater. The power is not consumed as it travels the circuit loop which, if it did, it would decrease after each component.

As the illustration suggest, power is not consumed or progressively dwindles as the current is followed to each component.

Voltage,

The last unit we will observe is the voltage. The voltage is the greatest when you measure across the source A and B. As you step the voltmeter from B to points 1, 2 and 3 respectively, the voltage will always decrease till at point 3, the voltage will no longer exist. The voltage is, therefore, consumed.



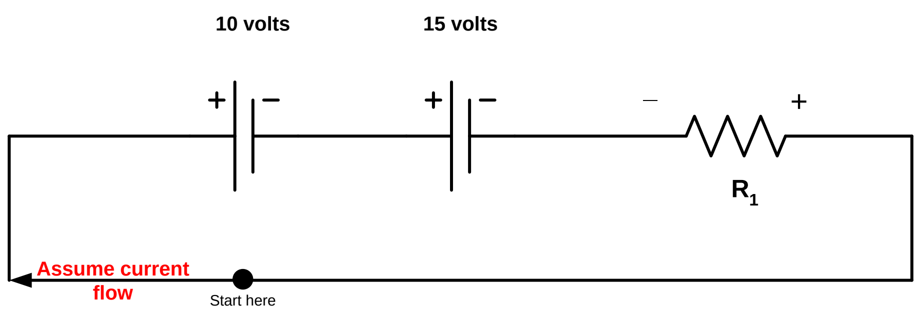
No matter what the resistances are the voltage will always dwindle across the three points 1,2 & 3 and at point 3 be equal to zero. The voltage is consumed across the circuit

Again no matter what the current is or the magnitudes of the resistors, the voltage will always decrease to zero as you measure across the circuit from points B, 1, 2, and 3. Voltage is the force which pushes the current through the resistance. Power is the rate in which the voltage (force) is doing the work in moving a current. The conclusion is that voltage is consumed within a circuit.

Series Aiding – Series Opposing

I am sure that most everyone has inserted multiple batteries into an electronic device or a flashlight. One must ensure that the proper polarity of the batteries must be observed while inserting the batteries so that the device will properly operate. But what is really going on when these batteries are being inserted?

When multiple batteries are inserted into a circuit in series, the batteries will become series aiding (adding voltage) or series opposing (subtracting voltage). Let's look at a series schematic which includes two voltage sources and a resistor. We will use Kirchhoff's voltage law to define the circuit.



We begin at a point and assume a current direction. The current will enter the first battery from the positive side, referencing that voltage as positive. This is true for the second source as well. When current enters the resistor, the voltage polarity will be negative at its entrance. Therefore according to Kirchhoff, the sum of these voltages equals zero. Let's assign a resistance to the resistor at 50Ω.

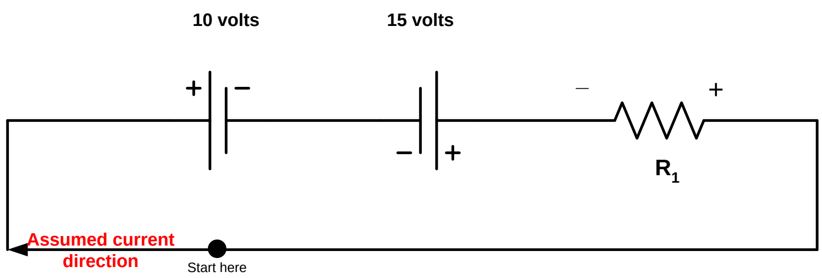
$$(+10)+(+15)+(-50\times I)=0$$
$$25+(-50\times I)=0$$
$$25=50\times I$$ $(-50I)$ is the voltage across the resistor or $I\times R$
$$I=\frac{25}{50}$$
$$I=0.5\ amps$$

Let's assume the current at the opposite direction on the same schematic. The current through the resistor is in the opposite direction; therefore the polarity signs on the resistor must be reversed. Kirchhoff's equation will be;

$$+(-50 \times I) + (-15) + (-10) = 0$$
$$(-50 \times I) - 25 = 0$$
$$-50 \times I = 25$$
$$I = \frac{25}{-50}$$
$$I = -0.5 \ amps$$

The negative current indicates that the assumed current direction is wrong. Just be careful when you assign the polarity to the voltages across the resistors as you assume the direction. As the current enters through a resistor, the entrance is negative and the exit is positive. This is an example of a series aiding battery source.

Now let's look at a series opposing circuit. We will use the same schematic but we will reverse the second battery. Again the resistance of R_1 will be 50Ω.

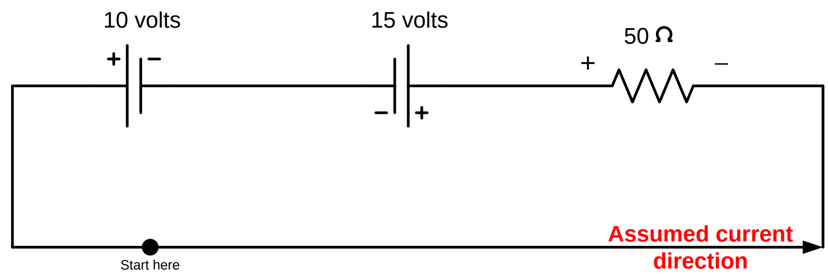


Again we will pick a start point and assume current direction. Label the resistor polarity according to the assumed current flow. The equation now, for Kirchhoff's voltage law, is stated as;

$$+10 + (-15) + (-50 \times I) = 0$$
$$-5 + (-50 \times I) = 0$$
$$-50 \times I = 5$$
$$I = \frac{5}{-50}$$
$$I = -0.1 \ amps$$

The negative number indicates that the assumed current direction is wrong. Let's reverse the assumed current direction. The polarity of the current through the resistor must be reversed because of the current flow.

Let's redraw the schematic showing the current in the other direction. Again label the resistor according to the direction of the assumed current,

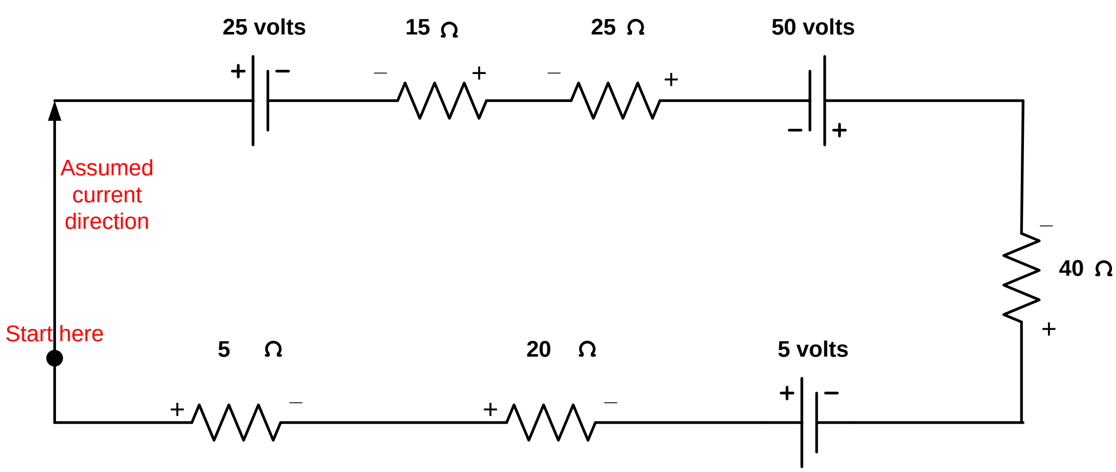


The equation should now be as;

$$(-50\times I)+15+(-10)=0$$
$$-50\times I+5=0$$
$$-50\times I=-5$$
$$I=\frac{-5}{-50}$$
$$I=0.1\ amps$$

The current is positive; therefore the assumed current direction is correct.

Let's tackle a more challenging example. Analyze the circuit below and determine the current magnitude and direction.

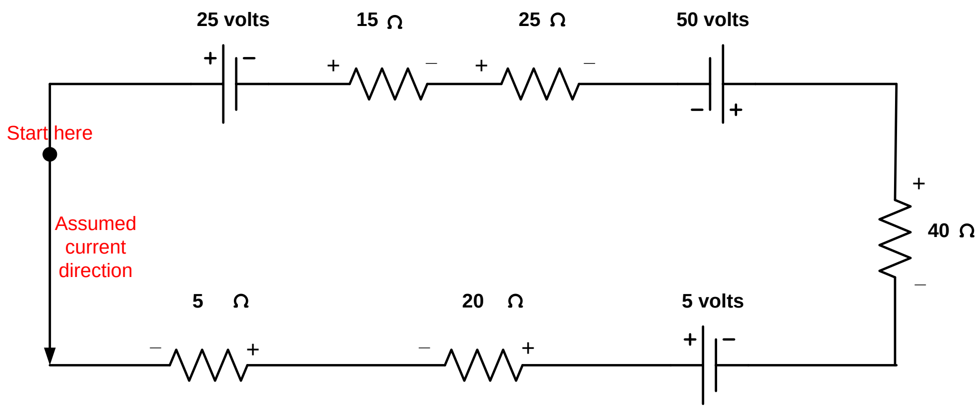


The polarities are assigned according to the assumed current flow

We will build an equation using Kirchhoff's voltage law and solve for current and current direction. This is where care must be given to ensure the proper polarity across the resistors.

$$+25+(-15I)+(-25I)+(-50)+(-40I)+(-5)+(-20I)+(-5I)=0$$
$$+25+(-50)+(-5)+(-105I)=0$$
$$-30-105I=0$$
$$-105I=30$$
$$I=\frac{30}{-105}$$
$$I=-0.286\ amps\ or\ -286mA$$

The current is a negative therefore the assumed direction was wrong. We will redraw the circuit showing the current in the proper direction. Note that the polarities or the resistors will reverse to reflect the change of current.



The polarities are assigned according to the assumed current flow

And the equation is;

$$(-5I)+(-20I)+5+(-40I)+50+(-25I)+(-15I)+(-25)=0$$
$$5+50+(-25)+(-105I)=0$$
$$30+(-105I)=0$$
$$-105I=-30$$
$$I=\frac{-30}{-105}$$
$$I=0.286\ amps\ or\ 286mA$$

The current is now displayed as positive indicating the current direction is correct.

Please complete the exercises contained in Practice 7 - Series aiding / Series opposing – DCCircuitsQuiz7_v0.03.tbk

Review:

1. Voltage is the fundamental force (phenomenon) that moves current (electrons) through an electrical circuit.

2. Voltage is the force that separates charge.

3. Current is the movement of electrons within an electrical circuit.

4. Resistance is the opposition to the currents movement.

5. Power (watts) is the measurement of electrical work being done over a given amount of time.

6. The four units above can be found or manipulated using Ohm's Law whose equations are;
   $P = I E$ and $E = I R$

7. The first sources of electricity beyond static charge (layden jars) was the Voltic pile or DC battery.

8. An electrical circuit is a conductive path in which electrical current may flow from its origin through conductors, usually to some components, then back to the origin.

9. Schematics and symbols are used to represent electrical components for specialized electrical drawings so the drawings will not be cluttered and easily understood.

10. There are three basic types of electrical circuits (DC). They are the series circuit, the parallel circuit and the combination circuit.

11. When working on or around electrical equipment a safety standard must be followed to prevent injury or death to personnel.

12. Electrocution is death by electrical shock. The lightest current that may cause death by electrocution averages around 100 milliamps.

13. Each major company within the electrical industry should have a safety program in which their employees follow. If the company does not have a program, strict OSHA rules must then be followed.

14. The series circuit is defined as a circuit in which the components of the circuit are connected from the source in a line, one after the other (in a string) then returning back to the source.

15. The source of an electrical circuit is usually defined as a voltage source.

16. The resistive components of a series circuit can be summed to represent a total resistance for the circuit.

17. The magnitude of the voltage source is equal to the total voltage drops across all of the components in a series circuit.

18. Kirchhoff's law for voltage is that the sum of all of the voltages (source and drops) equals zero.

19. On components connected in series, the polarities of the components are more negative on connection side which connects to the negative pole of the source. This is true even if another component is between the source and the component being questioned.

20. The total power dissipated in a series circuit is equal to the sum of the individual power dissipations across the components of the series circuit.

21. The voltage across a resistive component of a series circuit is directly proportional to the components resistance. The law of proportionality exists with this relationship.

22. Any open within a series circuit will stop the current flow within the circuit.

23. Any short across any component within a series circuit will effectively remove any contribution that component has to the circuit.

24. The more loads you add to a series circuit, the lower the current magnitude will become. The lower the current, the lower the voltage drop becomes across each component in a series circuit.

25. Unequal load (resistances) components will yield unequal voltage drop across the different components, therefore it is not wise to use a series circuit to deliver a constant voltage to the components of that circuit.

26. When a series circuit contains two sources they may become series aiding or series opposing depending upon the polarity connections.

Memorize these parameters

27. The six circuit parameters for a series circuit are;

    - The same current flows through each part of a series circuit.
    - The total resistance of a series circuit is equal to the sum of the individual resistances.
    - The total voltage across a series circuit is equal to the sum of the individual voltage drops.
    - The voltage drop across a resistor in a series circuit is directly proportional to the size of the resistor.
    - The total power dissipated in a series circuit is equal to the sum of the individual power dissipations.
    - Ohm's Law applies to each component and to the entire circuit.