FHSST Authors

The Free High School Science Texts: Textbooks for High School Students Studying the Sciences Physics Grades 10 - 12

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Contents

Chapter 10

Electric Circuits - Grade 10

10.1 Electric Circuits

In South Africa, people depend on electricity to provide power for most appliances in the home, at work and out in the world in general. For example, flourescent lights, electric heating and cooking (on electric stoves), all depend on electricity to work. To realise just how big an impact electricity has on our daily lives, just think about what happens when there is a power failure or load shedding.

Activity :: Discussion : Uses of electricity
With a partner, take the following topics and, for each topic, write down at least 5 items/appliances/machines which need electricity to work. Try not to use the same item more than once.

- At home
- At school
- At the hospital
- In the city

Once you have finished making your lists, compare with the lists of other people in your class. (Save your lists somewhere safe for later because there will be another activity for which you'll need them.)
When you start comparing, you should notice that there are many different items which we use in our daily lives which rely on electricity to work!

!

Important: Safety Warning: We believe in experimenting and learning about physics at every opportunity, BUT playing with electricity can be **EXTREMELY DANGEROUS**! Do not try to build home made circuits alone. Make sure you have someone with you who knows if what you are doing is safe. Normal electrical outlets are dangerous. Treat electricity with respect in your everyday life.

10.1.1 Closed circuits

In the following activity we will investigate what is needed to cause charge to flow in an electric circuit.

Activity :: Experiment : Closed circuits

Aim:
To determine what is required to make electrical charges flow. In this experiment, we will use a lightbulb to check whether electrical charge is flowing in the circuit or not. If charge is flowing, the lightbulb should glow. On the other hand, if no charge is flowing, the lightbulb will not glow.

Apparatus:
You will need a small lightbulb which is attached to a metal conductor (e.g. a bulb from a school electrical kit), some connecting leads and a battery.

Method:
Take the apparatus items and try to connect them in a way that you cause the light bulb to glow (i.e. charge flows in the circuit).

Questions:

1. Once you have arranged your circuit elements to make the lightbulb glow, draw your circuit.
2. What can you say about how the battery is connected? (i.e. does it have one or two connecting leads attached? Where are they attached?)
3. What can you say about how the light bulb is connected in your circuit? (i.e. does it connect to one or two connecting leads, and where are they attached?)
4. Are there any items in your circuit which are not attached to something? In other words, are there any gaps in your circuit?

Write down your conclusion about what is needed to make an electric circuit work and charge to flow.

In the experiment above, you will have seen that the light bulb only glows when there is a *closed* circuit i.e. there are no gaps in the circuit and all the circuit elements are connected in a *closed loop*. Therefore, in order for charges to flow, a closed circuit and an energy source (in this case the battery) are needed. (Note: you do not have to have a lightbulb in the circuit! We used this as a check that charge was flowing.)

Definition: Electric circuit
An electric circuit is a closed path (with no breaks or gaps) along which electrical charges (electrons) flow powered by an energy source.

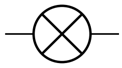
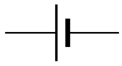
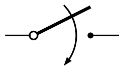
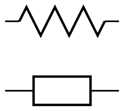
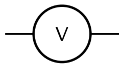
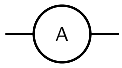
10.1.2 Representing electric circuits

Components of electrical circuits

Some common elements (components) which can be found in electrical circuits include light bulbs, batteries, connecting leads, switches, resistors, voltmeters and ammeters. You will learn more about these items in later sections, but it is important to know what their symbols are and how to represent them in circuit diagrams. Below is a table with the items and their symbols:

Circuit diagrams

Definition: Representing circuits
A **physical circuit** is the electric circuit you create with real components.
A **circuit diagram** is a drawing which uses symbols to represent the different components in the physical circuit.

Component	Symbol	Usage
light bulb		glows when charge moves through it
battery		provides energy for charge to move
switch		allows a circuit to be open or closed
resistor		resists the flow of charge
voltmeter		measures potential difference
ammeter		measures current in a circuit
connecting lead		connects circuit elements together

We use circuit diagrams to represent circuits because they are much simpler and more general than drawing the physical circuit because they only show the workings of the electrical components. You can see this in the two pictures below. The first picture shows the *physical circuit* for an electric torch. You can see the light bulb, the batteries, the switch and the outside plastic casing of the torch. The picture is actually a *cross-section* of the torch so that we can see inside it.

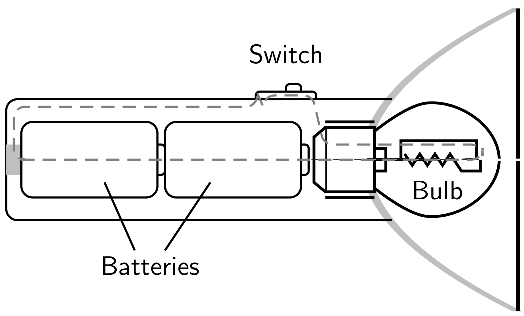


Figure 10.1: Physical components of an electric torch. The dotted line shows the path of the electrical circuit.

Below is the *circuit diagram* for the electric torch. Now the light bulb is represented by its symbol, as are the batteries, the switch and the connecting wires. It is not necessary to show the plastic casing of the torch since it has nothing to do with the electric workings of the torch. You can see that the circuit diagram is much simpler than the physical circuit drawing!

Series and parallel circuits

There are two ways to connect electrical components in a circuit: **in series** or **in parallel**.

Definition: Series circuit
In a series circuit, the charge has a **single** path from the battery, returning to the battery.

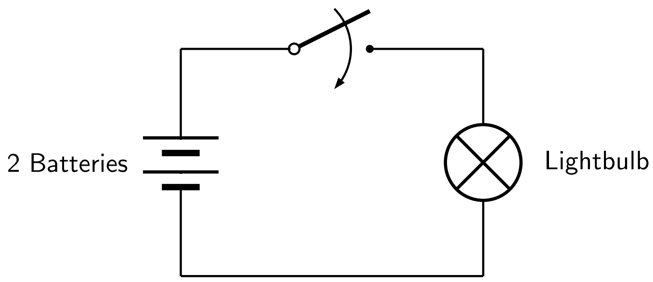
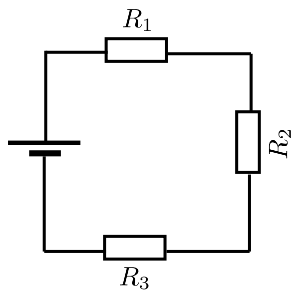


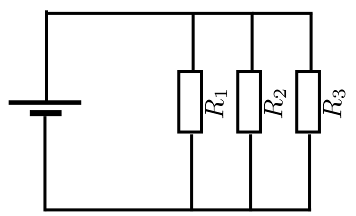
Figure 10.2: Circuit diagram of an electric torch.

Definition: Parallel circuit
In a parallel circuit, the charge has **multiple** paths from the battery, returning to the battery.

The picture below shows a circuit with three resistors connected *in series* on the left and a circuit with three resistors connected *in parallel* on the right:



3 resistors in a series circuit



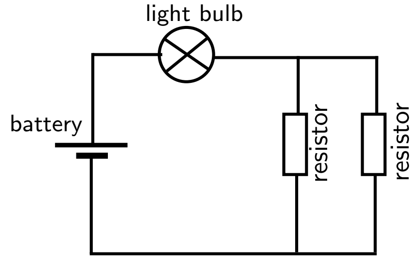
3 resistors in a parallel circuit

Worked Example 43: Drawing circuits I

Question: Draw the circuit diagram for a circuit which has the following components:

1. 1 battery
2. 1 lightbulb connected in series
3. 2 resistors connected in parallel

Answer
Step 1 : Identify the components and their symbols and draw according to the instructions:



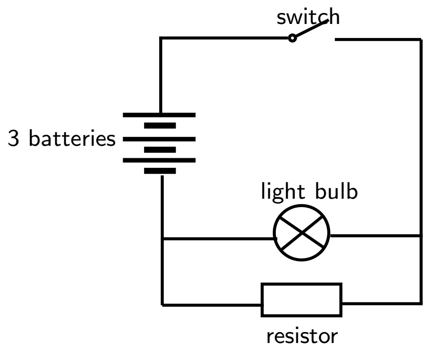
Worked Example 44: Drawing circuits II

Question: Draw the circuit diagram for a circuit which has the following components:

1. 3 batteries in series
2. 1 lightbulb connected in parallel with 1 resistor
3. a switch in series

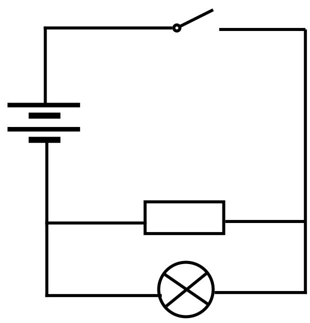
Answer

Step 1 : Identify the symbol for each component and draw according to the instructions:



Exercise: Circuits

1. Using physical components, set up the physical circuit which is described by the circuit diagram below:



   1.1 Now draw a picture of the physical circuit you have built.

2. Using physical components, set up a closed circuit which has one battery and a light bulb in series with a resistor.
   2.1 Draw the physical circuit.
   2.2 Draw the resulting circuit diagram.
   2.3 How do you know that you have built a closed circuit? (What happens to the light bulb?)
   2.4 If you add one more resistor to your circuit (also in series), what do you notice? (What happens to the light from the light bulb?)
   2.5 Draw the new circuit diagram which includes the second resistor.

3. Draw the circuit diagram for the following circuit: 2 batteries, a switch in series and 1 lightbulb which is in parallel with two resistors.
   3.1 Now use physical components to set up the circuit.

3.2 What happens when you close the switch? What does does this mean about the circuit?
3.3 Draw the physical circuit.

Activity :: Discussion : Alternative Energy
At the moment, electric power is produced by burning fossil fuels such as coal and oil. In South Africa, our main source of electric power is coal burning power stations. (We also have one nuclear power plant called Koeberg in the Western Cape). However, burning fossil fuels releases large amounts of pollution into the earth's atmosphere and can contribute to global warming. Also, the earth's fossil fuel reserves (especially oil) are starting to run low. For these reasons, people all across the world are working to find *alternative*/other sources of energy and on ways to *conserve*/save energy. Other sources of energy include wind power, solar power (from the sun), hydro-electric power (from water) among others.
With a partner, take out the lists you made earlier of the item/appliances/machines which used electricity in the following environments. For each item, try to think of an *alternative* AND a way to *conserve* or save power.
For example, if you had a flourescent light as an item used in the home, then:

- Alternative: use candles at supper time to reduce electricity consumption
- Conservation: turn off lights when not in a room, or during the day.

Topics:

- At home
- At school
- At the hospital
- In the city

Once you have finished making your lists, compare with the lists of other people in your class.

10.2 Potential Difference

10.2.1 Potential Difference

When a circuit is connected and is a complete circuit charge can move through the circuit. Charge will not move unless there is a reason, a force. Think of it as though charge is at rest and something has to push it along. This means that work needs to be done to make charge move. A force acts on the charges, doing work, to make them move. The force is provided by the battery in the circuit.

We call the moving charge "current" and we will talk about this later.

The position of the charge in the circuit tells you how much potential energy it has because of the force being exerted on it. This is like the force from gravity, the higher an object is above the ground (position) the more potential energy it has.

The amount of work to move a charge from one point to another point is how much the potential energy has changed. This is the difference in potential energy, called potential difference. Notice that it is a difference between the value of potential energy at two points so we say that potential difference is measured between or across two points. We do not say potential difference through something.

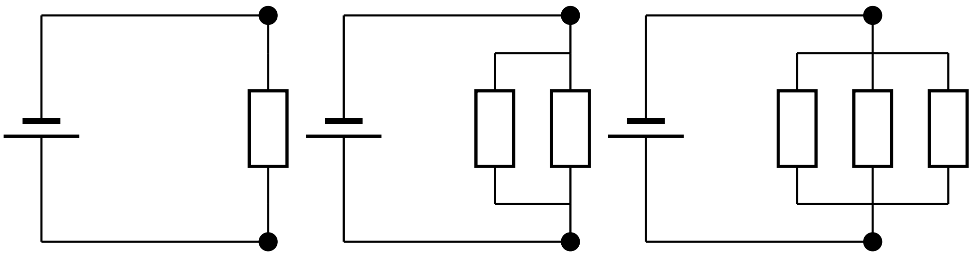
Definition: Potential Difference
Electrical potential difference as the difference in electrical potential energy per unit charge between two points. The units of potential difference are the volt (V).

The units are volt (V), which is the same as joule per coulomb, the amount of work done per unit charge. Electrical potential difference is also called voltage.

10.2.2 Potential Difference and Parallel Resistors

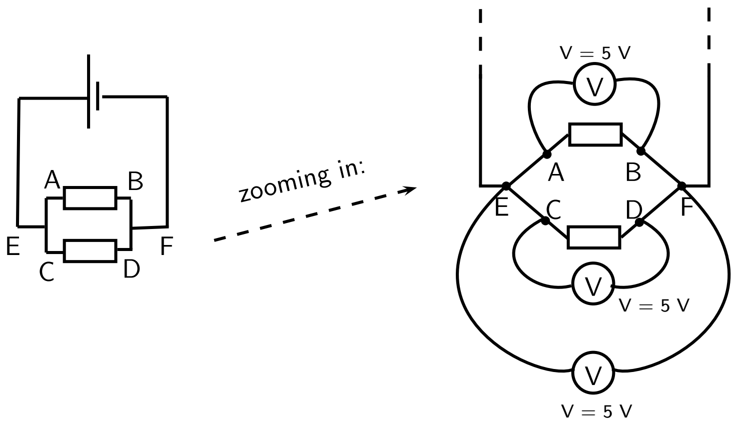
When resistors are connected in parallel the start and end points for all the resistors are the same. These points have the same potential energy and so the potential difference between them is the same no matter what is put in between them. You can have one, two or many resistors between the two points, the potential difference will not change. You can ignore whatever components are between two points in a circuit when calculating the difference between the two points.

Look at the following circuit diagrams. The battery is the same in all cases, all that changes is more resistors are added between the points marked by the black dots. If we were to measure the potential difference between the two dots in these circuits we would get the same answer for all three cases.



Lets look at two resistors in parallel more closely. When you construct a circuit you use wires and you might think that measuring the voltage in different places on the wires will make a difference. This is not true. The potential difference or voltage measurement will only be different if you measure a different set of components. All points on the wires that have no circuit components between them will give you the same measurements.

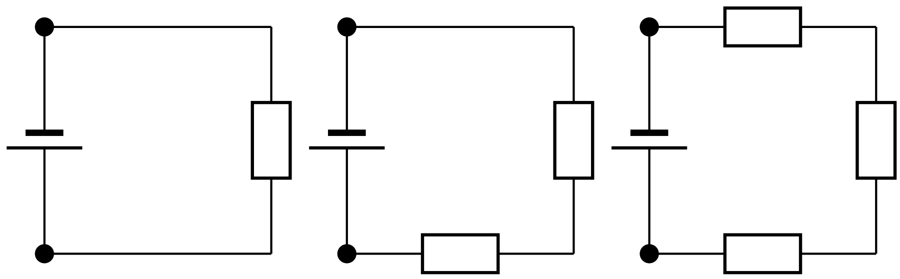
All three of the measurements shown in the picture below will give you the same voltages. The different measurement points on the left have no components between them so there is no change in potential energy. Exactly the same applies to the different points on the right. When you measure the potential difference between the points on the left and right you will get the same answer.



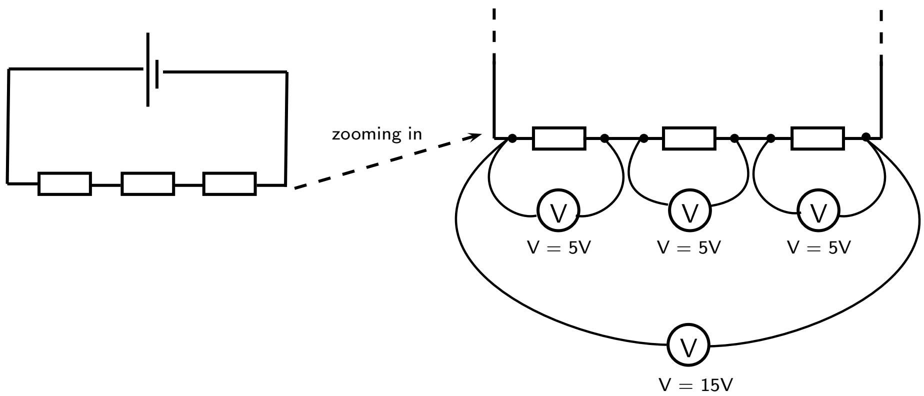
10.2.3 Potential Difference and Series Resistors

When resistors are in series, one after the other, there is a potential difference across each resistor. The total potential difference across a set of resistors in series is the sum of the potential differences across each of the resistors in the set. This is the same as falling a large distance under gravity or falling that same distance (difference) in many smaller steps. The total distance (difference) is the same.

Look at the circuits below. If we measured the potential difference between the black dots in all of these circuits it would be the same just like we saw above. So we now know the total potential difference is the same across one, two or three resistors. We also know that some work is required to make charge flow through each one, each is a step down in potential energy. These steps add up to the total drop which we know is the difference between the two dots.



Let us look at this in a bit more detail. In the picture below you can see what the different measurements for 3 identical resistors in series could look like. The total voltage across all three resistors is the sum of the voltages across the individual resistors.

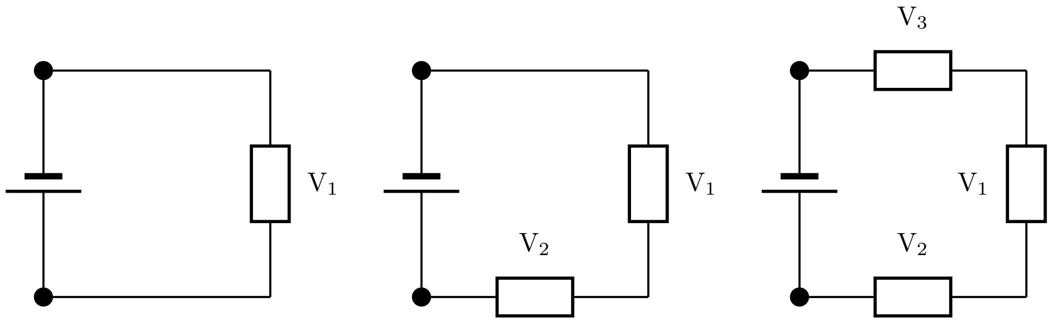


10.2.4 Ohm's Law

The voltage is the change in potential energy or work done when charge moves between two points in the circuit. The greater the resistance to charge moving the more work that needs to be done. The work done or voltage thus depends on the resistance. The potential difference is proportional to the resistance.

Definition: Ohm's Law
Voltage across a circuit component is proportional to the resistance of the component.

Use the fact that voltage is proportional to resistance to calculate what proportion of the total voltage of a circuit will be found across each circuit element.



We know that the total voltage is equal to V_1 in the first circuit, to $\mathrm{V}_1 + \mathrm{V}_2$ in the second circuit and $\mathrm{V}_1 + \mathrm{V}_2 + \mathrm{V}_3$ in the third circuit.

We know that the potential energy lost across a resistor is proportional to the resistance of the component. The total potential difference is shared evenly across the total resistance of the circuit. This means that the potential difference per unit of resistance is

$$V_{per\ unit\ of\ resistance} = \frac{V_{total}}{R_{total}}$$

Then the voltage across a resistor is just the resistance times the potential difference per unit of resistance

$$V_{resistor} = R_{resistor} \cdot \frac{V_{total}}{R_{total}}.$$

10.2.5 EMF

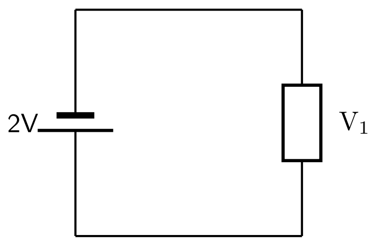
When you measure the potential difference across (or between) the terminals of a battery you are measuring the "electromotive force" (emf) of the battery. This is how much potential energy the battery has to make charges move through the circuit. This driving potential energy is equal to the total potential energy drops in the circuit. This means that the voltage across the battery is equal to the sum of the voltages in the circuit.

We can use this information to solve problems in which the voltages across elements in a circuit add up to the emf.

$$EMF = V_{total}$$

Worked Example 45: Voltages I

Question: What is the voltage across the resistor in the circuit shown?



Answer

Step 1 : Check what you have and the units

We have a circuit with a battery and one resistor. We know the voltage across the battery. We want to find that voltage across the resistor.

$$V_{battery} = 2\mathrm{V}$$

Step 2 : Applicable principles

We know that the voltage across the battery must be equal to the total voltage across all other circuit components.

$$V_{battery} = V_{total}$$

There is only one other circuit component, the resistor.

$$V_{total} = V_1$$

This means that the voltage across the battery is the same as the voltage across the resistor.

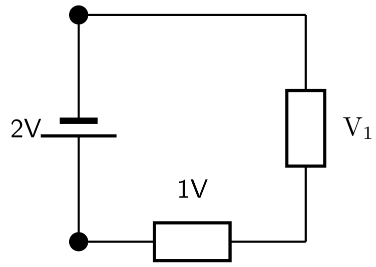
$$V_{battery} = V_{total} = V_1$$

$$V_{battery} = V_{total} = V_1$$

$$V_1 = 2\text{V}$$

Worked Example 46: Voltages II

Question: What is the voltage across the unknown resistor in the circuit shown?



Answer

Step 1 : Check what you have and the units

We have a circuit with a battery and two resistors. We know the voltage across the battery and one of the resistors. We want to find that voltage across the resistor.

$$V_{battery} = 2\text{V}$$

$$V_{resistor} = 1\text{V}$$

Step 2 : Applicable principles

We know that the voltage across the battery must be equal to the total voltage across all other circuit components.

$$V_{battery} = V_{total}$$

The total voltage in the circuit is the sum of the voltages across the individual resistors

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

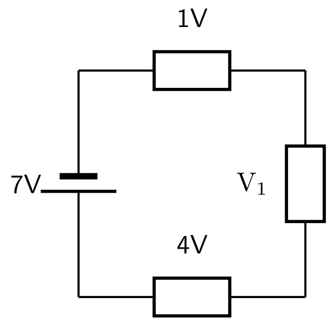
Using the relationship between the voltage across the battery and total voltage across the resistors

$$V_{battery} = V_{total}$$

$$\begin{aligned} V_{battery} &= V_1 + V_{resistor} \\ 2\text{V} &= V_1 + 1\text{V} \\ V_1 &= 1\text{V} \end{aligned}$$

Worked Example 47: Voltages III

Question: What is the voltage across the unknown resistor in the circuit shown?



Answer

Step 1 : Check what you have and the units

We have a circuit with a battery and three resistors. We know the voltage across the battery and two of the resistors. We want to find that voltage across the unknown resistor.

$$V_{battery} = 7\text{V}$$

$$V_{known} = 1\text{V} + 4\text{V}$$

Step 2 : Applicable principles

We know that the voltage across the battery must be equal to the total voltage across all other circuit components.

$$V_{battery} = V_{total}$$

The total voltage in the circuit is the sum of the voltages across the individual resistors

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

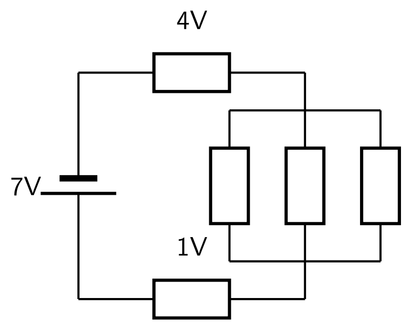
Using the relationship between the voltage across the battery and total voltage across the resistors

$$V_{battery} = V_{total}$$

$$\begin{aligned} V_{battery} &= V_1 + V_{known} \\ 7\text{V} &= V_1 + 5\text{V} \\ V_1 &= 2\text{V} \end{aligned}$$

Worked Example 48: Voltages IV

Question: What is the voltage across the parallel resistor combination in the circuit shown? Hint: the rest of the circuit is the same as the previous problem.



Answer

Step 1 : Quick Answer

The circuit is the same as the previous example and we know that the voltage difference between two points in a circuit does not depend on what is between them so the answer is the same as above $V_{parallel} = 2\text{V}$.

Step 2 : Check what you have and the units - long answer

We have a circuit with a battery and three resistors. We know the voltage across the battery and two of the resistors. We want to find that voltage across the parallel resistors, $V_{parallel}$.

$$V_{battery} = 7\text{V}$$

$$V_{known} = 1\text{V} + 4\text{V}$$

Step 3 : Applicable principles
We know that the voltage across the battery must be equal to the total voltage across all other circuit components.

$$V_{battery} = V_{total}$$

The total voltage in the circuit is the sum of the voltages across the individual resistors

$$V_{total} = V_{parallel} + V_{known}$$

Using the relationship between the voltage across the battery and total voltage across the resistors

$$V_{battery} = V_{total}$$

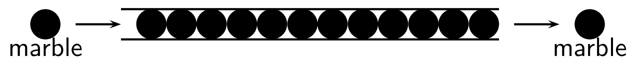
$$\begin{aligned} V_{battery} &= V_{parallel} + V_{known} \\ 7\text{V} &= V_1 + 5\text{V} \\ V_{parallel} &= 2\text{V} \end{aligned}$$

10.3 Current

10.3.1 Flow of Charge

We have been talking about moving charge. We need to be able to deal with numbers, how much charge is moving, how fast is it moving? The concept that gives us this information is called *current*. Current allows us to quantify the movement of charge.

When we talk about current we talk about how much charge moves past a fixed point in circuit in one second. Think of charges being pushed around the circuit by the battery, there are charges in the wires but unless there is a battery they won't move. When one charge moves the charges next to it also move. They keep their spacing. If you had a tube of marbles like in this picture.



If you push one marble into the tube one must come out the other side. If you look at any point in the tube and push one marble into the tube, one marble will move past the point you are looking at. This is similar to charges in the wires of a circuit.

If a charge moves they all move and the same number move at every point in the circuit.

10.3.2 Current

Now that we've thought about the moving charges and visualised what is happening we need to get back to quantifying moving charge. I've already told you that we use current but we still need to define it.

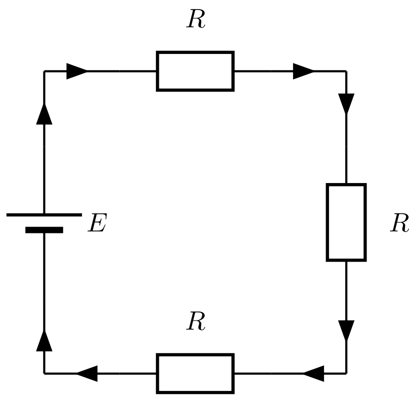
Definition: Current
Current is the rate at which charges moves past a fixed point in a circuit. We use the symbol I to show current and it is measured in amperes (A). One ampere is one coulomb of charge moving in one second.

$$I = \frac{Q}{\Delta t}$$

When current flows in a circuit we show this on a diagram by adding arrows. The arrows show the direction of flow in a circuit. By convention we say that charge flows from the positive terminal on a battery to the negative terminal.

10.3.3 Series Circuits

In a series circuit, the charge has a single path from the battery, returning to the battery.



The arrows in this picture show you the direction that charge will flow in the circuit. They don't show you much charge will flow, only the direction.

Interesting Fact

Benjamin Franklin made a guess about the direction of charge flow when rubbing smooth wax with rough wool. He thought that the charges flowed from the wax to the wool (i.e. from positive to negative) which was opposite to the real direction. Due to this, electrons are said to have a *negative* charge and so objects which Ben Franklin called "negative" (meaning a shortage of charge) really have an excess of electrons. By the time the true direction of electron flow was discovered, the convention of "positive" and "negative" had already been so well accepted in the scientific world that no effort was made to change it.

Important: A cell **does not** produce the same amount of current no matter what is connected to it. While the voltage produced by a cell is constant, the amount of current supplied depends on what is in the circuit.

How does the current through the battery in a circuit with several resistors in series compare to the current in a circuit with a single resistor?

Activity :: Experiment : Current in Series Circuits

Aim:

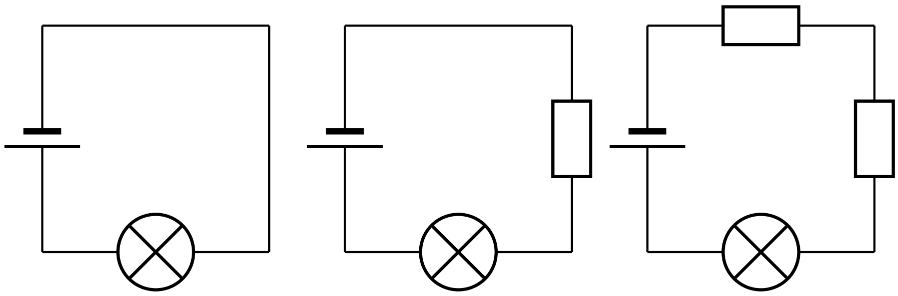
To determine the effect of multiple resistors on current in a circuit

Apparatus:

- Battery
- Resistors
- Light bulb
- Wires

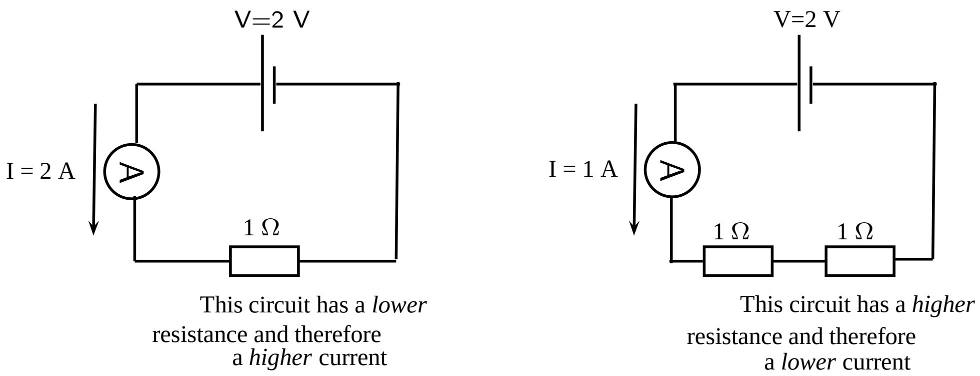
Method:

1. Construct the following circuits

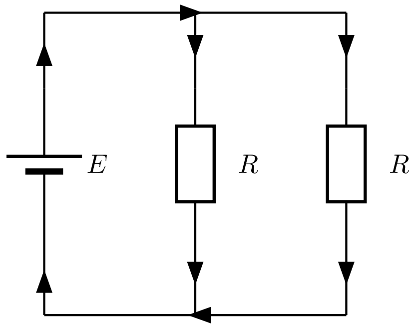


2. Rank the three circuits in terms of the brightness of the bulb.

Conclusions:
The brightness of the bulb is an indicator of how much current is flowing. If the bulb gets brighter because of a change then more current is flowing. If the bulb gets dimmer less current is flowing. You will find that the more resistors you have the dimmer the bulb.



10.3.4 Parallel Circuits



How does the current through the battery in a circuit with several resistors in parallel compare to the current in a circuit with a single resistor?

Activity :: Experiment : Current in Series Circuits

Aim:

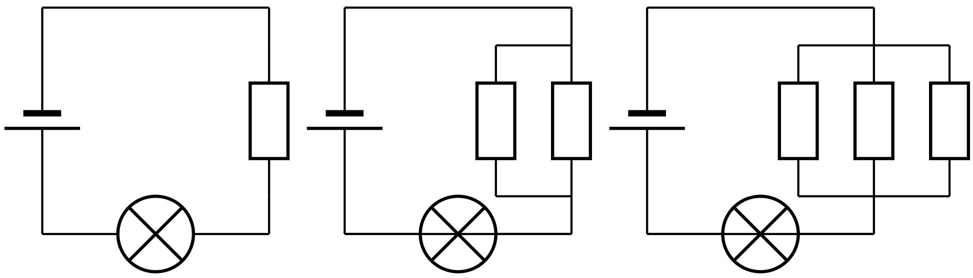
To determine the effect of multiple resistors on current in a circuit

Apparatus:

- Battery
- Resistors
- Light bulb
- Wires

Method:

1. Construct the following circuits

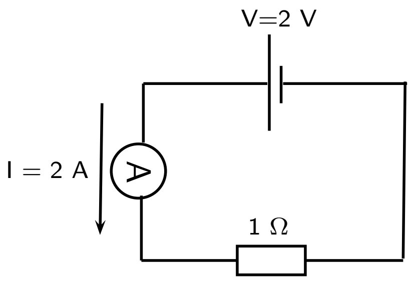


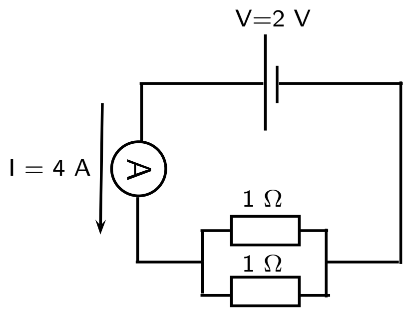
2. Rank the three circuits in terms of the brightness of the bulb.

Conclusions:

The brightness of the bulb is an indicator of how much current is flowing. If the bulb gets brighter because of a change then more current is flowing. If the bulb gets dimmer less current is flowing. You will find that the more resistors you have the brighter the bulb.

Why is this the case? Why do more resistors make it easier for charge to flow in the circuit? It is because they are in parallel so there are more paths for charge to take to move. You can think of it like a highway with more lanes, or the tube of marbles splitting into multiple parallel tubes. The more branches there are, the easier it is for charge to flow. You will learn more about the total resistance of parallel resistors later but always remember that more resistors in parallel mean more pathways. In series the pathways come one after the other so it does not make it easier for charge to flow.





the 2 resistors in parallel result in a *lower* total resistance and therefore a *higher* current in the circuit

10.4 Resistance

10.4.1 What causes resistance?

We have spoken about resistors that slow down the flow of charge in a conductor. On a microscopic level, electrons moving through the conductor collide with the particles of which the conductor (metal) is made. When they collide, they transfer kinetic energy. The electrons therefore lose kinetic energy and slow down. This leads to resistance. The transferred energy causes the conductor to heat up. You can feel this directly if you touch a cellphone charger when you are charging a cell phone - the charger gets warm!

Definition: Resistance
Resistance slows down the flow of charge in a circuit. We use the symbol **R** to show resistance and it is measured in units called **Ohms** with the symbol Ω.

$$1 \text{ Ohm} = 1 \frac{\text{Volt}}{\text{Ampere}}.$$

All conductors have some resistance. For example, a piece of wire has less resistance than a light bulb, but both have resistance. The high resistance of the filament (small wire) in a lightbulb causes the electrons to transfer a lot of their kinetic energy in the form of heat. The heat energy is enough to cause the filament to glow white-hot which produces light. The wires connecting the lamp to the cell or battery hardly even get warm while conducting the same amount of current. This is because of their much lower resistance due to their larger cross-section (they are thicker).

An important effect of a resistor is that it *converts* electrical energy into other forms of energy, such as **heat** and **light**.

Interesting Fact

There is a special type of conductor, called a **superconductor** that has no resistance, but the materials that make up superconductors only start superconducting at very low temperatures (approximately -170°C).

Why do batteries go flat?

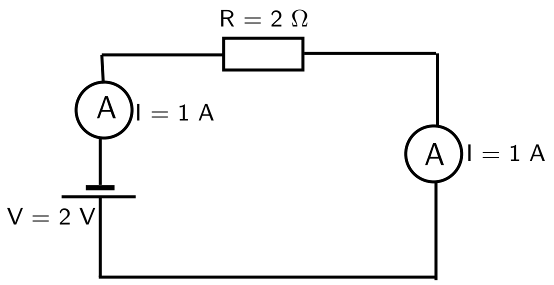
A battery stores chemical potential energy. When it is connected in a circuit, a chemical reaction takes place inside the battery which converts chemical potential energy to electrical energy which powers the electrons to move through the circuit. All the circuit elements (such as the conducting leads, resistors and lightbulbs) have some resistance to the flow of charge and convert the electrical energy to heat and/or light. The battery goes flat when all its chemical potential energy has been converted into other forms of energy.

10.4.2 Resistors in electric circuits

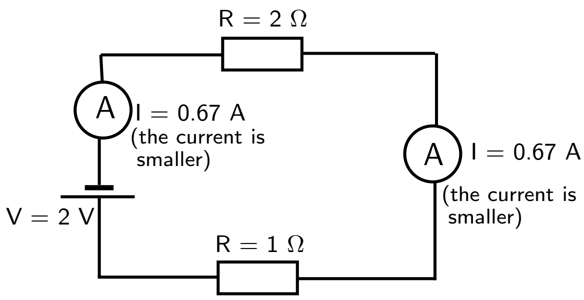
It is important to understand what effect adding resistors to a circuit has on the *total* resistance of a circuit and on the current that can flow in the circuit.

Resistors in series

When we add resistors in series to a circuit, we *increase* the resistance to the flow of current. There is only **one path** that the current can flow down and the current is the same at all places in the series circuit. Take a look at the diagram below: On the left there is a circuit with a single resistor and a battery. No matter where we measure the current, it is the same in a series circuit. On the right, we have added a second resistor in series to the circuit. The *total* resistance of the circuit has *increased* and you can see from the reading on the ammeter that the current in the circuit has decreased.



The current in a series circuit is the same everywhere

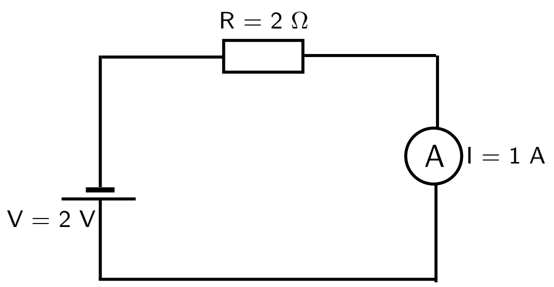


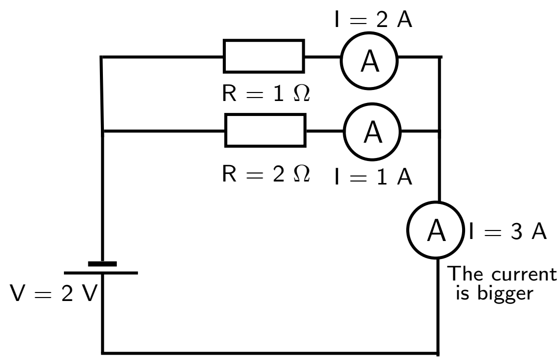
Adding a resistor to the circuit increases the total resistance

Resistors in parallel

In contrast to the series case, when we add resistors in parallel, we create **more paths** along which current can flow. By doing this we *decrease* the total resistance of the circuit!

Take a look at the diagram below. On the left we have the same circuit as in the previous diagram with a battery and a resistor. The ammeter shows a current of 1 ampere. On the right we have added a second resistor in parallel to the first resistor. This has increased the number of paths (branches) the charge can take through the circuit - the total resistance has decreased. You can see that the current in the circuit has increased. Also notice that the current in the different branches can be different.





Adding a resistor to the circuit in parallel decreases the total resistance

?

Exercise: Resistance

1. What is the unit of resistance called and what is its symbol?
2. Explain what happens to the total resistance of a circuit when resistors are added in series?

3. Explain what happens to the total resistance of a circuit when resistors are added in parallel?
4. Why do batteries go flat?

10.5 Instruments to Measure voltage, current and resistance

As we have seen in previous sections, an electric circuit is made up of a number of different components such as batteries, resistors and light bulbs. There are devices to measure the properties of these components. These devices are called meters.

For example, one may be interested in measuring the amount of current flowing through a circuit using an *ammeter* or measuring the voltage provided by a battery using a *voltmeter*. In this section we will discuss the practical usage of voltmeters, ammeters, and *ohmmeters*.

10.5.1 Voltmeter

A voltmeter is an instrument for measuring the voltage between two points in an electric circuit. In analogy with a water circuit, a voltmeter is like a meter designed to measure pressure difference. Since one is interested in measuring the voltage between two points in a circuit, a voltmeter must be connected in *parallel* with the portion of the circuit on which the measurement is made.

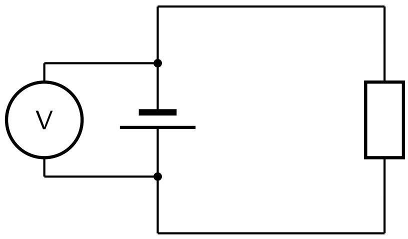


Figure 10.3: A voltmeter should be connected in parallel in a circuit.

Figure 10.3 shows a voltmeter connected in parallel with a battery. One lead of the voltmeter is connected to one end of the battery and the other lead is connected to the opposite end. The voltmeter may also be used to measure the voltage across a resistor or any other component of a circuit that has a voltage drop.

10.5.2 Ammeter

An ammeter is an instrument used to measure the flow of electric current in a circuit. Since one is interested in measuring the current flowing *through* a circuit component, the ammeter must be connected in *series* with the measured circuit component (Figure 10.4).

10.5.3 Ohmmeter

An ohmmeter is an instrument for measuring electrical resistance. The basic ohmmeter can function much like an ammeter. The ohmmeter works by suppling a constant voltage to the resistor and measuring the current flowing through it. The measured current is then converted into a corresponding resistance reading through Ohm's Law. Ohmmeters only function correctly when measuring resistance that is not being powered by a voltage or current source. In other words, you cannot measure the resistance of a component that is already connected to a circuit. This is because the ohmmeter's accurate indication depends only on its own source of voltage.

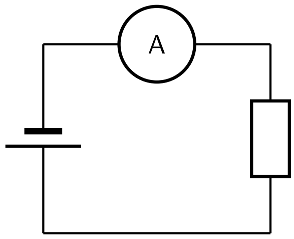


Figure 10.4: An ammeter should be connected in series in a circuit.

The presence of **any other** voltage across the measured circuit component interferes with the ohmmeter's operation. Figure 10.5 shows an ohmmeter connected with a resistor.

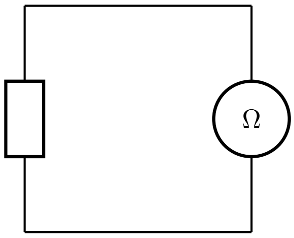


Figure 10.5: An ohmmeter should be used outside when there are no voltages present in the circuit.

10.5.4 Meters Impact on Circuit

A good quality meter used correctly will not significantly change the values it is used to measure. This means that an ammeter has very low resistance to not slow down the flow of charge.

A voltmeter has a very high resistance so that it does not add another parallel pathway to the circuit for the charge to flow along.

Activity :: Investigation : Using meters
If possible, connect meters in circuits to get used to the use of meters to measure electrical quantities. If the meters have more than one scale, always connect to the **largest scale** first so that the meter will not be damaged by having to measure values that exceed its limits.

The table below summarises the use of each measuring instrument that we discussed and the way it should be connected to a circuit component.

Instrument	Measured Quantity	Proper Connection
Voltmeter	Voltage	In Parallel
Ammeter	Current	In Series
Ohmmeter	Resistance	Only with Resistor

10.6 Exercises - Electric circuits

1. Write definitions for each of the following:

1.1 resistor
1.2 coulomb
1.3 voltmeter

2. Draw a circuit diagram which consists of the following components:

   2.1 2 batteries in parallel
   2.2 an open switch
   2.3 2 resistors in parallel
   2.4 an ammeter measuring total current
   2.5 a voltmeter measuring potential difference across one of the parallel resistors

3. Complete the table below:

Quantity	**Symbol**	**Unit of meaurement**	**Symbol of unit**
e.g. Distance	e.g. d	e.g. kilometer	e.g. km
Resistance			
Current			
Potential difference			

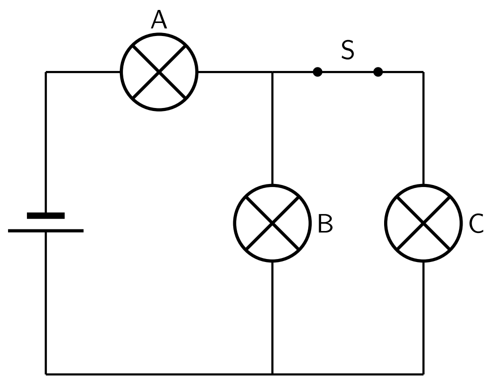
4. [SC 2003/11] The emf of a battery can best be explained as the ...

   4.1 rate of energy delivered per unit current
   4.2 rate at which charge is delivered
   4.3 rate at which energy is delivered
   4.4 charge per unit of energy delivered by the battery

5. [IEB 2002/11 HG1] Which of the following is the correct definition of the emf of a cell?

   5.1 It is the product of current and the external resistance of the circuit.
   5.2 It is a measure of the cell's ability to conduct an electric current.
   5.3 It is equal to the "lost volts" in the internal resistance of the circuit.
   5.4 It is the power dissipated per unit current passing through the cell.

6. [IEB 2005/11 HG] Three identical light bulbs A, B and C are connected in an electric circuit as shown in the diagram below.



How do the currents in bulbs A and B change when switch S is opened?

	Current in A	**Current in B**
(a)	decreases	increases
(b)	decreases	decreases
(c)	increases	increases
(d)	increases	decreases

7. [IEB 2004/11 HG1] When a current I is maintained in a conductor for a time of t, how many electrons with charge e pass any cross-section of the conductor per second?

   7.1 It

   7.2 It/e

   7.3 Ite

   7.4 e/It

Appendix A

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PREAMBLE

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