Blix ROBOTIX

45+ FUN EXPERIMENTS

EASY CONNECTIONS

25+ SCIENCE TOPICS

E-O CIRCUITS

STEM EDUCATION

SCIENCE, TECHNOLOGY, ENGINEERING, MATH

Name: ______________________________

Class:______________________________

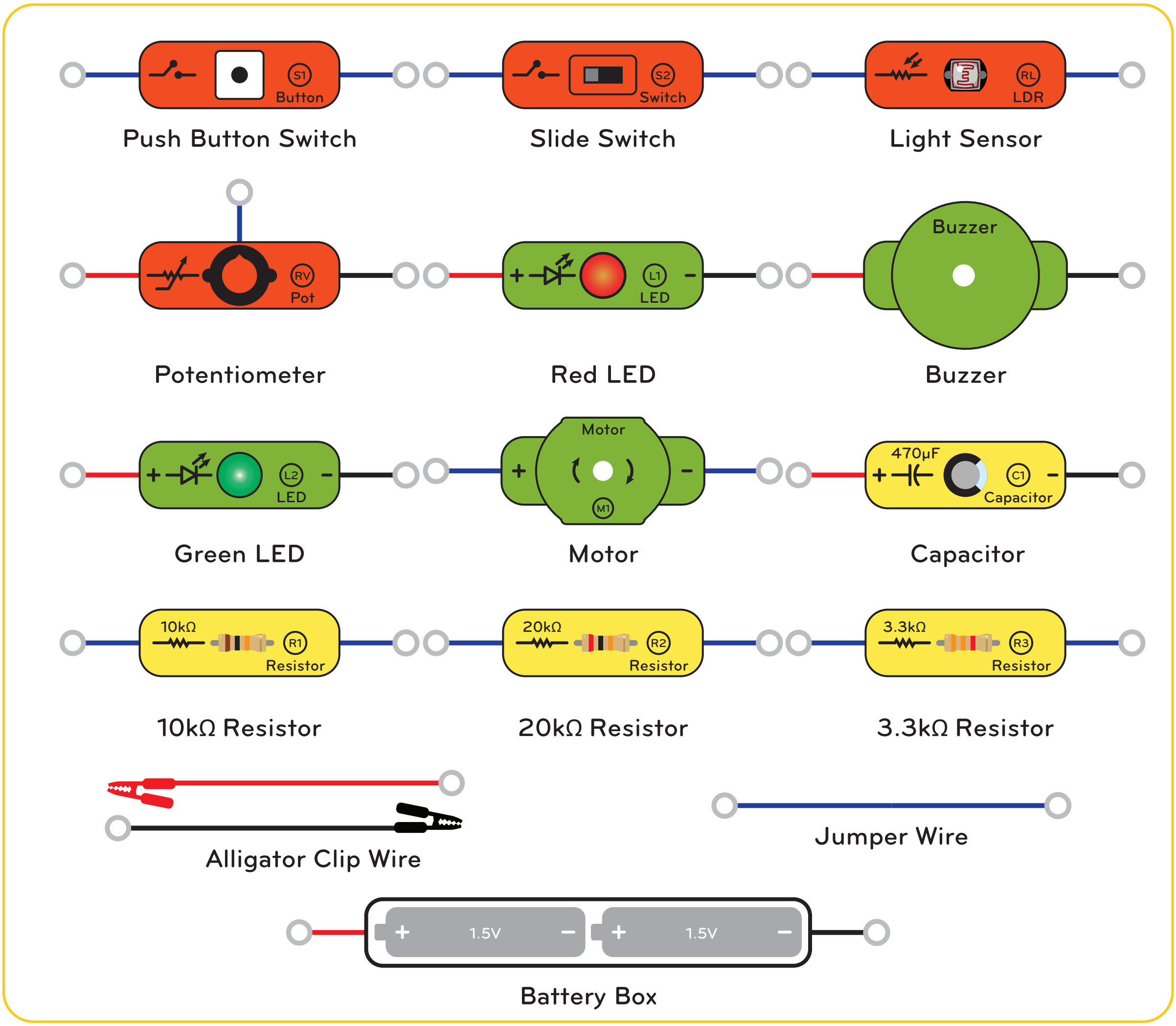
Call:_______________________________

INTRODUCTION TO THE KIT

This kit is aimed at giving you a glimpse into the world of electrical & electronics engineering! Going through this journal, you will discover & learn more about various electronic components that are used in all the gadgets and appliances we see around us. With the help of some theory, you will also start making your own electric circuits and learn how these work in the real world!

As we go further experimenting, learning and making projects, you will develop an understanding of how to make your own circuits and bring your ideas to life.

So, let's start the journey by meeting our friends!



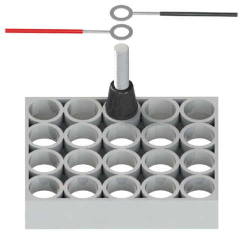
***Disclaimer:** Although we have taken all reasonable care in preparing this book, we make no warranty about the accuracy or completeness of its content and to the maximum extent permitted, disclaim all liability arising from its use.*

IMPORTANT INSTRUCTIONS

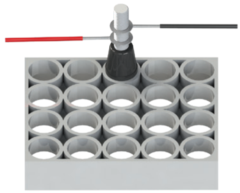
Please read all these important instructions, useful tips and warnings carefully before we proceed further, to avoid mistakes and to avoid damaging the electronic components.

HOW TO CONNECT

Fix connecting tower on the baseboard



Slide loops of wires you want to connect



Connection completed!

USEFUL TIPS

- Most circuit problems are due to incorrect assembly, so always double check that your circuit exactly matches the diagram.
- Always connect the battery in the end, after you have connected all the other components properly and check all the connections before turning on a circuit. This ensures that no component is damaged if the circuit is accidentally connected in a wrong manner.
- Be sure that parts with positive/negative markings are positioned as per the drawing.
- Insert the batteries with correct polarity.
- Use only two, 1.5V AA type batteries.

WARNINGS!!!

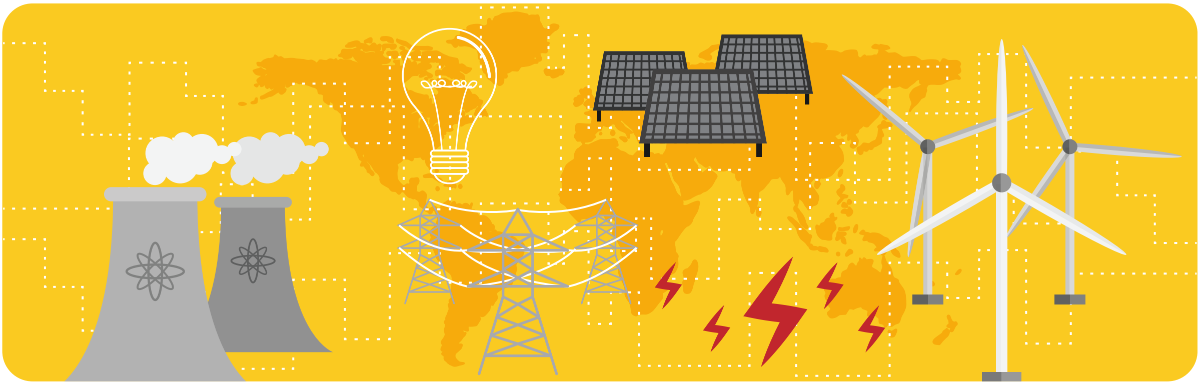
- Never leave a circuit unattended while batteries are installed.
- Never connect additional batteries or any other power sources to your circuits.
- Do not short circuit the battery terminals.
- Do not touch the motor when it is spinning at high speed.

TABLE OF CONTENTS

T1. WHAT IS ELECTRICITY?

Today, electricity is everywhere and it has perhaps become the most important form of energy for humans. Our home appliances, phones, computers, internet and now even cars run on electricity. So, what exactly is electricity?

Electricity is a form of energy which is created by the flow of "electric charges" through any material. Electricity, i.e. this flow of "charges", can be generated by various sources like power stations, batteries, solar panels or even lightning!

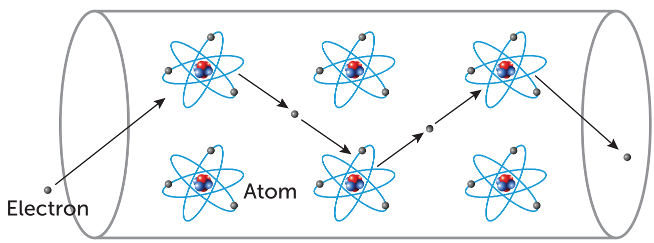


We know that all matter around us is made up of tiny particles called Atoms. Atoms are made up of 3 basic units: Protons (positively charged), Electrons (negatively charged) & Neutrons (no charge). Electrons are the primary reason behind electricity and hence the name!

IT'S ALL ABOUT ELECTRONS!

Whenever any "electric field" is present in a material, the electrons get excited and start flowing in the material.

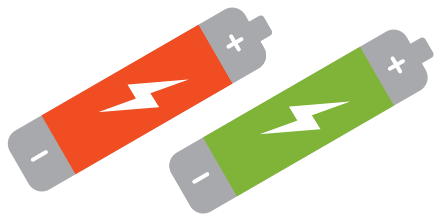
We call this flow of electrons as Electricity in general!



Material under Electric Field

WHAT'S A BATTERY?

Battery is like a portable power station. It stores electrical energy and can provide it whenever and wherever needed! That's why we are able to charge our phones & laptops with electricity and then use them everywhere even if not connected to electricity!

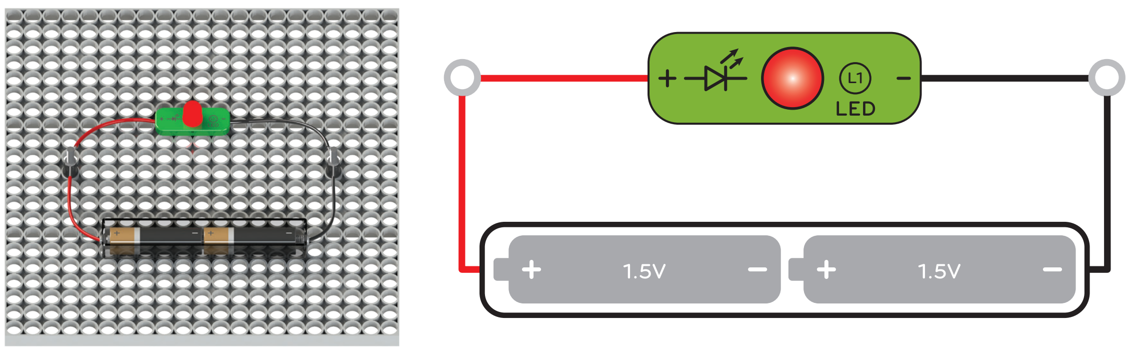


E1. MAKE YOUR FIRST ELECTRIC CIRCUIT!

- Attach the LED, Battery Box (WITHOUT batteries) & Connecting Towers to the Base Board.

- Connect the Red wire of the battery to the Red wire of the LED with the help of the Connecting Towers. Do the same for the Black wire.

- Double check with this image and connect EXACTLY as shown:



- Now insert the Batteries in the Box as indicated in the image. See the LED light up?

- Congratulations! You have just made your first circuit!

DID NOT WORK?

Don't worry, it is common in electronics for things not to work because of tiny errors.
Just check if all the wires are firmly connected & are connected as per the directions above.
Also make sure the batteries are new and are inserted correctly in the box.
Your circuit should work now!

KEEP IN MIND!

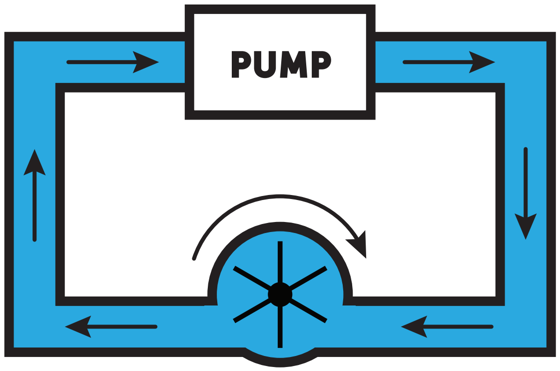
Remember all the steps that we followed here to make and check the circuit. These will be very helpful in making the other circuits in this book work quickly!

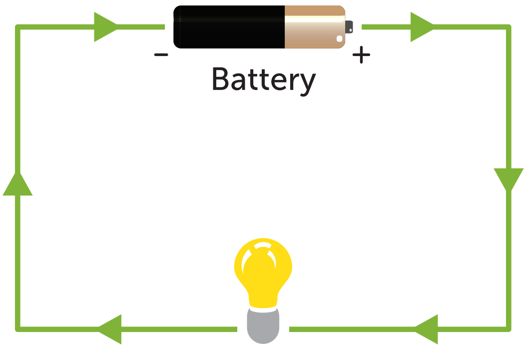
Once you are confident and are able to make connections properly in the first go, you can connect the battery box with batteries from the start. But for the first few circuits, follow above steps to ensure no component gets damaged.

T2. WHAT IS AN ELECTRIC CIRCUIT?

An electric circuit is like a path for electricity. A circuit is completed when two terminals ("+" & "-") of a battery are connected through a wire or any other conducting material. When this happens, the electricity starts flowing from "+" to "-" terminal of the battery.

You can think of the battery as a water pump and the wire like a water pipe. The battery pumps electricity into the wire from one terminal to the other.





Thus battery is the "power source" that is required in every electric circuit. The components connected in the circuit make use of this power. For example, a bulb glows by using power from the battery just in the same way as a water wheel will rotate by using the power of a pump!

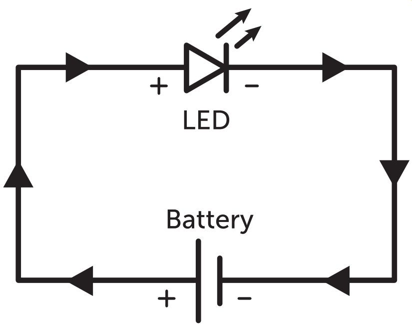
JUST REMEMBER THIS!

If you want to check whether a circuit is complete or not, look for a continuous path from the '+' to the '-' terminal of a battery!

CIRCUIT DIAGRAMS!

Engineers use "Circuit Symbols" to represent circuits in a concise way. The diagrams made using these symbols are called "Circuit Diagrams".

- Can you identify the components from this diagram?
- Can you now relate the previous circuit to the water diagram and this circuit diagram?

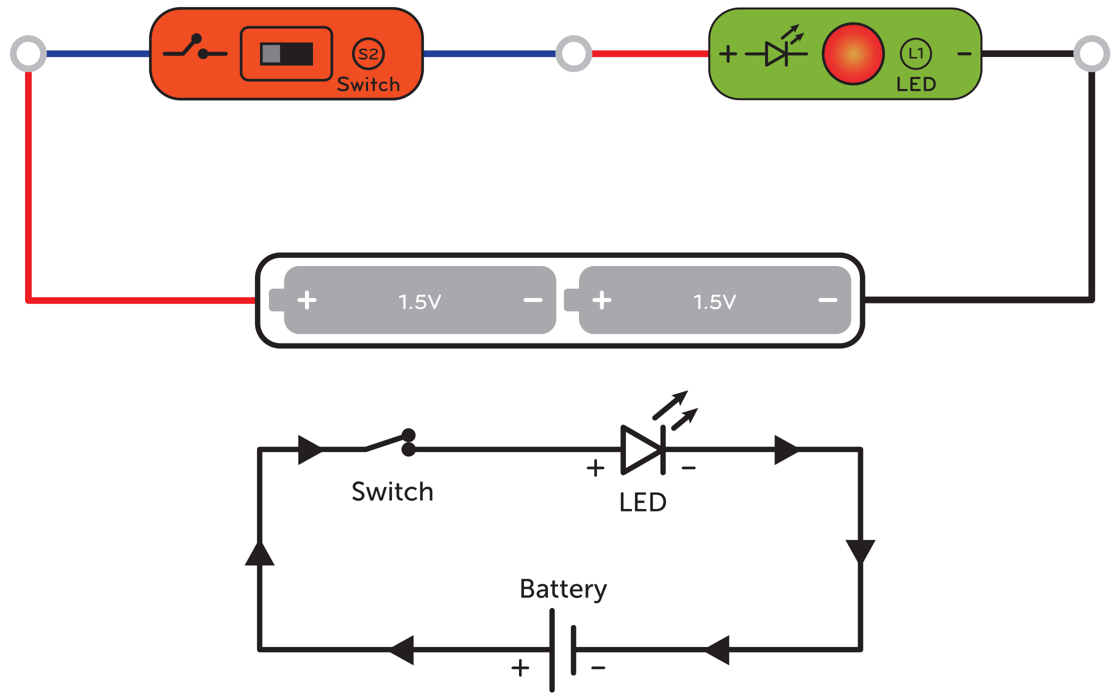


E2. SWITCH ON THE LIGHTS!

• Connect the Slide Switch & LED as shown. Set the Switch to OFF position.

• Then connect the battery.

• Remember to always connect the battery in the end, only after you have connected all the other components properly. This will ensure that no component is damaged if the circuit is accidentally connected in a wrong manner.



• Now turn ON the switch to light up!

DID YOU UNDERSTAND...

• How the connections worked here to complete the circuit?

• How a circuit diagram can be used to represent a circuit?

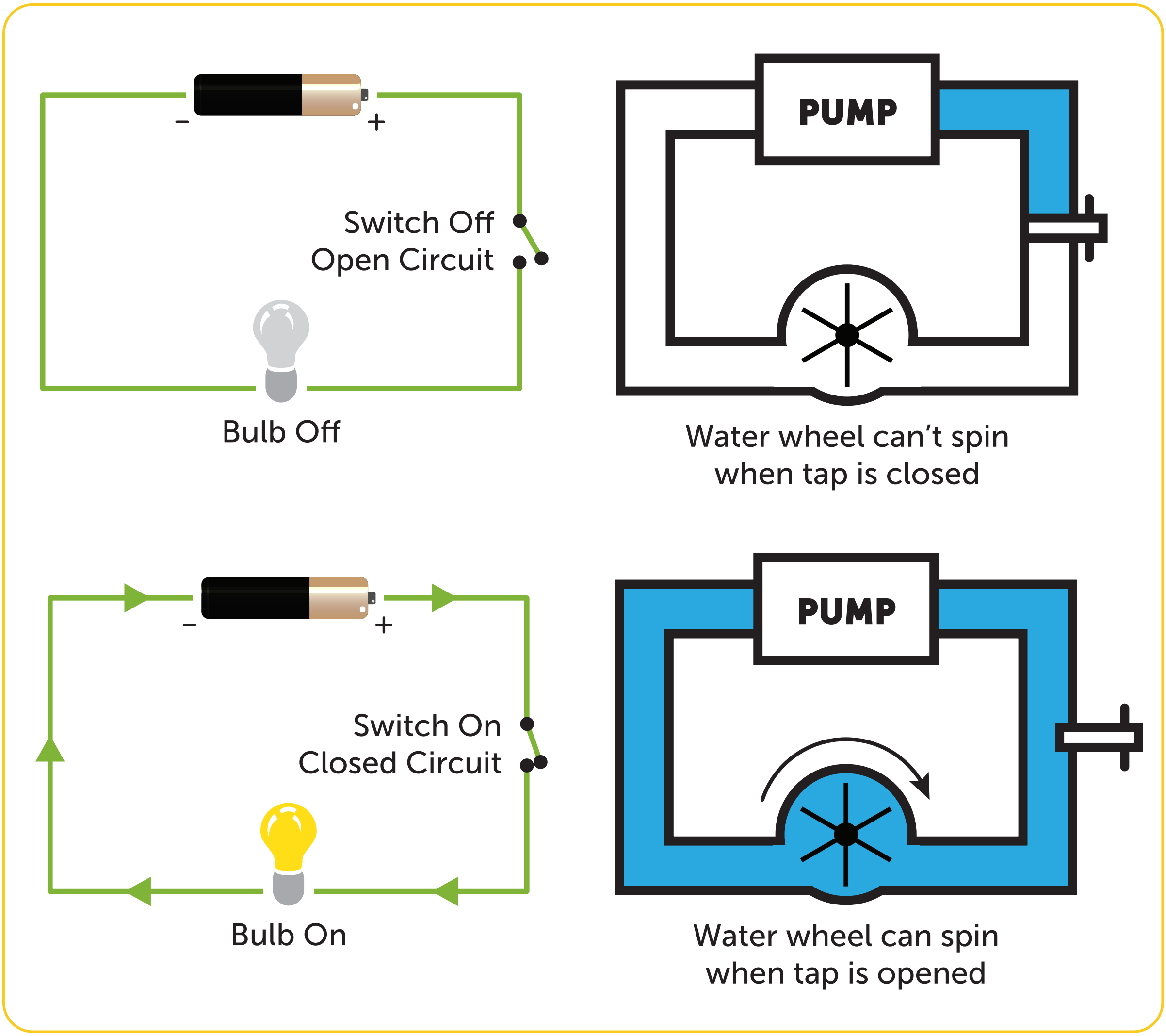
But most importantly, how did the Switch magically make & break the circuit?
Find all about it in the next topic!

T3. OPEN AND CLOSED CIRCUITS

We learnt that for a circuit to be complete, there should be a continuous path for electricity to flow from one terminal of the battery to the other.

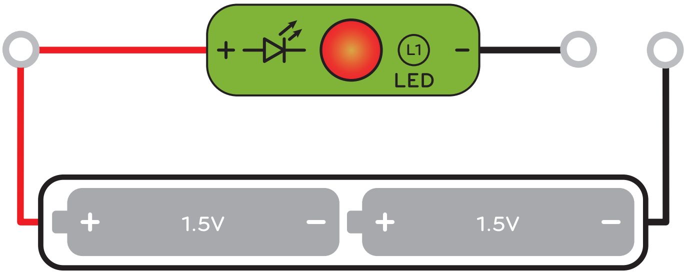
If you disconnect the wire from even one terminal of the battery, the circuit will not be complete and this is called "Open Circuit". If you connect it again, the circuit is completed and is called "Closed Circuit". (Try doing this in E1 !)

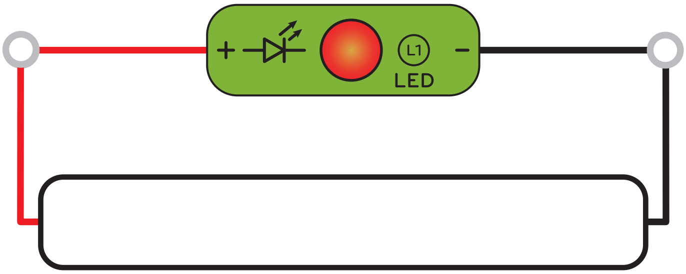
A Switch helps you do just that. It helps you to open & close circuits with ease. It acts like a water tap, which when open, lets electricity to flow, else doesn't.

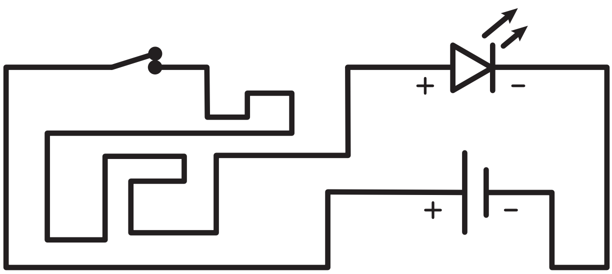


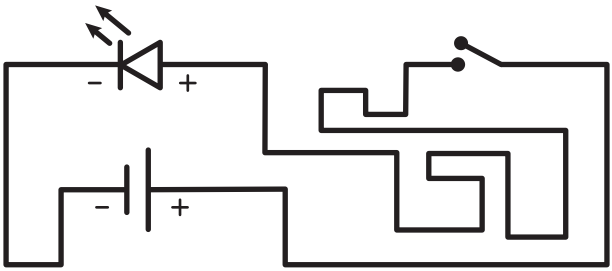
CIRCUIT PUZZLE!

It is time for your first puzzle! These puzzles are fun to solve and at the same time they will help you revise all the concepts that you have learnt till now! Answer whether the circuits below are open or closed circuits, along with reasons:









An electric circuit cannot be completed if a conductor is not connected between the different components and the two terminals of a battery.

"Conductors" are materials that allow electricity to pass easily whereas "Insulators" are materials that do not allow electricity to pass easily.

So conductors are like nice, new, big, smooth pipes that allow water to flow easily but insulators are liked choked pipes that won't let water flow!

Conductors are like smooth pipes

Insulators are like choked pipes

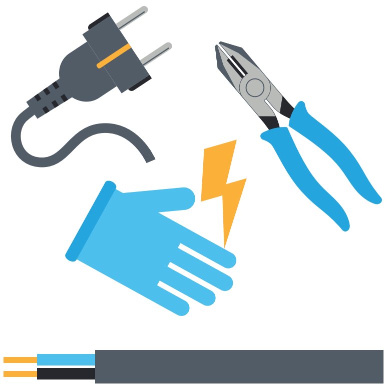
In general, remember that metals like iron, copper, gold are conductors where as non-metals like wood, rubber, plastic are insulators.

ARE INSULATORS OF NO USE?

You might be wondering that insulators are no good right?

Think again! Yes, insulators do obstruct the flow of electricity, but that means that they can be very useful in protecting us from electric shocks! Infact, almost every electrical gadget or tool is covered by insulating material like rubber or plastic to prevent electric shocks.

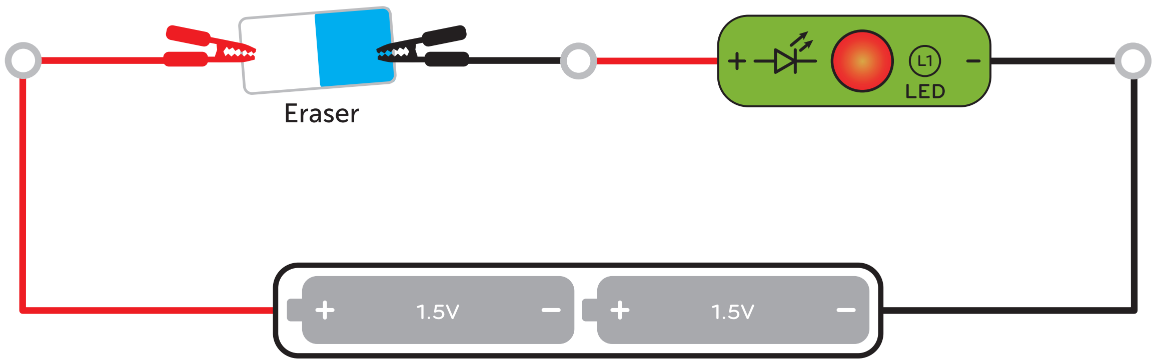
Even the electric cables used in our homes are "insulated" using rubber, though their inner material is obviously a conductor like copper.



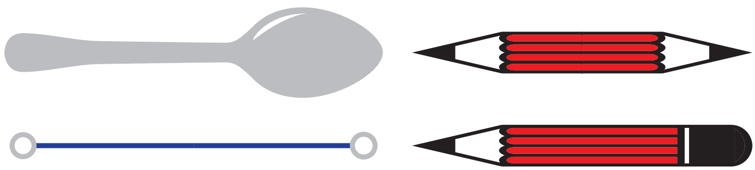
Want to test this concept practically? Let's make a cool conductor tester!

E3. CONDUCTOR TESTER

- Connect the Clip Wire and LED as shown.
- Then connect the battery.
- Try connecting different materials like spoon, eraser, pencil, pencil sharpened from both ends, jumper wire, jumper wire's outer covering etc. between the 2 clips.
- If you connect a conductor between the clips the circuit will be completed, but for an insulator, it won't be!



Also try connecting these objects between the clips



- What did you observe? Could you distinguish between conductors & insulators?

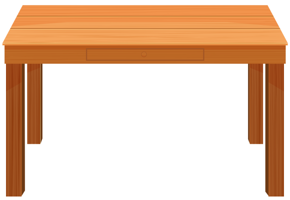
FUN FACT!

Did you notice that the Clip Wire is actually just like a Switch? When you touch the two clips, the circuit gets "closed" else it is "open"!

In fact, if you look at the circuit diagram and think about it, you will find that theoretically, the circuit is essentially the same as E2!

CONDUCTOR PUZZLE!

Let's test if you have understood the concept of conductors & insulators. Can you identify whether these materials are conductors or insulators? Check with the E3 circuit if in doubt!

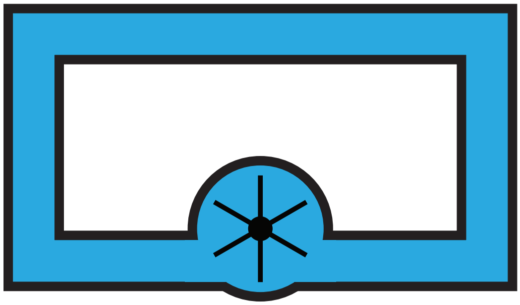


T5. VOLTAGE & CURRENT

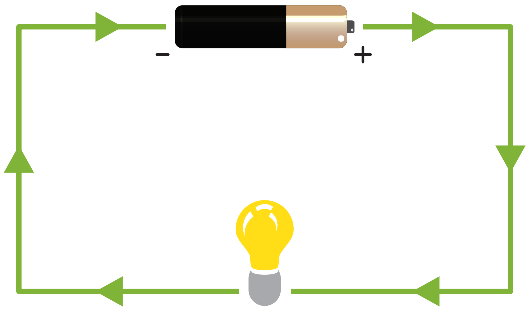
You would have seen these figures written many times on batteries, chargers and other home appliances: 1.5 Volt, 9 Volt, 1 Ampere, 16 Ampere etc. Wondered what are these?

Voltage, which is measured in Volt (V), is similar to pressure. Since battery acts like a pump, a high voltage is like high pressure of the pump on water. Current, which is measured in Ampere (A), is like the flow rate or speed of water in a pipe. This current or flow rate depends mainly on the voltage, but it also depends on the “properties” of the wire & other components in the circuit.

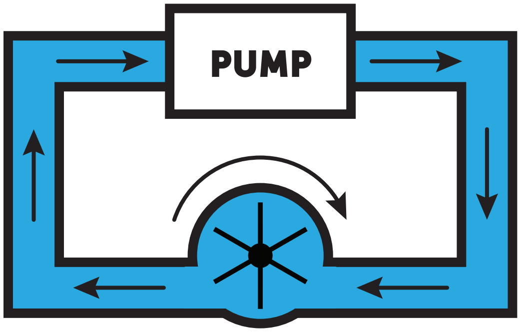
No Voltage, No Current



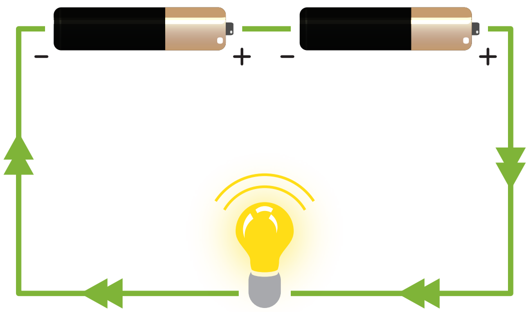
No Pressure, No Flow



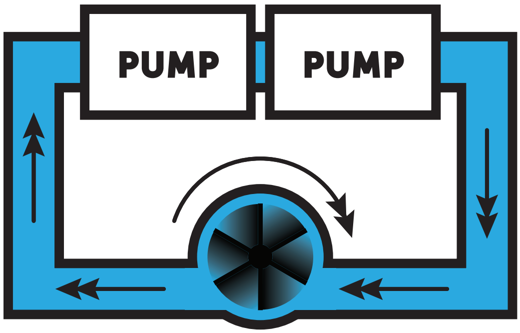
Low Voltage, Low Current



Low Pressure, Low Flow



High Voltage, High Current



High Pressure, High Flow

"PROPERTIES" OF A CONDUCTOR?

Properties of a conductor are just like the properties of a pipe. If the pipe is choked or narrow, it will allow less water to pass, but if it is smooth or wide enough, the water can easily pass. Remember the conductors & insulators topic!

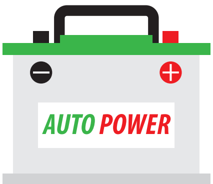
So, if a conductor has poor properties, then even if the voltage is high, the current would be low because electricity can't pass easily through it!

Apart from properties of the wire/conductor, the type of components and the way in which they are connected also decide how the Voltage & Current will be distributed!

For now just keep these few points in mind. We will explore more about Voltage & Current in the next topics.

VOLT-AMPERE PUZZLE!

Time for some adventure! You will surely find the below objects at your home or around you. Let's see if you can find out the Voltage and/or Current of these objects!



Vehicle Battery

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Television

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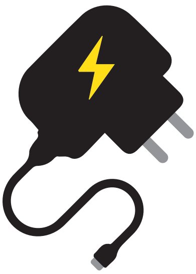

Mobile Charger

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Mixer-Grinder

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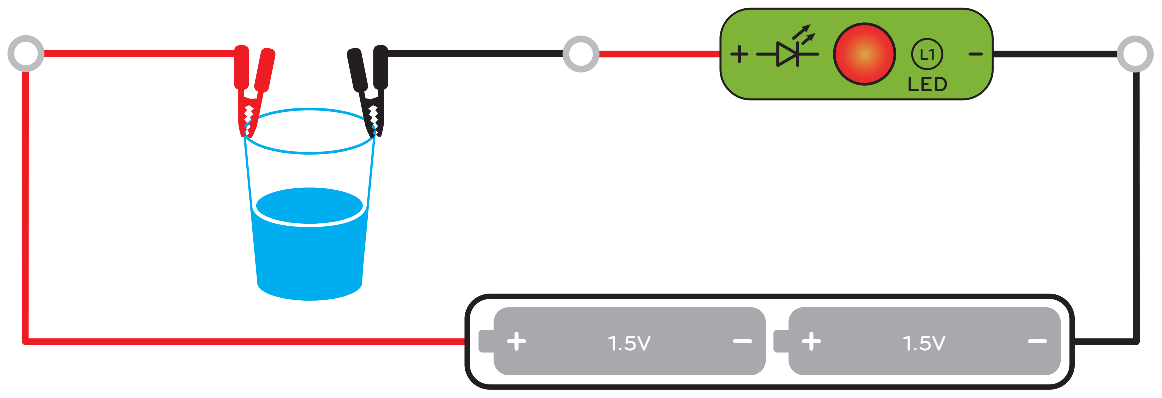
• Connect the same circuit as E3.

• Use a dark room for this experiment.

• Now connect the clips to a NON-METALLIC glass as shown.

• Slowly start pouring TAP WATER into the glass.



• As soon as water reaches the top, the LED will glow, alerting that the glass is full!

Can you tell why this happens? Well, because tap water generally contains minerals which make it a fairly decent conductor of electricity! When the water reached the top, it touched both the clips and completed the circuit! Thus we made use of the simple concept of conductors & open-close circuits to make such an important circuit. Saving water is now easy!

This is also why you should not touch electric appliances or switches with wet hands, else you can get a shock! Now, try the following things in this experiment & write your observations:

QUESTION 1

What would happen if we used distilled water? Why?

QUESTION 2

What if we added salt to this filtered distilled water and then tried this experiment?

QUESTION 3

LED was glowing weak and so we had to check this circuit in the dark. Why did this happen?

QUESTION 4

Why did we use a non-metallic glass here? What would have happened with a metallic glass?

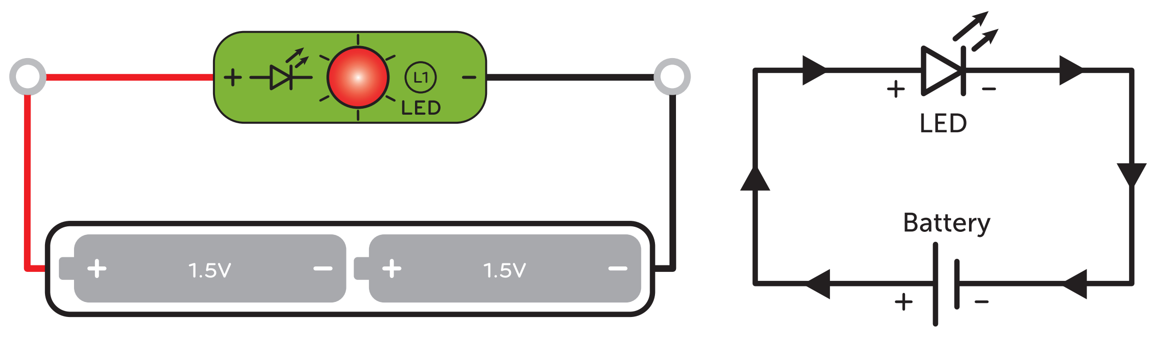
T6. POLARITY: RED, BLACK & BLUE

We've used the + & - signs so many times in the circuits and we also see these signs on batteries and many other electrical appliances. What do they mean?

Actually + & - are referred to as "Polarities". This means that the component is not uniform but rather polar. It will behave differently when connected in one way, and differently the other way.

All components are not polar. Batteries & LEDs are polar but Switch is not! A Switch works when connected in any direction and hence is called "non-polar".

Let's have a look at our basic circuit diagram:

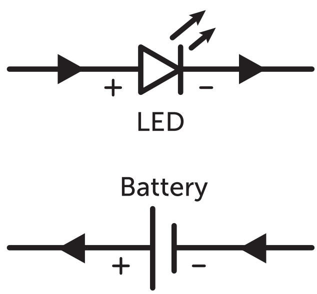


We know that for a circuit to be complete, there has to be a continuous path from + to - terminal of the battery. But why does the electric current flow from + to - as shown by the arrows?

FOLLOW THE CONVENTION!

We need to remember a very important convention in order to properly connect polar components in a circuit.

For the battery, the electric current leaves from the + terminal and comes back from -, whereas for most of the other components, the current enters from + of the component and exits from -. This is also indicated by their circuit symbols!



But also understand that this is just a convention, because in reality, the electrons flow from - to + since they are -ve and are attracted towards +ve charges!

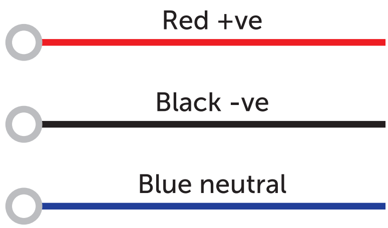
Ok, so everything is clear about + & - but what do the colours Red, Black & Blue have to do with this? Let's find out now!

You would have observed that some components have 1 red & 1 black wire whereas some have 2 blue wires. We also mentioned several times that the components must be connected EXACTLY as shown. Well, now it must be clear that you had to follow these rules because the components like battery & LED are polar and will work properly only if connected in this manner!

COLOURFUL CONVENTION!

Generally the colours Red, Black & Blue are used to make it easier to connect the components and identify which components are polar & which are not!

The red & black wires help you follow the convention of + & - when connecting a polar component!

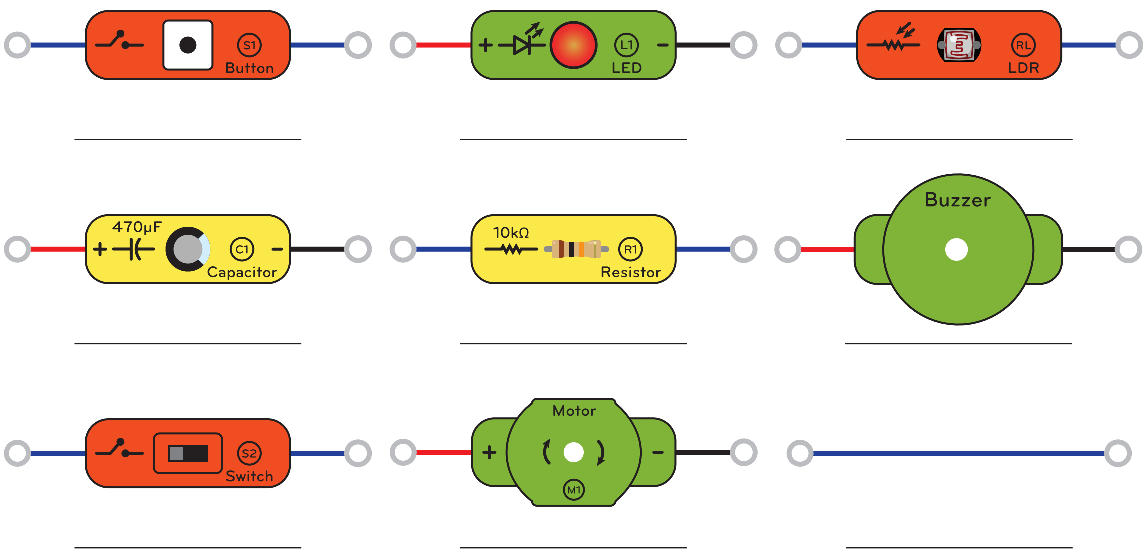


Have a look at the diagrams again and see if now you are able to understand why the red wire of the LED was connected to the red wire of the battery!

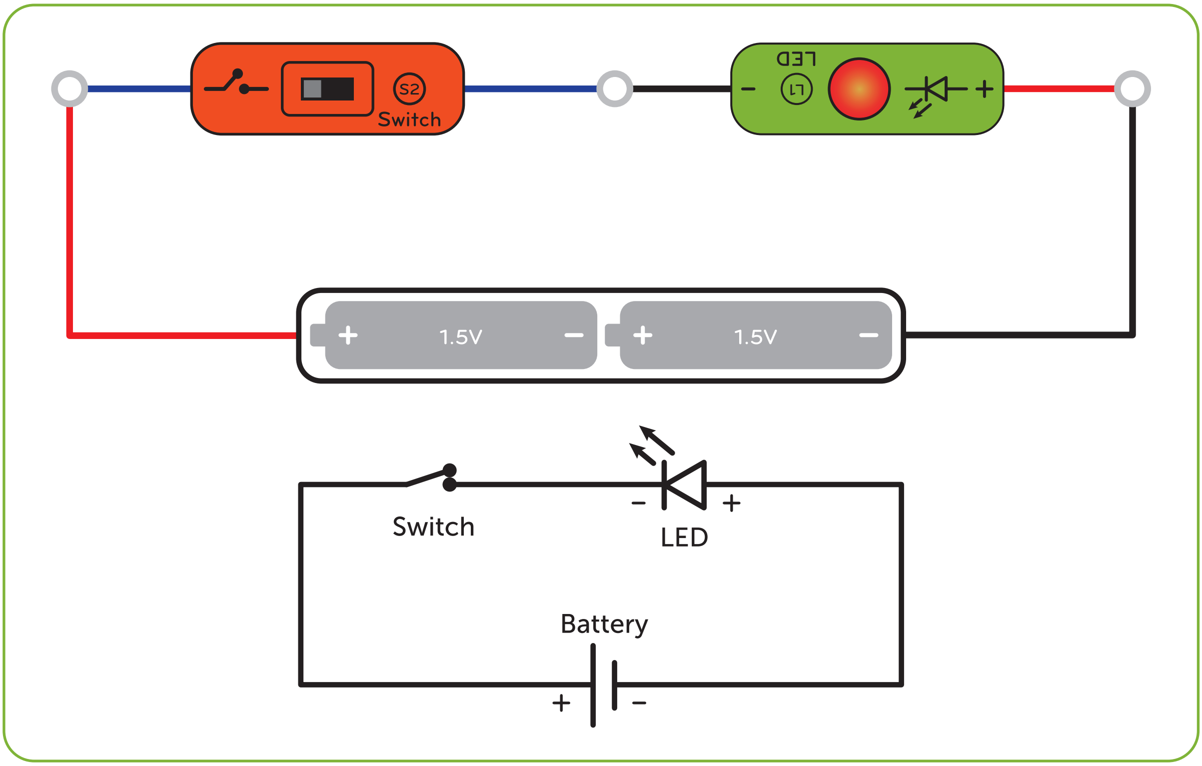
You should take special care when connecting the polar components because they might not work as expected or get damaged if connected improperly.

POLARITY PUZZLE!

Just for fun, have a look at all these components included in the kit and see if you can tell which ones are polar and non-polar!



- Connect the same circuit as E2 and reverse the LED as shown.
- Turn ON the switch. Does the LED glow?
- Put the LED back in the original "forward" direction.
- Turn ON the switch. Does it glow now?



This proves that LED is "polar" and works properly only if connected in "forward" direction, when the electric current enters at the +/red and leaves at the -/black terminal.

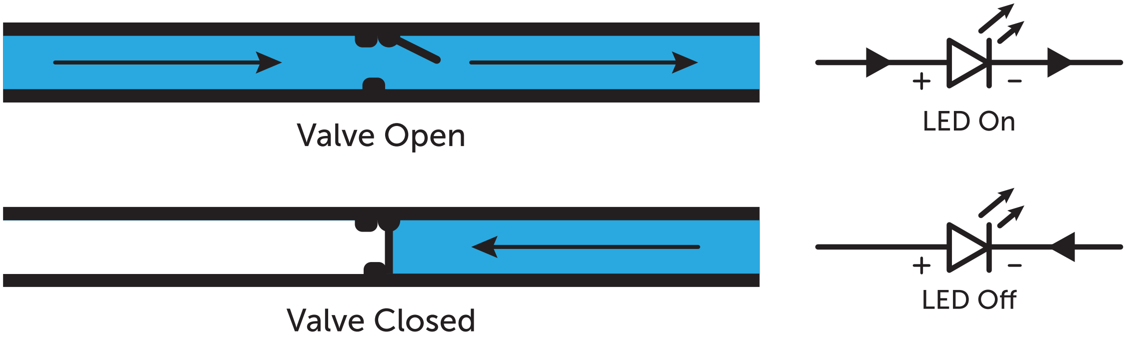
WHAT ABOUT BATTERY & SWITCH?

Try reversing the switch first and then battery. What do you observe? Are these polar or not?

T7. LED = LIGHT EMITTING DIODE!

The word LED stands for Light Emitting Diode. It is a special kind of "diode" which emits light. "Diode" is a very important electronic component that allows electricity to pass in only one direction. That's the reason why an LED does not glow when connected in "reverse"!

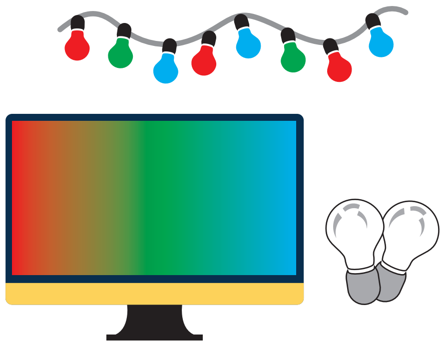
Thus, LEDs and diodes in general, are like valves that allow water/air to pass only in one direction. You would have seen valves in action in cycle tubes. You can push air inside the valve but the air can't come outside (unless you press-open the valve)!



LEDs ARE EVERYWHERE!

Today we see so many LEDs. They are everywhere - from mobile phones to televisions to lighting and everyone just loves these blinkies!

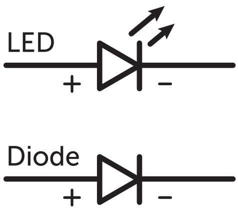
The LED that we have provided with the kit is very big compared to the tiny LEDs that are used inside LED TVs and many other gadgets - especially those tiny lights that blink to indicate different things, but all of them are conceptually the same.



MORE ON DIODES

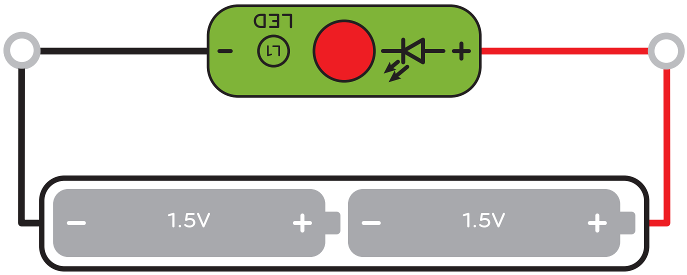
The circuit symbol of LED & Diode is almost same other than the "arrows" symbols that are depicted in LED.

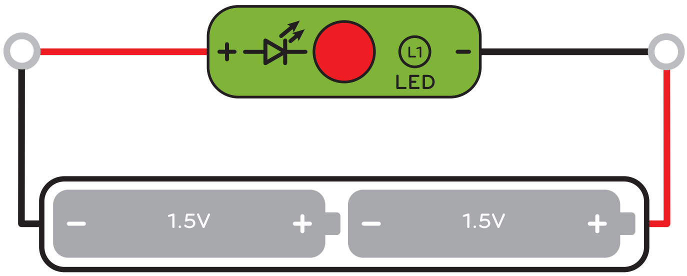
Diodes are used in circuits where it is important to allow electricity to pass in only one direction, to either protect some components or to convert certain electrical signals.

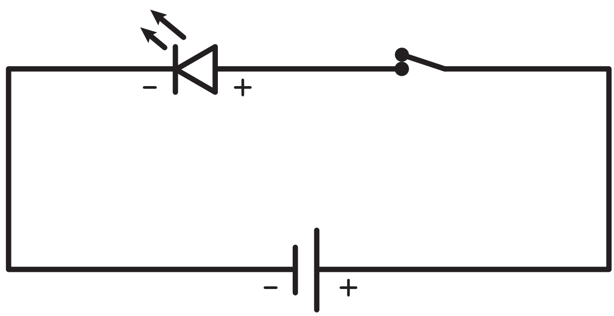


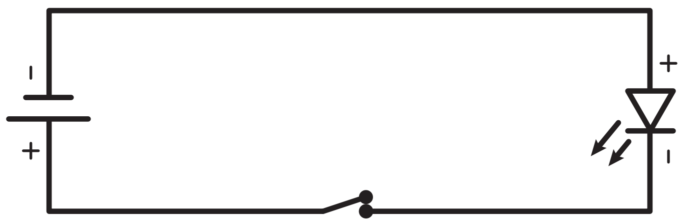
DIODE PUZZLE!

Okay, so let's check whether you have understood the concept of Diodes. Tell us whether the LEDs will glow or not in the following circuits, along with reasons for that:



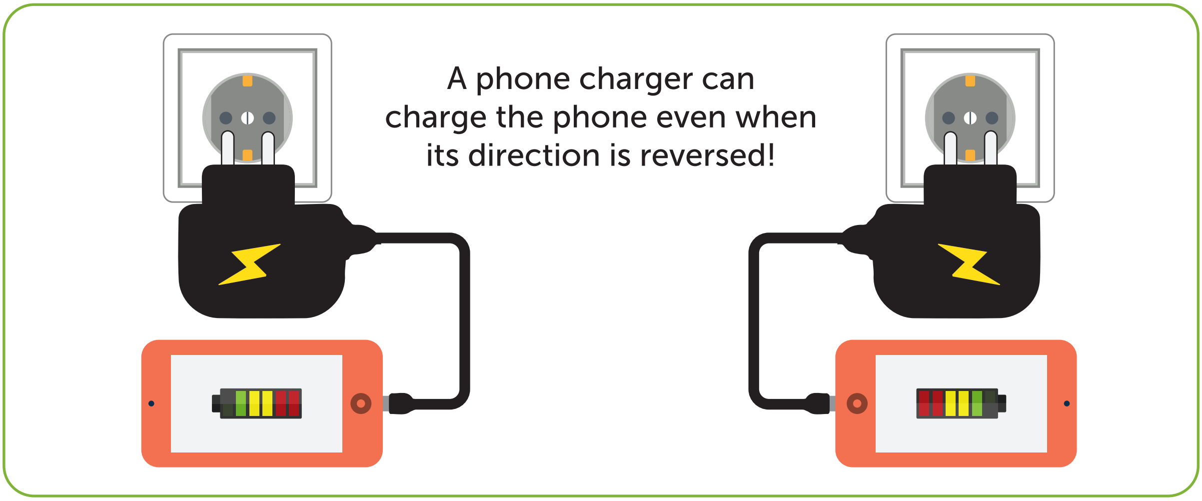






Let's try to understand a circuit that you would have been using daily! We will be needing a mobile phone, its charger and a plug-point for this experiment. Please do this experiment under ADULT SUPERVISION!

- Get a mobile phone charger and connect it to your phone.
- Plug-in the charger in to the socket and switch it on. The phone should start getting charged.
- Keep the charger connected to your phone and flip the charger at the plug point. Does the phone still charge or not?



Why did the phone charge? Shouldn't the charger act like a "polar" battery and not work in reverse? This is because the charger works on "AC" or Alternating Current, a type of current that comes to our houses. This is different from the "DC" or Direct Current supplied by batteries.

INTERESTING FACT!

Did you observe that the charger connects to the plug-point in two ways but it connects to the phone in only one way? This is because the charger actually converts AC to DC and hence, just like batteries, it can give voltage only in one direction!

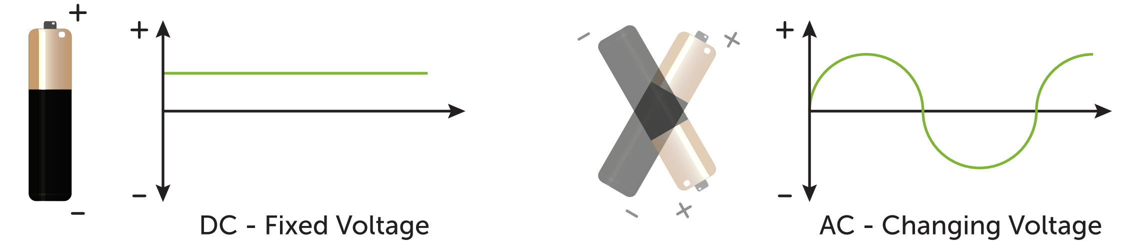
So, all appliances that we use in our homes either use AC directly or have to convert AC to DC before supplying to the main circuit of the appliance!

We will learn more about AC & DC in the next topic.

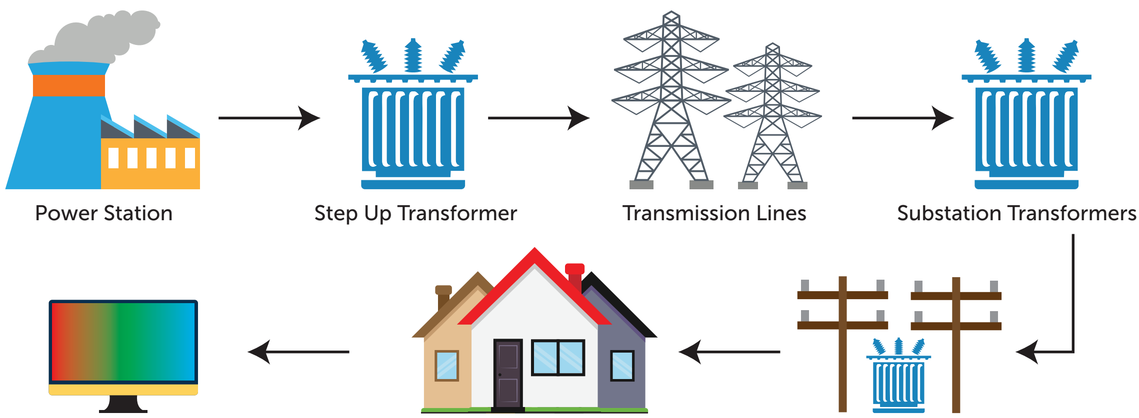
T8. AC & DC

We saw that there are 2 types of currents: AC & DC. AC seemed to be not affected by polarity where as DC was affected by it.

Basically Alternating Current is a current whose polarity constantly keeps on changing from positive to negative. It is as if one moment the battery is connected one way and the other moment its opposite way. So the voltage keeps on fluctuating and is never at a fixed value like in case of a battery.



The reason AC is used in our homes is because scientists have found that AC can be easily and efficiently be transmitted over larger distances as compared to DC. But AC is difficult to be used directly by most appliances. DC on the other hand can't be transmitted over long distances but is usable by most appliances. Hence most of the times, the AC received in our homes is converted to DC before use, as we saw in the previous experiment.



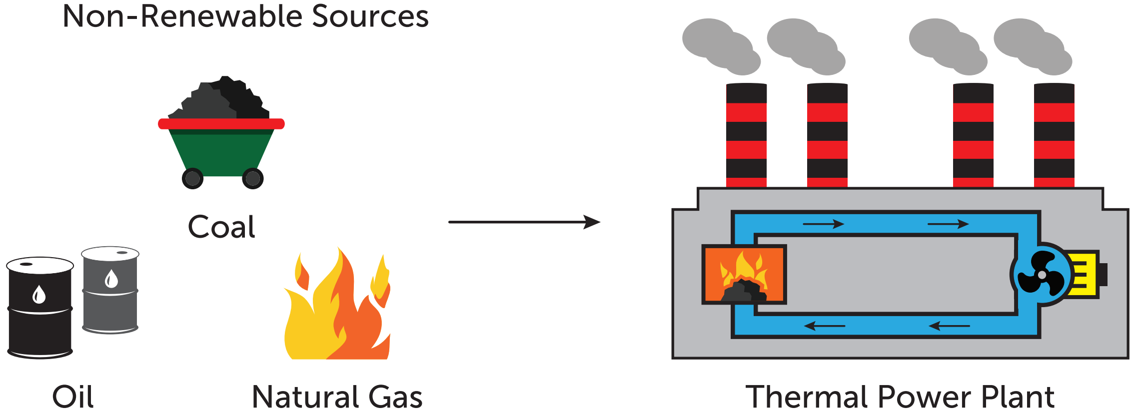
Another advantage of using AC is that its voltage can be increased or decreased very easily and efficiently using devices known as "Transformers". You would have often seen these devices in your city. DC voltage can't be very easily changed hence transformers are first used to lower the AC voltage that comes to our homes before converting to DC voltage!

T9. TYPES OF POWER SOURCES

Today, electricity is produced in multiple ways by using various energy sources. Thermal, solar, wind & hydro are the main types of power sources in use today. Each power source has its advantages and disadvantages and is selected by considering various factors. But broadly, there are two types of power sources: Renewable & Non-Renewable.

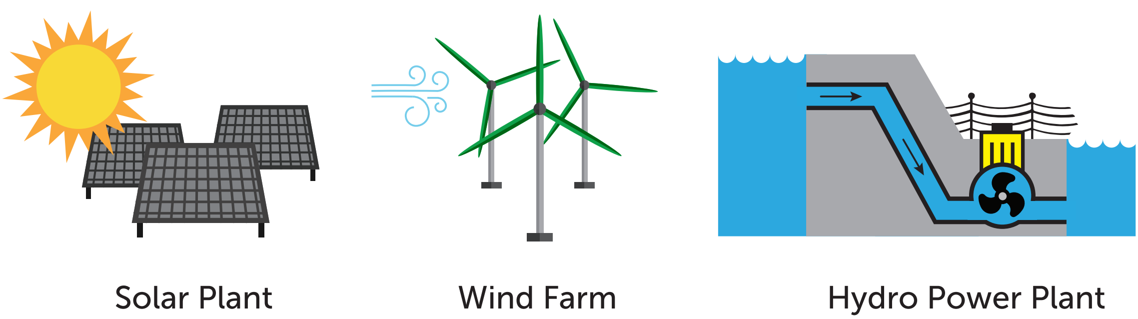
Non-Renewable power is obtained from fossil fuels like coal, oil & gas which are natural resources that are finite and will exhaust one day. These fossil fuels are first burned to produce steam, which is then used to produce electricity using Steam Turbines. Hence this power source is commonly called Thermal Power and the power plants are called Thermal Power Plants!

Non-Renewable Sources



Renewable power is obtained by using resources like solar, wind & hydro which are in abundance and almost infinite. Wind & Hydro power is generated using the energy of wind & water with the help of Wind Mills & Hydro Turbines respectively. Solar power uses the light from the sun and converts it into electricity using Solar Panels of "Photovoltaic Cells". Note that no material is burned here and hence this is a pollution free, clean & green source of power!

Renewable Sources



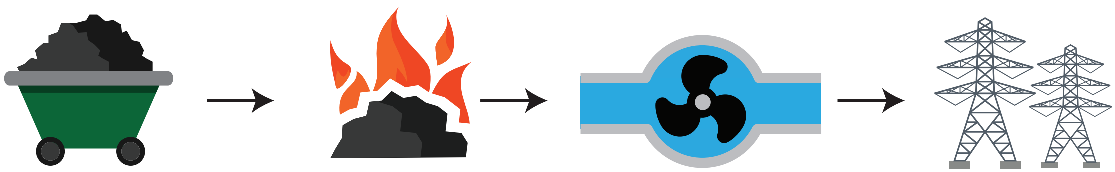
We saw that there are various power sources that produce electricity, But how does say solar energy or thermal energy get converted into electricity?

This happens through Transformation of Energy!

ENERGY TRANSFORMATION

The Law of Conservation of Energy states that energy can neither be created nor destroyed, but is only converted from one form to another. This means that the power sources are not generating electricity but rather just converting some form of energy into electrical energy!

Let's take some examples. Thermal power plants use coal as a source of energy. This coal is heated to produce steam, the steam moves turbines which convert this mechanical energy into electrical energy. Same happens with wind and hydro energy where the mechanical energy of wind and water is transformed to electrical energy.



Coal → Burned to produce Steam → Steam Turbine → Electricity

In case of solar, the light falls onto the solar cells, who with the help of an effect called the "Photo-Electric Effect", convert light energy into electrical energy.

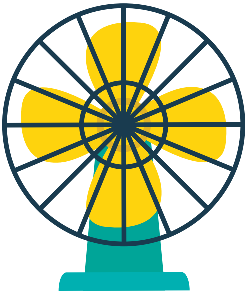
A battery is made up of chemical compounds and thus when we use it, the stored chemical energy is converted into electrical energy!

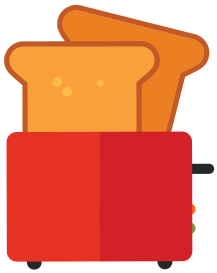
Not only this, even when electricity reaches our homes, we further convert electrical energy into some other form of energy. For eg. fan would convert electrical to mechanical, bulb would convert electrical to light etc.

Thus, this cycle of transformation continues!

ENERGY TRANSFORMATION PUZZLE

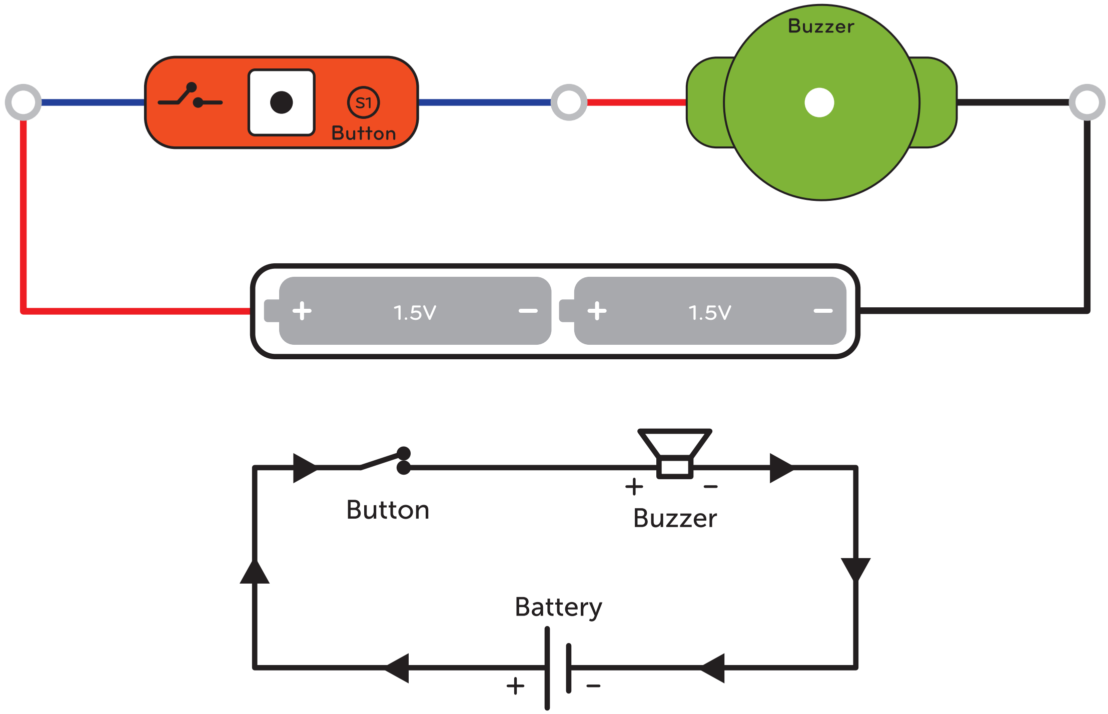
Let's test if you have understood the concept of energy transformation. Write down the energy transformation that happens in the following objects:





E7. DOORBELL

- Connect the Push Button Switch and Buzzer as shown.
- Now connect the Battery.
- Press the Button to hear the buzz. Tap the Button for some super fun!



A Button is similar to the Slide Switch but it "closes" the circuit only as long as you keep it pressed and "opens" it as soon as you lift your finger. This helps you make a temporary closed circuit and the circuit remains open most of the times.

Such buttons or switches are found in doorbells, remotes, mobile phones, keyboards etc. You can now understand how these work and why we selected them instead of a Slide Switch!

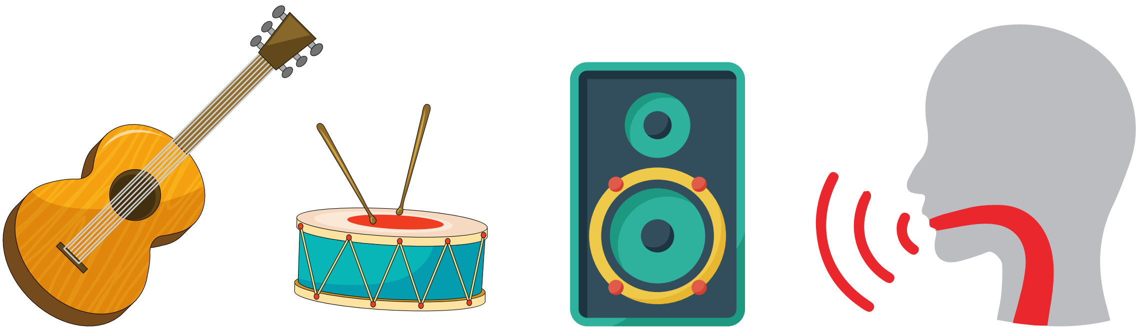
SWITCH HUNT!

Find at least 5 objects (other than ones mentioned above!) which use push button switches!

Have you ever noticed that when you stand close to a loud speaker or a woofer, you can FEEL the sound? This is because sound waves are nothing but basically vibrations which cause a "pressure difference" in their surrounding environment. These vibrations can start by a simple tug on a guitar string or a drumstick hitting a drum and we experience these vibrations as sound.

Also you must have noticed, a guitar has many strings of different thicknesses. Each of those strings vibrate at a different speed, and this difference in vibration speeds, creates different sounds which in turn creates music. The thicker strings vibrate slower and give us a deeper sound which we refer to as bass and the thinner strings vibrate faster and give us a high pitched sound that we generally refer to as treble.

This is the same concept used by every speaker, which is why you will see the diaphragm of speakers vibrating when you play loud music. The vocal chords in our throats are amazing devices that can vibrate at so many different speeds, which is why we can talk, sing, shout and communicate with each other in such a vibrant manner.



All types of sounds are produced through vibrations!

The speed of vibration is called Frequency and it is measured in hertz (Hz). So if a guitar string vibrates 100 times in 1 second, it is said to be vibrating at 100 Hz.

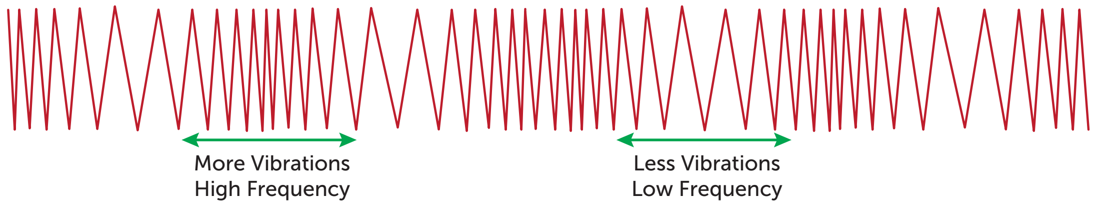
Basically, more vibrations per second means higher frequency and higher pitch sound whereas less vibrations means lower frequency & lower pitch.

FUN FACT!

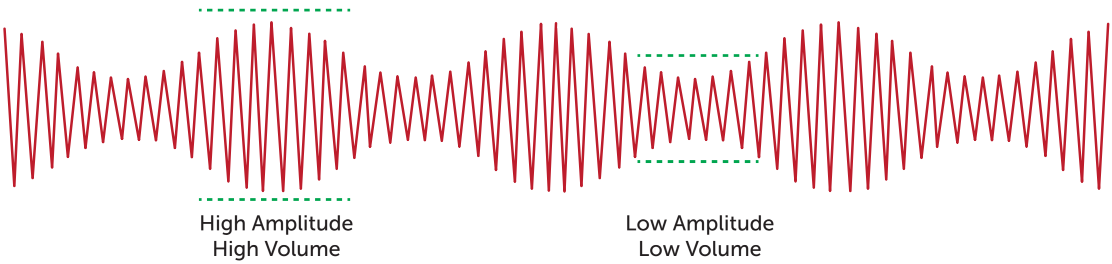
The human ear is capable of listening to sound frequencies between 20 Hz & 20,000 Hz or 20 kilo hertz (20 kHz), whereas dogs can hear sounds of frequency upto 45 kHz. That's why dogs can hear a dog whistle while humans can't!

Now that we have understood frequency, there is one more thing you can do with sound. You can make it loud and you can make it soft. When you listen to music, and you want to change the volume, you do not change frequency, instead you change the "Amplitude" of the sound.

That's why when you want very loud music, you need a device called "Amplifier" that can change the amplitude of a sound wave drastically. For example, at a concert, the singers voice is too soft for everyone to hear, therefore an amplifier is used to increase the volume (amplitude).



Frequency



Amplitude

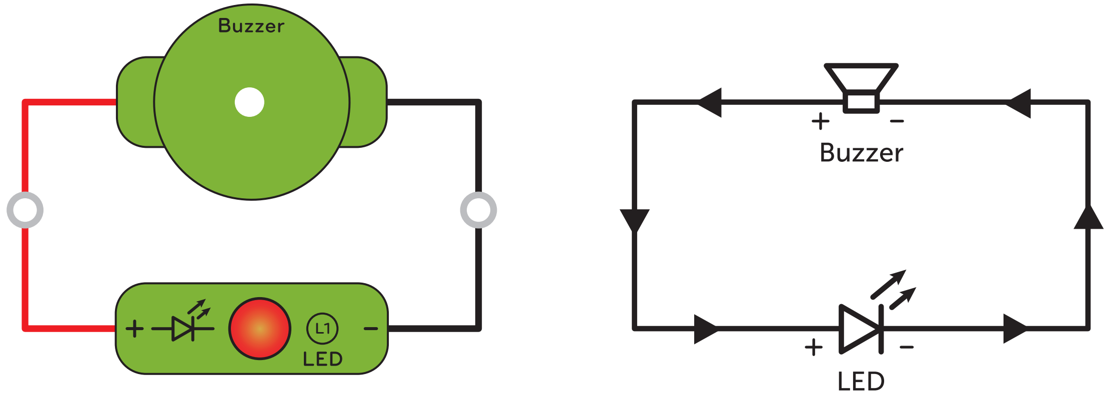
Buzzers that we used in the previous circuit are components that produce a buzzing sound when electric signals are passed through them, just like an LED glows when electricity passes. You will find them in all sorts of things from toys to alarm clocks to door bells etc.

The buzzer that we use in this set, is called a 'Piezo electric' buzzer. It gets it's name from this special material that has a tendency to vibrate when a current is applied. Therefore when you apply voltage to a piezo buzzer, the material inside vibrates, and we experience this vibration as sound.

E8. PIEZO-ELECTRICITY

This is a really magical project. For the first time, we are NOT going to connect a battery and yet, the LED will glow!!

• Connect the Buzzer & LED on your baseboard as shown.



• Now tap on the buzzer with a pen/pencil. Tap continuously as fast as you can.

• Did you see the LED turn on for some time? This is Piezo-Electricity in action!

PIEZO-ELECTRICITY!

Interestingly, Piezo Buzzers work in two ways. Just like they produce vibrations/pressure differences when electricity is passed, the vibrations made on the Buzzer can also in turn generate electricity! This phenomenon is known as "Piezo-Electricity".

Buzzer can generate very little electricity in this manner but a lot of research is going on to generate large amounts of electricity through similar technology by using the walking movement of people and the movement of cars!

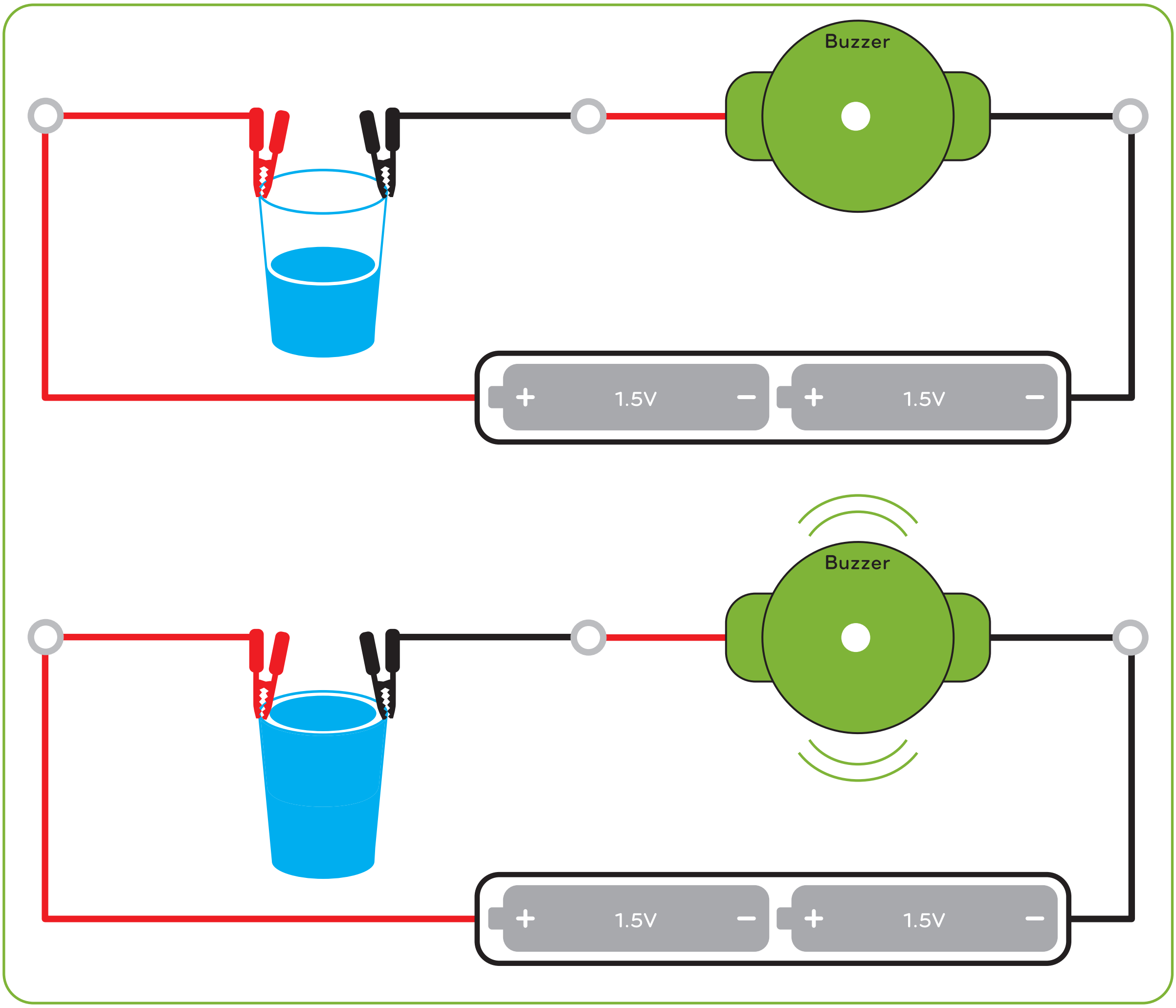
DID YOU NOTICE?

The connections of the buzzer were similar to that of a battery this time. The red wire of the buzzer was connected to the red wire of the LED and vice-versa for black. This is because the buzzer wasn't using electricity this time but instead producing it!

E9. WATER OVERFLOW ALARM!

• Connect the same circuit as E4 but instead of the LED, connect the Buzzer.

• Keep in mind the polarity of the Buzzer.



• Now pour tap water again. Do you hear a beeping sound this time?

Real-life water overflow alarms and alarms in general, make a sound so that you can be alerted even if you are not looking at the alarm or are away!

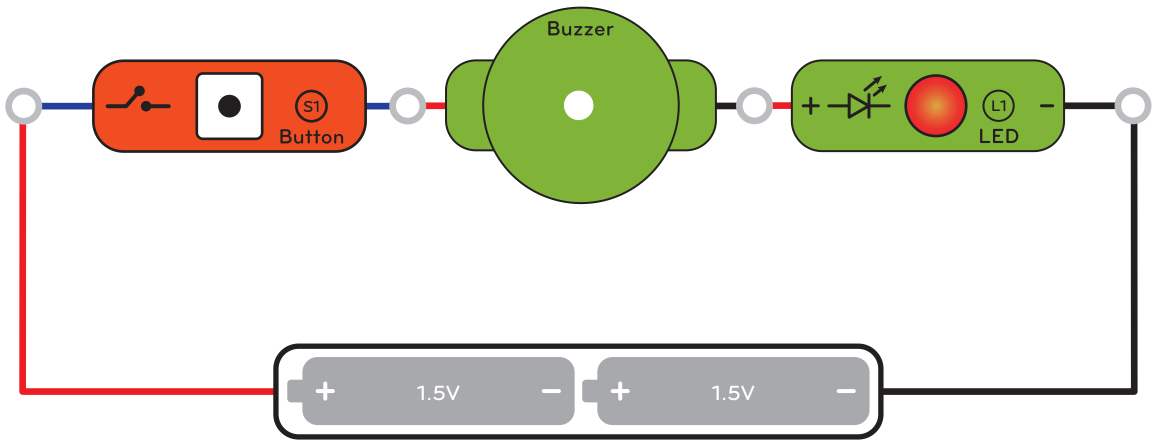
E10. THE PARTY DOORBELL!!

Let's enhance the functionality of our previous doorbell and make it party ready!

• Connect the Push Button Switch, Buzzer and LED as shown.

• Now connect the Battery.

• Press the Button for super fun!



Now, this doorbell will also alert you via light in case you are not able to hear the sound due to loud music around you or in case you have earphones plugged-in! You would have seen such doorbells in homes as well, where a bulb glows along with a ringing bell.

ONE MORE ACTIVITY!

Try changing the order of components i.e. LED-Button-Buzzer, Buzzer-LED-Button etc. Remember we are NOT changing the DIRECTION of any component, just the POSITION

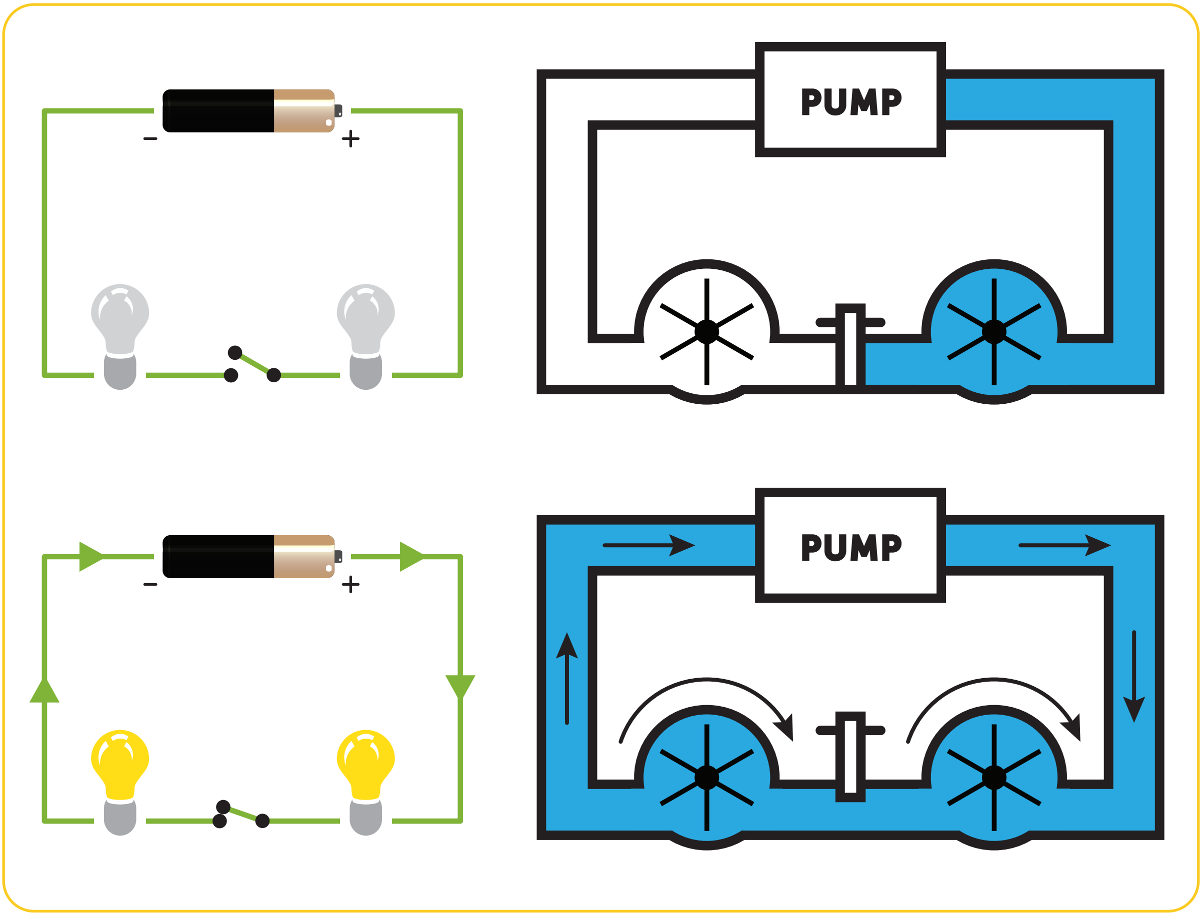
Does LED/Buzzer work when Button is not pressed? Do they work on pressing the Button? Why does this happen? Shouldn't the LED or Buzzer work if it comes before the button? Hint: Switches are like taps...We will solve this mystery in the next topic!

Till now, we have connected very few components in the circuits and made only a few connections. So, we did't realise the pattern in these connections.

In electronics, there are two major types of connections - "Series" & "Parallel".

Series connection means that we are connecting components one after the other in a line, such that electricity has only one path to flow. If any one component is removed or the circuit "opens" at any point, no current will pass through the circuit!

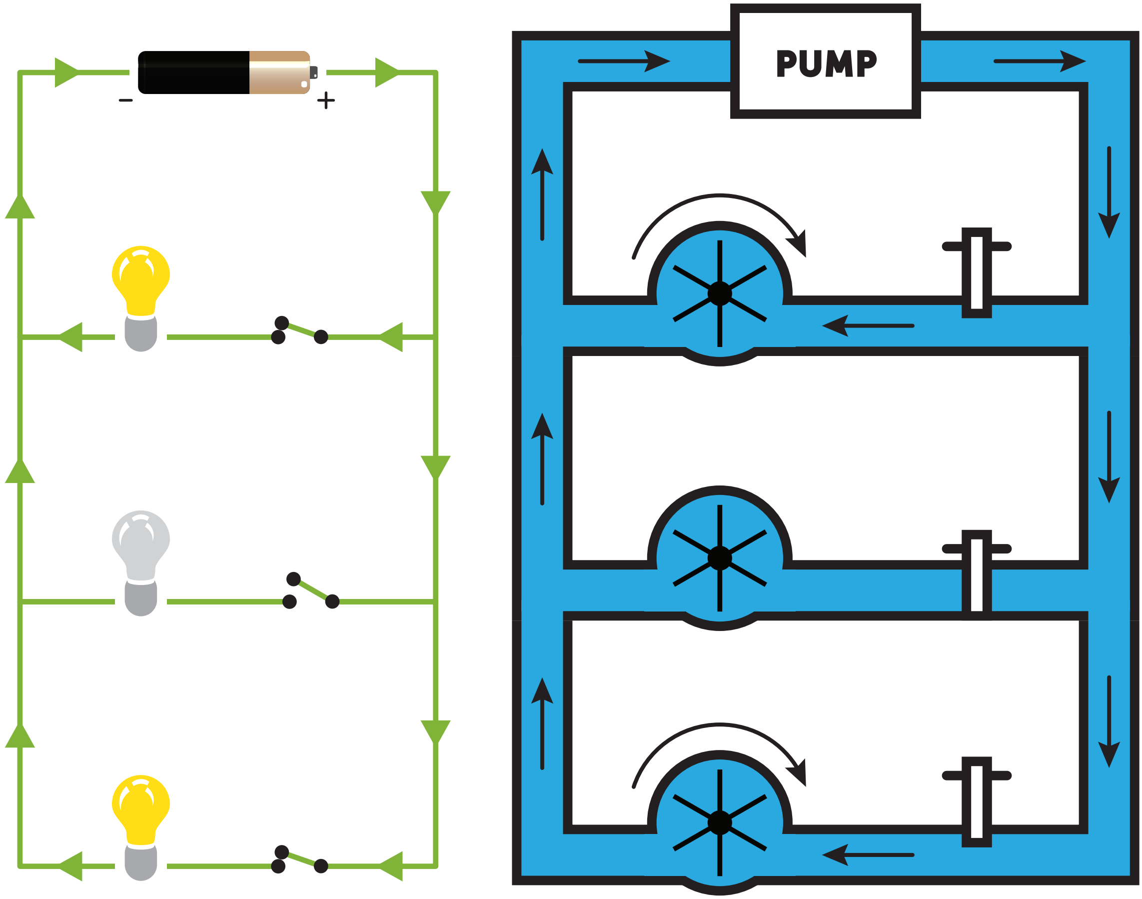
The previous circuit was a "Series Circuit" because it had 3 components in a line. And so, even when we changed the position of the Button, the LED or Buzzer didn't work as the "tap" (Button) was blocking the flow of current!



The disadvantage of series connections is that if one of the components is off or damaged, then no other component will work as electricity has no other path to flow through them!

In a parallel connection, we connect components side by side, such that electricity has multiple parallel paths to flow and flows through each path independently. Electricity is split between all these paths and if components in one path are damaged or off, other paths are not affected!

Our homes use parallel circuits, so when you turn off the lights, the fans don't get turned off!

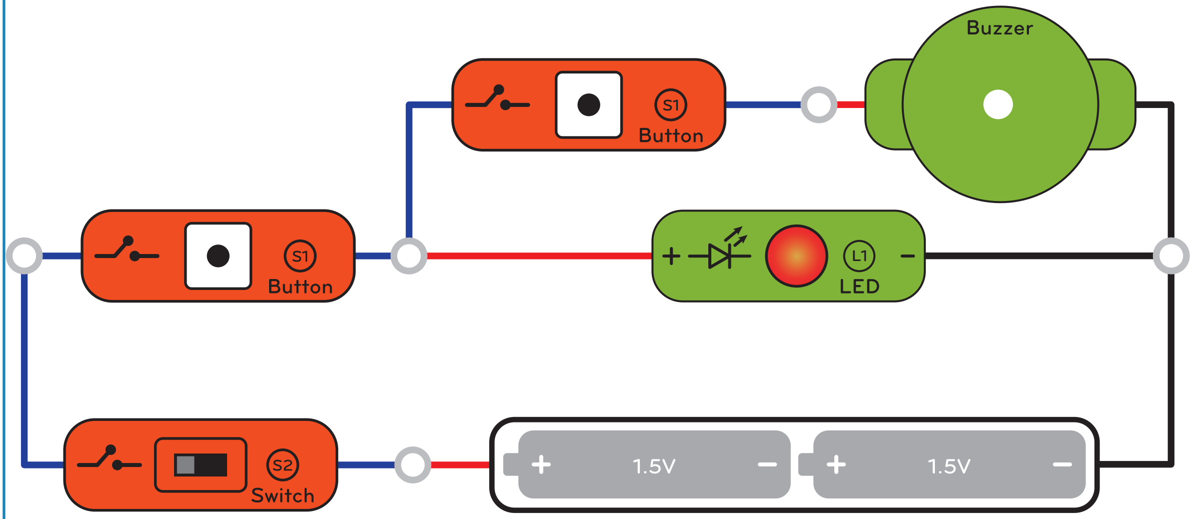


DID YOU NOTICE...

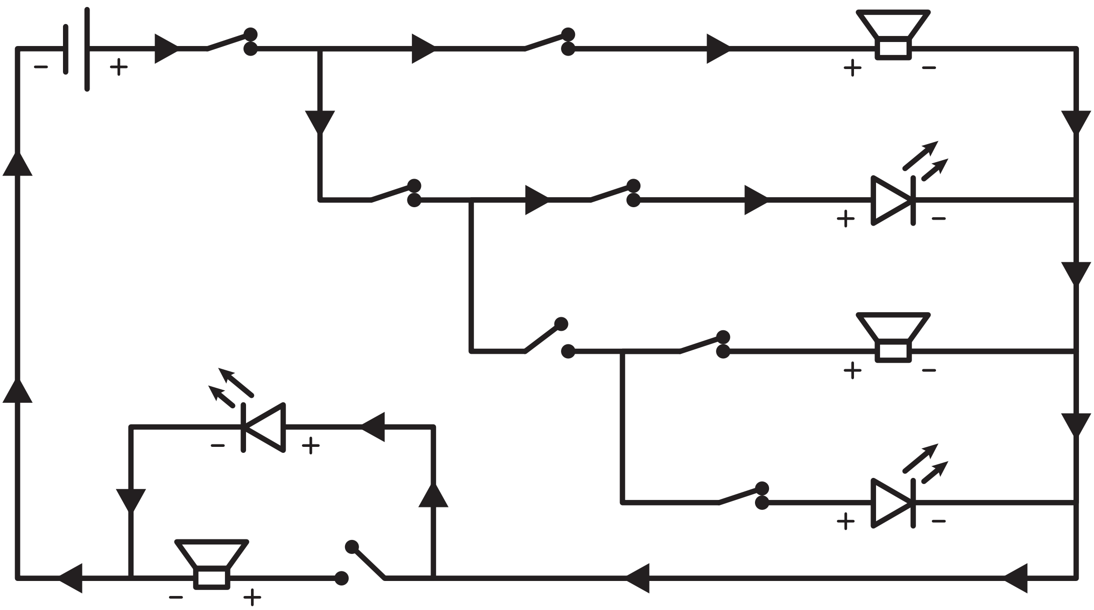
- All the circuits we made till now were series circuits! Even the batteries inside the battery box were individually connected in series!
- The above example is a parallel connection of three series connections! In practice, circuits will mostly be a combination of series & parallel connections.

SERIES-PARALLEL-PUZZLE!

Let's solve some puzzles to get a complete grasp of series and parallel circuits!
Encircle ALL the series sections in the below diagram:



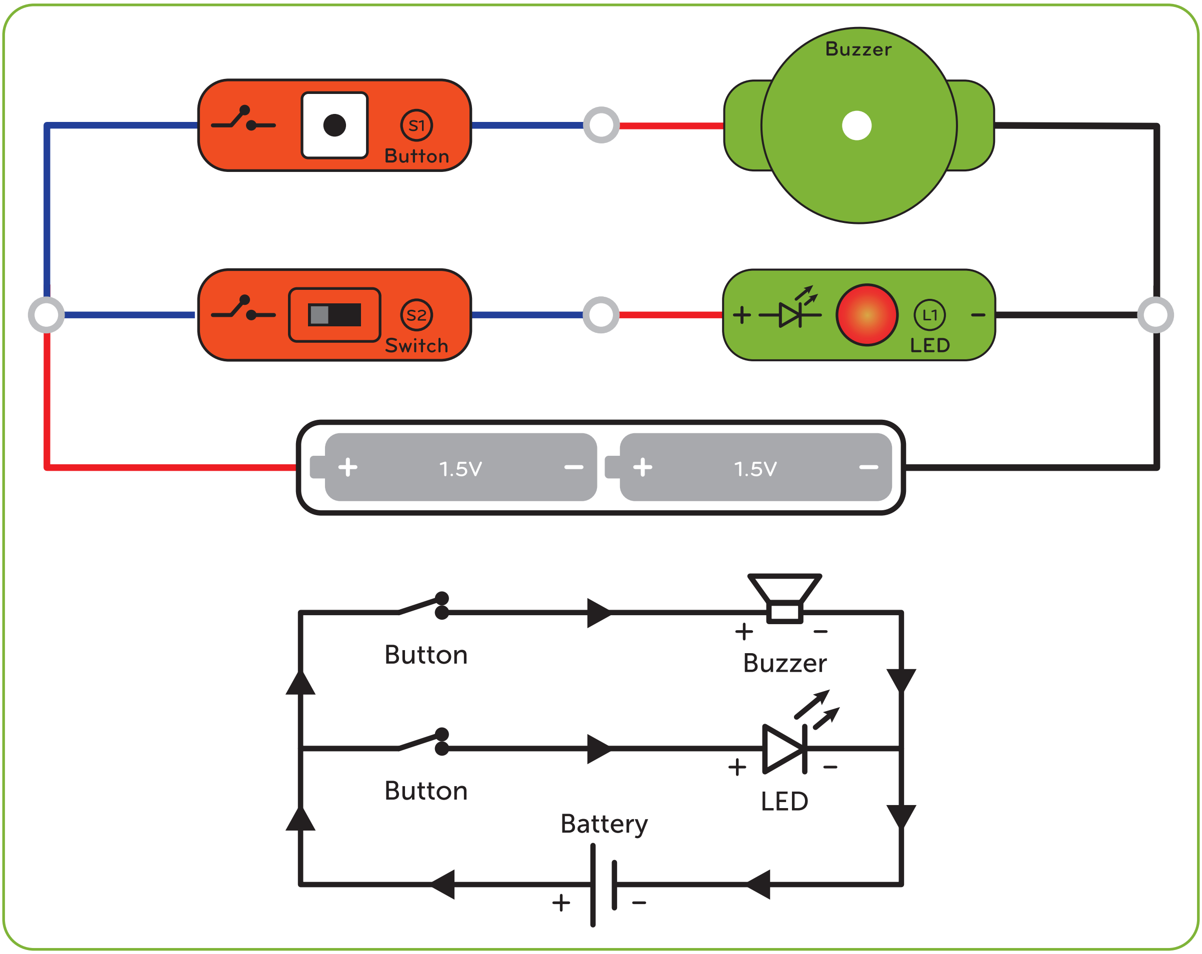
Encircle ALL the parallel sections in the below diagram:



E11. HOME WIRING

Let's connect the same components of the party doorbell, but this time in parallel. We also add a switch for each circuit path.

• Connect the Button, Buzzer, Slide Switch, LED and Battery in "Parallel" as shown.



• Try pushing the Button and sliding the Switch to ON.

• You will observe that now the LED & Buzzer can both run independently unlike the doorbell in E10. Using either the switch or buttons, both will work!

• This is because both of them are connected in Parallel and so the electricity has two different paths to flow through!

Just like in our homes, switching on the fan doesn't also turn on the lights! You can control both of them independently. Besides, if one appliance gets damaged, the others are not affected!

E12. SECRET MORSE CODES!

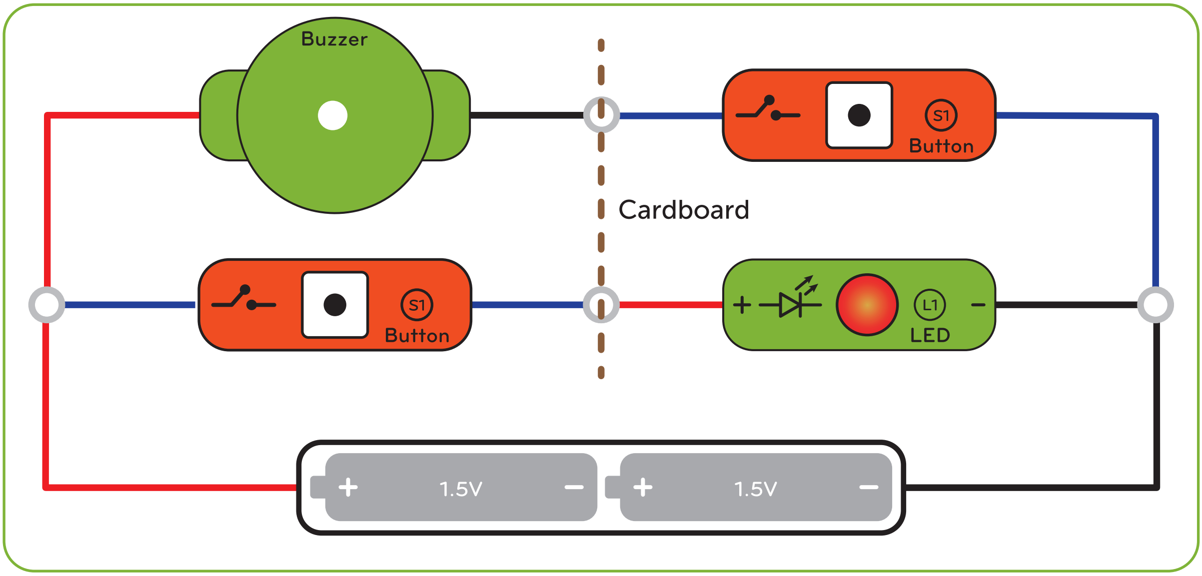
Morse Codes are a very popular signalling technique and were used to send messages through a Telegraph. Besides, this technique is also widely used when sending emergency messages like SOS through flash lights or big horns. They are also used by spies to send secret messages!

The messages are sent in the form of "dots" & "dashes". A particular sequence of these dots & dashes stands for a particular alphabet or number. For example, the emergency message, SOS (Save Our Souls) would be written in Morse Codes as: ••• ——— •••, where "•" can be represented by turning light/sound on for short amount of time, "—" can be represented by turning light/sound on for long amount of time and the white spaces mean silence/pause.

Now, let's make our own secret signalling system!

• Connect the home wiring circuit with some minor modifications as shown.

• We've just changed the position of buzzer's button and replaced LED's switch with a button. Remember, changing the position of components in a series path won't affect the operation!



• Here one button controls the LED & the other one controls buzzer. You can use the Button-LED pair to send secret messages to your friend and s/he can use the Button-Buzzer pair!

• Place a cardboard piece in between as shown so that none of you are able to cheat and see what message your friend is sending!

Just ensure that the circuit is functioning properly and get ready to play the code game!

CRACK THE CODE!

Use the buttons to encode the messages in Morse Code format. The challenge is to decode the messages using the LED or Buzzer!

Here's how to play:

- Use the table provided to encode the message you want to send.

A •—	G ——•	M ——	S •••	Y —•——	4 ••••—
B —•••	H ••••	N —•	T —	Z ——••	5 •••••
C —•—•	I ••	O ———	U ••—	0 —————	6 —••••
D —••	J •———	P •——•	V •••—	1 •————	7 ——•••
E •	K —•—	Q ——•—	W •——	2 ••———	8 ———••
F ••—•	L •—••	R •—•	X —••—	3 •••——	9 ————•

- Here dot means a short button press and dash means a long button press.

- After sending one character, pause for some time and then send the next one.

- Practice with your friend first and fix the time duration for dot, dash & pause, so that there is no confusion while playing the game.

- First you send the messages using the button and let your friend decode them using LED. Next s/he will send it using the other button and you decode them using buzzer.

Below are some messages that you can try on this system. Write it down in coded format first so that you don't make any mistakes while sending!

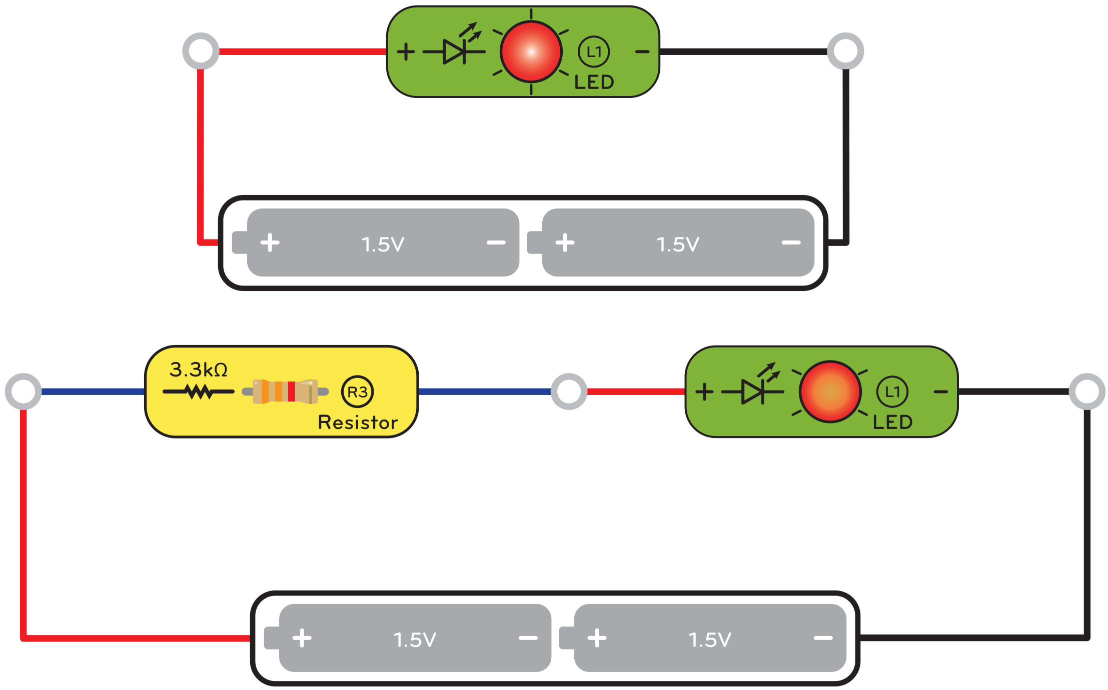
HELLO	______________	ROGER	______________
OVER	______________	GOT IT	______________
007	______________	NEGATIVE	______________
CAKE	______________	READY	______________
LOCATE	______________	GO GO GO	______________

Try sending more messages as well. You can even develop your own secret coding system!

E13. BRIGHTNESS UNDER CONTROL!

• First connect the LED & Battery as shown in the 1st diagram below. Notice LED's brightness.

• Now connect the 3.3kΩ R3 Resistor in series with the LED as shown in the 2nd diagram.



• The LED will glow but its brightness would have decreased a bit after connecting the resistor.

• Now replace the R3 with first R1 (10kΩ) and then with R2 (20kΩ) and observe carefully.

OBSERVATIONS

What did you observe when we connected these different resistors?

____

____

____

Keep these in mind as we explore more about these fantastic resistors in the next topic!

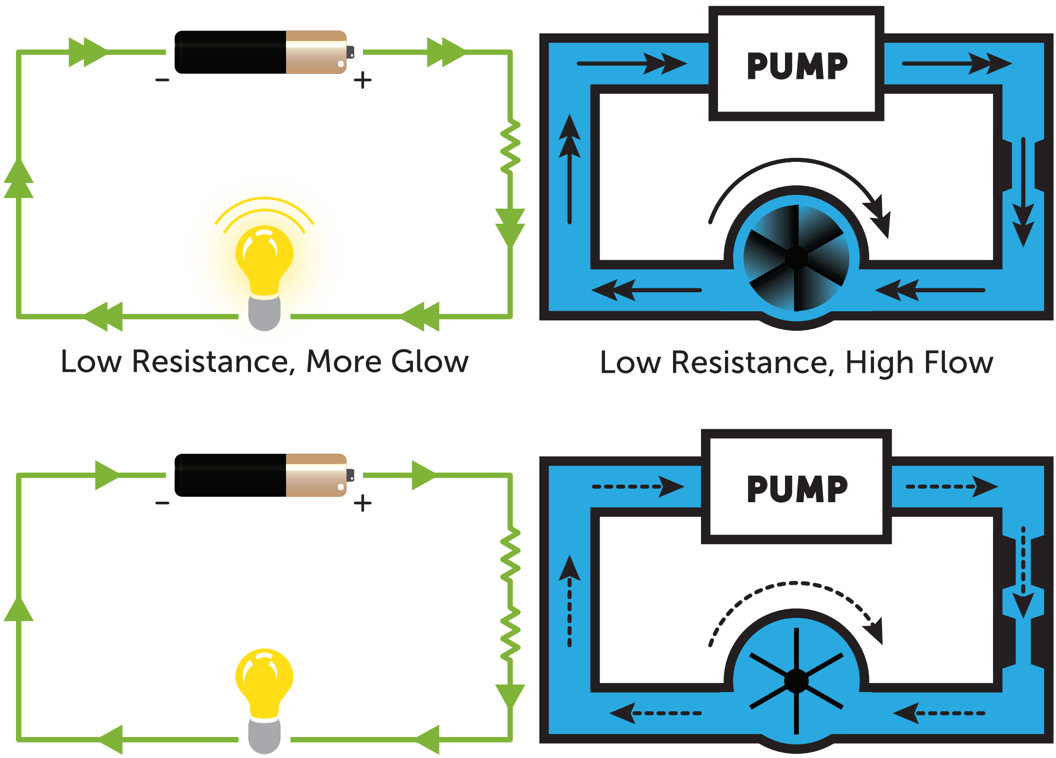
T13. RESISTANCE & RESISTORS!

Resistance is the phenomenon of opposing the flow of electricity.

Ohm (Ω) is the unit of "Resistance", in the same way as metre is the unit of length. So, just as 10 km would mean 10,000 metres of length or distance, 10 kΩ means 10,000 ohms of resistance!

Remember conductors allow electricity to pass easily whereas insulators don't? This is because conductors have very low resistance whereas insulators have very high resistance! In general, every material has a certain resistance.

Following our water analogy, low value resistors will be like wide & smooth pipes from which a lot of water can flow easily & quickly whereas high value resistors will be very narrow and in some cases choked pipes which allow very less water to pass through and that too very slowly!



Low Resistance, More Glow

Low Resistance, High Flow

High Resistance, Less Glow

High Resistance, Low Flow

Resistance is not always bad. In fact it is very important in electronics. When we add resistor to a circuit, it controls the flow of current! That's why resistors have specific values, so that they can precisely control the flow of electricity! Moreover, each and every component has some value of resistance internally, even if we don't connect any resistor to it!

T14. OHM'S LAW

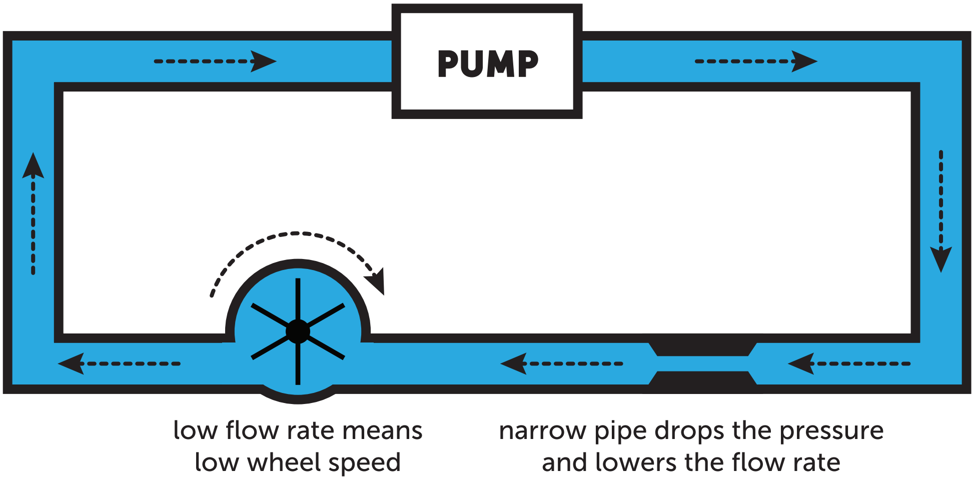
We learnt that the type of components and the way in which they are connected decide how the voltage & current will be distributed. Ohm's Law helps us find out how this happens. Yes, you guessed it right, its the same Ohm from resistance!

Ohm's law gives us the relation between the current, voltage and resistance for a given circuit. This allows us to find out how a component affects voltage & current in the the circuit.

Voltage (V) = Current (I) x Resistance (R)

So, if you apply some fixed voltage in a circuit, and the resistance of the components is high, the current will be low and if the resistance is low, current will be high! This explains why the LED was glowing dimmer on increasing the resistance!

VOLTAGE DROP!

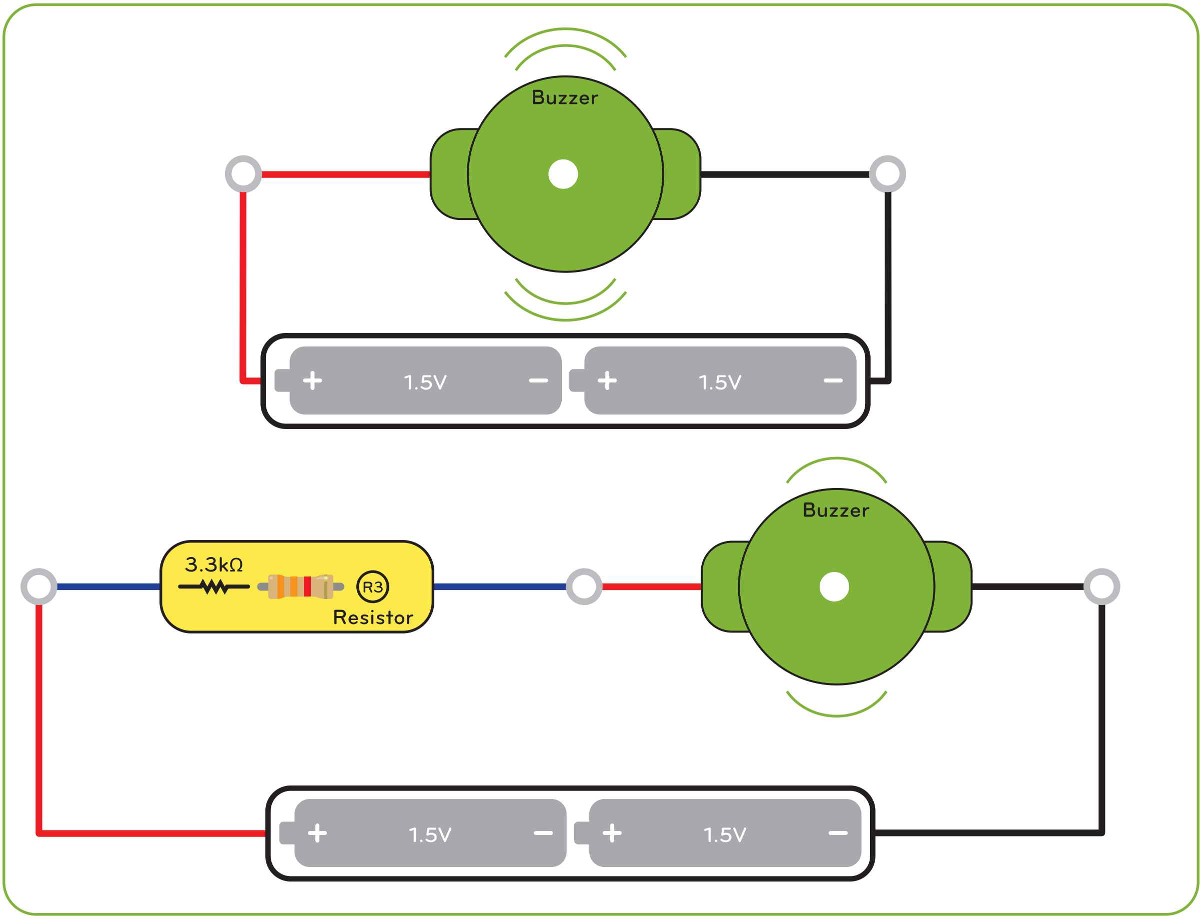


As we can see in this system, as the pipe becomes narrower (high resistance), even though the pump is applying same pressure (battery voltage), the water's flow rate (current) goes down because less water can pass through the narrow area. Not only this, but also the pressure of water in the remaining pipe goes down because so much of the pump's pressure is lost when forcing the water through the narrow zone! Imagine what happens when you squeeze a garden's water pipe from the middle!

This is called "Voltage Drop" across a resistor! Ohm's law can help us calculate this Voltage Drop for each component, if we know the value of its resistance and the current!

E14. VOLUME DOWN!

- First connect the basic circuit of Battery & Buzzer as shown in the 1st diagram below. Keep in mind the polarity of the Buzzer.
- Now connect the 3.3kΩ R3 Resistor in series with the Buzzer as shown in the 2nd diagram.



- The Buzzer will beep but its volume would have decreased a bit after connecting the resistor.
- Now replace the R3 first with R1 (10kΩ) and then with R2 (20kΩ) and observe carefully.
- You will observe that the volume of the Buzzer goes down as the resistance goes up!

The reason can now be explained easily with Ohm's Law. For a circuit having a fixed battery voltage, the current will go down when the resistance increases. Now, as the component gets less current, its output also decreases!

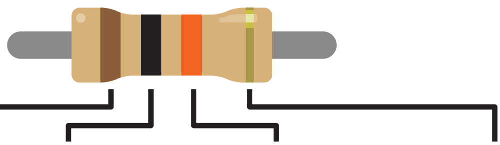
Think in terms of the water wheel. When the flow of water is less, the wheel spins slowly!

T15. WHAT ARE THOSE STRIPES?

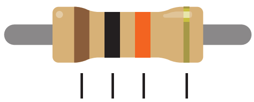
You surely must have noticed the colourful stripes on the resistor. They are for a reason. These stripes are a code that let you know the resistor's value!

These stripes are actually a colour coding scheme that can help you determine the value of a resistor simply by looking at it!

Take a look at the table and the method given to calculate the exact value of the Resistor. Just a little bit of math but its super fun!



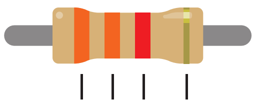
1st band, 1st digit	2nd band, 2nd digit	3rd band, Multiplier	4th band, Precision
0	0	x 1Ω	
1	1	x 10Ω	
2	2	x 100Ω	± 1%
3	3	x 1kΩ	± 2%
4	4	x 10kΩ	
5	5	x 100kΩ	
6	6	x 1MΩ	
7	7		
8	8	x 0.1Ω	± 5%
9	9	x 0.01Ω	± 10%



1 0 x 1kΩ ±5%

10 x 1kΩ ±5%

10kΩ ±5%



3 3 x 100Ω ±5%

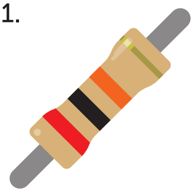
33 x 100Ω ±5%

3300Ω ±5%

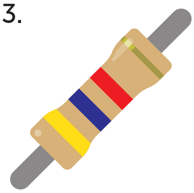
3.3kΩ ±5%

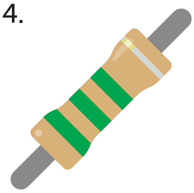
COLOUR CODING PUZZLE!

Ok so let's try calculating some resistor values with the help of the coloured stripes. You can take the help of the previous table for the colour coding. Also, don't forget to show your calculations in the space provided!

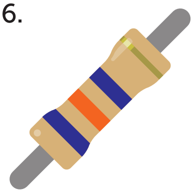
1. 

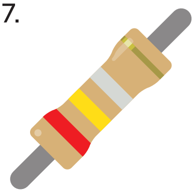
2. 

3. 

4. 

5. 

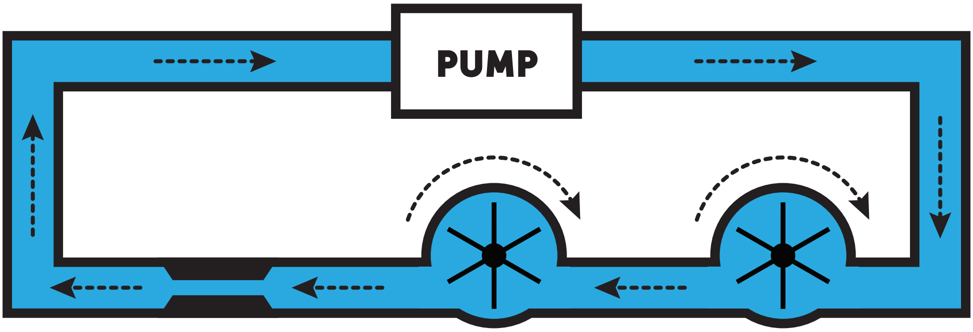
6. 

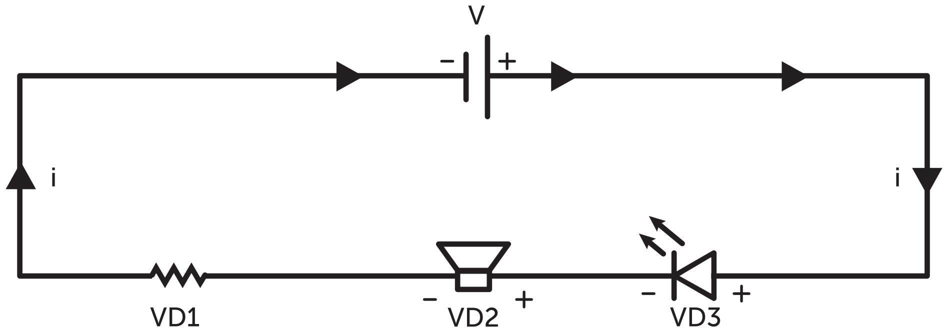
7. 

8. 

A water wheel spins by using the pressure of water. So the energy or pressure of the water will be consumed in spinning the water wheel which will result in a pressure (voltage) drop across the wheel as well. If the wheel is heavy, the drop will be more and if the wheel is light, the drop will be low because less energy will be spent in spinning it!

This means that apart from the resistor, components like LED, buzzer etc. also cause a voltage drop in the circuit. How much the voltage drops, depends on the component.





Here, two water wheels and a resistance are connected in series. As discussed, the water wheels will first consume some pressure and drop it. The remaining pressure acts on the resistance. Thus, in this type of series arrangement, the sum of pressure drops across all the components would be equal to the pressure of the pump!

As all components are connected in series, the same water is going to flow through them and so, the flow rate (current) will be same throughout the series! This flow rate will be determined by the pressure remaining for the resistance and the amount of resistance as per Ohm's Law!

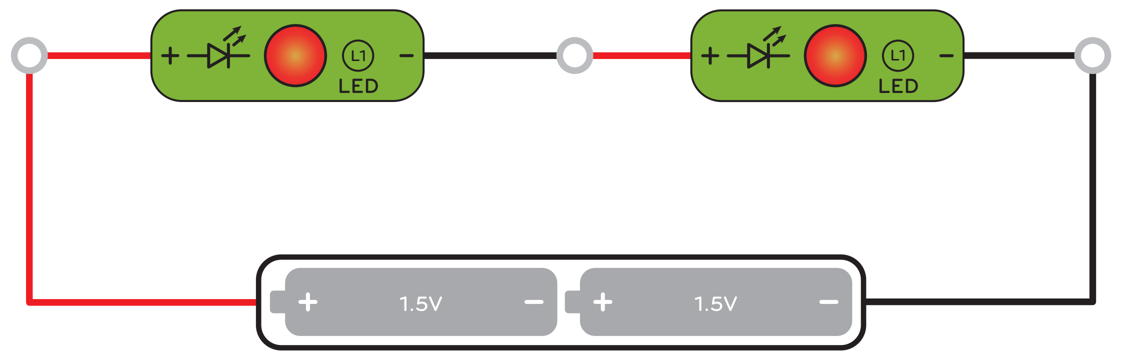
If the total voltage of a battery is V and voltage drops across the series circuit components are VD1, VD2, VD3,... then V = VD1 + VD2 + VD3 + ...

Hence, current remains same while voltage gets divided in a series connection!

E15. SERIES LED

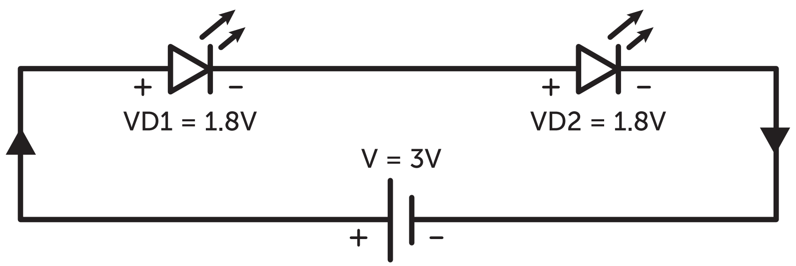
Let's test the previous theory with a circuit.

- Make this series circuit of 2 LEDs as shown.
- Connect the battery.



- Did the LEDs glow? Why??

Let's do some calculations based on the voltage drop theory:

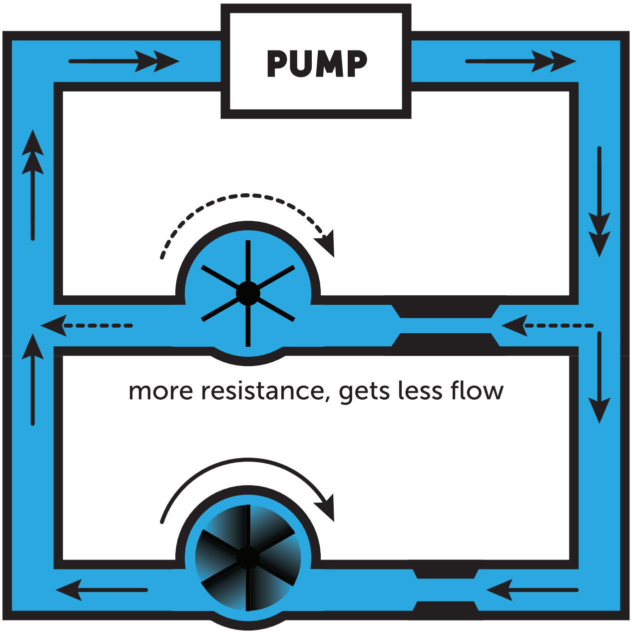


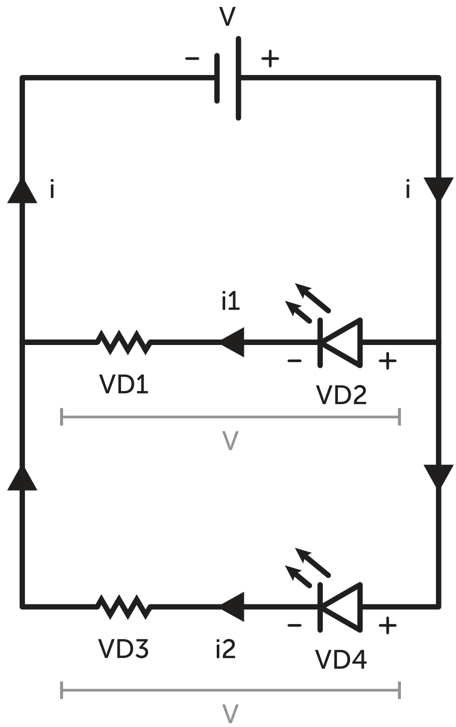
- LEDs need a minimum of 1.8V to operate. So, they make voltage drop by 1.8V.
- We have 2 LEDs in series. So, total voltage drop is 1.8 + 1.8 = 3.6V
- We also have 2, 1.5V batteries in series. So total supply voltage is 1.5 + 1.5 = 3V
- Means that the total voltage drop created by 2 LEDs is more than the battery supply voltage!

So, even after all the battery voltage is applied, no current will flow in the circuit and as a result, the LEDs won't glow!

We saw that in series, the voltage gets divided while the current remains same.

But, when a water pipe is split into two, the amount of water going into the two pipes, must obviously be equal to the water that was there in the bigger pipe!





This means that the flow rate (current) gets divided in a parallel circuit!

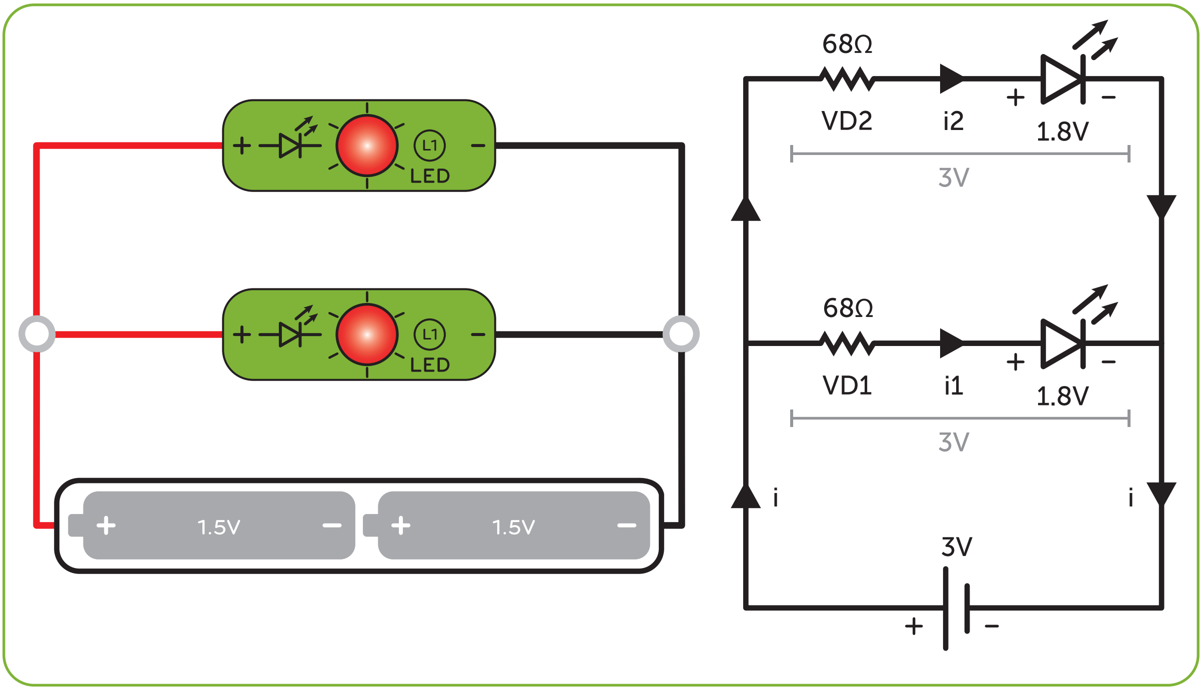
But, since both of these paths will be powered by the same pump (battery), the pressure does not get divided. All paths in a parallel circuit receive the same pressure (voltage)!

The amount of current that goes into each path will depend on the resistance of that path. So the path with more resistance will get less current and the one with less resistance will get more current. Electricity will always choose the path of least resistance in a circuit!

Hence, if total current going into a parallel connection is i and the current going into the branches are i1 and i2 then $i = i1 + i2$

So, voltage remains same but current gets divided in a parallel connection!

Let's make a parallel circuit with 2 LEDs as shown, to test the previous theory.



Did the LEDs glow? Let's find out why:

- Since this is a parallel circuit, the battery will give 3V to both the paths.
- But LEDs need only 1.8V to work which is less than 3V.
- So both LEDs will glow here unlike the series circuit!
- The additional voltage drop that happens across the resistors will determine the currents!

Note one thing that you don't know yet. The LEDs that we have provided have an inbuilt resistance of 68Ω which is connected to protect them from over-current.

Let's calculate the currents for both paths:

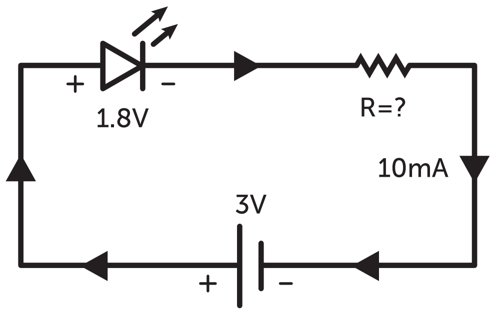
Path 1: $3V = VD1 + 1.8V \Rightarrow VD1 = 1.2V$
By using Ohm's Law, $i1 = V \div R = 1.2 \div 68 = 0.017A$

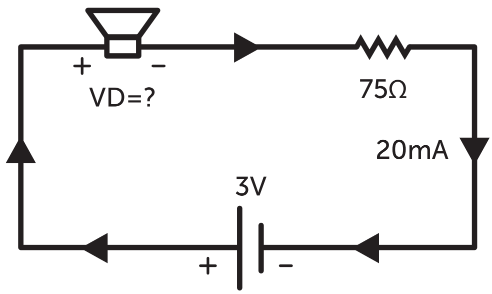
Same calculations for path 2 as the components are same, hence $i2 = 0.017A$

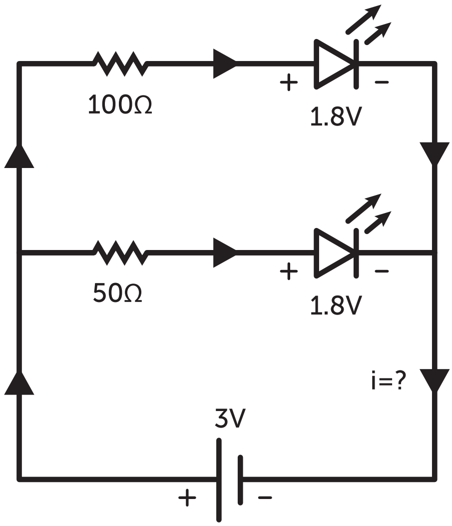
Therefore, $i = i1 + i2 = 0.034A$

VOLTAGE DROP PUZZLE

Let's check out some more circuits and calculate their voltages & currents. These puzzles will help you understand the concept of Voltage Drop and Ohm's Law with much more clarity! Find out the value of labels marked with '?'







E17. WATER LEVEL INDICATOR

We made a cool Water Overflow Alarm before. But, the problem with it was that we were alerted only when the water overflowed. What if we could keep a track of the water level continuously!

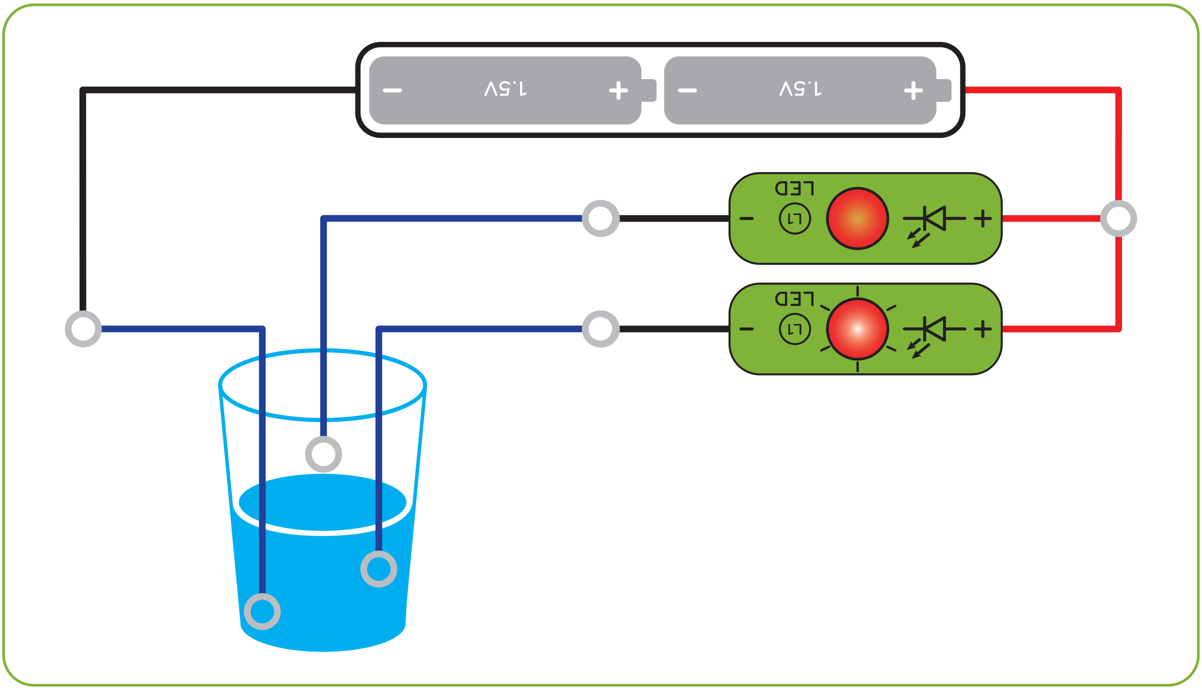
The principle behind this Level Indicator is a combination of the Overflow Alarm and the parallel circuit that we just made.

- Connect the LEDs, Jumper Wires and the Battery as shown.

- Use a dark room for this experiment.

- Here the Jumper Wires will act as a switch in the same way as the Clip Wires.

- Now tape the Jumper Wire pairs to the glass at 3 different depths as shown. The jumper connected to –ve goes at the bottom, one jumper at around middle depth and the other one near the top.



- Slowly start pouring tap water.

- As soon as a particular Jumper Wire pair completes the circuit, the corresponding LED will glow since all LEDs are connected in Parallel.

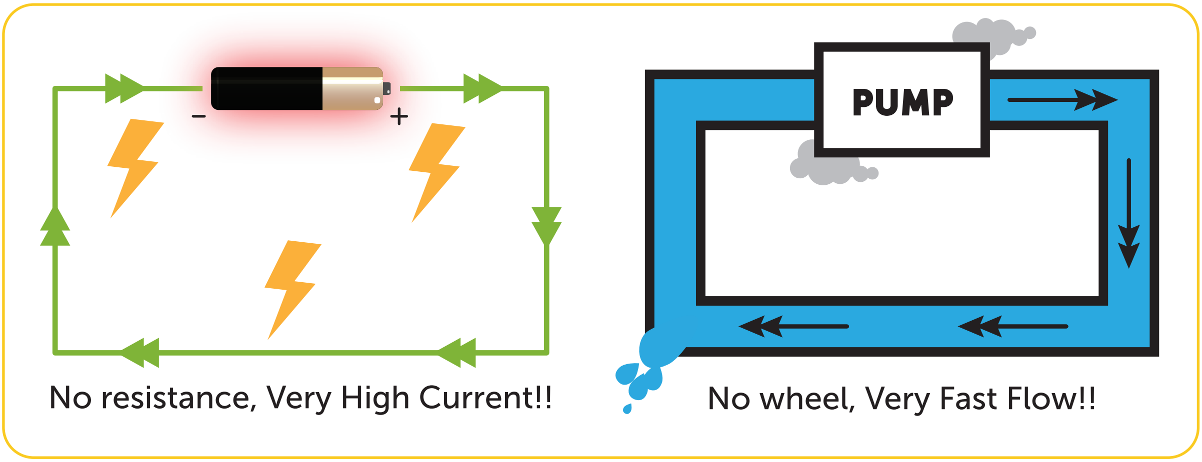
- This way you can tell the level of water from the number of the LEDs glowing!

Short Circuit! - the word is often heard when there's electrical damage. Let's learn about it.

A Short Circuit happens when electricity decides to take a short-cut and in most cases, this is unintended & dangerous!

Whenever electricity has a lower resistive path available, it will opt for it. So, when electricity gets a very very low resistance path, the current will run like anything - leading to a short circuit!

So, a short-circuit is like a near-zero resistance path for electricity!



For example, if you connect the + & - of a battery (DON'T!!!) using a normal wire, the resistance will be very less and so, a large amount of current will pass causing sparks, excessive heat and damage to the battery, wires and to you!

So, never connect the two terminals of a battery directly, especially if it's high voltage!!

FULLY LOADED!

What we learn from here is that, it is very important for a circuit to have an adequate load in order to function properly. If a very tiny load is connected to a very high voltage circuit, then also it can result in short-circuits!

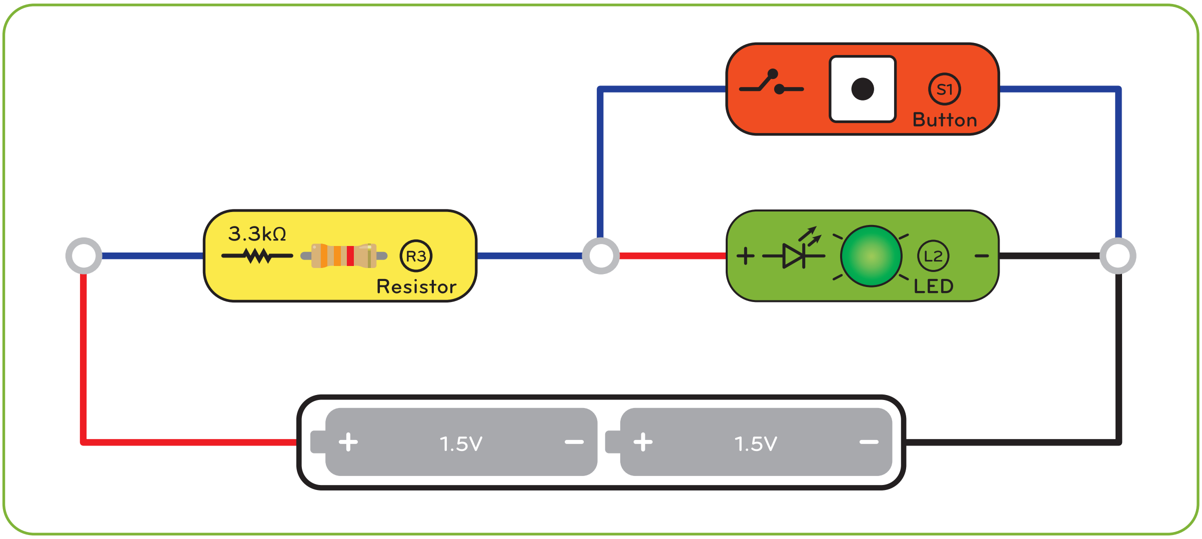
That's why you see danger markings on very high voltage transformers or heavy duty electric appliances because in case you make a contact with the device, a lot of current can pass through your body and could turn out to be fatal!

E18. SHORT-NOT!

Short circuits can cause excessive current to flow in the circuit & damage the components. But short circuits can be used in a smart way too! Let's make a switch that does NOT listen to you!

• Connect the 3.3kΩ R3 Resistor, Button, LED & Battery as shown.

• The LED will glow by default but as soon as you press the Button, it goes off!



But why does this happen?

• The switch's path offers very little load to electricity compared to the LED in parallel.

• So, all of the current gushes through that path whenever it's available.

• As a result, the LED gets no current and goes off whenever you press the button!

• The resistor protects over-current and avoids a classical short!

NOT GATES!

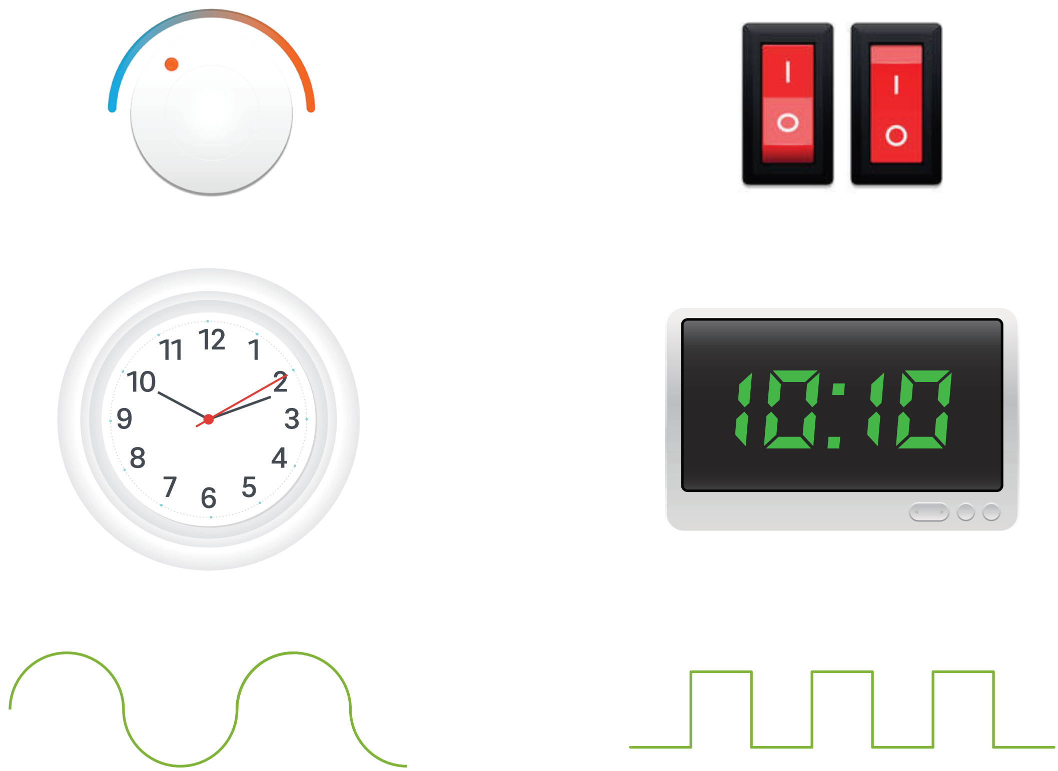
In a way you have inverted the operation of the Button, which now turns off the LED when pressed and that's why this circuit is called a "NOT" circuit!

NOT Circuits or NOT "Gates" are used internally in almost all the digital electronics we use!

T19. DIGITAL ELECTRONICS

Digital Electronics, as you would have seen in many visuals, deals with 1s & 0s i.e. ON & OFF. All inputs and outputs are either ON or OFF and nothing else in between. This is the basis of all the computing systems around us!

The opposite of digital is analog electronics where values between ON & OFF also exist. This is somewhat like controlling the speed of a fan versus just switching the bulb either on or off!



Analog

Digital

So, circuits like the doorbell, morse code, short-not etc. are digital circuits, whereas brightness under control, volume down etc. are analog circuits!

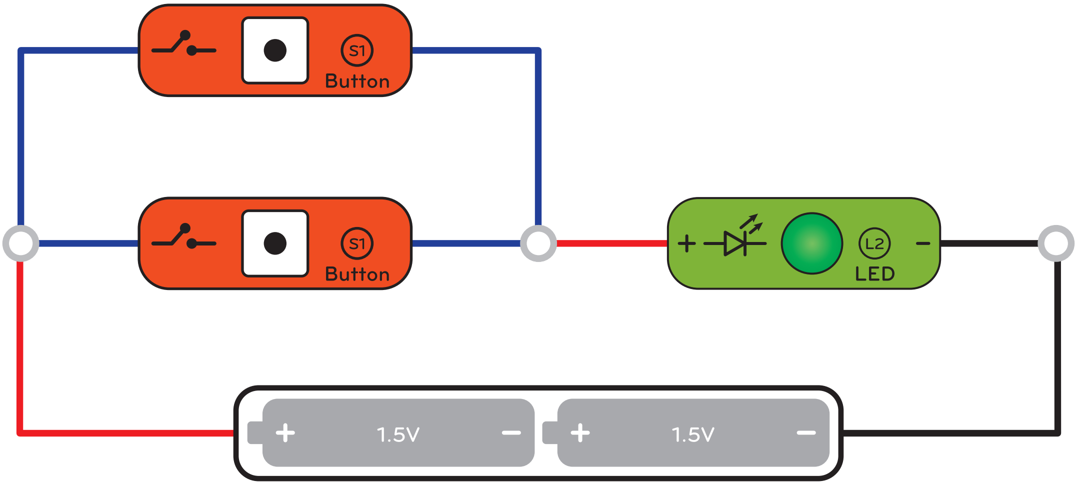
The E18 circuit was a very fundamental digital circuit called a NOT Gate which reverses the input value. So, if you press the button (input 1), the LED goes off (output 0) and vice-versa!

The entire world of digital electronics is made up of such gates which process the inputs (1s & 0s) and give a corresponding output (1s & 0s).

We will make more such digital circuits now!

E19. THIS OR THAT!

- Connect the Buttons, LED & Battery as shown.
- Now first press either of the Buttons. Then press both of the Buttons together.
- What do you observe?



Here you can see that electricity has two parallel paths to flow and the circuit can be completed by pressing either of the two buttons!

The LED will be ON (output 1) if EITHER of the Buttons is pressed (either input is 1) and so, it is called an "OR" Circuit!

Like the NOT Gate, OR Gates are also used widely in digital electronics!

WHAT "OR"?

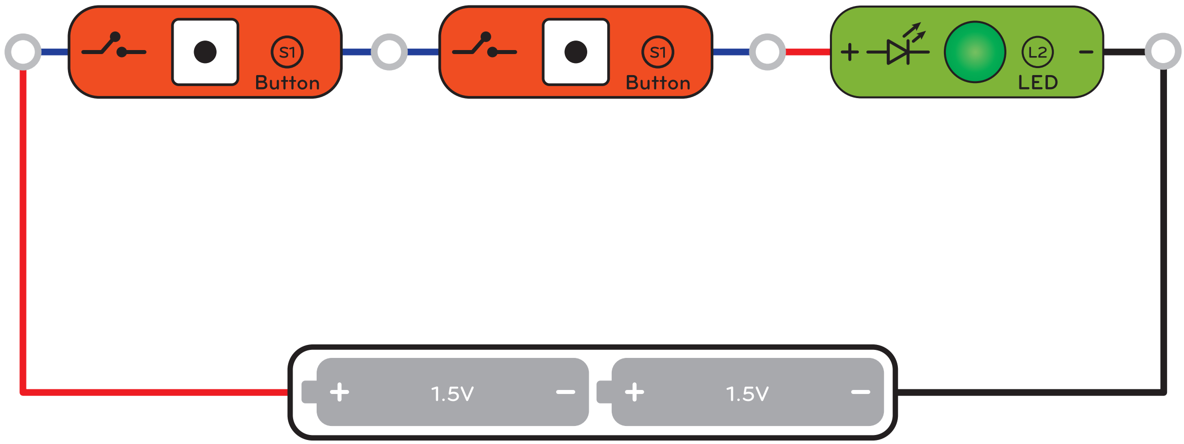
Can you think of any practical use cases of the OR Logic? Eg. unlock the phone if correct fingerprint is detected OR correct password is entered!

E20. THIS AND THAT!

• Connect the Buttons, LED & Battery as shown.

• Now first press either of the Buttons. Then press both of the Buttons together.

• What do you observe?



Here the 2 buttons are in series, this means that the circuit will be completed if and only if both of them are pressed!

So, the LED will be ON (output 1) only if BOTH the Buttons are pressed (both inputs are 1) and so, it is called an "AND" Circuit!

AND gates, like OR & NOT, are also very important in digital electronics.

WHAT "AND"?

Can you think of any practical use cases of the AND Logic? Eg. you can go to watch a movie only if both your mom AND dad agree!

T20. TRUTH TABLES

A Truth Table is used by engineers to analyse and design digital circuits. It helps in relating the output of a digital circuit to its inputs. This is especially useful when a circuit contains lots of gates, inputs & outputs.

Let's make one for the previous OR and AND circuits to understand how this works.

Fill the LED's value in E19's Truth Table. Here 1 means ON (Pressed) and 0 means OFF (Not Pressed).

Button 1	Button 2	LED
0	0	
0	1	
1	0	
1	1	

Now fill the LED's value in E20's Truth Table. Again, 1 means ON and 0 means OFF.

Button 1	Button 2	LED
0	0	
0	1	
1	0	
1	1	

This is exactly how an OR and AND Gate should behave! Truth Table gives us the relation between the input & output of the circuit, which further helps engineers in designing it.

You would have seen 110001101011 like numbers in movies and ads when people talk about computers. Does our Truth Table now look interesting?

T21. LOGIC & PROGRAMMING

The digital circuits or gates that we saw are also called Logic Gates. The reason to call them so is that they represent and enable the use of logic.

We saw simple examples of OR and AND logic previously. This logic is very important for computers as it enables them to think and take decisions. In fact, computer chips are made by a combination of millions of these logic gates!

Not only this, but also the software inside a computer, which is also called a computer program, uses logic like OR and AND to make decisions. A software engineer programs the computer to take certain decisions based on the inputs and produce a desired output.

Examples of programming logic in terms of a computer could be: type a capital letter if either the 'shift' OR 'caps lock' key has been pressed, or a challenging car racing game that lets you play the next level only if you finish the race 1st AND also complete the assigned tasks, or a website/app that allows you to login only if both your username & password match!

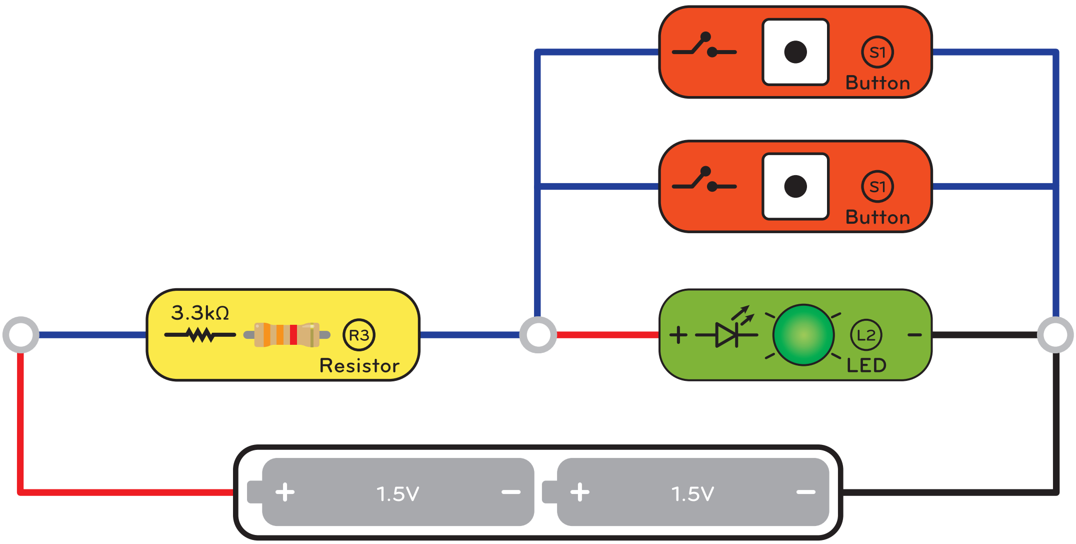
So, logic & programming are at the very core of all the computers, phones & other electronic gadgets that we see around us everyday!

SOME EXAMPLES?

Can you think of some examples of logic and programming in a computer or other digital/electronic gadgets? Hint: think in the If-Then pattern!

E21. NEITHER THIS NOR THAT!

Connect the 3.3kΩ R3 Resistor, Buttons, LED & Battery as shown, do the Button ritual and write your observations in the Truth Table below.



Button 1	Button 2	LED
0	0	
0	1	
1	0	
1	1	

NOR = NOT + OR!

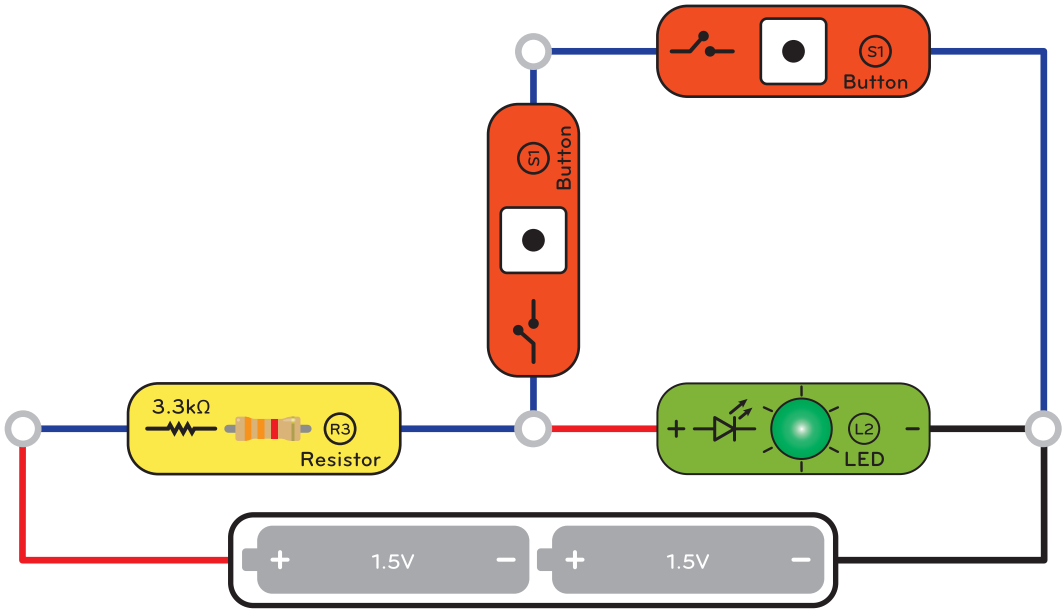
In this circuit, the LED goes OFF when EITHER of the Buttons is pressed. So this is called a "NOR" (NOT-OR) Circuit!

Interestingly, the circuit too is a combination of the NOT & OR circuits. Here, the LED gets bypassed (like the short circuit in NOT) if either of the buttons are pressed (like OR)!

You can also connect more than 2 Buttons or Switches in a similar fashion to these gate circuits, but the logic will still remain the same. Try it out!

E22. NOT THIS AND THAT!

Connect the 3.3kΩ R3 Resistor, Buttons, LED & Battery as shown, do the Button ritual and write your observations in the Truth Table below.



Button 1	Button 2	LED
0	0	
0	1	
1	0	
1	1	

NAND = NOT + AND!

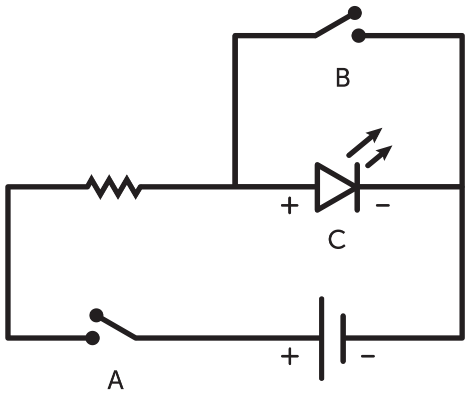
In this circuit, the LED goes OFF when BOTH the Buttons are pressed. So this is called a "NAND" (NOT-AND) Circuit!

Interestingly, the circuit too is a combination of the NOT & AND circuits. Here, the LED gets bypassed (like the short circuit in NOT) only if both the buttons are pressed (like AND)!

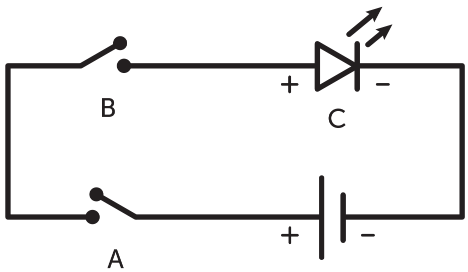
NAND & NOR Gates are the basic building blocks of all Computers. You can make all the other gates by combinations of just NOR & NAND! Therefore these gates are called Universal Gates!

TRUTH TABLE PUZZLE - 1

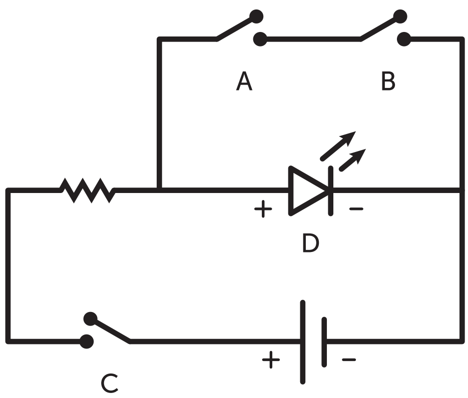
Let's try making Truth Tables for some more circuits to get a better grip of the concept.
Note: 0 means that switch is open and 1 means that switch is closed.



A	B	C
0	0	
0	1	
1	0	
1	1	



A	B	C
0	0	
0	1	
1	0	
1	1	



A	B	C	D
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

TRUTH TABLE PUZZLE - 2

Time for the reverse now! Draw the Circuit Diagrams for the Truth Tables given below.
Note: Here A,B & C represent switches in the circuit and D represents LED.

A	B	D
0	0	0
0	1	1
1	0	1
1	1	1

A	B	D
0	0	1
0	1	1
1	0	1
1	1	0

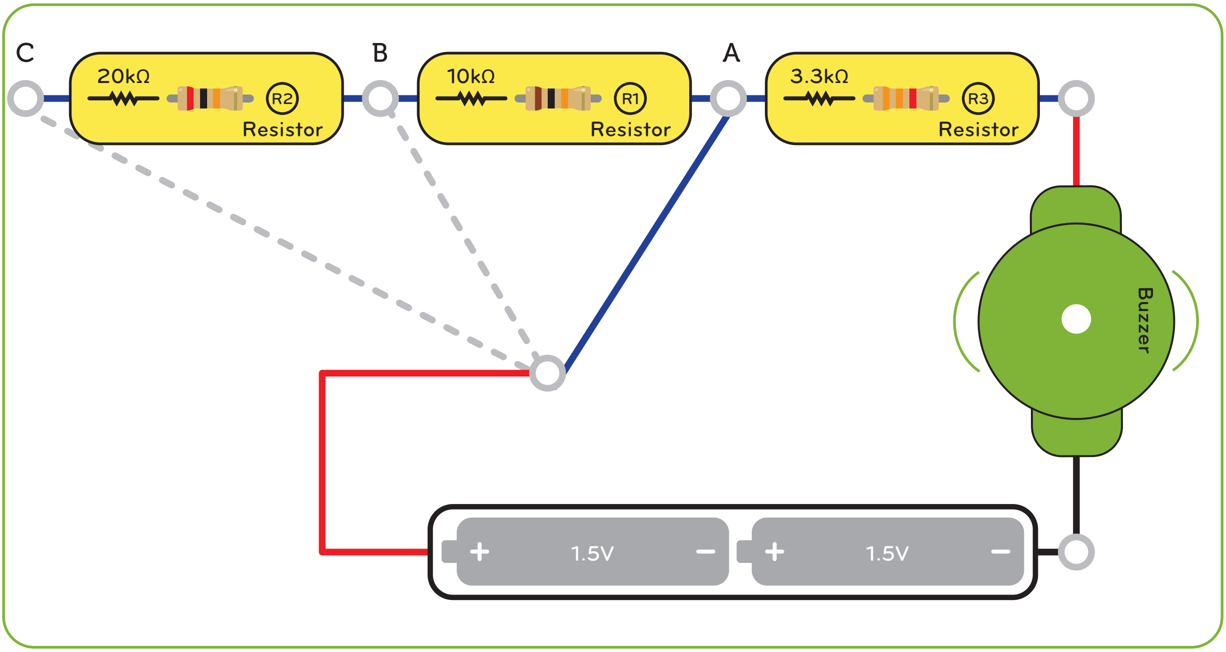
A	B	C	D
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0

E23. RESISTORS IN SERIES

• Connect the Buzzer, 3.3kΩ, 10kΩ & 20kΩ Resistors as shown.

• Now connect the Battery and Jumper Wire exactly as shown.

• Connect the Jumper Wire first to A, then B & finally C as shown.



• Did you observe that the volume of the Buzzer is decreasing constantly?

IT ALL ADDS UP!

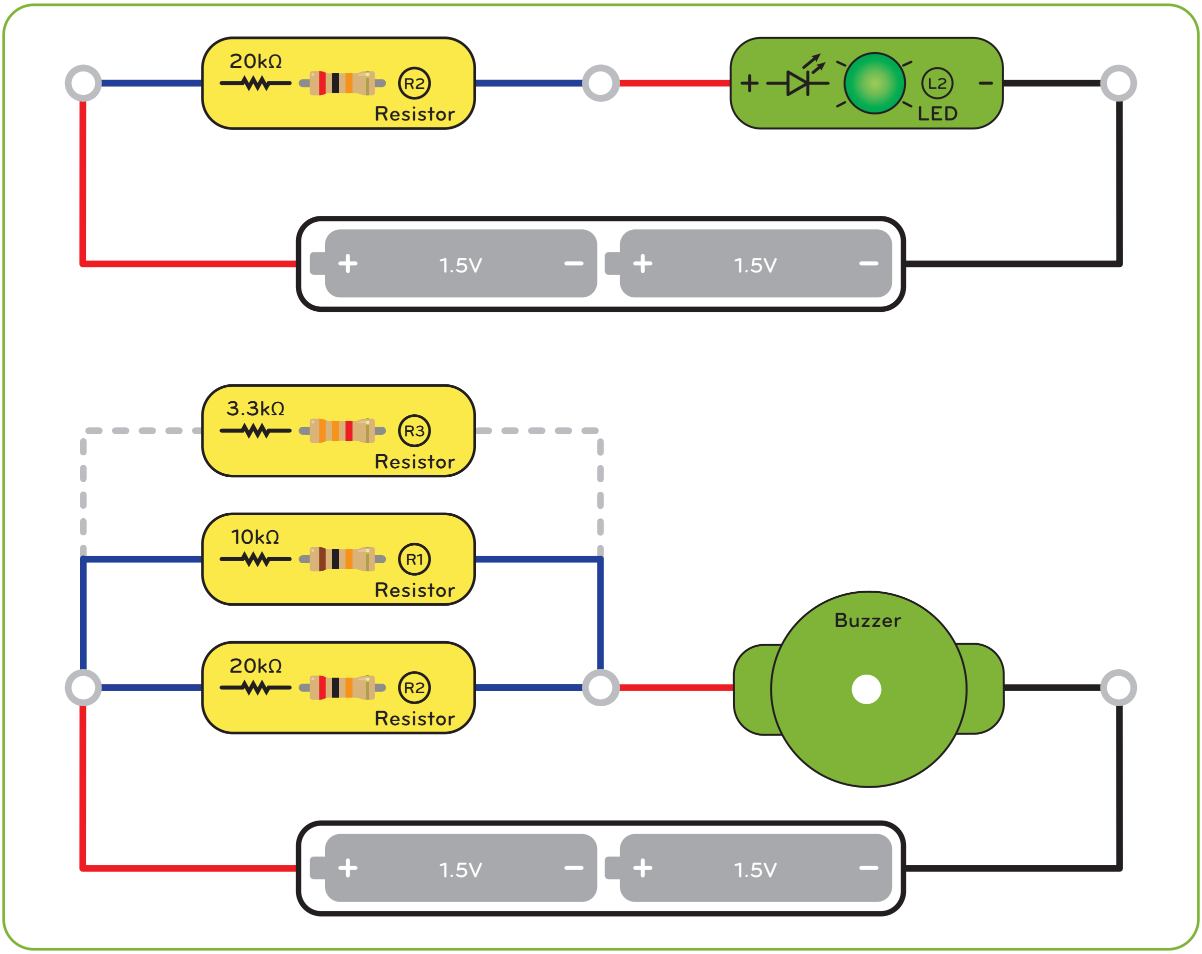
Here we are connecting the Resistors in Series. When we do this, the total resistance adds up and increases, and as the resistance is increasing, the volume of the Buzzer goes on decreasing. We'll see why this happens in the next topic, but for now, just remember that resistance adds up in series!

You can actually use the setup as a "Variable Resistance", since you can change the total Resistance in the circuit! Try changing the order of the resistors and see what happens!

E24. RESISTORS IN PARALLEL

• Connect the 20kΩ Resistor, Buzzer & Battery as shown.

• Now first connect the 10kΩ and then the 3.3kΩ Resistor in Parallel as shown.



• Did you observe that the Volume of the Buzzer is increasing constantly?

SPLIT THE BILL!

Here we are connecting the Resistors in Parallel. When we do this, the resistance gets split up and decreases. The total resistance is Lower than the Least value of Resistance!

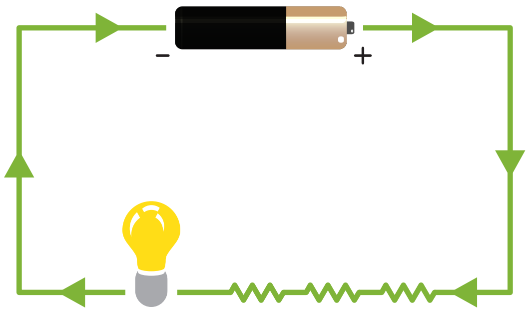
We started with 20kΩ and then added 10kΩ in parallel, so the Net Resistance became lower than 10kΩ and the Volume of the Buzzer increased! Same happened when we added 3.3kΩ. We'll see why this happens in the next topic, but for now, just remember that resistance splits up in parallel and is lower than the least value of resistance!

T22. SERIES & PARALLEL RESISTANCE

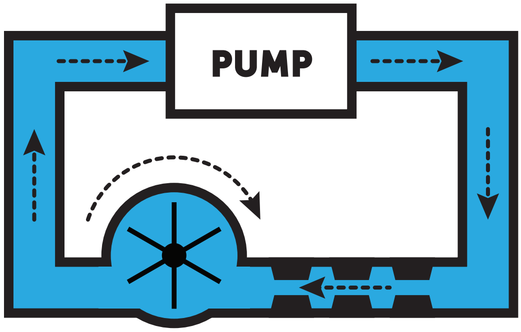
We saw that on adding resistors in series, the Buzzer volume went down got dimmer, but on adding resistors in parallel, the Buzzer volume went up . This is because the resistance adds up in series and decreases in parallel.

Let's understand from the water analogy. When you have a smooth & wide pipe and you go on adding narrower pipes in front of it, the flow rate of water (current) goes on decreasing constantly and results in a higher net resistance for the whole system.

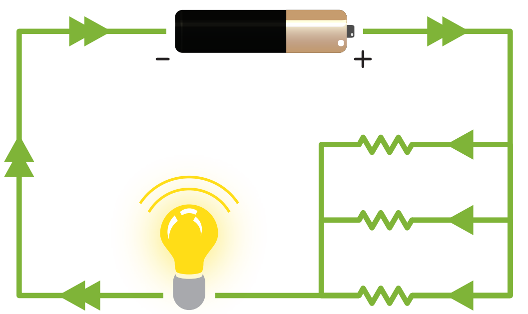
When we connect resistors in parallel, though the additional resistor blocks the flow of current, it also gives a new path for current to flow. As a result more current passes through the circuit and the net resistance goes down!



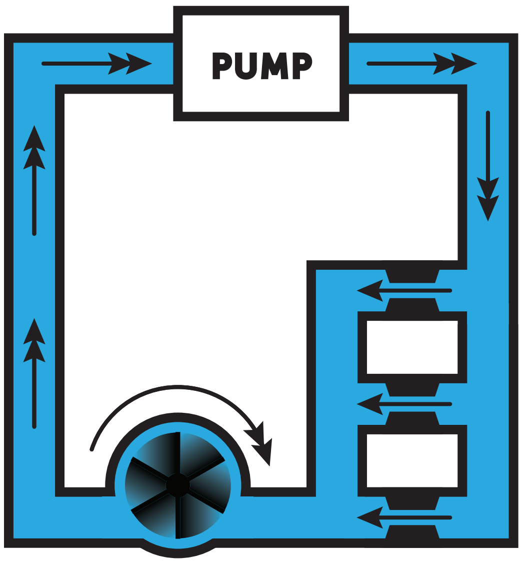
R adds up, current decreases



R adds up, flow decreases



R sp lits up, current increases



R splits up, more water can flow

The total resistance of a series circuit will be the sum of all series resistances.
Thus, in the E23 circuit, total resistance would be:

$$R = R1 + R2 + R3 = 3{\cdot}3\ k\Omega + 10\ k\Omega + 20\ k\Omega \Rightarrow R = 33{\cdot}3\ k\Omega$$

So, connecting these 3 resistors in series is equivalent to connecting a 33.3 kΩ resistor!

For parallel circuits, the resistance gets divided and the net resistance is lower than the lowest resistance in the circuit! So, in the E24 circuit, total resistance R would be given as:

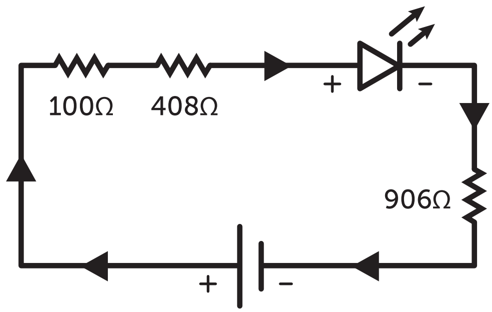
$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} = \frac{1}{3.3\ k\Omega} + \frac{1}{10\ k\Omega} + \frac{1}{20\ k\Omega} \Rightarrow R = 2.2\ k\Omega$$

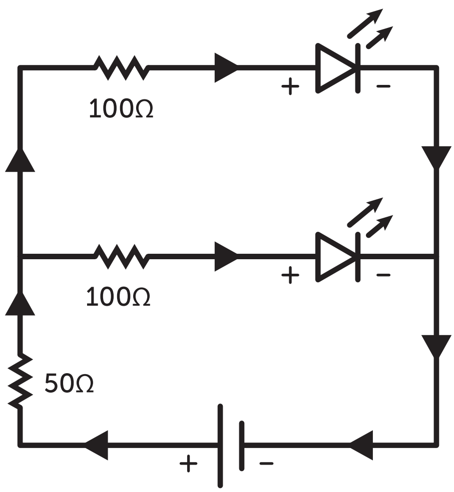
So, connecting these 3 resistors in parallel is equivalent to connecting a 2.2 kΩ resistor!

In general, if we connect two same valued resistors in parallel, the net resistance would be half their value! For other cases, use the above formula!

CIRCUIT RESISTANCE PUZZLE!

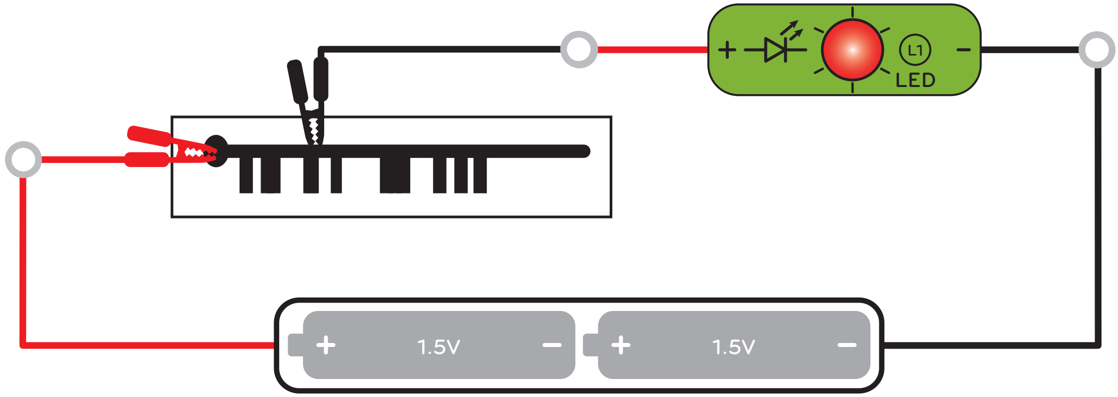
Let's see if you grasped the above concept or not. Calculate the total R for the circuits below:

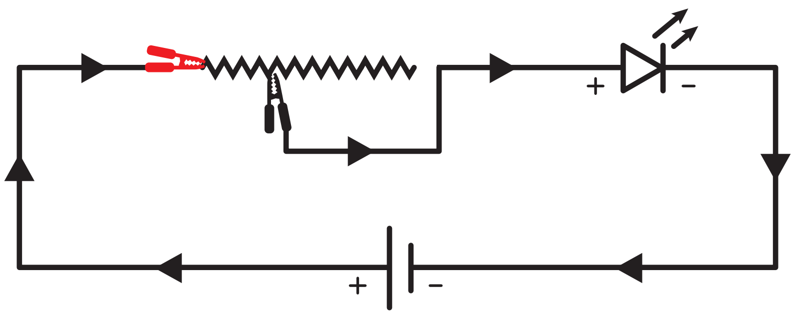




E25. SLIDER DISCO LIGHTS!

- Connect the Clip Wire, LED & Battery as shown.
- Draw a long, thick & dark line with a pencil on paper.
- Keep the red clip fixed at an end & slide the black one away from it as shown.
- Do you see the LED dimming down?



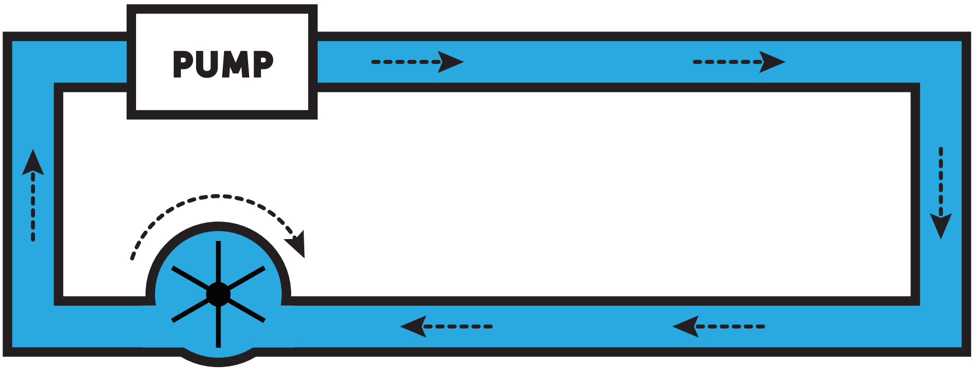


- Did you also observe that the brightness is more when the clips are near to each other and less when they are far apart?
- This is because, when you slide the clips on the pencil stroke's graphite (ok-ish conductor!), you are varying the resistance that is connected in series with the LED!

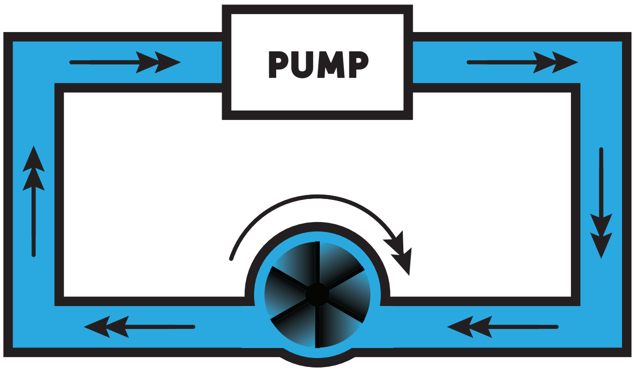
T23. RESISTANCE DEPENDS ON AREA & LENGTH

In the previous experiment, we saw that as the length of the pencil line was changing, the brightness of the LED was also changing and this was due to a change in resistance.

Previously, we learnt that low resistance is like a wide pipe. But resistance does not only depend on its cross-sectional area of a conductor but also depends on its length!



long pipe makes it difficult to pump water, so the flow rate goes down



short pipe makes it easy to pump water,
so the flow rate is maintained

Consider this, if the pipe is wide enough but is very long then, even if we pump water with a lot of pressure (voltage), the flow rate (current) of the water will not be high since it is very long and water will take more time to flow through it.

So, length of the pipe acts as a resistance and the higher the length, the higher the resistance!

As a mathematical formula, $R = \rho \times L/A$

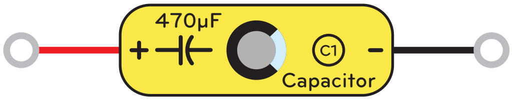
Where ρ (rho) is the resistivity of the material and varies with each type of material, L is the length of the conductor and A is the cross-sectional area of the conductor.

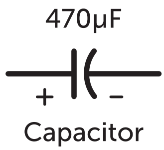
T24. CAPACITORS

Capacitors are again one of the very fundamental electronic components. They are found in almost all electronic circuits and have a crucial role to play. You definitely would have seen them on circuit boards, inside fans, motors etc.

Capacitors are like small & temporary electric storage tanks! When supplied with electricity, they store it inside them temporarily and provide it back to the circuit when electricity is cut-off.

This feature has many applications, for example, storing & releasing the high electricity required in camera flashes, providing sufficient electricity to motors & fans on starting etc.





Capacitors come in various shapes, sizes & types!

A capacitor and its circuit symbol looks as shown above.

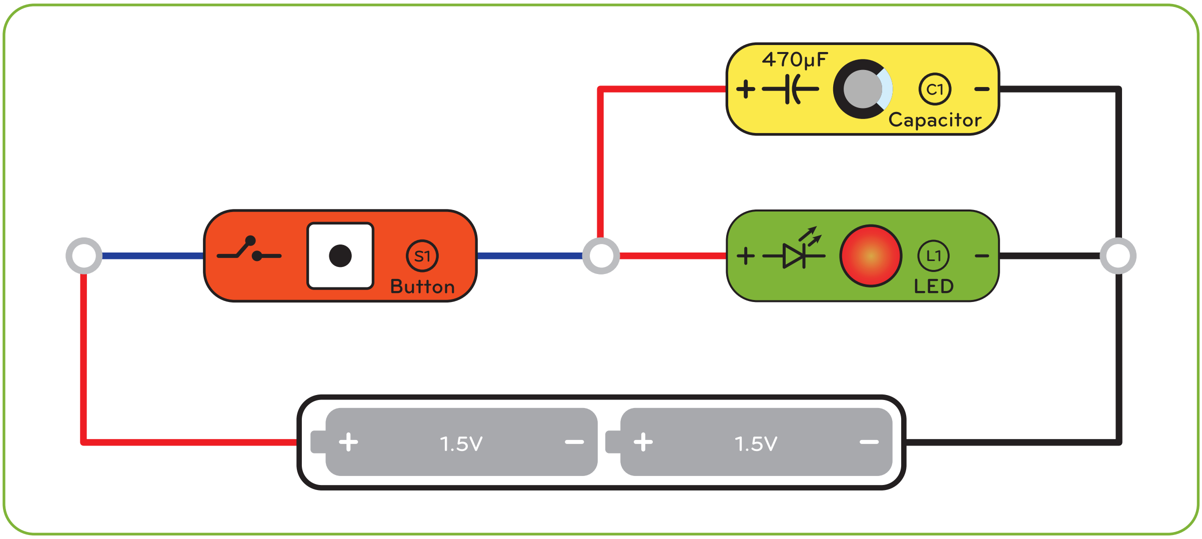
As you can read on its body and label, the value of this capacitor is 470µF (micro Farad). Farad is the unit of capacitance (after the scientist Michael Faraday).

We will learn about capacitors next and make some cool circuits using them!

E26. ON & FAAAAAAAAADE!

• Connect the Button, Capacitor, LED & Battery as shown.

• Mind the polarity of the Capacitor and connect EXACTLY as shown!



• Now press the Button for some time and then release it.

• Did you see something cool? The lights didn't go off instantly but instead they slowly faded!

All thanks to the Capacitor for this!

• When you press the button, not only does the LED glow but it also charges the capacitor connected in parallel.

• On releasing, the battery gets cut off but the capacitor discharges slowly and provides electricity to the LED for some time!

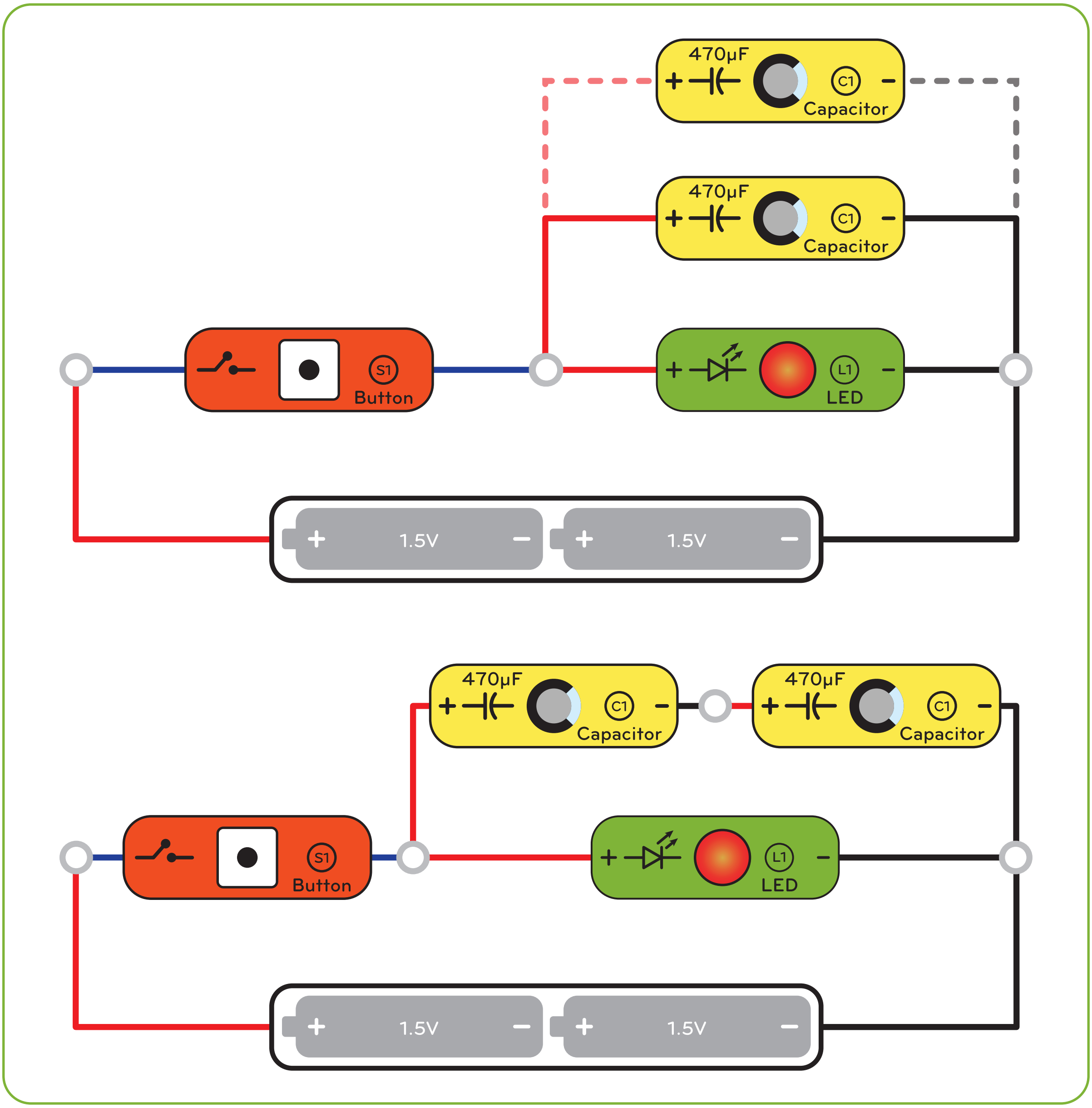
• Also try out this circuit with a Buzzer in place of the LED for some fun!

CAPACITOR INSIDE!

You would have seen such fading LEDs many times when you turn off your TV, mobile charger, LED lights etc. You guessed it right. This is because the mighty Capacitor is used in the circuits of all these gadgets!

E27. CAPACITANCE IN SERIES & PARALLEL

- Connect the same circuit as E26. Press & release the Button and observe the LED carefully.
- Then connect one more Capacitor in parallel as shown. Press & release the button.
- Now connect the Capacitor in series as shown. Press & release the button.
- Did you observe the LED take more time to fade in the parallel circuit than the series circuit?



This is because the rules for Capacitors are opposite to that of the Resistors!
Capacitance gets added in Parallel & divided in Series!

The total capacitance of a circuit can be calculated by the following formulae:

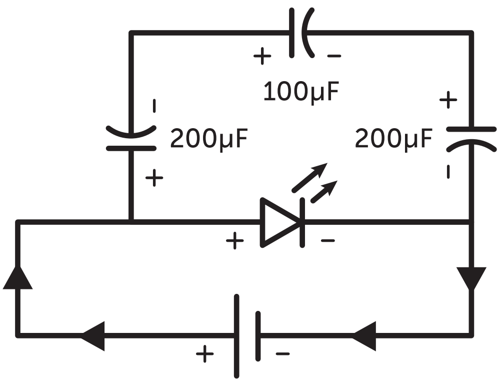
In series, net capacitance C: $\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} + \ldots$

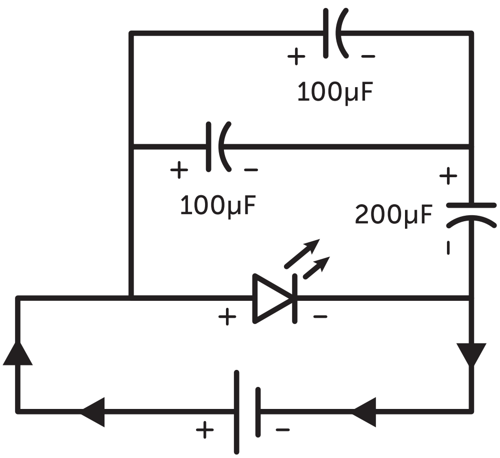
In parallel, net capacitance C: $C = C1 + C2 + C3 + \ldots$

So, the total capacitance of the parallel circuit was more than that of the series circuit, and hence the LED took more time to fade there!

CIRCUIT CAPACITANCE PUZZLE!

Let's see if you grasped the above concept or not. Calculate the total C for the circuits below:

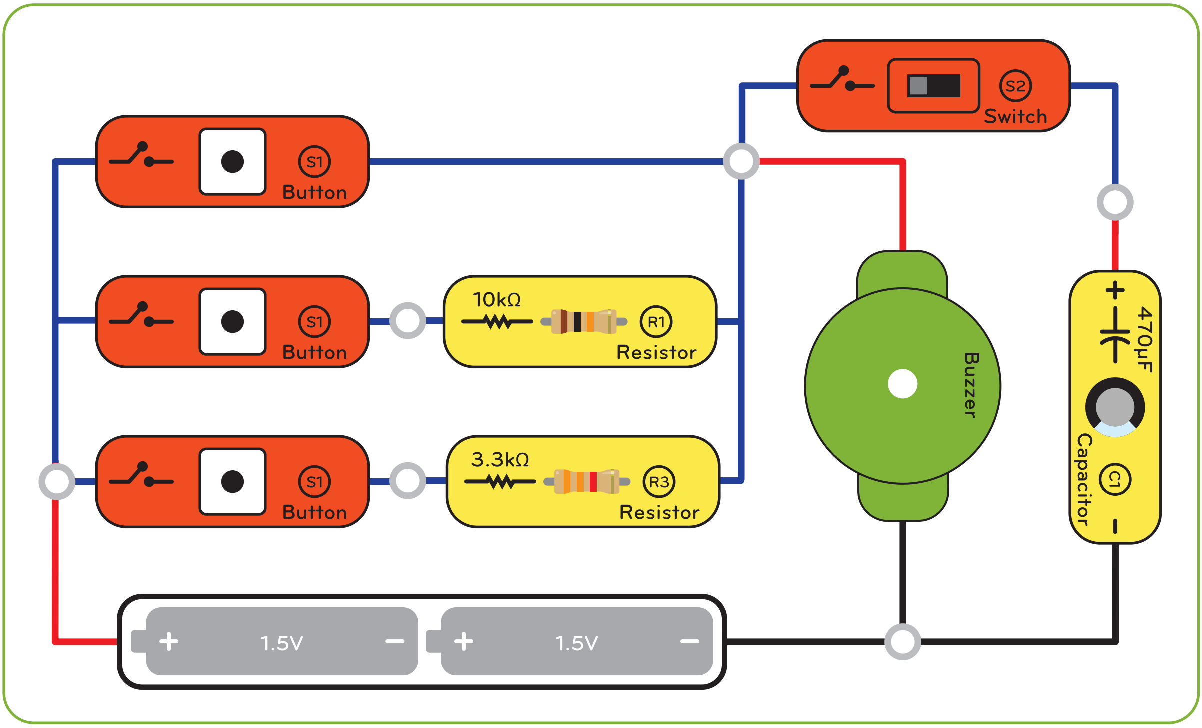




E28. SOUND EFFECTS

• Connect Buttons, Resistors, Switch, Capacitor, Buzzer & Battery as shown.

• Keep the Switch OFF and tap the Buttons. Hear your piano play?



• Now time for the twist! Turn the Switch ON and then press the Buttons. You can now get the cool fading effect on all the keys!

• We combined the Capacitor's fading property with the Resistor's volume property here!

• Could you figure out the Series & Parallel parts in the circuit?

• Cool isn't it! Try different combinations and tricks you learnt from previous circuits. How about a water piano! Or a variable volume piano!

ELECTRONIC MUSIC!

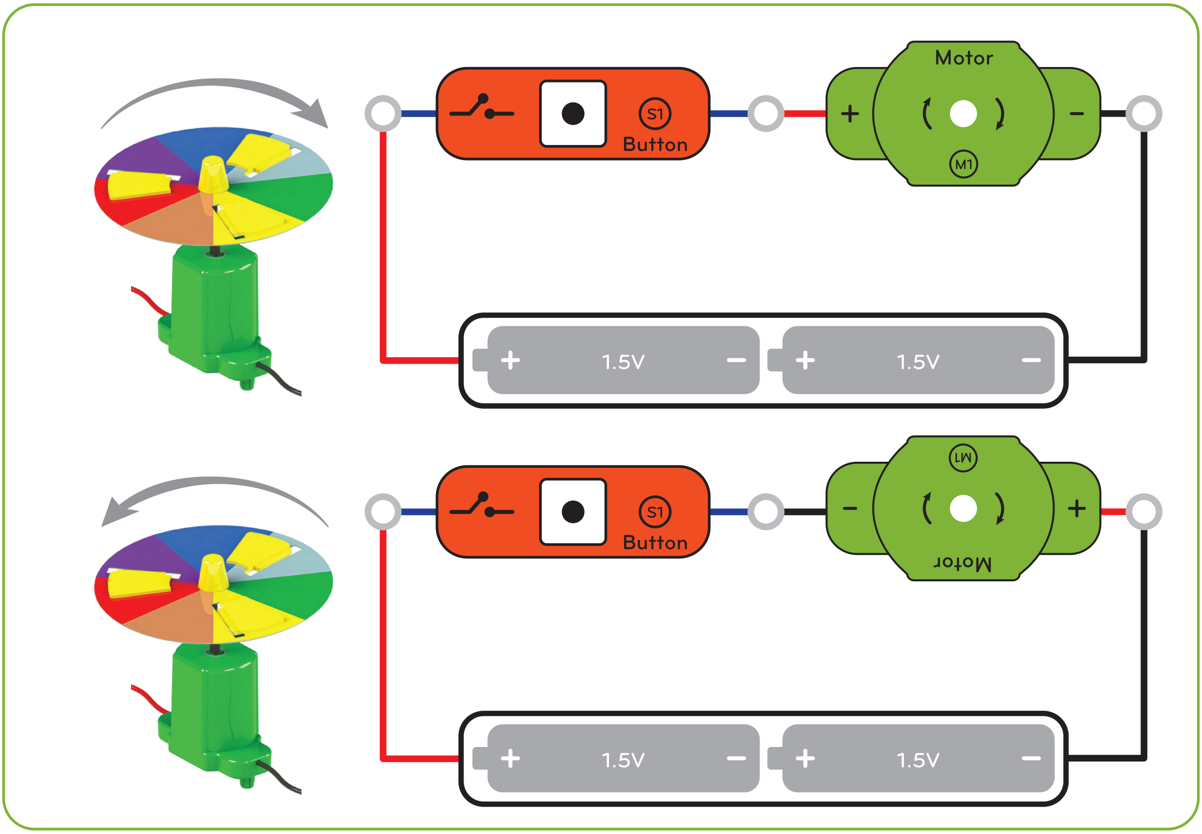
Music and electronics have been deeply related since many years right from the classical 8-bit video game music to the latest home theatres. Today almost all of the music is digitally created, modified, recorded & distributed!

E29. THE MIGHTY MOTOR

• Connect the Button, Motor & Battery as shown.

• Mount the wheel given in the kit on the Motor.

• Press the Button and see the motor spin!



• Noticed that the Motor also has polarity? What happens if we flip the Motor?

• Connect the Motor in reverse and press the Button.

• The Motor still works but now spins Anti-Clockwise!

KEEP SPINNING!

Observed that the Motor keeps on spinning for some time even after you release the Button?

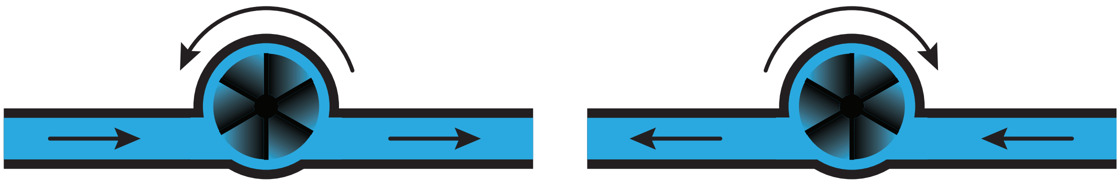
You'd have seen a similar situation with a fan. This is due to "Inertia". The Motor already has some energy while spinning and when you power it off, it keeps spinning with that energy!

T25. HOW MOTORS WORK

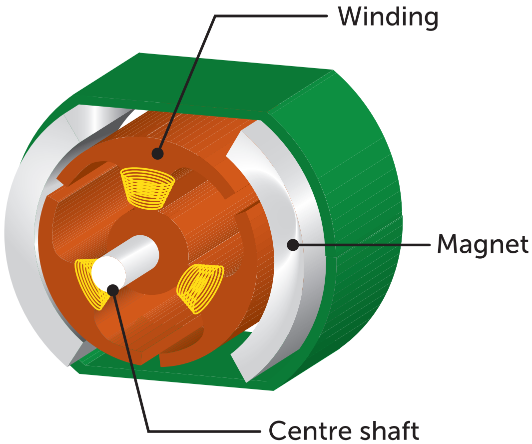
Motors convert Electrical Energy into Mechanical Energy.

Interestingly, Motors work with the help of Magnets and by the principle of Electromagnetism! When we apply electric current to the Motor, a "Magnetic Field" is produced by the current. This field interacts with the magnetic field of motor's magnets and creates a rotational motion!

Since motors are polar, applying voltage in one direction makes them spin clockwise while in the other direction, they spin anti-clockwise. But unlike the LEDs, they do work in both directions.



motor rotates as per the direction of current,
like a water wheel rotates as per the water flow



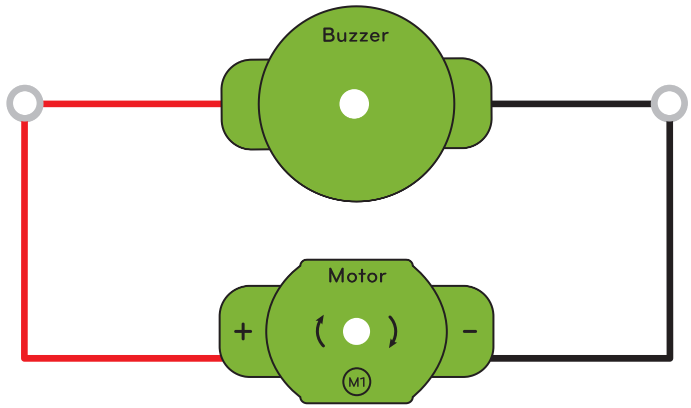
This is similar to the Water Wheel analogy. When water flows through the pipes and hits the water wheel, it forces the wheel to move!

Also, more the pressure of the water, more will be the speed of the water wheel. Thus, applying more voltage to the Motor will increase its speed. But too much can also damage it!

In a way, we can say that motors transform the electrical energy into mechanical energy just like the water wheel transforms the mechanical energy of the flowing water into the mechanical energy of the rotation!

E30. THE DYNAMO

- Connect the Motor & Buzzer as shown.
- Mind the polarity!
- Now spin the motor Clockwise using your fingers. Do it with as much force as you can.



- Did you hear the Buzzer beep?
- Congratulations, you just made a dynamo!

MOTOR OR DYNAMO?

Dynamos are made in the same way as motors but work opposite. They convert mechanical energy into electrical. Dynamos, are used in almost all power plants to convert mechanical energy to electricity, but they are generally referred as "Turbines".

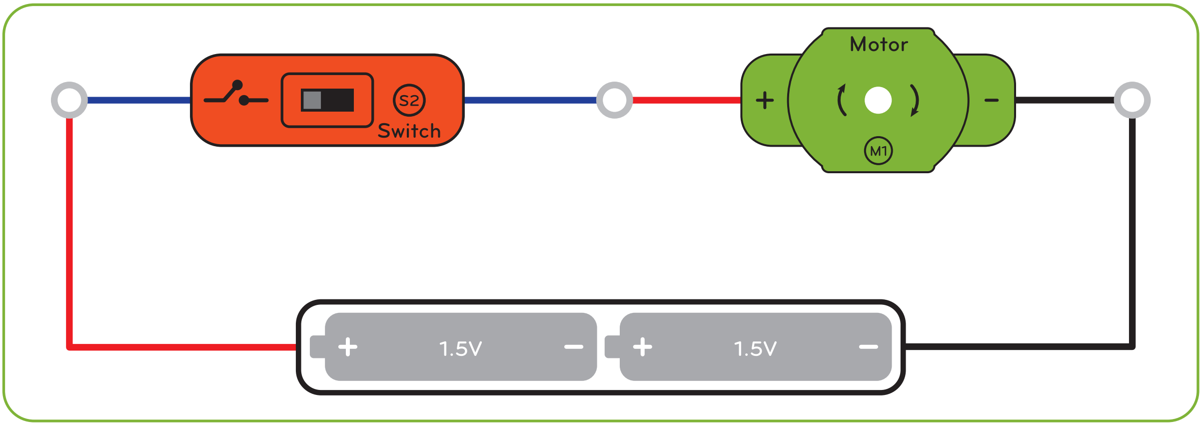
As we saw in T9 & 10, Thermal power plants use turbines to convert the energy of steam, Hydel power plants use them to convert the energy of water flow and Windmills use them to convert the energy of wind, into electricity! You'd also have seen small dynamos in bicycles!

Think about this - if you spin the water wheel, will it not start pumping water?

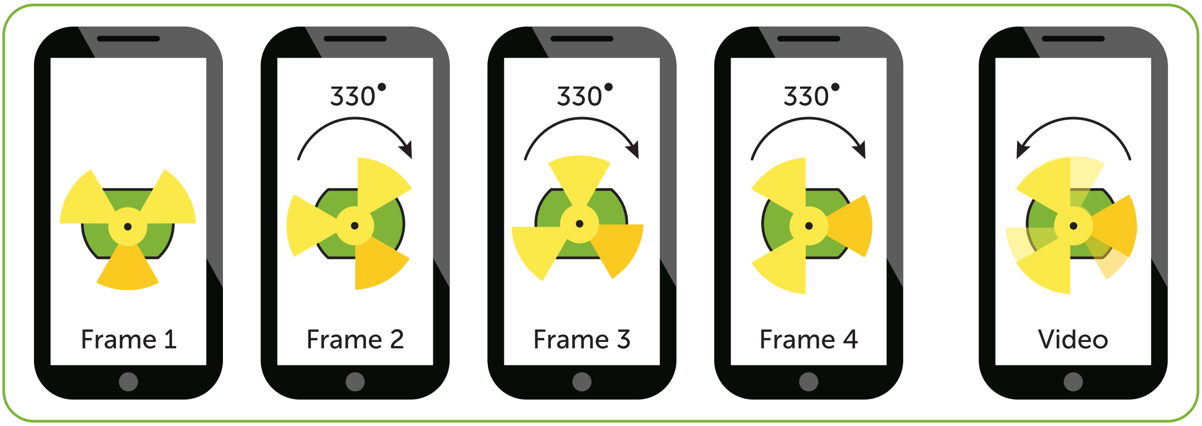
Noticed the polarity? The polarity of the motor is such that it acts as a battery here just like we did with the buzzer in the case of piezo-electricity!

E31. STROBOSCOPIC EFFECT

- Connect the Switch, Motor and Battery as shown.
- Mount the wheel given in the kit on the Motor, without the rainbow disc.
- Switch the Motor ON. The wheel will start spinning and you will see it spinning clockwise.



- View it from your phone's camera and turn the Motor OFF. Does it appear to spin in reverse?
- This is due to "Stroboscopic Effect". You would have seen this effect many times on TV and in movies where the wheels of a car that is moving forward, seem to move in reverse!
- It happens because the speed of the wheels, and that of the camera capture are different.
- For eg. the camera's speed could be such, that when it tries to capture the next "frame" of the video, the wheel gets rotated by 330°, which is 30° less than 1 full clockwise rotation.



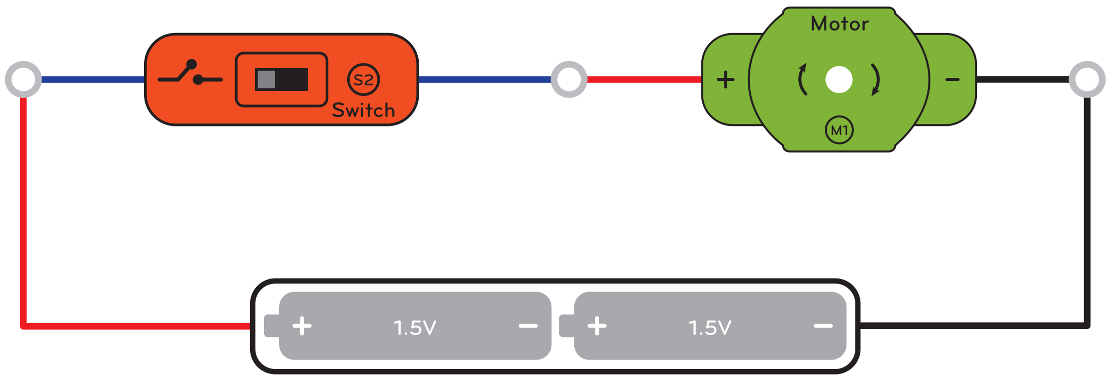
- But when we see these frames together as a video, it feels like the wheel is rotating in reverse!

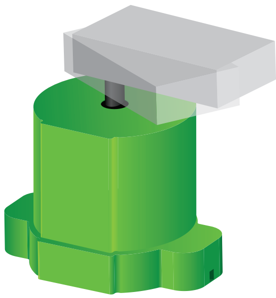
E32. THE VIBRATOR

• Connect the same circuit as E31.

• Instead of the wheel, mount an eraser on the motor shaft as shown.

• Now Switch ON the motor.





Mount the eraser on the motor shaft as shown
It should be slightly off centered,
with one side longer than the other

• Can you feel the vibrations?

• This is because we are applying an “Unbalanced Force” on the Motor shaft.

• When you put the eraser on the motor shaft, this increased the weight only on one side of the Motor which created this unstable force and vibration.

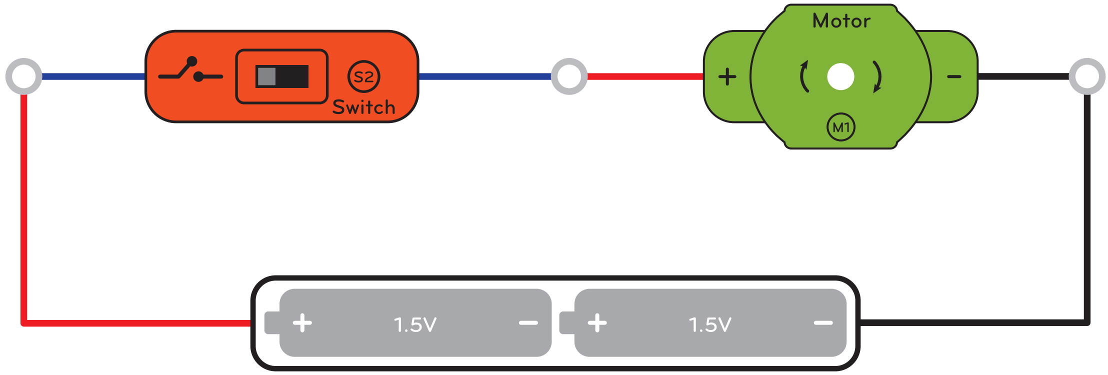
• That’s why a fan has 3 same sized blades for stability where as the tiny phone vibrator motors use a weight only on one side of the shaft like we did, in order to produce vibrations!

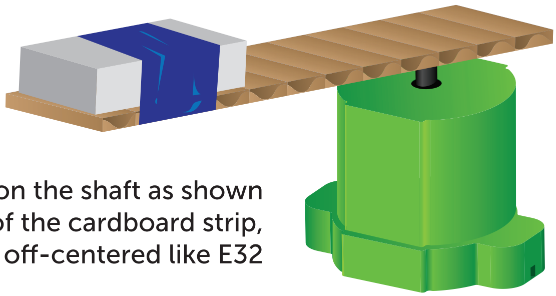
E33. SUPER VIBRATOR EARTHQUAKE!

• Connect the same circuit as E32.

• Take a cardboard strip and tape an eraser on to it as shown.

• Mount it on the Motor & Switch ON.





Mount the eraser and cardboard on the shaft as shown
The eraser should be at the end of the cardboard strip,
and the strip should be off-centered like E32

• Do you feel more extreme vibrations than before!

• This is because, using this arrangement of the strip & eraser, we have increased the “Torque”!

WHAT IS TORQUE?

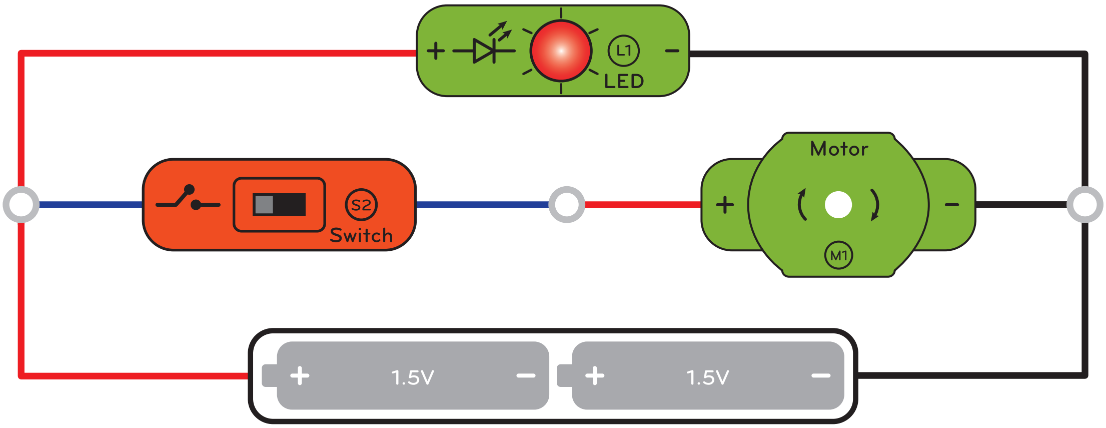
Torque is a kind of rotational force that causes an object to rotate about an axis.

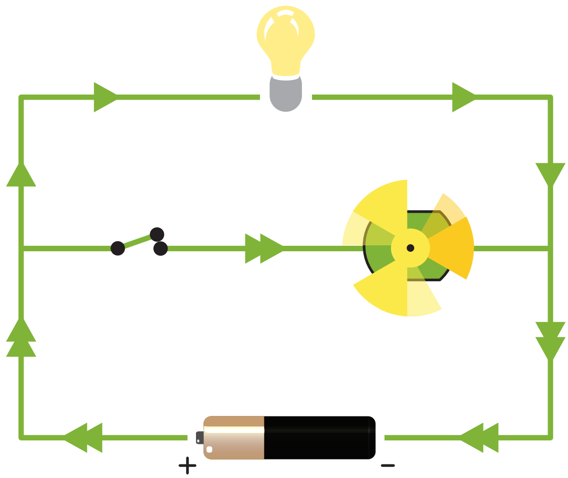
The longer the distance from the centre of a rotating shaft, more will be the torque. Have you felt that pulling a door from the handle is easier compared to pulling it from near the hinge?

Here we have increased the torque on the motor by increasing the distance of the eraser from the Motor shaft by using a long cardboard strip!

E34. BIG BULLY THE SMALL!

- Connect the LED, Switch, Motor and Battery as shown.
- Now turn the Switch ON.



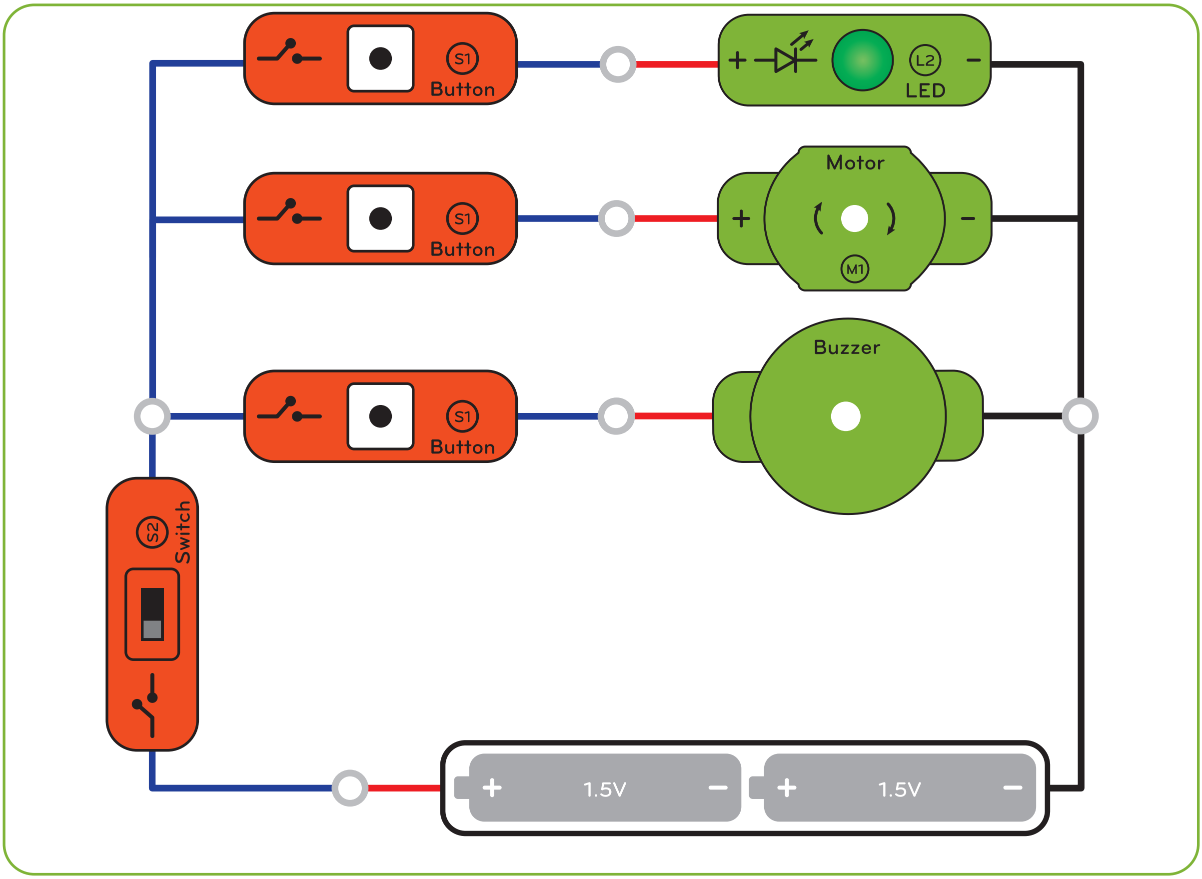


As the motor draws more current on starting up, the LED connected in parallel gets less current

- Did you notice that the LED got dimmed for a while when you switched the Motor ON?
- This happened because the Motor needs lot of current to start. So when it tries to draw this high current from the Battery, the LED, being connected in Parallel, gets less current and goes dim!
- You would have seen the exact same thing happen in your home when you turn on a heavy appliance such as washing machine, fridge, AC, oven etc.

E35. FUSE

- Connect the Switch, Buttons, LED, Motor, Buzzer & Battery as shown.
- Try turning ON the components one by one or together, first when the Switch is OFF and then when its ON.



- The Switch here, is like the main switch or fuse which is connected in series to all the other three components, which are internally connected in parallel.
- So, all the components can function independently but only if the main switch or fuse is connected, similar to what happens in our homes!
- In reality, fuse protects our home from electric surges. If too much current passes from the fuse, it breaks and thus disconnects all the other appliances!

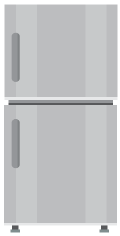
T26. MORE POWER TO YOU!

You might be wondering that we have discussed about voltage, current, resistance, energy etc. but what about the very common electrical term - power? Well, more power to you now!

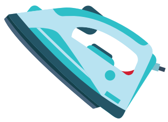
Power is simply defined as the rate of energy per unit time. This means that if more energy is consumed per second, we call it high power & if less energy is consumed, we call it low power.

The unit of power is Watt (W), which is generally written on many electrical appliances, just like the voltage and current are. Generally, small gadgets have a low power rating whereas the heavier appliances have a high power rating.

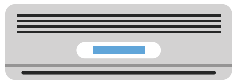
Light Bulb
5-50W



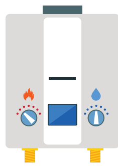
Refrigerator
100-500W



Electric Iron
700-800W



Air Conditioner
1-2kW



Geyser
1-3kW

The formula for electric power is given as Power (P) = Voltage (V) x Current (I)
This means that if a device is running at 5V and drawing 1A current, its power rating is 5W.

So, an appliance with a higher power rating will draw more current, just like you noted in E34 or what you observe when switching on a geyser or AC at your home. Eg. a 3kW geyser would draw about 13A current at a standard AC voltage of 230V, which is a very high current!

POWER PUZZLE!

1. If an Air Conditioner runs at 200V & draws 5A current, how much power does it consume?

____

____

2. If an Electric Iron rated at 600W runs at 200V, then how much current does it draw?

____

____

KNOW YOUR ELECTRICITY BILL!

Electrical energy consumed is measured in kilowatt-hour (kWh) and 1 Unit of your electricity bill equals 1 kWh. This means that if you use a 1000W A/C for 5 hours, you use about 5kWh or 5 units of electricity and these 5 units get added to your electricity bill!

Check your bill to find out the number of units consumed and compare it with your friends!

So, now it must be clear how the power rating of electrical appliances & the time for which we use them have an impact on our electricity bills. Therefore, "Star Ratings" are given to appliances to indicate their efficiency & that's why people prefer a 4-5 star appliance versus a 1-2 star one!

Energy bill puzzle!

Calculate the missing numbers & John Calculate his electricity

Appliance (Illustrations)	Operating Voltage (V)	Power Rating of the appliance (W)	Power Ratings in (kW) = (W / 1000)	Run Time Hours (H)	Power Consumed kWh = (kW * H)
Tube Light	230 V	40	0.04	8	0.32
Ceiling Fan	230 V	80	0.08		0.8
40" Television	230 V	260	0.26	4	
Geyser	230 V	3000	3		6
Air Condition	230 V	2000	2	6	

Total power consumed (kwh) - ____________

No. Of electricity units consumed - ____________

Electricity charges for 1 unit - 4 rs.

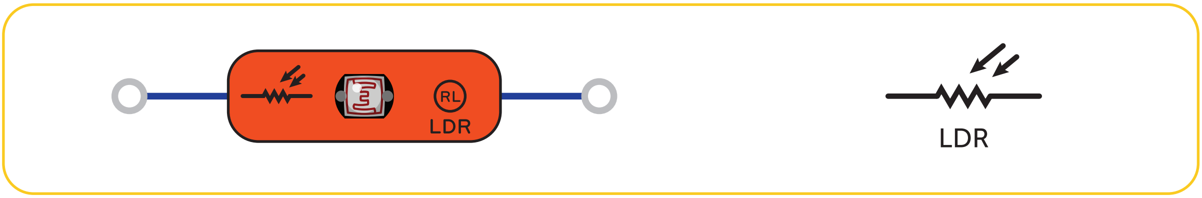
Total electricity bill for a day - ____________

The actual electricity bill that we get may have additional charges for Transmission of electricity and taxes etc. So go ahead and calculate electricity bill of your own house.

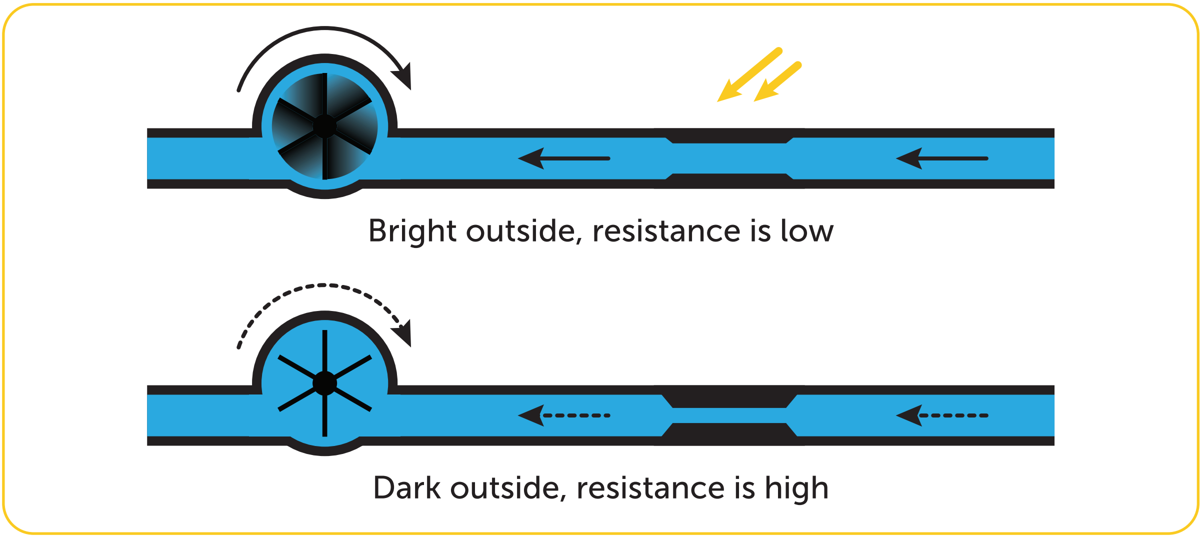
The above puzzle shows how small devices like bulbs can contribute significantly to our total energy consumption. LED bulbs are a great example of this. A 15W LED bulb can give the same brightness as that of a traditional 100W filament bulb, thus saving about 85W per bulb. This might not seem a lot, but think about what happens when millions of people start using LED bulbs, keeping them on for many hours a day. What a great amount of energy is saved!

LDR stands for Light Dependent Resistor. As the name suggests, it's a resistor whose resistance changes with light!

LDR's circuit symbol is shown below, which indicates a resistor whose value depends on light.



If more light falls on it, the resistance goes down and if it's dark around, the resistance goes up! Imagine as if there's a pipe which becomes narrow when it's dark, thus obstructing the flow of water, on the other hand becoming wider when it's bright!



Thus LDRs are used widely as light sensors in places that require action to be taken depending on the lighting conditions.

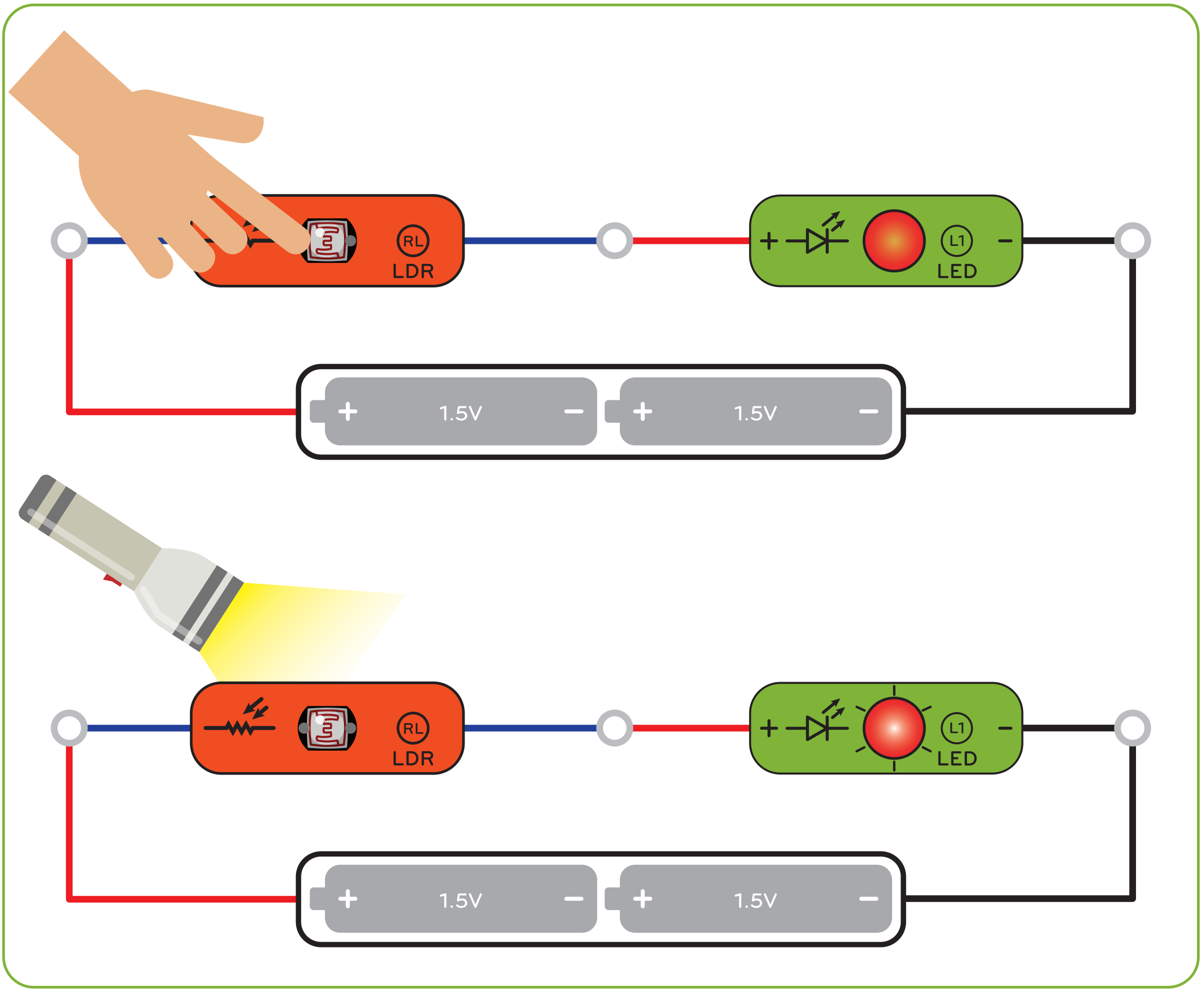
Some example applications are: automated street lights which turn on when it's dark, automated car headlights, mobile phone's light sensor which changes the brightness & contrast of the screen when you're out in the sun!

We will be making some really cool projects using LDRs!

E36. LIGHT CONTROLS LIGHT!

- Make sure that you are in a well lit up place. Avoid a dark room for this project.

- Connect the LDR, LED & Battery as shown.



- Now slowly bring your hand closer to the LDR. Whoa! the LED goes dim!

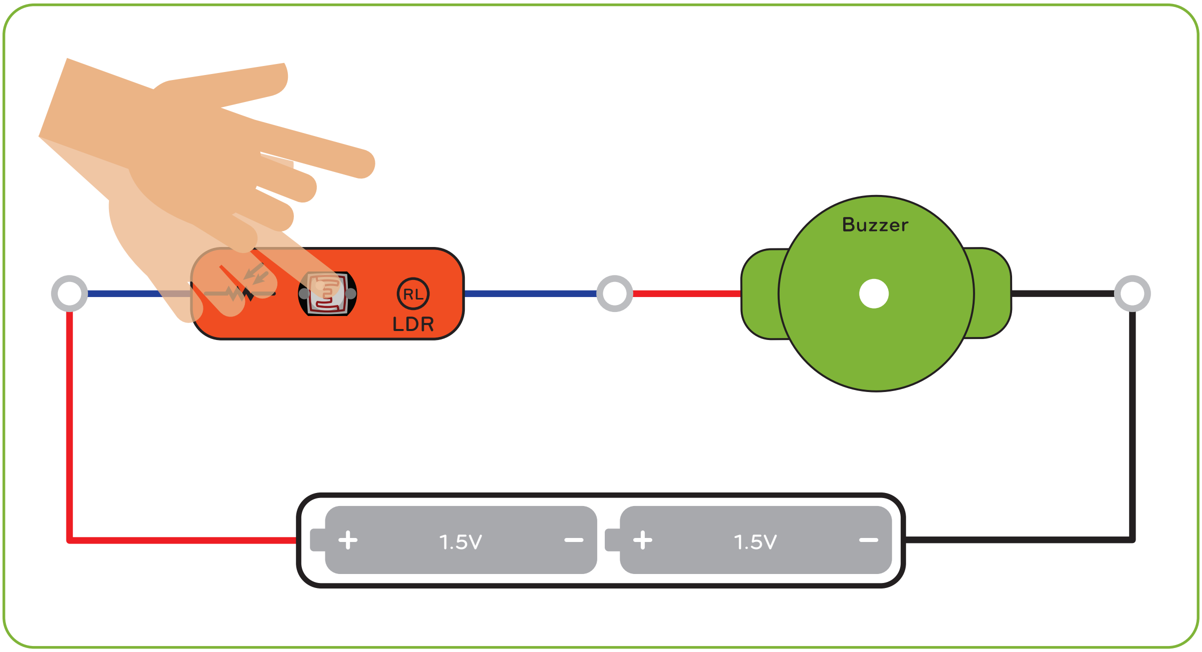
- Throw some light, by a torch or phone's flash, on the LDR. The LED goes bright!

- You can also try switching your room's lights on and off!

- This awesome phenomenon happened because of the LDR! Here the LDR and LED are connected in series. When LDR is in the dark, its resistance increases and so the LED gets dim, but when light falls on the LDR, its resistance decereases and the LED brightens up!

E37. LIGHT THEREMIN

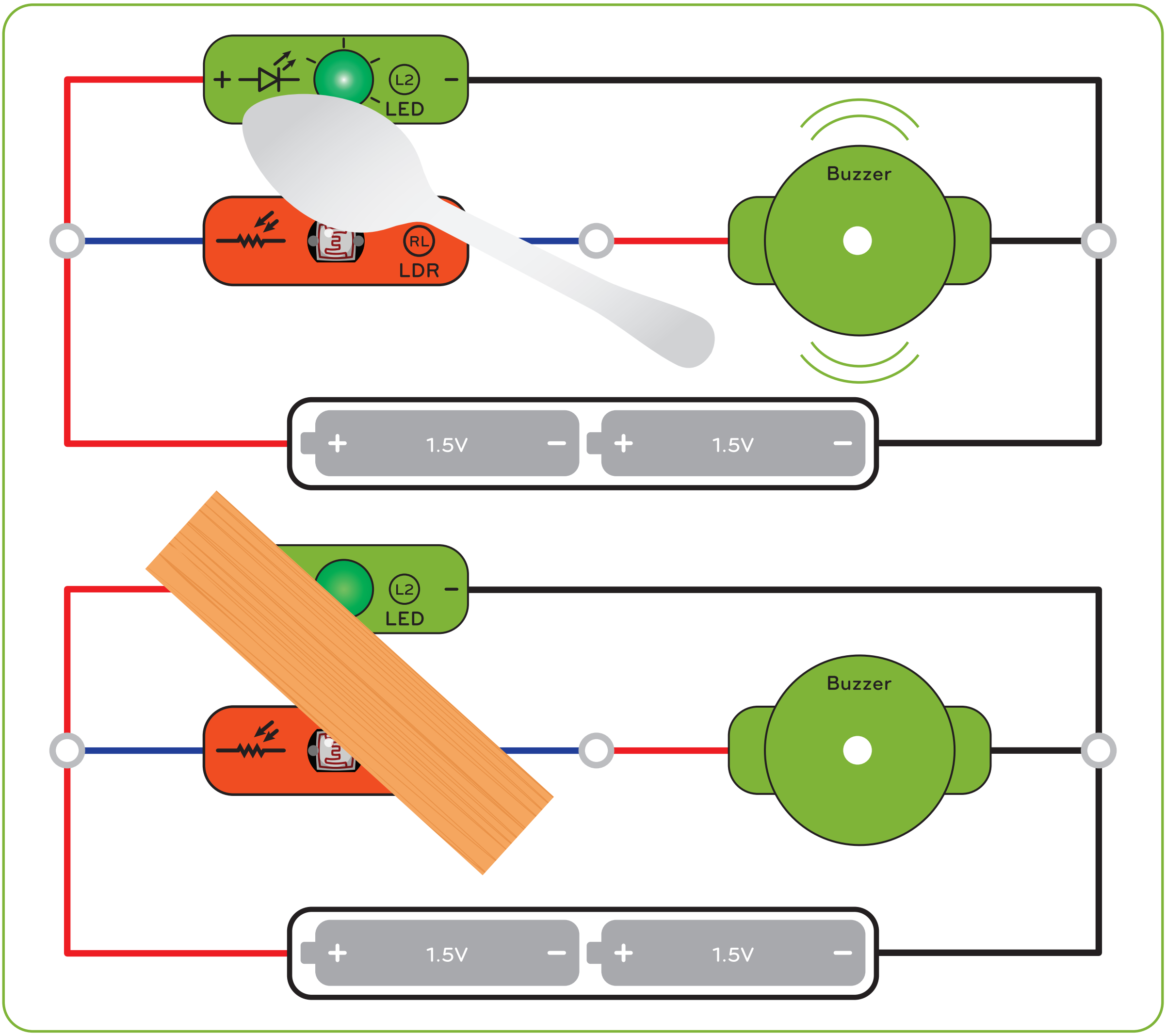
- Make sure that you are in a well lit up place. Avoid a dark room for this project.
- Connect the LDR, Buzzer & Battery as shown.
- Now try to block the light falling on the LDR by moving your hand near to it. Then move your hand away from the LDR. Hear the volume change?



- Move your hand from one side of the LDR to the other very fast and also go on changing the distance from the LDR as shown. Do you hear crazy sounds?
- Theremin is exactly such an instrument that's played by waving hands in the air! You just made your own Light Theremin!
- Go on maestro, create your own new tunes and ways of playing this instrument!

E38. REFLECTION DETECTOR

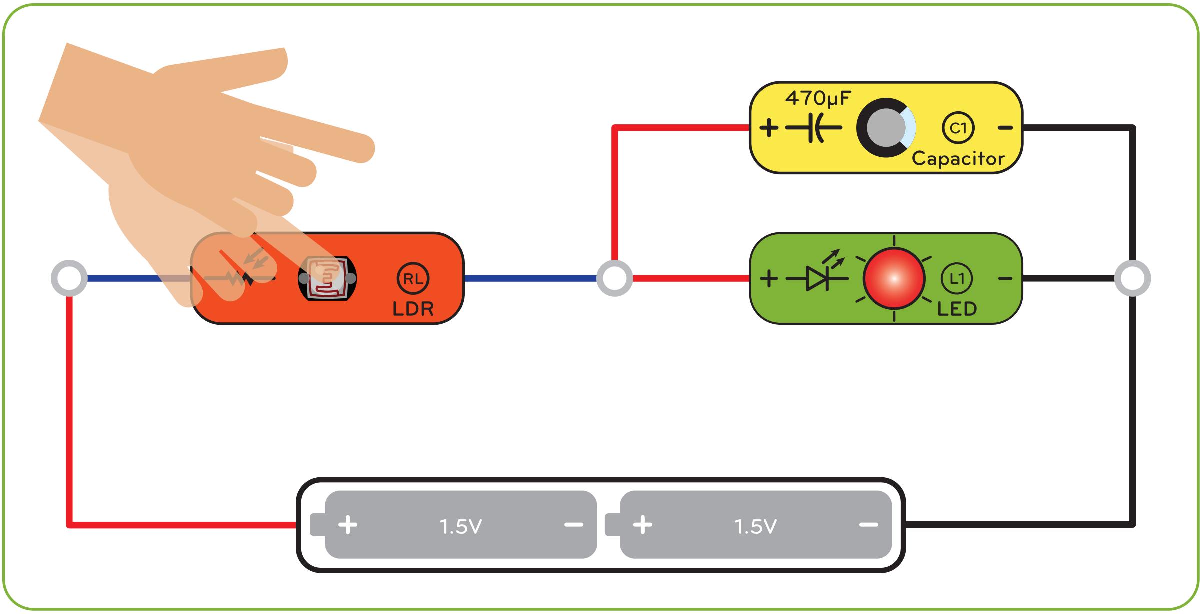
- Connect the LED, LDR, Buzzer & Battery and place them as shown.
- Now go to a slightly dark area. Get any reflective object like a small mirror, steel spoon, mobile screen etc. and bring it close to the LED & LDR pair. Did the Buzzer start beeping?
- Does it beep when you bring a non-shiny object like wood, plastic or cloth near the pair?



- When light from the LED reflects and falls on the LDR, it triggers the connected Buzzer similar to the Light Theremin. So, if light falls on the LDR, the Buzzer will beep else it will not!
- This same concept is used in a phone's proximity sensor, coin slot machines & people counting sensors, where one needs to detect whether any object has passed through a point or not!

E39. SMOOTH FADE!

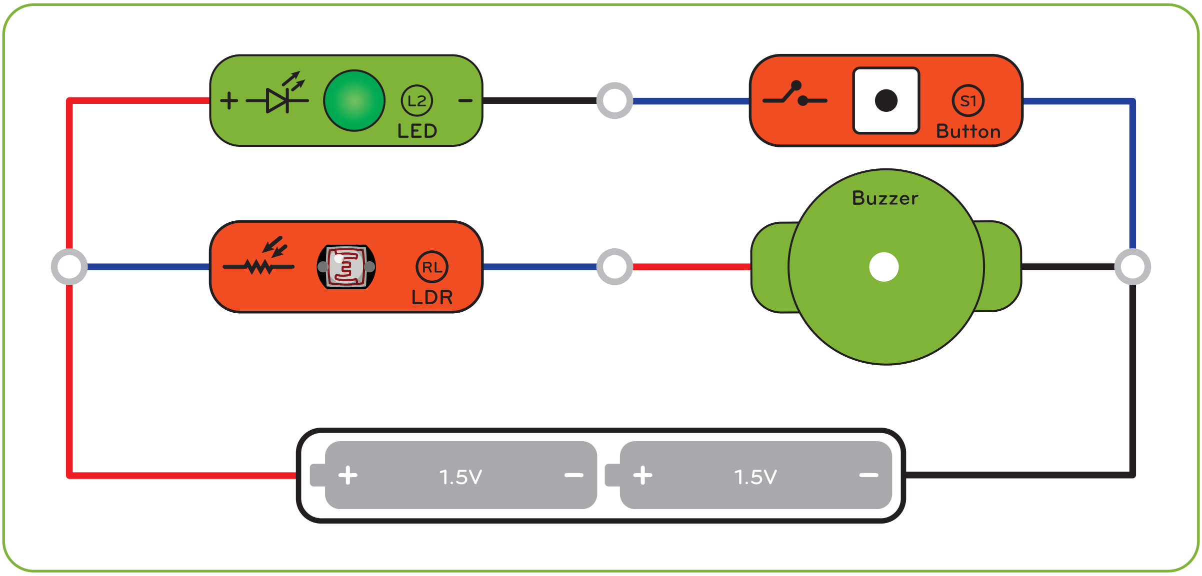
- Let's add some cool fading effects to the light controlled LED circuit!
- Make sure that you are in a well lit up place. Avoid a dark room for this project.
- Connect the LDR, Capacitor, LED & Battery as shown.
- This is same as E36 with just a capacitor added in parallel to the LED.



- Keep your hand on the LDR for some time and then move it away.
- Saw the cool and smooth fading effect! Try turning the room's lights on & off!
- This happens because when the LED normally dims due to the change in resistance of the LDR, it doesn't immediately receive a lower voltage. The capacitor steps in and prevents the LED from dimming for some time and thus the LED gradually fades!
- Think of this experiment as a combo of E36 & E26.
- Try tweaking the capacitance, by connecting another capacitor first in series and then in parallel, to modify the effects. What do you observe?

E40. OPTICAL COMMUNICATION

- Connect the LED, Button, LDR, Buzzer & Battery and place them as shown.
- Move to a slightly dark area before running this circuit.
- Tap the Button and you'll see that as the LED blinks, the Buzzer also beeps.



- But, the Button isn't directly connected to the Buzzer. So why does this happen?
- The button controls the LED and when the LED's light falls on the LDR, the Buzzer beeps!
- This is Optical Communication! You are sending data in form of light pulses! How about sending out Morse Codes through this system?

THE INTERNET WINKS?

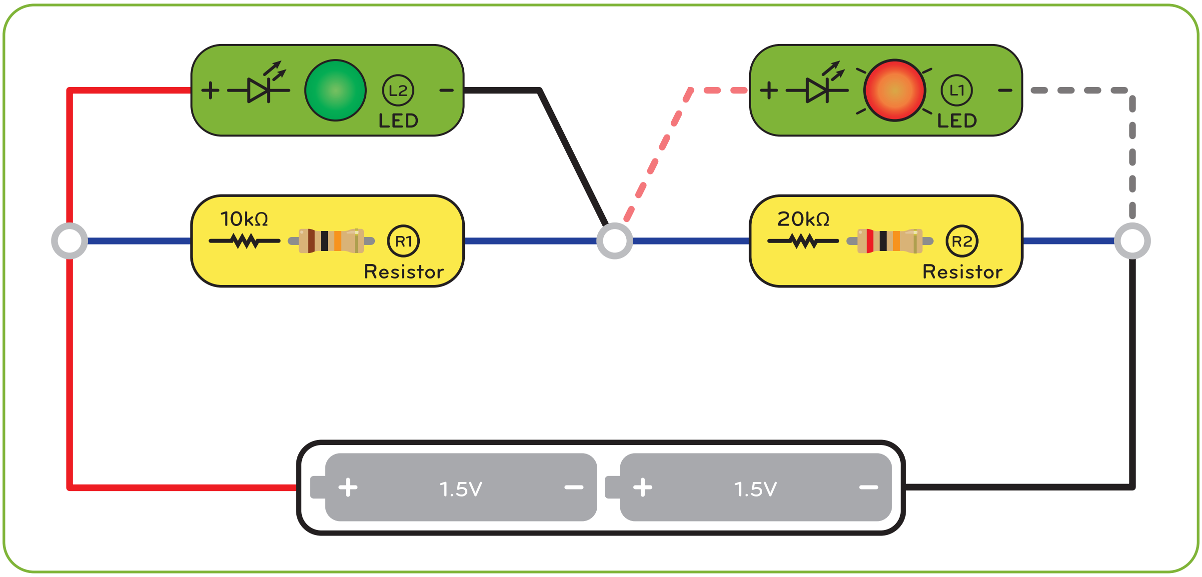
Today, a lot of digital communication, especially the internet communication, happens optically through the Optical Fibre Cables and Laser lights. The Lasers send out streams of data in form of 1s & 0s by blinking On & Off. The receiver has sensors, similar to an LDR that sense the pulses of light and convert them back to data.

Optical communication has many advantages: it is super fast as transmission happens at the speed of light, it is reliable as the optical fiber cables don't corrode like copper wires and it is also secure as it cannot be "wire-tapped" like telephone cables!

Even TV remote controls transmit data to the TV by blinking Infrared LEDs! And humans also wink to communicate optically sometimes ;-)

E41. HERE ON THERE OFF!

- Connect the Battery, 10kΩ & 20kΩ Resistors in Series as shown.
- First connect the LED in Parallel with the 10kΩ Resistor and then with 20kΩ.



- Did the LED glow when you connected it in parallel to the 10kΩ resistor?

This is because of the “Voltage Divider” that we have created using the resistors!

- Here, as the two resistors are in series, same current will flow through them but the voltage gets divided. The voltage drop across them depends on the value of resistance. Simply put: Higher resistance, higher voltage drop (because current is the same)!
- LED is connected in parallel to the resistor. This means that the voltage drop across both these components will be same since voltage is same in parallel.
- So, the reason for the LED not glowing could only be if the voltage drop across the 10kΩ resistor is less than 1.8V, as that’s the voltage it needs to operate!

We will perform the detailed calculations using Ohm’s Law in the next topic!

T28. VOLTAGE DIVIDERS

We saw in the previous circuit how a Voltage Divider divides the voltage in series circuits.

Let's calculate the voltage drops across each resistor of that voltage divider:

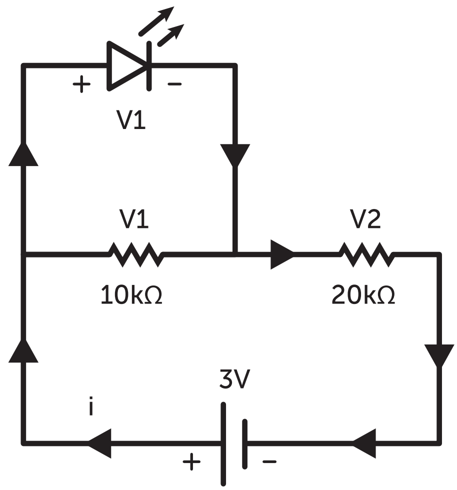
Total battery suply voltage V = 3V

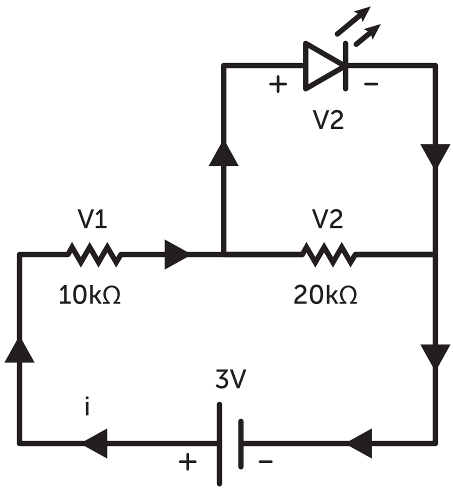
Total series resistance R = 10kΩ + 20kΩ = 30kΩ

Therefore, by Ohm's Law, Total Current i = 3V/30kΩ = 0.1 mA

Now, the same current flows through both resistors as they are in series.
The voltage drops V1 & V2 across the 2 resistors can be again given by Ohm's Law as follows:

V1 = 0.1 mA x 10kΩ = 1V, V2 = 0.1 mA x 20kΩ = 2V





So, now it's clear why the LED didn't glow across the 10kΩ resistor! Its voltage drop of 1V was less than the 1.8V required for the LED connected in parallel!

Voltage dividers are very common in electronics and have many applications, as we'll see soon!

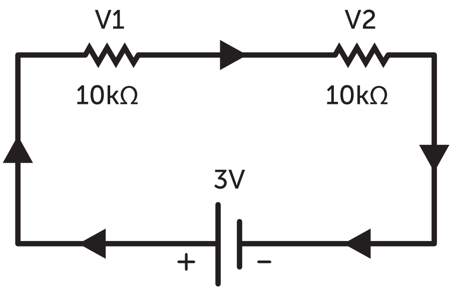
VOLTAGE DIVISION RATIO!

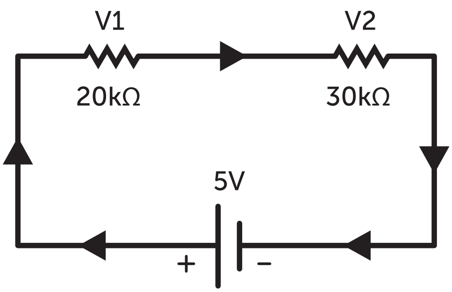
We can easily calculate the voltage drop by just taking a ratio of the resistances!

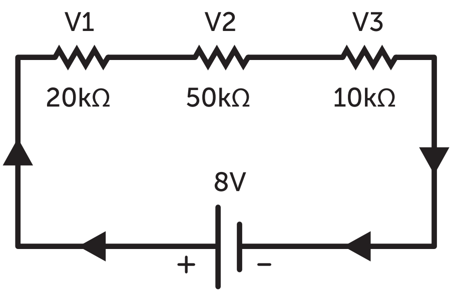
The two resistor values here are 10kΩ & 20kΩ and hence their ratio is 1:2. So, the voltage (3V) is divided in the ratio of 1:2 (1V & 2V) across the respective resistors!

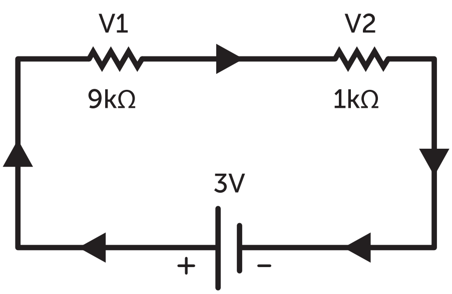
VOLTAGE DIVIDER PUZZLE

Let's check out some more circuits and calculate voltage divisions in those. Calculate the voltages marked with V1, V2 etc. in the following circuits.
Hint: See if you can use the easy formula shared in T28!



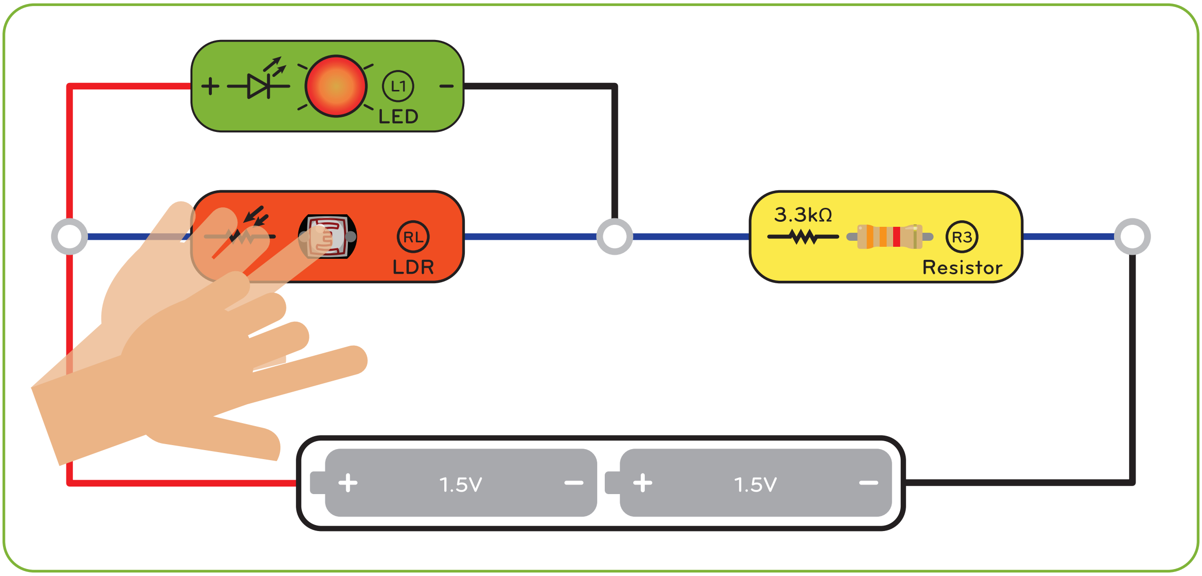






E42. AUTO NIGHT LIGHTS!

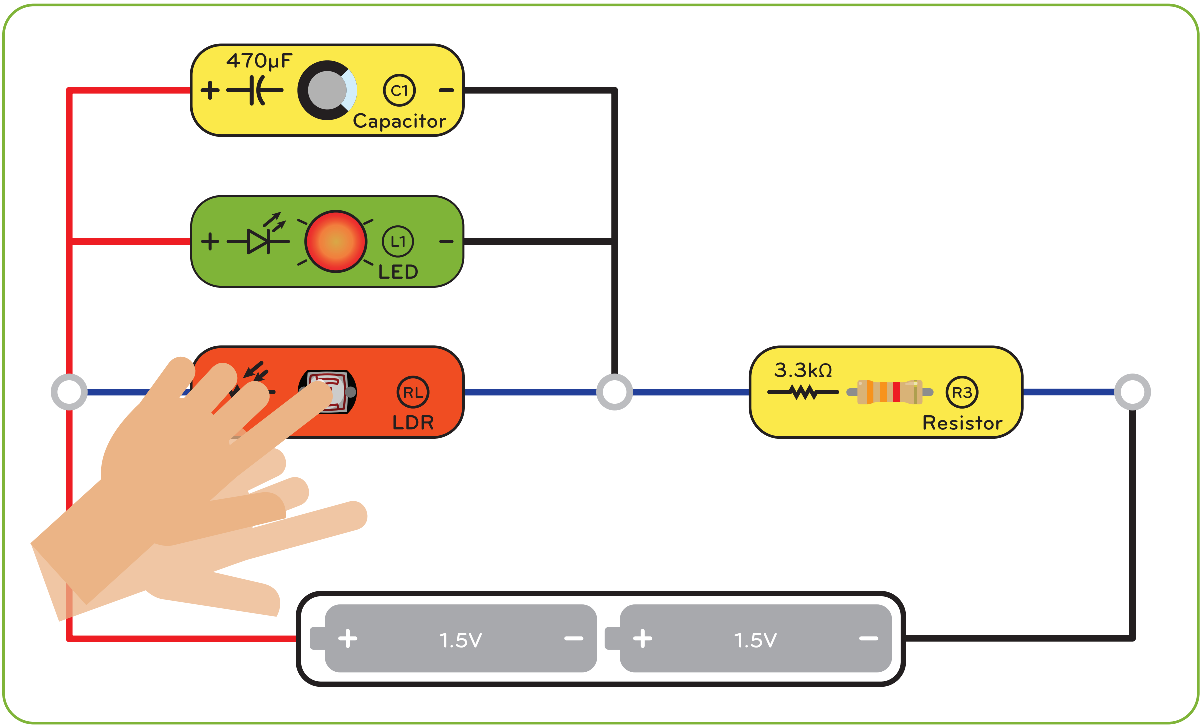
- Make sure that you are in a well lit up place. Avoid a dark room for this project.
- Connect the Battery, LDR and 3.3kΩ resistor in series as shown.
- Connect the LED in parallel to the LDR.



- Now move your hand closer to the LDR. The LED starts glowing!
- You can also try switching your room's lights on and off!
- Why did this happen? This is because the LED is connected in a Voltage Divider Circuit of the LDR and the 10kΩ Resistor.
- As it becomes darker, the resistance of LDR increases and as a result, more and more voltage drop occurs there. So, the LED starts getting more voltage and starts to glow!
- So, basically, we've flipped the operation of the E36 through a voltage divider!
- This is now a much more useful circuit that turns on the light automatically when it's dark outside and turns it off when it's bright!

E43. MAGICAL LIGHTS!

- Make sure that you are in a well lit up place. Avoid a dark room for this project.
- Connect the same circuit as E42.
- Then connect a Capacitor in parallel to the LED as shown.

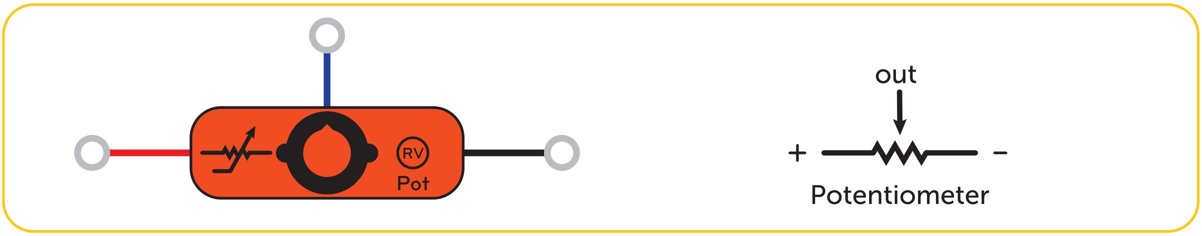


- Now bring your hand close, place it on the LDR, do your favourite magical action, spell some magical words and wait in this position for some time.
- The LED will slowly receive energy from you and come to life!
- Move away from the LDR and it will slowly fade!
- All this magic was due to the Capacitor!
- Interesting isn't it! Make your own cool magic tricks from the things you learnt!

T29. POTENTIOMETER

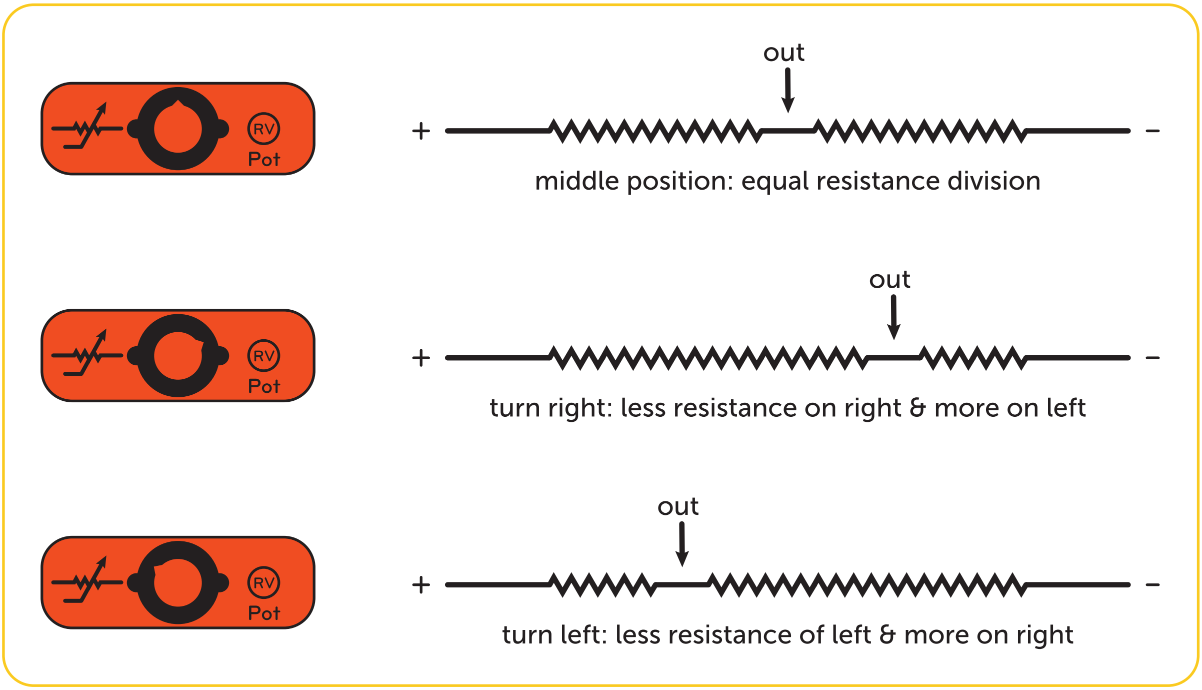
Potentiometers are used widely in electronics, starting from fan regulators to volume control knobs to radio tuners etc.

They have a mechanism, which lets us choose the amount of resistance we want with the help of a knob. So, they are also sometimes referred to as “Variable Resistors”.



This mechanism is similar to the pencil slider of E25. When we turn the knob, a central pin slides on a resistive track, thus increasing the resistance in one part and decreasing it in the other. When we apply voltage, it gets divided between these two resistive parts connected internally in series. Thus, Potentiometers can infact be called Variable Voltage Dividers!

These diagrams show what happens internally when the pot’s knob is turned:

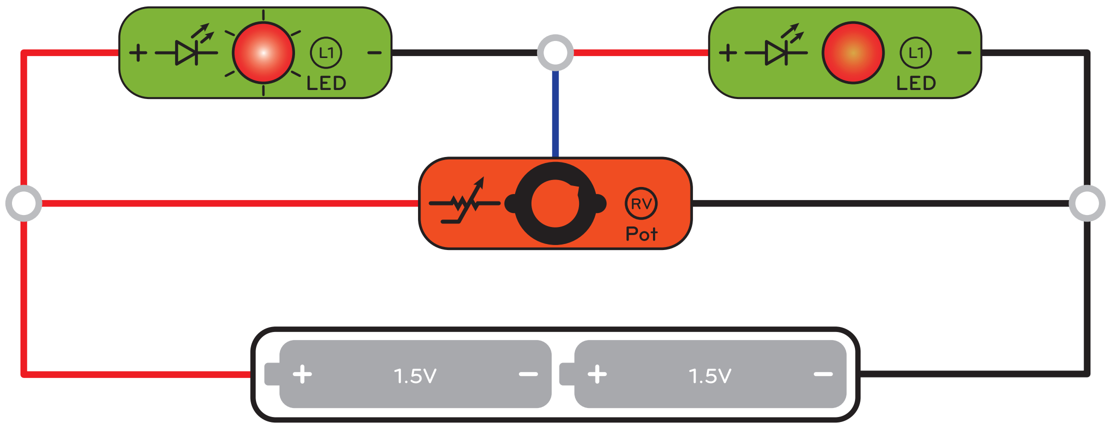


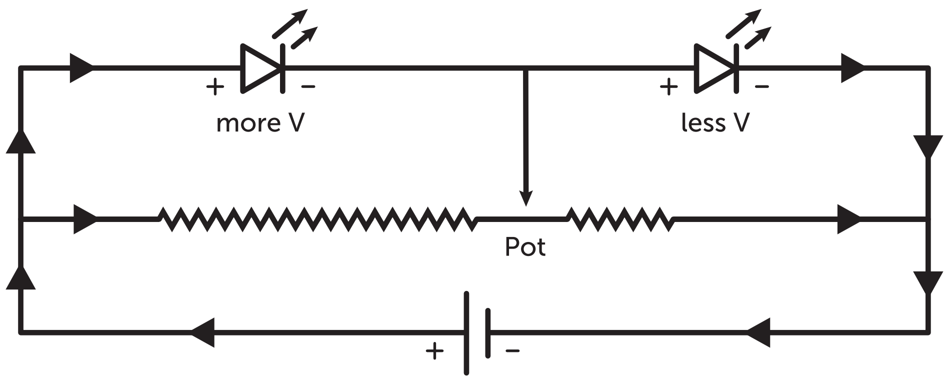
Note that the “+,out,-” positions here are just a convention. You can also connect it like “-,out,+”, but the behaviour will be inverted because internally, Pot is like a voltage divider and is polar!

E44. FADE-IN FADE-OUT

• Connect the LEDs, Potentiometer & Battery as shown.

• Turn the knob from one side to the other.





• As you turn the knob, one LED fades-in and the other fades-out!

• The voltage divider is in action! More the resistance, more the voltage drop & brightness!

• At the middle position, both sides have equal resistance and hence equal voltage division happens in a 1:1 ratio.

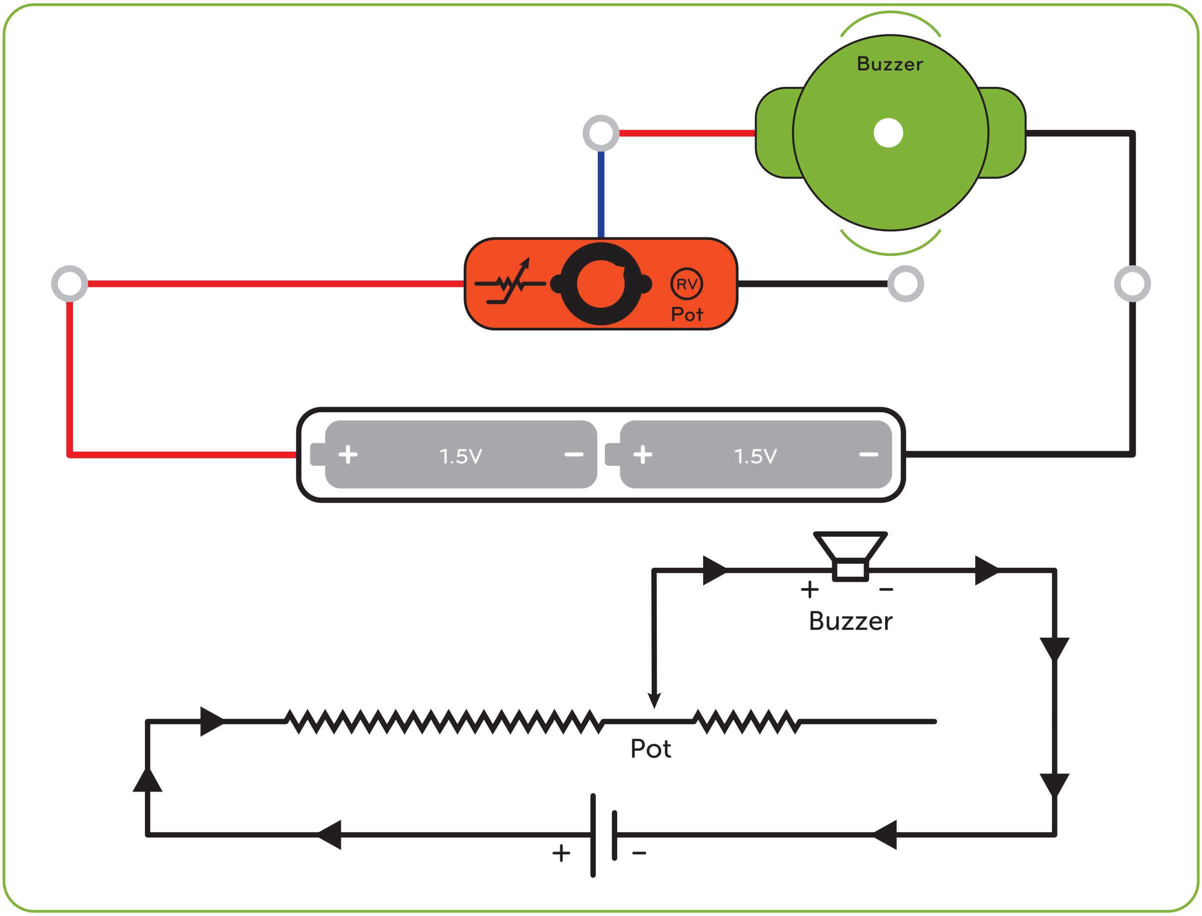
• Thus, each LED gets 3/2 = 1.5V and so both of them remain off!

• When the knob moves either to the left or right, that side gets lesser voltage and the other side gets more voltage, and hence one LED fades-in while the other fades-out!

E45. VOLUME KNOB

• Connect the Buzzer, Potentiometer & Battery as shown and rotate the knob.

• You will hear that the volume of the buzzer changes as we turn the knob.



• Did you notice that we've connected only 2 terminals of the pot here?

• We've hacked the potentiometer and are using it as a variable resistor instead!

• Instead of using all three terminals and dividing the voltage, we can just use the two consecutive terminals of the pot and use it as a variable resistor!

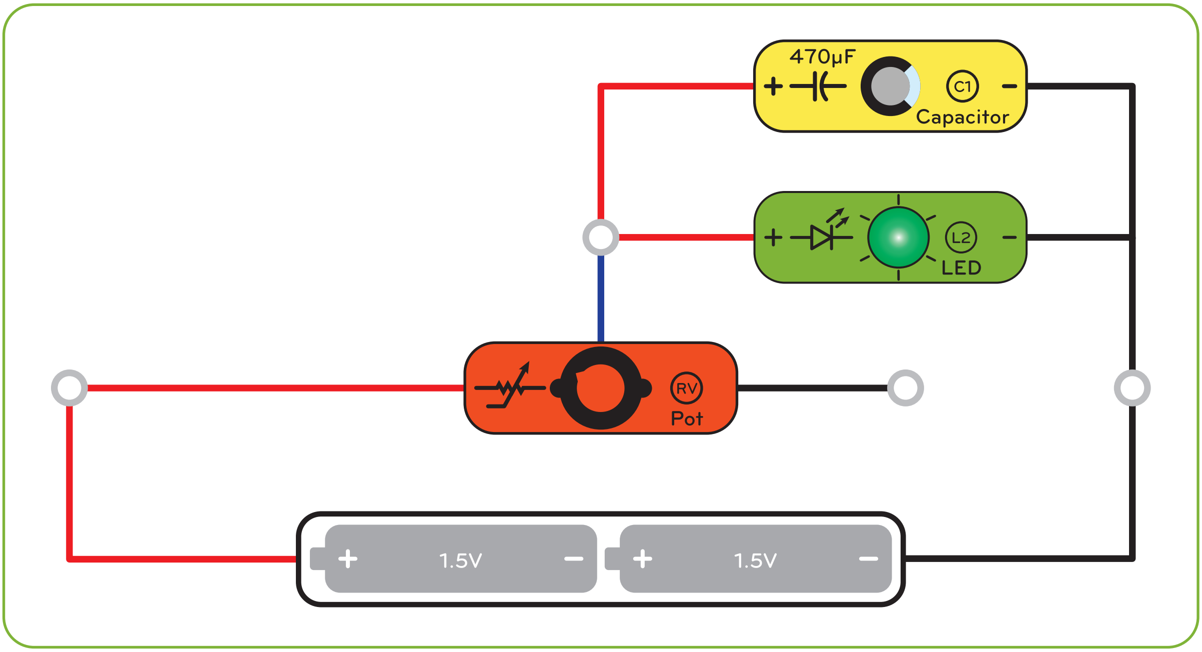
• Here, the pot acts as a regular resistor connected in series to the buzzer. But the fun part is that by turning the knob, we can change that resistance!

• Try this same circuit with an LED instead of the Buzzer!

E46. SMOOTH KNOB!

• Connect the Capacitor, LED, Potentiometer & Battery as shown.

• Turn the knob from one side to the other.



• This time when you turn the knob, you will see that the LED fades smoothly!

• This magic is again aided by the Capacitor, just like we did in the E39 circuit!

• Also note that here again we have used the Potentiometer as a variable resistor like E45.

• So essentially, this circuit is a combination of E39 and E45 circuits!

• Try tweaking the capacitance, by connecting another capacitor first in series and then in parallel, to modify the fading.

• Try the same circuit with a Buzzer instead of the LED!

Circuit Puzzle, Page 6:

1) Open Circuit: The black wires of LED & Battery are not connected, thus breaking the path.
2) Open Circuit: Battery is not present hence circuit can't be formed.
3) Closed Circuit: A path is connecting both terminals of the battery & switch is closed.
4) Open Circuit: A path is connecting both terminals of the battery but the switch is open.

Conductor Puzzle, Page 9:

Softdrink Can, Metal Ring = Conductor
T-shirt, Wooden Table, Coffee Mug, Notebook = Insulator

Volt-Ampere Puzzle, Page 11:

Vehicle Battery = 12 Volts
TV, Charger, Mixer = Varies with each device model. Look for voltage/current rating label on it.

Polarity Puzzle, Page 15:

Button, LDR, Resistor R1, Resistor R2, Switch = Non-Polar (indicated by both blue wires)
LED, Capacitor, Buzzer, Motor = Polar (indicated by red-black wires)

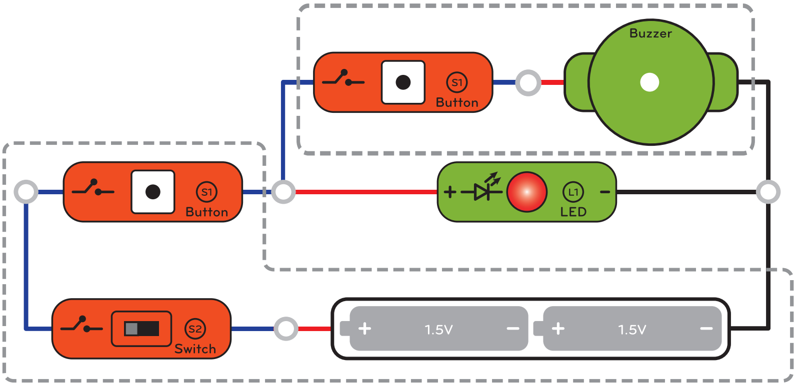
Diode Puzzle, Page 18:

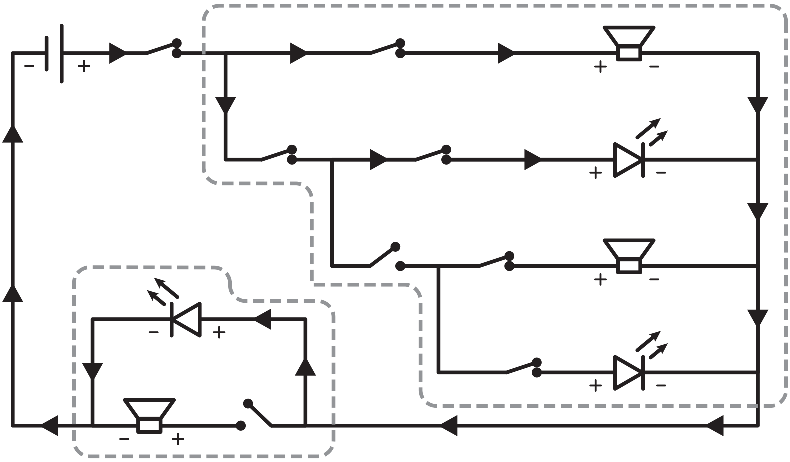
1) LED Glows: Circuit is connected properly and polarity of LED is correct.
2) LED Won't Glow: Circuit is connected properly but polarity of LED is wrong.
3) LED Glows: Circuit is connected properly, LED's polarity is correct & switch is closed.
4) LED Won't Glow: Circuit is connected properly & switch is closed but LED's polarity is wrong.

Energy Transformation Puzzle, Page 23:

CAR:	chemical energy (fuel) --> mechanical energy (motion of wheels)
FAN:	electrical energy (electricity) --> mechanical energy (motion of blades)
BULB:	electrical energy (electricity) --> light energy (glow)
TOASTER:	electrical energy (electricity) --> heat/thermal energy (heating coil)
DIYA:	chemical energy (ghee/oil) --> light & thermal energy (glow)
HEADPHONE:	electrical energy (electric signals) --> sound energy (audio output)

Series-Parallel Puzzle, Page 32:





Voltage Drop Puzzle, Page 46:

1) R = 120Ω 2) VD = 1.5V 3) i = 0.036A or 36mA

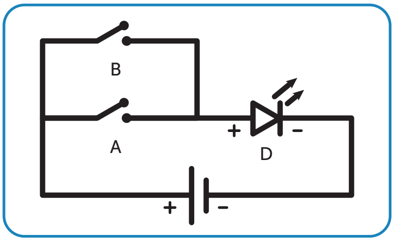
Truth Table Puzzle - 1, Page 57:

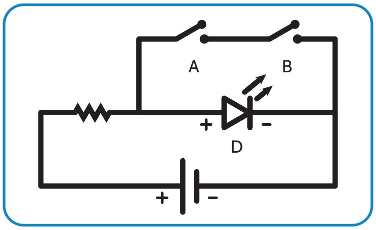
A	B	C
0	0	0
0	1	0
1	0	1
1	1	0

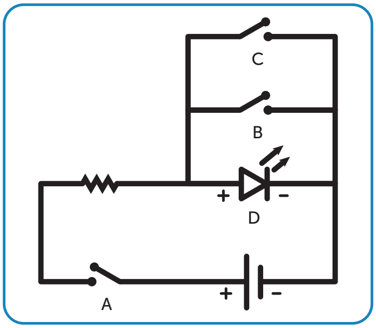
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

A	B	C	D
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	0

Truth Table Puzzle - 2, Page 58:







Circuit Resistance Puzzle, Page 62:

1) R = 1414Ω   2) R = 100Ω

Circuit Capacitance Puzzle, Page 68:

1) C = 50µF   2) C = 100µF

Power Puzzle, Page 78:

1) 1000W or 1kW   2) 3A

Series-Parallel Puzzle, Page 79:

Appliance (Illustrations)	Operating Voltage (V)	Power Rating of the appliance (W)	Power Ratings in (kW) = (W / 1000)	Run Time Hours (H)	Power Consumed kWh = (kW * H)
Tube Light	230 V	40	0.04	8	0.32
Ceiling Fan	230 V	80	0.08	10	0.8
40" Television	230 V	260	0.26	4	1.04
Geyser	230 V	3000	3	2	6
Air Condition	230 V	2000	2	6	12

Total power consumed (kwh) - 20.16	Electricity charges for 1 unit - 4 rs.
No. Of electricity units consumed - 5.38	Total electricity bill for a day - 21.52

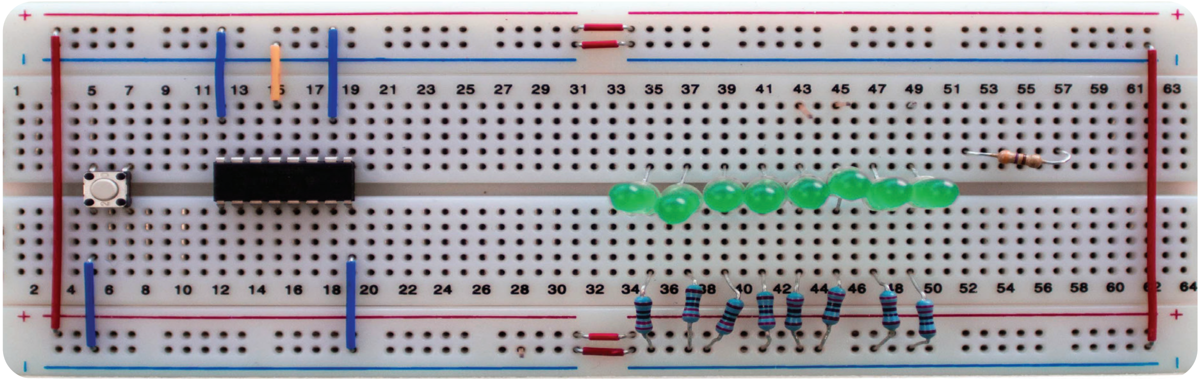
Voltage Divider Puzzle, Page 89:

1) V1 = 1.5V   V2 = 1.5V   2) V1 = 2V   V2 = 3V
3) V1 = 2V   V2 = 5V   V3 = 1V
4) V1 = 2.7V   V2 = 0.3V

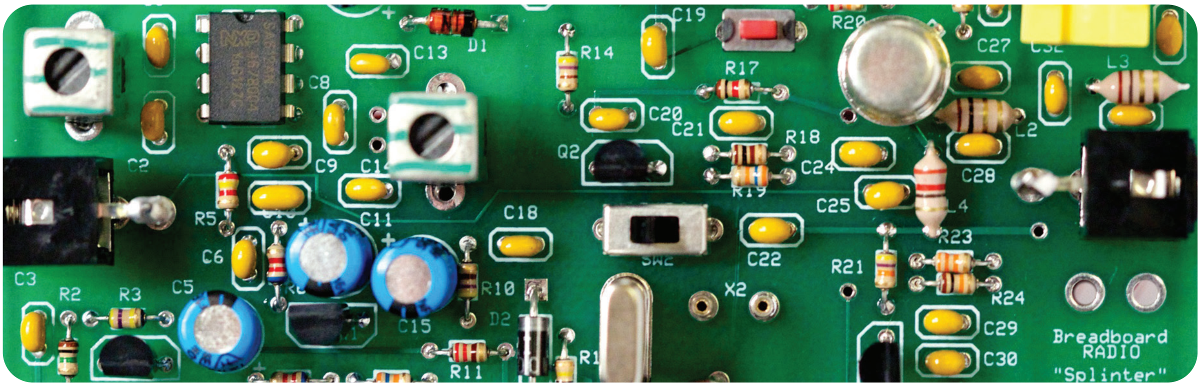
TOPIC	PAGE NO.

FROM BASEBOARD TO PCB!

Like you young engineers, real engineers too use a board for testing out electronic circuits! Before making the final circuits that go inside all our electronic gadgets and appliances, engineers often try out various parts of the circuit on a Breadboard like the one below.



Once they are confident, they move on to designing the actual circuits – the Printed Circuit Boards – PCBs! If you've ever opened up a toy or an old electronic gadget, you would have seen a green board with lots of components similar to the one below.



Do you now recognise some of these nice colourful components on the PCB? PCBs are prepared and assembled mostly by machines. Once the engineers have tested the design of their circuits, they give these PCBs for manufacturing where the circuit paths are "printed" on a board and all the various components are placed and "soldered" onto them!

So, now that you've learnt all the basics about electronic circuits and made lots of cool projects, we bet that you'll be able to see things differently, understand how they work and find out what they're made of. You should definitely try to break open old gadgets & toys and learn more about them. Also, try searching on the internet and learn more about the concepts or projects that appeal to you the most!

We hope that you had a great time learning and playing with this kit!

More Than Just Play

Version 1.4

For suggestions or feedback, please contact on
feedback@ztpl.in

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