

The  
**DANGEROUS**  
Book  
for  
**Boys**™

*Essential*

**ELECTRONICS**

SCIENCE EDUCATION SET

**WARNING** – This set contains chemicals and parts that may be harmful if misused. Read cautions on individual containers and in the manual carefully. Not to be used by children except under adult supervision.

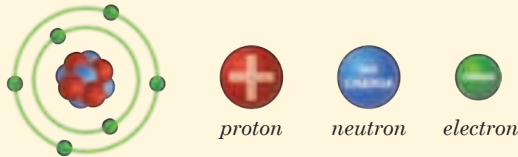
 Thames & Kosmos

# WHAT IS ELECTRICITY?

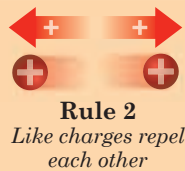
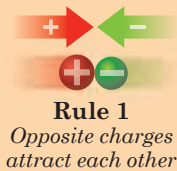


**E**lectricity is a common word used to describe a number of different physical phenomena. When you think of electricity, you might think of something coming from a wall outlet to power your computer, or a bolt of lightning, or getting shocked when you touch a metal doorknob. And you would be correct — these are all examples of the presence of electricity.

To a scientist, electricity is the presence and flow of **electric charge**. Electric charge is an invisible property of matter. We can't see it, but we know it's there because it affects the way matter behaves. To understand electrical charge, you first have to know that all matter is made of small particles called atoms, and atoms in turn are composed of smaller subatomic particles called **protons**, **neutrons**, and **electrons**. Protons and electrons have an electrical charge.



Protons have a positive electrical charge and electrons have a negative electrical charge. Neutrons are neutral, with no charge. Electric charge has two simple fundamental rules.



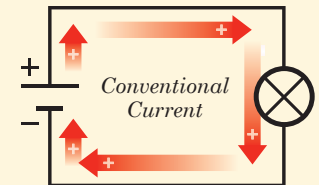
Because of these rules, protons and electrons attract each other, but protons repel other protons and electrons repel other electrons. In a neutral atom, the number of protons and the number of electrons are the same. This balances the charge out. If an atom loses an electron, it becomes an ion with a positive charge. Conversely, if an atom gains an electron, it becomes an ion with a negative charge.

An **electric current** occurs when an electric charge flows through a material. Electric currents can be caused by the movement of electrons, ions, or both. Depending on the

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material, this can mean that electrons are flowing from a negatively charged area to a positively charged one, such as in a metal, or that positively charged ions are flowing from a positively charged area to a negatively charged one, or that both positively and negatively charged particles are flowing in both directions. This may sound a bit complicated, but scientists have devised a way to simplify it a little. The overall electric current is the same regardless of whether it is negative charges or positive charges that are actually moving. When a negative charge flows in one direction, there is always an equal positive charge that flows in the other direction. So, scientists have decided to always focus on the flow of positive charge, regardless of what particles or charges are actually moving. This is called **conventional current**. By definition, **conventional current** always flows from positive to negative.



In this kit, we'll mainly be dealing with electric currents flowing through metals, such as wires and other electronic components. In metals, electrons flow from a negative pole to a positive pole. But because we're using conventional current, we'll always talk about current flowing from the positive pole to the negative pole.



# RESISTORS



Electrical components designed to create resistance by opposing electric current are called **resistors**. Resistance is measured in units called **ohms**, named after German physicist Georg Ohm.

Georg Ohm defined the relationship between voltage, current, and resistance, as expressed in Ohm's Law:

$$V = R \times I$$

V stands for voltage, R stands for resistance, and I stands for electrical current. This equation means that the resistance of an object to electrical current multiplied by the "rate" of the current itself equals the "pressure" of the current across the object. But since this section is about resistance, let's divide both sides of the equation by I, so we can think about resistance by itself:

$$R = V / I$$

Resistance equals voltage divided by current. This shows that at a given voltage, a higher resistance means a lower current. And if we put Ohm's Law and Joule's Law together, we derive another way to calculate power:

$$P = I^2 \times R$$

So if you know the current and the resistance, you can use the equation above to calculate the power.



A resistor is like a sponge in a stream of water. It limits the flow of current.



Two of the same resistors connected in series will double the total resistance.



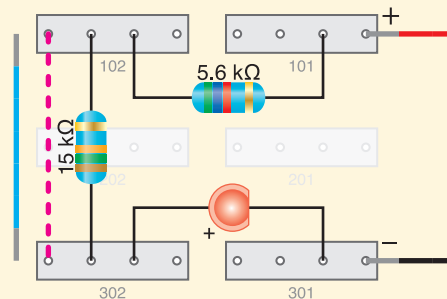
Connect those two resistors in parallel, and the total resistance is half.

## EXPERIMENT NO. 11 — RESISTORS IN SERIES

**Materials:** assembled circuit board, 5.6 kΩ resistor, 15 kΩ resistor, red LED, jumper wire, 9V battery

### Procedure

1. Assemble Circuit V, shown in the diagram.
2. Add the jumper wire between clips 102 and 302, where the dotted line is shown. What happens to the LED?



CIRCUIT V: RESISTORS IN SERIES

### Explanation

The two resistors are in series, so they are both limiting the current in the LED. When you bypass the 15 kΩ resistor with the wire, the LED gets brighter because the current no longer has to flow through that resistor; it flows through the wire instead. When resistors are in series, the total resistance is simply equal to the sum of all the individual resistances:  $R_1 + R_2 = R_{Total}$

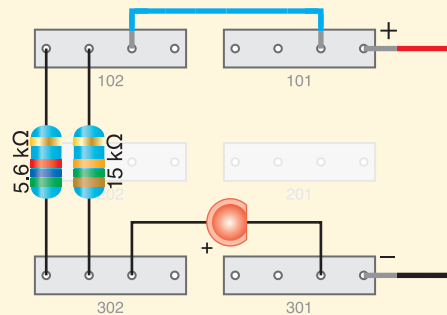
## EXPERIMENT NO. 12 — RESISTORS IN PARALLEL

### Procedure

1. Rearrange Circuit V into Circuit VI. What happens to the LED?

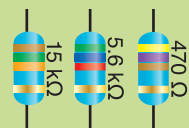
### Explanation

The LED is now brighter than before! Both resistors have the same voltage across them, so current can flow through each one. Instead of just one path, there are now two paths, so more current can flow. Resistors connected in parallel will have a lower total resistance than those same resistors connected in series.



CIRCUIT VI: RESISTORS IN PARALLEL

When resistors are in parallel, the total resistance is calculated with the following equation:  $(1/R_1) + (1/R_2) = (1/R_{Total})$



Resistors are color-coded with bands indicating their resistance value in ohms. Here is the key.



1st Ring = 1st Digit  
2nd Ring = 2nd Digit  
3rd Ring = Multiplier  
4th Ring = Tolerance

	BLACK	BROWN	RED	ORANGE	YELLOW	GREEN	BLUE	VIOLET	GRAY	WHITE	GOLD	SILVER	NO RING
0	0	1	2	3	4	5	6	7	8	9	-	-	-
10	0	1	2	3	4	5	6	7	8	9	-	-	-
100	10	100	1000	10k	100k	1000k	1M	10M	-	-	0.1	0.01	-
-	-	±1%	±2%	-	-	-	-	-	-	-	±5%	±10%	±20%



# LOGICAL CIRCUITS

You already know that circuits are sequences of electrical components in a closed loop, around which electrical current flows. **Logical circuits** are a type of circuit that use logic. Let's explain what that means. It may go without saying that science builds on itself, but you may be surprised to learn that modern computers are based not on the decimal number system, which uses multiples of 10, but on the binary system, which was developed 300 years earlier and only uses 0s and 1s. The binary system uses combinations of 0s and 1s to represent all numbers — for example,  $0 = 0$ ,  $1 = 1$ ,  $2 = 10$ ,  $3 = 11$ , and so on — and unlike the decimal system, it can perform logical calculations.

In a logical circuit, 0 means the switch is open (no flow of current) and 1 means the switch is closed (flow of current). We call these two states “false” (0) and “true” (1). The devices

that allow current to flow or not flow in logical circuits are called **logic gates**.

There are seven types of logic gates that go by these names: NOT, AND, OR, NAND, NOR, XOR, and XNOR. Let's start with two circuits to demonstrate the NOT gate. First, we will build a YES circuit, which is not really one of the seven logic gates, but it is important for understanding the NOT gate.

## BINARY CODE

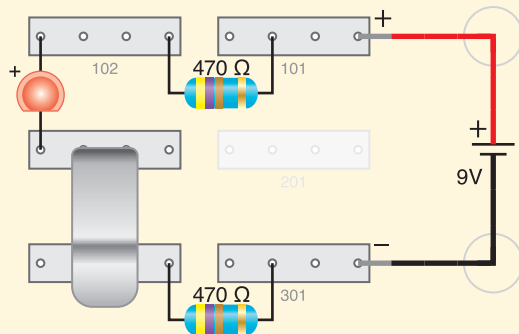
Decimal Number	Binary Number
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010

### EXPERIMENT No. 16 — YES CIRCUIT

**Materials:** assembled circuit board, two  $470\ \Omega$  resistors, red LED, push-button switch,  $9V$  battery

#### Procedure

1. Assemble Circuit X, shown in the diagram below.
2. Press the push-button switch to close the circuit. What happens?



CIRCUIT X: YES

#### Explanation

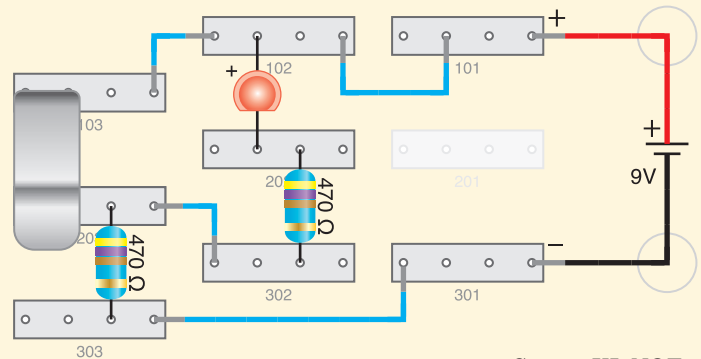
This circuit illustrates a simple YES circuit. When the button is pressed (true), the LED lights up (true). There is a direct correlation between the two “true” conditions.

### EXPERIMENT No. 17 — NOT GATE

**Materials:** assembled circuit board, two  $470\ \Omega$  resistors, red LED, four jumper wires, push-button switch,  $9V$  battery

#### Procedure

1. Assemble Circuit XI, shown in the diagram below.
2. Press the push-button switch to activate the circuit. What happens?



CIRCUIT XI: NOT

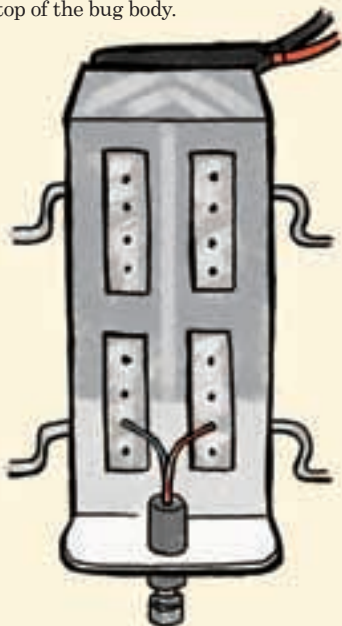
#### Explanation

This time, the LED lights up (true) when the switch is not pressed (false). There is an indirect relationship between the two “true” conditions. This happens because when the switch is open, the current must travel through the LED and the 202-302 resistor, but when the switch is closed, the current finds an easier path by traveling through the switch (which offers less resistance than the LED) and the 203-303 resistor.

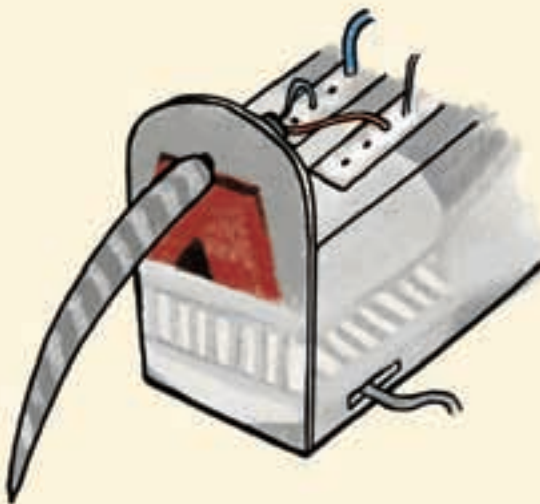
10. Insert the battery pack into the bug body as shown.



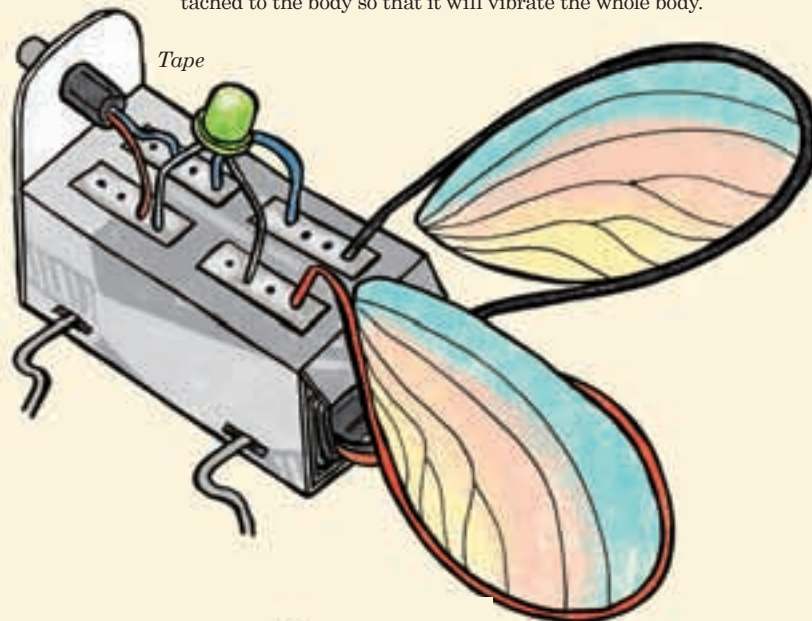
11. Insert four connector clips into the rectangular holes in the top of the bug body.



12. If you didn't strip the plastic ends of the motor wires in Experiment No. 29, do it now. Insert the motor into the body as shown and insert the motor wires into the connector clips.



13. Complete the circuit for the bug by adding a jumper wire and an LED. Make sure the LED is pointed in the right direction, with its positive side facing the positive red battery wire. Tape the vibrating motor to the circuit board platform. The motor should be securely attached to the body so that it will vibrate the whole body.



14. As soon as you connect the battery wire, the circuit is completed, and the motor will start to vibrate the bug.

15. Disconnect the motor wire for a moment in order to attach the nose piece to the vibrating motor. To do that, simply fold the nose piece in half, and tape it around the motor.

### Explanation

The vibrating motor causes the bug to wiggle around on the table. It works best on a very smooth surface, like glass or a smooth counter top. If your bug isn't moving around, try adjusting the legs a little so the bug's weight is distributed differently.