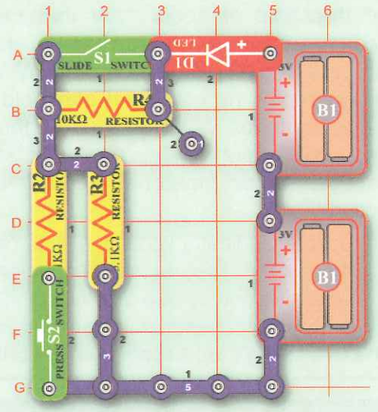
Experiments

As a review, consider this circuit (which is project 173):



If the slide switch (S1) is on, then the LED will be on but not very bright as the 5.1K resistor limits the current. Turning off the slide switch places the 10K resistor in series and the LED becomes very dim. If both switches are on, the 1K resistor is in parallel with the 5.1K and so the LED becomes very bright.

You've learned that when you increase resistance in a circuit, less current flows (making an LED dimmer). This relationship between voltage, current, and resistance is the most important one in electronics. It is known as **Ohm's Law** (after George Ohm who discovered it in 1828):

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

The most basic rules for analyzing circuits as known as **Kirchhoff's Laws** (known after Gustav Kirchhoff, who stated them in 1847):

1. The total voltages driving a circuit must equal the voltage drops within it.
2. All current flowing into a point must flow out of it.

The "**power**" of electricity is a measure of how much energy is moving through a wire. It is expressed in **Watts** (W, after James Watt for his work with engines). It is a combination of the electrical voltage (pressure) and current:

Power = Voltage x Current

OR

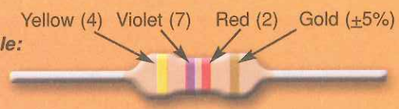
$$\text{Power} = \frac{\text{Voltage} \times \text{Voltage}}{\text{Resistance}}$$

Resistor Color Code:

You may have seen the colored bands on the resistors and may be wondering what they mean. They are the method for marking the value of resistance on the part. The first ring represents the first digit of the resistor's value. The second ring represents the second digit of the resistor's value. The third ring tells you the power of ten to multiply by, (or the number of zeros to add). The fourth and final ring represents the construction tolerance. Most resistors have a gold band for a 5% tolerance. The colors on the right are used to represent the numbers 0 through 9.

COLOR	VALUE
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Example: Yellow (4) Violet (7) Red (2) Gold (±5%) — 4,700Ω *OR* 4.7kΩ



Use the color code to check the values of the five snap circuits resistors. They are all 5% tolerance.

3-4 Resistance

Just what is Resistance? Take your hands and rub them together very fast. Your hands should feel warm. The friction between your hands converts your effort into heat. **Resistance** is the electrical friction between an electric current and the material it is flowing through; it is the loss of energy from sub-atomic particles as they move through the material.

You can also compare resistors to the friction with the ground when you walk. If there is too much friction (like two feet of snow) you have to go very slow or get stuck. If there is too little friction (like ice) then you have no control and will slip and fall.

Resistors are made from carbon and can be constructed with different resistive values, such as the five parts included in snap circuits. If a large amount of current is passed through a resistor then it will become warm due to the electrical friction. Resistors get warm because they exert control by wasting power as heat. Light bulbs use a small piece of a highly resistive material called tungsten. Enough current is passed through this tungsten to heat it until it glows white hot, producing light.

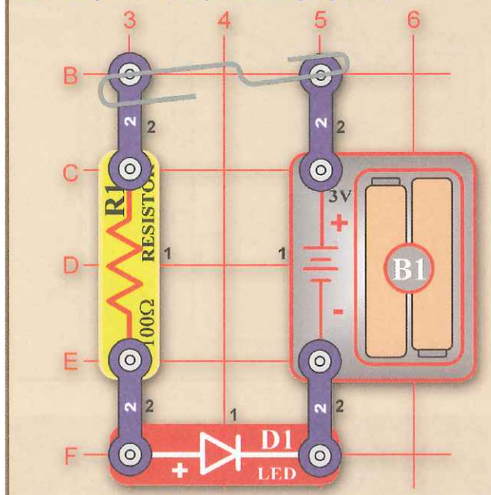
Electric stoves and heaters use resistors to change electricity into heat.

Metal wires have some electrical resistance, but it is very low (less than 1Ω per foot) and can be ignored in almost all circuits. Materials, such as metals, which have low resistance are called **conductors**. The best conductor material known is silver, but it is too expensive to be widely used. Copper is second best, and it is used in most wires and printed circuit boards in the electronics industry.

Materials such as paper, plastic, and air have extremely high values of resistance and are called **insulators**.

Experiments

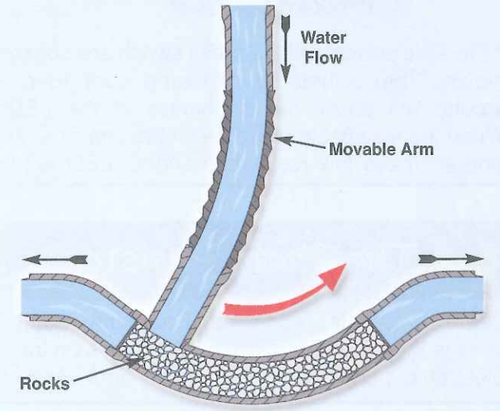
You can use snap circuits to test whether materials are conductors or insulators. Consider this simple circuit (which is project 9):



Place any material across the 2-snap wires (the circuit shows a paperclip). If the LED is bright then it is a conductor, if the LED is off then it is an insulator.

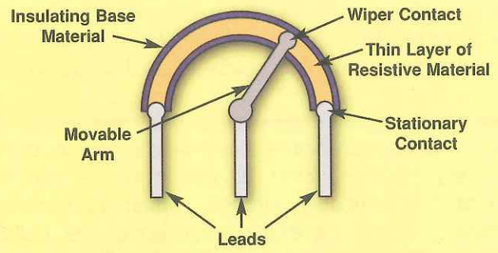
3-5 The Adjustable Resistor

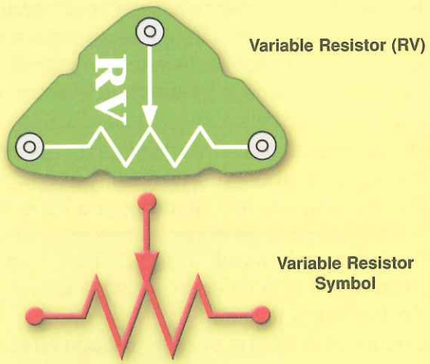
A switch is used to turn the electricity on and off just like a valve is used to turn the water on and off. But there are many times when you want some water but don't need all that the pipe can deliver, so you control the water by adjusting an opening in the pipe with a faucet. Unfortunately, you can't adjust the thickness of an already thin wire. But you could also control the water flow by forcing the water through an adjustable length of rocks, as in the rock arm shown below.



Introducing New Parts

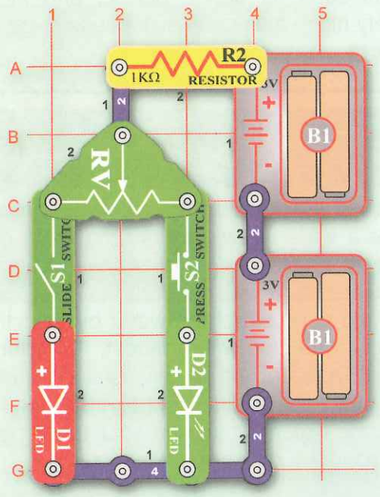
In electronics we use an adjustable resistor. This is a normal resistor (50KΩ in snap circuits) with an additional arm contact that can move along the resistive material and tap off a portion of it.





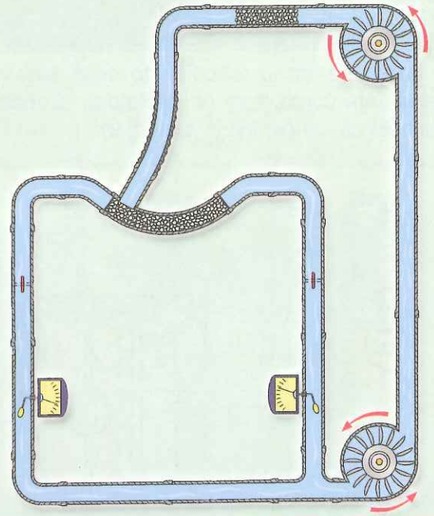
Experiments

Consider this circuit (which is project 172):



If the slide switch and the press switch are both on, moving the adjustable resistor's control lever around will adjust the brightness of the LEDs. When the adjustable resistor is set to one side, that side will have low resistance and its LED will be bright while the other side will have high resistance and its LED will be dim or off. The 1K resistor (R2) limits the current so the LEDs cannot be damaged.

This circuit can also be thought of as if it were water flowing through pipes:



3-6 The Photo Resistor

Some materials, such as Cadmium Sulfide, change their resistance when light shines on them. Electronic parts made with these light-sensitive materials are called photoresistors. Their resistance decreases as the light becomes brighter.

Introducing New Parts

Snap circuits includes one photoresistor. Its resistance value changes from nearly infinite in total darkness to about 1KΩ when bright light shines directly on it. Note that a black plastic case partially shields the Cadmium Sulfide part.

Photo Resistor (RP)

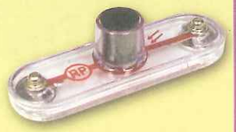
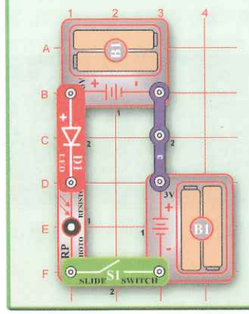


Photo Resistor Symbol

Experiments

Consider this circuit (which is project 272):



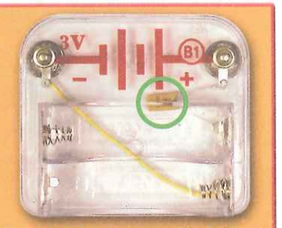
The brightness of the LED depends on how much light shines directly on the photoresistor. If the photoresistor were held next to a flashlight or other bright light, then the LED would be very bright.

Photoresistors are used in applications such as streetlamps, which come on as it gets dark due to night or a severe storm.

Thermistors: Resistors can also be made to change resistance as the temperature changes. These are called thermo-resistors. They are used in applications like electronic thermometers, or to compensate for other circuit characteristics that are changing with temperature.

Thermistors can also be made to act as fuses. At low currents they have only slight resistance and don't affect a circuit. High currents (due to a short circuit) cause them to heat up and greatly increase resistance, limiting the current to prevent damage.

A thermistor like this is inside each of the battery holders in snap circuits:

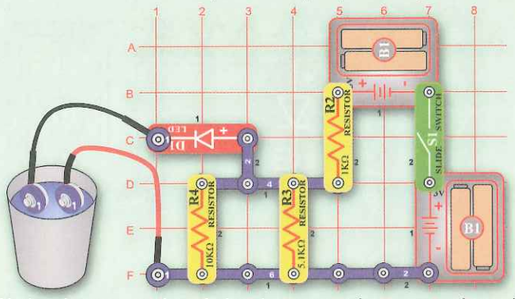


This thermistor will activate to limit current if a short circuit occurs for more than a few seconds. Running the motor for long periods will sometimes activate it, since the motor draws a high current.

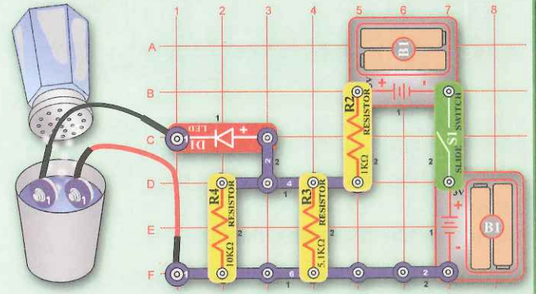
3-7 Resistance of Water

Experiments

Consider this circuit (which is project 166):



If the loose ends of the jumper wires are placed into a cup of water, the LED will be dimly lit. The circuit was designed so that the LED acts as a water detector. The brightness depends on your local water supply. If more water were added to the cup, the LED brightness would increase slightly. Adding more water is like placing more "water resistors" in parallel; and so decreases the total resistance. Pure water (like distilled water) has very high resistance, but drinking water has impurities mixed in that lower the resistance. What would happen if salt was added to the cup and dissolved in the water?



Dissolving salt in water decreases the resistance of the water, so the LED would get brighter. It could be used as a salt-water detector. Adding more water to dilute the salt could reduce the brightness.