

## Simple Electronics

1. Terms – volts, amps, ohms, watts, positive, negative, AC, DC
2. Matching voltages
  - a. Series vs. parallel
3. Battery capacity
4. Simple electronic circuit – light bulb
5. Chose the right kind of wire
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7. Switches – simple on/off
8. Reversing voltage
9. Connecting multiple things to one power supply
10. What's wrong with my circuit?
  - a. Dead battery
  - b. Short circuit
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  - d. Broken switch

### **Volts:**

Volts measure the strength of a power source (battery, wall outlet in your house).

If equated to a river, the voltage of an electrical circuit would be how wide the river is.

1. House outlets are between 110 and 125 volts.
2. A single “AAA”, “AA”, “C”, or “D” battery are all 1 ½ volts.
3. Big rectangular shaped “lantern” batteries are 6 volts.
4. Small rectangular shaped batteries are 9 volts.
5. A car battery is 12 volts.

When higher voltage is used, the device being powered will do more work. For example, a motor will turn faster, or a light bulb will give off more light. However, if you use too much voltage, the light bulb will burn out, the wire will melt, or the motor will “burn out”.

### **Amps:**

Amps measure how “fast” electricity is moving through a circuit.

If equated to a river, the amps in an electrical circuit would be how fast the water in the river is moving.

Car batteries in some ways are more dangerous than a house outlet. A typical electrical outlet in a house, while it has 110 volts, can only supply about 12 amps before it will shut off. A car battery can supply around 600 amps. This is why OotM does not allow car batteries to be used.

### **Ohms:**

Ohms measure how much “resistance” there is in the circuit to “slow down” the electricity.

If equated to a river, the ohms in an electrical circuit are like a dam on the river.

Circuits with lots of ohms need higher voltage to do the same amount of work (power a motor at the same speed for example.)

**Watts:**

Watts are a measure of how much “work” is being done by the circuit.

Watts = volts X amps

220 watts = 110 volts X 2 amps

Motors and light bulbs usually tell you how many watts they use (at their correct voltage). Most house light bulbs are 60 watts. How many amps does a single 60 watt light bulb use (estimate)?

60 watts = 110 volts X ??? amps

**Positive and Negative:**

Batteries are always marked, and one end is positive (+ sign), and the other end is negative (- sign). To get stuff to work, you need to connect one side of your stuff (motor or light bulb) to the positive end of the battery, and the other side of your stuff to the negative end.

**AC and DC:**

Batteries always provide “direct current” or “DC”. Your house provides “alternating current” or AC. AC power has the voltage change from positive to negative 60 times per second (at least that’s the case in the United States). So, generally speaking, if you are using batteries to power your device, you are working with DC power, and if you are plugging something into a wall outlet, you are working with AC power.

Light bulbs will work off AC or DC. LEDs are a special case, and may only work with DC power – check the specifications. Motors may be designed to work with AC, or DC, or both. So, check your motor to see if it needs AC or DC voltage.

**Matching voltages:**

When you are building your own circuit, the first thing you need to decide is how many volts you need, and how you are going to get that voltage connected to your device.

Let’s say you have a motor that’s designed to run on 6 volts. You know that “D cell” batteries are 1.5 volts. So, you need to add enough “D cell” batteries together to get to 6 volts.

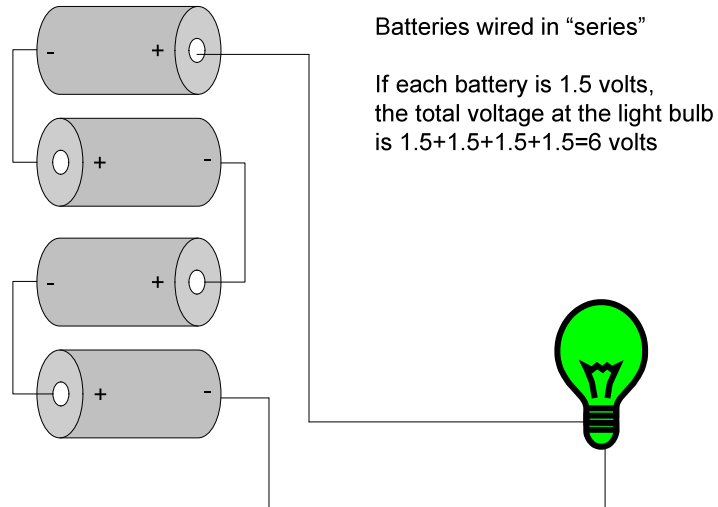
$$1.5 + 1.5 + 1.5 + 1.5 = 6$$

So, four “D cell” batteries together can deliver 6 volts.

But, you have to be careful how you connect them.

## Series vs. Parallel

In order to get two or more batteries to add their voltage together to get a higher voltage, you must connect the positive (+) end of the 2<sup>nd</sup> battery to the negative (-) end of the 1<sup>st</sup> battery. If you add a 3<sup>rd</sup> battery, connect its positive (+) end to the negative (-) end of the 2<sup>nd</sup> battery. When you connect batteries this way, you are connecting them “in series”.



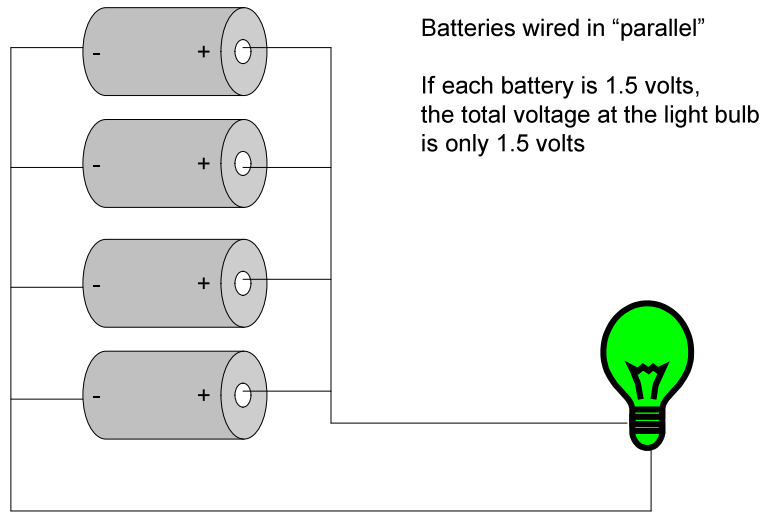
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When you connect batteries in series, all of the batteries discharge (get weaker) together, and at the same rate. So, they will all “go dead” relatively quickly.

You can wire batteries together “in parallel” and make the batteries last much longer. To connect batteries “in parallel”, wire all the positive (+) ends together, and all the negative ends together. Connect your device to the positive and negative wires just like normal.



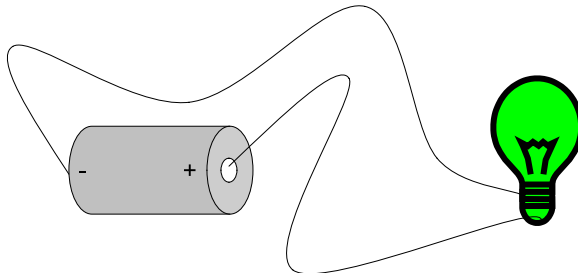
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When batteries are wired in parallel, each battery lasts much longer! Compare Diagram #2 and Diagram #3. Each one of the four batteries in Diagram #2 will last four times as long as the single battery in diagram #3.

Simple circuit – battery and light bulb



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**Battery capacity:**

Once you know how much voltage you need, you then need to decide how long you need to be able to run your “stuff” before your battery will go dead. Batteries capacity to run “stuff” before they go dead is measured in watt hours.

Watts X Hours = Watt-hours

A 5 watt motor running for 2 hours = 10 watt-hours

Typical watt-hour capacity for regular alkaline “long life” batteries you can buy in a store (these are typical – use as estimates for how long an average battery will last):

AAA:	1.5 watt-hours
AA:	2.5 watt-hours
C:	9.5 watt-hours
D:	21 watt-hours
9 volt:	5 watt-hours
6 volt lantern battery:	97 watt hours

So, a single AAA battery running a 1 watt light bulb will go dead in about 90 minutes. The same light bulb running on a single D cell battery will run for 21 hours before the battery goes dead. The same light bulb running on a 6 volt lantern battery will run for four days!

**Chose the right kind of wire:**

Two basic kinds of wire:

Stranded  
Solid

Stranded wire is a bundle of very small wires all wrapped together. It's very flexible, but harder to get to stay in one place – unless you attach it to something.

Solid wire bends easily, and will stay in one place easier than stranded wire, but it is also easier to break it.

The thickness of the wire is called the “gauge” of the wire. Thicker wire has a smaller gauge number. Thinner wire has a higher gauge number. For OotM projects you are likely to be using wire from 18 to 22-gauge.

House wiring is typically 14-gauge (except for big appliances like an oven). You need to choose the correct gauge of wire for your circuit. The higher the amps you need to run, the smaller gauge wire (thicker).

Typical amp capacity of wire gauges (conservative numbers):

22 gauge, max of 2 amps  
18 gauge, max of 5 amps  
16 gauge, max of 8 amps

Remember that amps of a circuit are what can be dangerous. So, stick to low amps. You should have a really good reason for using anything more than just a few (less than 5) amps.

High amps running through thin wire will result in very bad things:

1. The wire will get hot
2. Hot wire might melt something (like the insulation on the wire)
3. Hot stuff can burn fingers
4. Small wire has higher “ohms” and so it slows down the electricity, and so it makes your motor run slower or your light bulb to be dimmer.

### **Simple ways to connect wires:**

Electricity will go from one wire to the next as long as the wires touch each other.

Plastic caps called “wire nuts” are available at Lowes, Home Depot, Radio Shack, etc.

To connect two wires together:

1. Wear eye protection (goggles). Use a wire stripping tool to strip off about ½” of the insulation, thus exposing about ½” of bare wire. Match the spot on the tool with the size (gauge) wire you are using.
2. Hold the two wires parallel to each other, putting the two ends together with the exposed ½” of wire.
3. With your fingers, wrap the wires around each other.
4. Take a plastic wire nut and screw the wire nut onto the end of the wires that are now wrapped together.
5. Look at the bottom of the wire nut and make sure you don’t see any exposed wire. All the ½” of exposed wire should now be inside the plastic wire nut.

For light bulbs, use a socket that makes it easy to connect the wires to the light socket. For light bulbs, it doesn’t matter which wire (positive or negative) that you connect to which side of the light socket.

Solder (pronounced as if it were spelled “sodder”):

Sometimes, connecting wires to motors or light bulbs gets tricky because the wires keep coming off of the motor or light bulb. If you have trouble with this, and you have someone available who can help you, you might decide to use solder to connect the wires to the motor (or light bulb). Solder can act as both a glue to hold the wire on, and conduct electricity too.

Solder is made of a very soft metal that melts at a relatively low temperature, and then cools and hardens back to a solid again. In this case, “relatively low temperature” is still quite hot, and absolutely will burn you (and hurt a lot) if you are not careful.

Safety precautions:

1. Absolutely make sure you have good adult supervision
2. Wear eye protection (goggles)
3. Wear a long sleeve shirt. T-shirts that fit close to your arms are good.
4. Make sure you have a stand to hold the soldering iron
5. Make sure you are soldering on a fire resistant surface
6. Unplug the soldering iron when you aren’t using it!!!

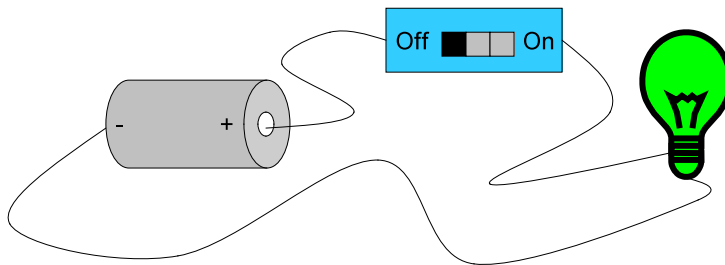


**Simple on/off switches:**

Look at Diagram #3. In this diagram, the light bulb will always be on, and the battery will go dead quickly. The only way to turn off the light bulb is to disconnect one of the wires.

Look at Diagram #4 – there is now an “on-off” switch in the middle of the wire.

Simple circuit – battery and light bulb  
Simple on/off switch added



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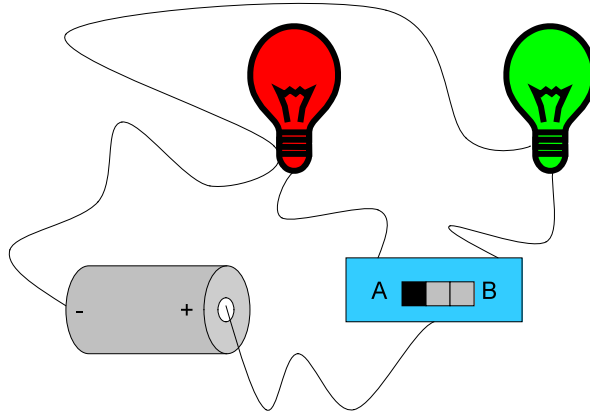
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Inside a simple on/off switch, the switch is either making the two wires touch each other, which allows electricity to go through the switch and to the light bulb or motor, or the switch causes the wires not to touch each other, and so no electricity can go through.

A simple on/off switch will only have two connections. These switches are called “SPST” or Single Pull, Single Throw switches.

**Single Pull, Double Throw switches:**

Simple circuit – battery and two light bulbs  
SPDT switch added



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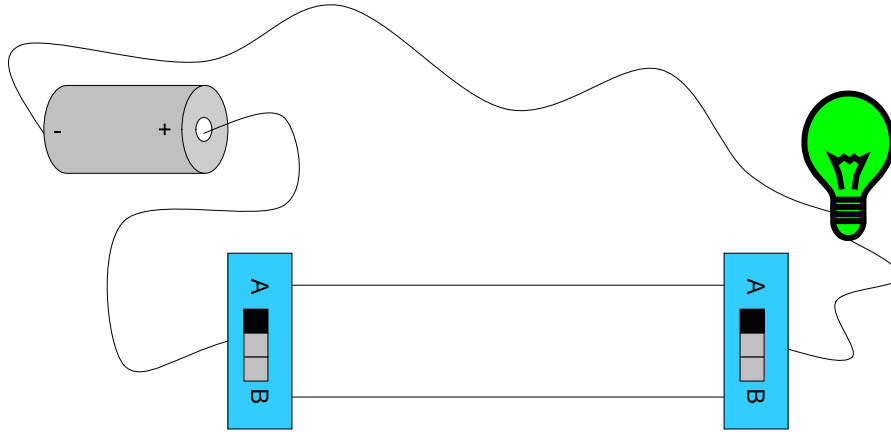
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These switches have 3 connections, one input and two outputs. The voltage from the input is directed to one or the other, but not both of the outputs. These switches are called “SPDT” switches. On the part of the switch that you move with your fingers, sometimes these switches will have 3 positions, with the middle position being “off”.

Another common use of SPDT switches is to use two of them together to control the same device. Sometimes, you might need to have two different on/off switches to control the same thing, especially if you need to have the two switches far apart from each other. This makes it easy to turn something on and off from two different places. In your house, sometimes there will be two light switches, on two different walls, that control the same light. SPDT switches are used for this.

Simple circuit – battery and light bulb  
Two SPDT switches added



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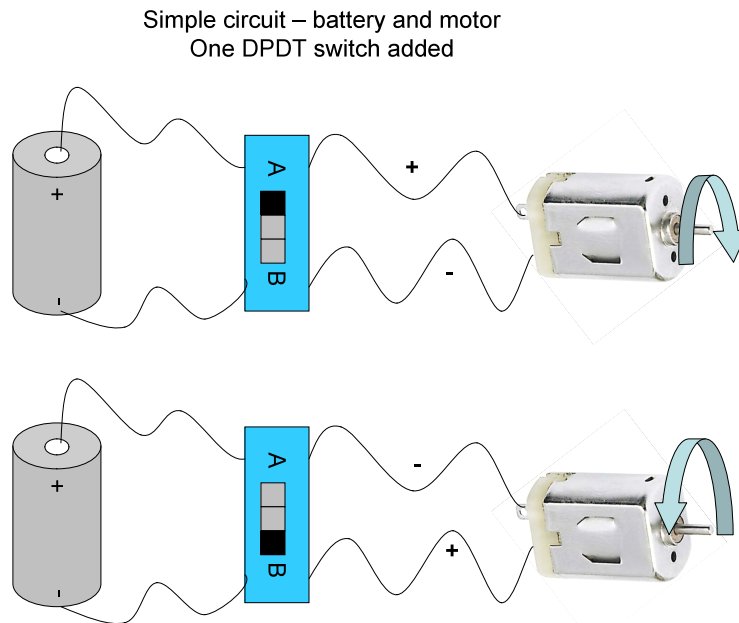
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When both switches are in the “A” position, electricity connects to the light bulb by going through the top wire in the diagram. If either switch is moved to the “B” position, the light will turn off. If both switches are moved to the “B” position, the light bulb will work, with electricity getting to it through the bottom wire in the diagram.

**Reversing voltage:**

On a typical DC motor, you connect the positive (+) side of the battery to one connection, the negative (-) side of the battery to the other connection, and then the motor spins. If you reverse the connections, the motor will turn the other way (reverse from the direction it originally was spinning). You can make this happen easily with a switch called a “double pull, double throw” or DPDT switch.

DPDT switches have four connections – two inputs, and two outputs. The part of the switch that you move with your fingers will usually have three positions (left, middle, right). In the left position, the two inputs are directly connected to the two outputs. In the middle position, the switch is off – no power passes through it. In the right position, the two inputs are reversed on the two outputs. This makes it very easy to use a DPDT switch to reverse the electricity (positive, negative vs. negative, positive) on the two outputs.



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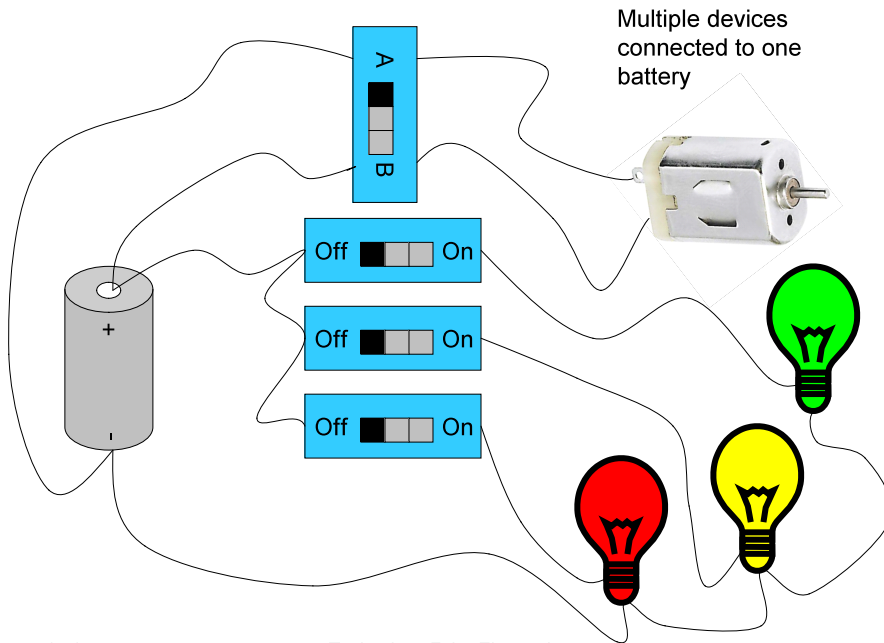
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With the DPDT switch in the A position, the top wire is positive and the bottom wire is negative. By switching the DPDT switch to the B position, the top wire becomes negative and the bottom wire becomes positive. This will reverse the direction of the motor.

**Connecting multiple things to one power supply:**

Think about a simple power strip. You can plug the power strip into the wall, and then plug several things into the power strip.

You can do the same thing with batteries and wires. You just have to be very careful to keep the wires separated. Don't cross a wire connected to the positive end of the battery with a wire connected to the negative end.



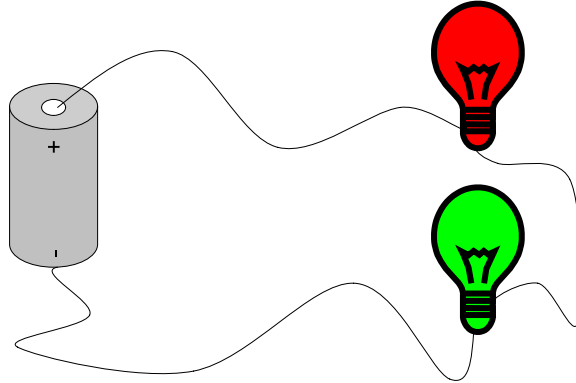
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All of these devices will work fine the way they are set up in this diagram. Each on/off switch controls one light bulb, and the DPDT switch at the top controls the motor. These devices (light bulbs and motor) are wired “in parallel”. That means that each device is connected to the battery without going through another device (other than the switch). This is almost always the way you will want to connect things to batteries.

Devices connected in series



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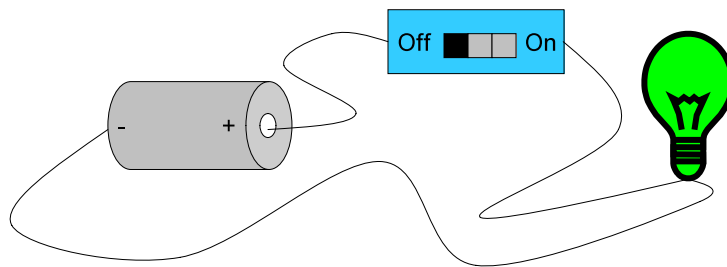
Follow the wire out the positive (+) end of the battery. It goes to the red light, passes through the light, goes to the green light, and then goes back to the negative (-) end of the battery. The lights are connected “in series”. This is almost always bad. What happens if the red light bulb burns out?

### What's wrong with my circuit?

Dead battery – happens all the time. This is the easiest thing to check. You can also use a volt meter to check the strength of a battery.

### Short Circuit:

Short circuit



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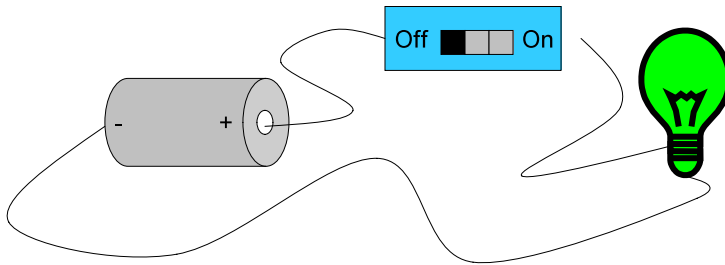
This happens when the positive (+) end of the battery gets directly connected to the negative (-) end of the battery. Very bad things happen!!!

1. Nothing connected to the battery will work
2. The battery will go very dead, very fast
3. The wire will get very hot, very fast
4. The insulation on the wire might melt
5. Hot wires burn fingers
6. The battery will get very hot, very fast
7. Sometimes hot batteries explode

If you think this is happening, disconnect the battery quickly. Check all the wires carefully, and replace the battery after you have corrected the problem.

**Open Circuit:**

Open circuit



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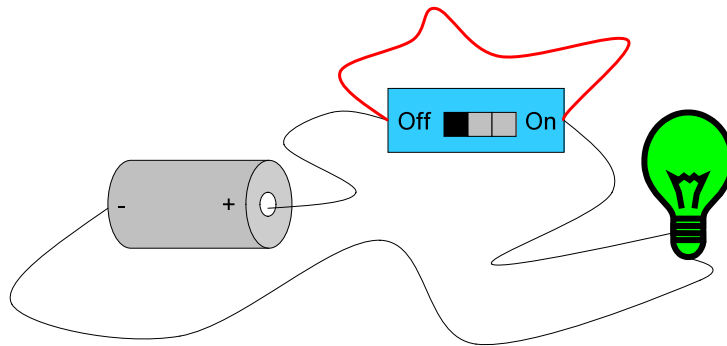
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This is the basic “loose wire problem”, and happens all the time. It’s easy to find if you only have a couple of wires. If you have lots of wires, this can be really tricky finding the one that’s loose. A volt meter helps a whole bunch. You can use it to find out where you do, and where you don’t have voltage.



Bypassing a suspected dead switch



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Another common problem is a broken switch. Switches have moving parts, and sometimes break. If you suspect that your switch may be the problem, try using a small spare piece of wire, and bypass the switch by connecting the two wires. The red wire in the diagram shows how to do this.