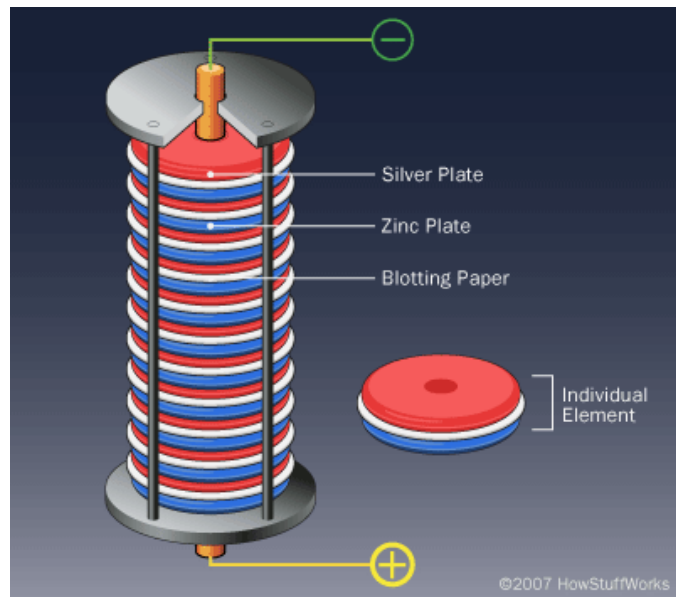


1. Spare Change Flashlight

1.1. Battery introduction

(Adapted from reference 10) Today, batteries are all around us. They power computers, phones, smoke detectors, etc. Batteries are critical not only for current power demands but they will play a critical role in increasing implementation of renewable energy technologies due to the non-overlapping times of power generation and societies power consumption. While there are many different types of batteries, the basic concept by which they function remains the same. When a device is connected to a battery, a reaction occurs that produces electrical energy. This is known as an **electrochemical reaction**. Italian physicist Count Alessandro Volta first discovered this process in 1799 when he created a simple battery from metal plates and brine-soaked cardboard or paper – like you will be doing shortly.

The internal workings of a battery are typically housed within a case. Inside this case are a **cathode**, which connects to the positive terminal, and an **anode**, which connects to the negative terminal. These components, more generally known as **electrodes**, occupy most of the space in a battery and are the place where the chemical reactions occur. A **separator** creates a barrier between the cathode and anode, preventing the electrodes from touching while allowing electrical charge to flow freely between them. The medium that allows the electric charge to flow between the cathode and anode is known as the **electrolyte**. Finally, the **collector** conducts the charge to the outside of the battery and through the load.



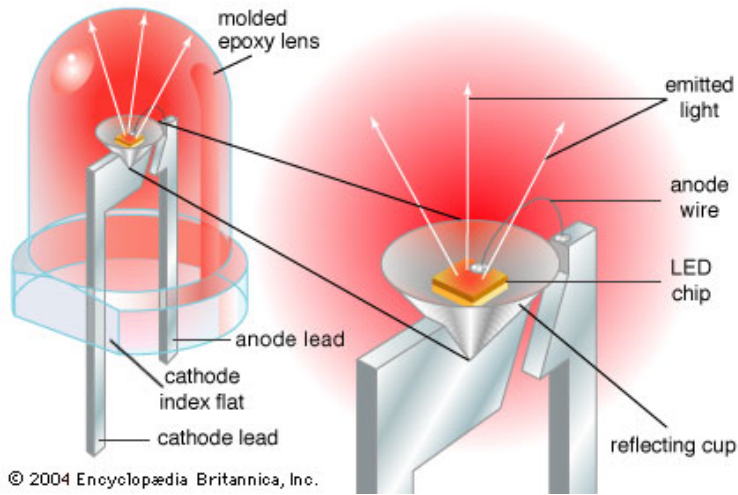
When a load completes the circuit between the two terminals, the battery produces electricity through a series of electrochemical reactions between the anode, cathode and electrolyte. The anode experiences an **oxidation reaction** in which **ions** (electrically charged atoms or molecules) from the electrolyte combine with the anode, producing a compound and releasing one or more electrons. At the same time, the cathode goes through a **reduction reaction** in which the cathode substance, ions and free electrons also combine to form compounds. The reaction in the anode creates electrons, and the reaction in the cathode absorbs them. The net product is electricity. The battery will continue to produce electricity until one or both of the electrodes run out of the substance necessary for the reactions to occur. Batteries are normally grouped together in a **serial arrangement** to increase the **voltage** or in a **parallel arrangement** to increase **current**. In series, the voltage is increased, and in parallel the current increases. Batteries are rated in amp-hours, or, in the case of smaller household batteries, milliamp-hours (mAH). A typical household cell rated at 500 milliamp-hours should be able to supply

500 milliamps of current to the load for one hour. You can slice and dice the milliamp-hour rating in many different ways in terms of current and time.

Cool video on how batteries work: www.youtube.com/watch?v=CX8415ZZHVg

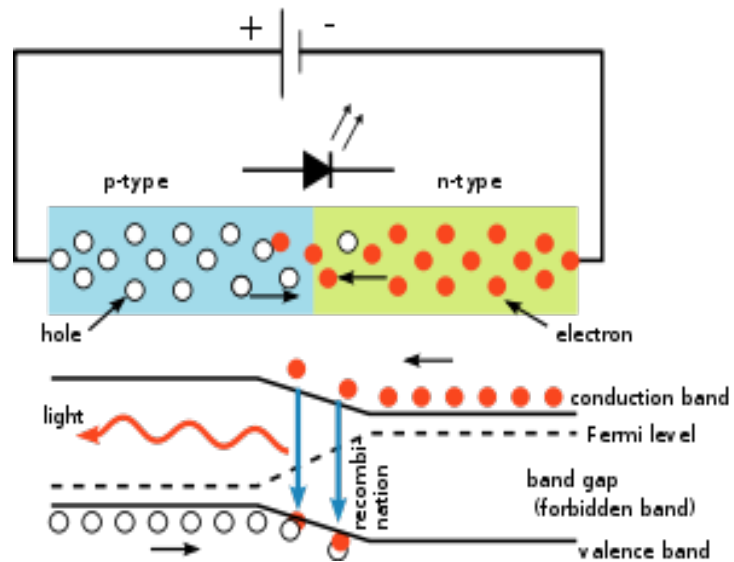
1.2. Light Emitting Diode (LED) introduction

(Adapted from how stuff works) Light emitting diodes (LEDs) are quite different than ordinary incandescent bulbs, they don't have a filament that will burn out, and they don't get especially hot. LEDs are illuminated solely by the movement of electrons in a semiconductor, and they last just as long as a standard transistor. The lifespan of an LED surpasses the short life of an incandescent bulb by thousands of hours.



Broadly speaking, a semiconductor is a material with a varying ability to conduct electrical current. Most semiconductors are made of a poor conductor that has had impurities (atoms of another material) added to it. The process of adding impurities is called doping. In doped material, additional atoms change the balance, either adding free electrons or creating holes where electrons can go. Either of these alterations make the material more conductive. A semiconductor with extra electrons is called *n*-type material, since it has extra negatively charged particles. In *n*-type material, free electrons move from a negatively charged area to a positively charged area. A semiconductor with extra holes is called *p*-type material, since it effectively has extra positively charged particles. Electrons can jump from hole to hole, moving from a negatively charged area to a positively charged area. As a result, the holes themselves appear to move from a positively charged area to a negatively charged area.

A diode consists of a section of *n*-type material bonded to a section of *p*-type material, with electrodes on each end. Applying a voltage to the diode pushing electronic from the *n*-type region to the *p*-type region. Once the



electron crosses the junction and into the *p*-type region it sees the extra holes, and fills the hole. The filling process is called recombination, and in LEDs this typically results in light emission, or so-called, radiative recombination. Radiative recombination emits a photon – or a quanta of light. Lots of recombination events ($\sim 10^{12}$) are required for the LED to become a bright light. As free electrons move across a diode and fall into empty holes in the *p*-type layer. This involves a drop from the electron conduction band to a lower energy state and the energy of the photon is directed related to the magnitude of this energy difference.

In conventional incandescent bulbs, the light-production process involves generating a lot of heat (the filament must be warmed). This is completely wasted energy, unless you're using the lamp as a heater, because a huge portion of the available electricity isn't going toward producing visible light. LEDs generate very little heat, relatively speaking. A much higher percentage of the electrical power is going directly to generating light, which cuts down on the electricity demands considerably.

1.3. Spare Change Battery Activity

Who: Group of 4 students

What: Build a battery out of pennies to light up an LED. The purpose of this activity is to learn concepts of energy storage, electricity, light, energy conversion from electrochemical energy to light energy.

Where: Classroom

Time: 4 hours

Supplies:

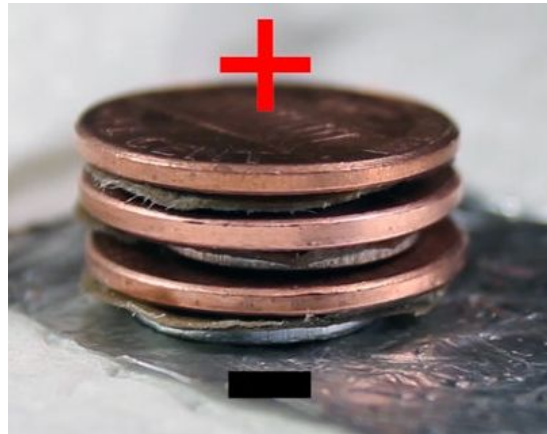
Item (Consumables)	Quantity	Check-out	Check-in	Notes
Pennies (1944-1982)	10		NA	
Zinc washers	10		NA	
Al foil – square	1		NA	
Cardboard – square 4”x4”	1		NA	
Multimeter	1			
Vinegar bottle	1			
LED - red	1			
LED – green	1			
LED – blue	1			
Scissors	1			
Electrical tape role	1			

Objective:

- Construct a simple battery using pennies, and electrolyte and zinc washers.
- Explore effects of series and parallel circuit configurations.
- Power an LED with the battery

Procedure:

- 1 Using scissors cut the cardboard into 10 small circular pieces, slightly larger than a penny.
- 2 Soak the cardboard pieces in your electrolyte (the salt water, lemon juice or vinegar) for 2-3 minutes.
- 3 While the cardboard is soaking, take your aluminum foil and place it in your workspace. Place a zinc washer on it.
- 4 Remove the cardboard from the electrolyte solution, using a paper towel blot each piece dry. This is just to keep the pieces from dripping, do not over dry the cardboard.
- 5 Place a single piece of cardboard on top of the zinc washer in your workspace.
- 6 Place a penny on top of the cardboard and you have finished the battery; however, we will use this as just one cell of our battery.
- 7 Using the DC voltage setting on the multi-meter, measure the voltage of the individual cell. You can do this by placing one lead of the meter on the aluminum foil and the other on the penny, make note of this reading (below). Using the DCA setting, measure the current of the cell as well.
- 8 Pick an LED, make sure to look at the required voltage.
- 9 Using the voltage reading from the first cell, and the required voltage of the LED, determine how many cells you will need to power the LED. The voltage of n number of cells can be found by $V=n*\text{voltage of one cell}$. Build the required number of cells and stack them together, the sequence from bottom to top should be: foil, washer, cardboard, penny, washer, cardboard, penny...
- 10 Test the voltage and current of your battery using the multi-meter. Compare these numbers to those of the individual cell, and calculated values.
- 11 Connect the LED to the battery, touch the long lead (positive) of the LED to the top of the penny and the short lead (negative) to the aluminum foil, it should illuminate.



- 12 Remove the aluminum foil from the bottom of the stack. Using the electrical tape wrap up the battery (with the LED connected). You now have a self powered LED, it could last anywhere from one to 16 days!
- 13 Attempt to make a switch for your LED flashlight such that you can turn on the light on demand.

Note:

- If the cardboard pieces touch while in the battery, the battery could short out and experience performance issues.
- The battery could be used to power other low current devices as well if wires were attached.
- The reason for wrapping the battery in electrical tape involves it's life span. Once the cardboard dries out, all the electrolyte, which drives the battery, is gone and it will not operate. The battery is wrapped in tape in an effort to provide an airtight seal, slow the drying process, and extend the battery's lifespan.
- This experiment can also be conducted by using pennies dated 1982 or later and sanding off one face of the penny to expose the zinc core while leaving the other side copper.
- The date range of pennies needs to be specified for this experiment due to the change of composition throughout history. Between 1944 and 1981 pennies were 95% copper and 5% tin, zinc or a mixture. Since 1982 pennies have been made of copper plated zinc cores (97.5% zinc, 2.5% copper).

Worksheet

Number of cells	Voltage Measured
1	
2	
3	
4	
5	

LED color	Voltage need	No. of cells to light LED

Working time	Cause of failure	How to improve
1		
2		

Notes: