February 20, 2007
P. Shields

Student Handout.

Demonstrate Knowledge of Electrochemistry.

Electric Cells are used to covert convert chemical energy into electrical energy the process is called Electrochemistry.

TERMINOLOGY

Battery versus a cell: Most people use these words the same way. Battery engineers only use "battery" to refer to two or more individual cells connected together within one package. Thus your watch probably only has a single cell, your flashlight has a couple of cells, and your camcorder has a complex battery with several cells inside the black plastic package.

Throw Away or Rechargeable: Engineers call throw-aways "primary," and rechargeable "secondary."

Power is expressed in Watts. Multiply current, measured in Amperes (Amps), by Volts to get power in Watts. Power is the ability to do work. If you imagine this as water in a hose, Volts is the water pressure and amps are how many gallons flow. How much you can spray off your driveway is thus the water pressure times how much water flows at that pressure. Volts, Amps and Watts are always capitalized since they are named after men who invented much of this: Alessandro Volta (Italian) who invented the first battery, James Watt (Scottish) who designed improvements to steam engines and mathematician André-Marie Ampère (French).

Energy is power over time, measured in Watt-seconds (Ws), also called a Joule, named after English physicist James Prescott Joule. A kilowatt-hour is 1,000 x 60 x 60 or 3,600,000 joules.

Capacity is how much current is stored by a cell. Even throwaway cells have these ratings, although only engineers worry about it or look it up. These ratings are plastered all over rechargeable. It's usually measured in Ampere-Hours or milliampere-Hours. 1 Ah is the same as 1,000 mAh. A 1,000 mAh cell can deliver 1,000 mA for an hour, or 1 mA for 1,000 hours.

In reality cells are measured at about a 20-hour discharge rate. Cells have less capacity when more power is drawn, thus a 1,000 mAh cell would probably die after a half hour if delivering 1,000 mA. When capacity is measured it is measured to a stated cut-of voltage and at a stated rate. The same cell will have completely different capacities when measured at different rates and to different cut-off voltages. Therefore when you see these numbers on a package they are meaningless unless the rate and cut-off are specified, which usually they aren't. In addition to plain lying, this explains why you shouldn't bother to compare different brand's ratings to each other.

TECHNOLOGIES

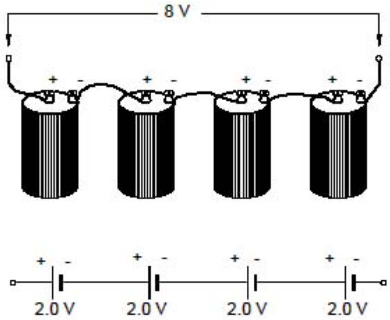
Throw-Away (Primary) (Non-Rechargeable)
The active materials of the cell are used up or exhausted during the process of providing electrical energy (doing electrical work). These 'dry cells' where initially developed (after an Italian Voltair invented the first Voltaic Cell in 1799), to provide relatively small amounts of energy to small portable electric appliances. The chemical reaction that takes place when electrical energy is produced changes the chemicals from one form to another thereby rendering them inactive after all the reaction has been completed. Each cell or Battery (group of cells) initially has a very low 'Internal Resistance", which is why you should never short the terminals of a cell/battery as to do so (Ohms Law) would cause a large initial current to flow due to this low IR and lack of any external resistance. These currents on large batteries and special types of batteries can be hazardous causing injury or fire damage. If you have accidentally shorted the terminals of a car battery with a screwdriver you will almost certainly seen this effect. However as the chemicals in the cell/battery are depleted the internal resistance of the cell increases dramatically and eventually it becomes to high to be an effective source of e.m.f.

Cell Capacity is the product of the current supplied by the cell/battery and the time the cell maintains this discharge. Normally measured in ampere/hours a cell might be rated at 3AH therefore be able to theoretically supply .3 amperes of current for 10 hours.

Desirable Qualities of a Primary Cell.

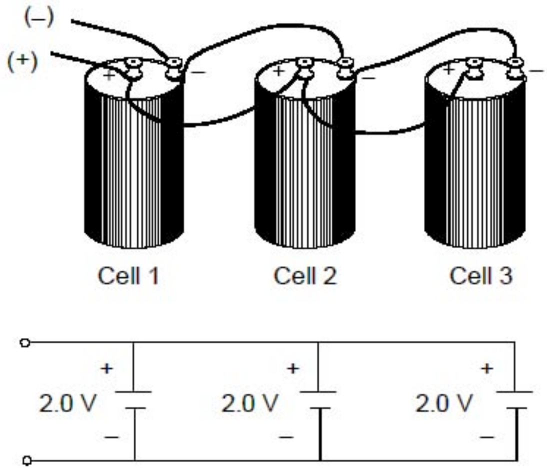
1. Low Internal Resistance
2. No Polarisation (The active chemicals are separated by chemicals that absorbed chemical by products that would interfere with the performance of the cell)
3. No Local Action (impurities in the active chemicals can act as mini cells themselves and act in opposition to the performance of the main chemical action.)
4. High Capacity
5. Long Shelf Life (The ability of a cell to be stored idle without leaking or depleting its stored energy.)
6. Quick restore time (Cells that have a large short term load put on them can have a certain ability to recover their initial output after being idle.)
7. Low Cost
8. Portability

Batteries are made by connecting two or more cells in series as follows:



Series Cells

The capacity of the battery remains the same but the total e.m.f. Available is the sum of all the individual cells. In contrast a number of cells connected in parallel does not form a battery but a cell with the same individual cell e.m.f. But with an Ah capacity equal to approximately the sum of all the individual cell capacities.



Parallel Cells

Note: The electrodes of the battery or cell are identified by the charge, the – negative or anode and the + positive or cathode.

"Heavy Duty"

Avoid these. They are also called carbon zinc, zinc-manganese dioxide, Zn/MnO2, and LeClanché. These are the oldest, crummiest kind. Remember when flashlights only worked for a few minutes before they started to get dim? These were the batteries! They never could deliver much power for anything. You can still get these throughout the third world and in discount stores. I was amused at seeing a Duracell ad poking fun of the Eveready brand of these. It was unfair since Eveready makes both these crappy kind as well as batteries far more advanced. Anyway, ignore these batteries for everything except things with very low drains. Don't use them for a flash. They work great in things that run for a year like smoke detectors and clocks. They die after a couple of years in storage.

Capacity: Eveready Heavy Duty AA: 1,100 mAh.

Alkaline

These are the most popular today and work great. There are some premium versions, like Eveready's e2 Titanium, that work a little better in high-power applications like flashes and digital cameras. Personally I find they cost more than the benefit they offer compared to the regular alkaline batteries. Alkalines come in every size, from regular AA, C and D sizes as well as little button cells for watches and light meters. They last for years in storage. I have a healthy set in a flashlight that still works great even though the install by date passed five years ago.

Capacity, AA size: 2,700 to 3,135 mAh. Most AA Alkaline cells offer a capacity of 2,850 mAh. The expensive Energizer e2 alkaline offer 3,135 mAh and the cheapest cells offer 2,700 mAh, all pretty much alike at low drains. That's why Consumer Report's testing suggested getting whatever's cheapest. Note that "Titanium" is just marketing poof; these are not Lithium or titanium, they're just alkaline.

Because Duracell, Eveready Energizer and Rayovac offer to repair any damage caused by leaking batteries I only buy them, and never store brands. Even though the discount brands offer the same performance for a lot less money, when you eventually have one leak in your camera you'll be very, very glad that you weren't using store brand alkalines!

Panasonic Oxyride

Panasonic introduced these in 2005. They sell for the same price as alkaline AA cells. They have a higher initial voltage, 1.7V, compared to ordinary alkalines, which are 1.5V. Thus when new flashlights will burn brighter with Oxyride than with other cells. This also means that the bulbs will burn out faster, too.

Fantastic for high drains like digital cameras and I would suggest them also for electronic flash, but a poor choice for clocks, pagers and radios and things that usually run a long time on a set. For these regular alkaline are still better.

Lithium (note that Lithium also comes as Lithium Ion rechargeable below)

These are expensive. They were developed for the US military because they offer double the power in the same size with half the weight.

Lithium batteries have shelf lives of ten years or more, so stock up and don't worry. They come in various special sizes for cameras and also AA. You have no choice for the special camera sizes; they only come in Lithium.

Capacity: Energizer Lithium AA cells offer 3,000 mAh, the same as Alkaline.

Tip: Use the AA lithium’s only for things that draw a lot of power, like a flash or a digital camera. They offer the same life as alkaline in things like clocks and pagers. They offer greater life only when you draw a lot of power as in a digital camera or flash. Lithium’s are supposed to work better than alkalines at cold (sub-zero) temperatures.

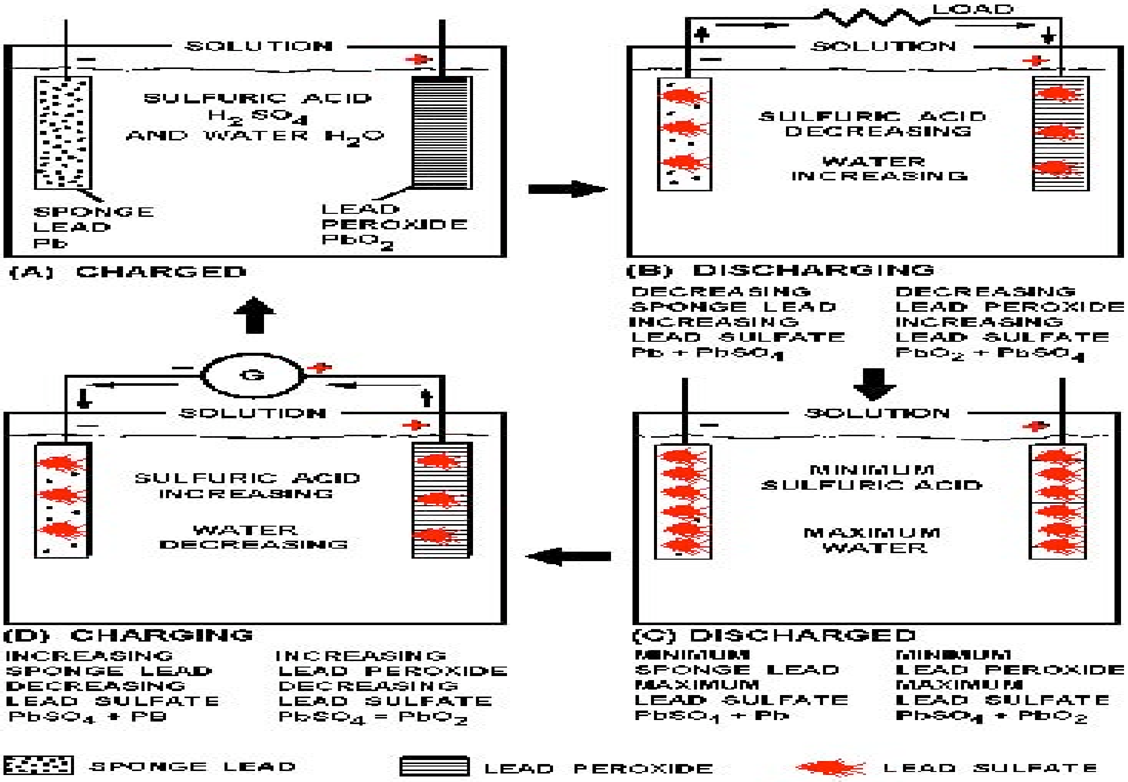
Mercury (obsolete)
They were used in cameras from the 1960s and 1970s. Mercury cells had the advantage of constant voltage all the time, so they were ideal as references powering CdS cell light meters.

Rechargeable (Secondary)

Used for heavy currents over long periods of time. When the chemical components are depleted, a current can be passed through the chemicals in the reverse direction restoring them to their original state.

Lead Acid and Gel Cells

The first lead-acid batteries were used for telegraphy by Gaston Planté in 1859 and became available commercially in the 1880s. It's interesting to note how rechargeable batteries have always been involved with communication; your cell phone today runs on a Lithium Ion battery described below. A lead-acid battery starts your car. They are filled with liquid sulphuric acid and you don't want to spill them. Lead acid batteries are also available with gelled acid, called gel cells, which doesn't spill and can be used upside down. Gel cells are used in home alarm systems, backup power systems and your home computer's uninterruptible power supply (UPS) if you have one. Lead acid is not used in photography, except as heavy-duty supplies for some lighting equipment.



Care and Use: Lead acid batteries prefer to be kept charged all the time. They can deliver very high power. That's why they are perfect for use in your car: they can deliver thousands of watts to start your car, and then are kept charged as you drive around. Deep cycling them is bad for them, and there are special kinds of lead acid batteries designed for this. Likewise, they are perfect for use in power backup systems where they are very happy being kept charged for years just waiting and can deliver enormous amounts of power instantly. Other kinds of battery need exercise; lead acid doesn't.

Charging: Lead acid is very easy to charge. They are charged to a constant voltage through some form of current limiter. The electrolyte in the lead acid cell is sulphuric acid water mix with a specific gravity of about 1.215 – 1.280 (Pure sulphuric acid has a specific gravity of 1.840 an water is of course 1.00).

Alkaline: Ray-o-Vac invented rechargeable alkalines in the 1990s. They never caught on.

Nickel-Cadmium (Ni-Cd)

These were the first popular rechargeable for modern electronics. They got popular in the 1960s. They still offer the most charge and recharge cycles of any technology. They also offer the lowest capacity so you'll be charging them much more often. Ni-Cds are unbeaten in their ability to provide dangerous amounts of current instantaneously if short-circuited. Therefore they're popular in cordless soldering irons because they heat up instantly. Caution: if you short circuit them with a wire the wire will immediately glow and maybe even burn up. You easily can hurt yourself if you throw them in a pocket with keys or change. This of course is a good thing allowing fast flash recycle times and fast frame rates when used in camera motor drives.

Capacity, AA size: 650 to 1,000 mAh, not very much.
Care and Use: Mandatory: they should always be fully charged and then run all the way down before being charged again. This means for most field uses you need two sets so you have a fresh set with you for when the first set dies. If instead you just charge them up when you need them you eventually will get very little run time. This is called the memory effect. They learn how little you use them and then only provide that much capacity. They're like muscles: you have to use them to keep them strong. You have to baby Ni-Cds so I don't recommend them for anything. They also contain poisonous cadmium and must be disposed of properly. I don't even know where you can buy these today.

Charging: At slow overnight rates even the simplest circuitry has been used to charge Ni-Cds, since you don't have to worry about them overcharging at the slow rate. More advanced circuitry is required to charge them more quickly since the Ni-Cds could blow up at faster charge rates if the charger is not smart enough to cut off the current. Smart chargers today are very common and can charge these in several hours or less. As soon as all the charge is put back you stop charging, simple.

Nickel-Metal Hydride (Ni-MH)

These are the most popular rechargeable today in AA and other regular sizes. They replaced Ni-Cds in notebook computers in the late 1980s and became available in AA size in the 1990s. They offer twice the capacity of Ni-Cds and require less babying. Most chargers recharge them in a couple of hours. Otherwise they are very similar to Ni-Cd, although don't have quite the peak current ability of the Ni-Cds or offer quite as many charge/discharge cycles.

Charging Speed:
The electrical energy fed to a cell turns to chemical energy as it charges. When the cell is full the power no longer can turn to chemical energy and instead turns to heat. If the charger isn't smart enough to know when to turn off, which was the case in the 1970s, the charging current needed to

be low enough not to damage the cell from overheating. This is why it took 15 hours to charge Ni-Cd cells back then, and why the crummiest chargers still take overnight.

The speed of any charging system today is limited its ability to know when to turn off. If you continue to jam a lot of power into a charged cell it will explode; whoops! Today most Ni-MH and Ni-Cd systems take a few hours.

Capacity in AA size: 1,350 to 2,500 mAh. Look out; many shifty brands lie about their capacity. 2,300 is pretty standard in 2004 and 1,350 was typical in 1999. My 1999 1450 mAh Sanyo's still outperform newer off brands marked 2300 MAH! In big letters, so buy quality and not specs. Anything from battery pioneers GE/Sanyo and Panasonic ought to be great.

Care and Use: They still should be completely run down and then fully charged each time. They give the best service and life this way. Avoid using Ni-MH if you don't intend to run them all the way down each time. I always have two sets with me, so I can replace the set in use when it runs down completely. The advantage of Ni-MH over Ni-Cd is that if they lose capacity from memory issues you easily can rejuvenate them by running them through a full discharge-charge cycle a couple of times. They do have memory issues, which is why you see so many sold as "memory free."

Caveat: 5 years ago Ni-MH was an advanced technology, so the only manufacturers who made them, like Sanyo, made them well. Today all sorts of garbage are out there, and on top of that many makers make bogus claims about capacity (mAh).

Charging: Ni-MH chargers are usually smart chargers, which measure voltage and temperature to stop charging as soon as the batteries are full. Thus they can charge batteries as quickly as an hour or less since there is no worry about overcharging at the fat rate due to the smart charger. As soon as all the charge is put back you stop charging, simple.

Lithium Ion

These are the newest and best rechargeables, since they offer the most power, the smallest size, the lowest weight and require no babying like the Ni-MH and Ni-Cd. They are also the most complex and expensive. They were introduced in laptop computers about 1994 and became common in camcorders and everywhere in the late 1990s. They removed many pounds from each laptop and doubled the run time almost overnight. We would have no iPods or tiny cell phones and microscopic digital cameras today without these. Today every camcorder or digital camera and laptop computer uses these.

Care and Use: Completely different from Ni-Cd and Ni-MH, lithium's prefer to be charged early and often. They don't like to be run all the way down. You will get only a few hundred cycles if you run them all the way down each time, and thousands if you charge them up while still mostly full. Lithium Ion's life tends to be measured by how much total energy comes in and out of the battery and not by cycles. Actually you can get more total energy from the battery by only partly using the battery's capacity.

Chargers: They require very special chargers, unlike Ni-Cd and Ni-MH. Lithium is charged at a fast rate to replace the majority of the charge, and then trickle charged to replace the last 25% or so. Thus you may see charge state indicators which let you know when they are almost done, which happens very fast, and completely done, which takes much longer. Because special charging circuitry is required they are not offered in sizes to replace regular AA or other batteries.

RECYCLING

All modern batteries are loaded with powerful, poisonous chemicals and metals.
Actually except for the old carbon-zinc, you ought to recycle every dead battery.

Student Assessment Questionnaire.

Note: This part of the assessment is open book and 100% is the required result.

Enter the types, characteristics and applications of at least 6 different types of cells four of which are given to you.
(Note: Internet research is allowed)

Type	**Nominal Voltage**	**Typical Capacity**	**Primary/Secondary**
Lead Acid			
Nickel-Iron			
Nickel-Cadmium			
Mercury			

Name: ______________________________

Course: ______________________________

Date: ______________________________

NSN #: ______________________________

Tutors Signature: __________________________