Batteries…
May the Force Be With You

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First… Some Terminology

- Battery capacity is rated in Ampere-Hours (Ah). The amount of time the battery can deliver a given amount of current. For instance, a 10Ah battery can theoretically provide 10A for one hour.
- "C" also refers to this Ah rating. So… a C/10 charge rate on a 35Ah battery means 3.5A charge current

Characteristics of Batteries

- Four primary components: positive and negative electrodes, separator, and electrolyte.
- The physical construction as well as the battery chemistry affect performance
- We'll focus on re-chargeable batteries… but don't forget Alkaline batteries…

Characteristics of Batteries

- Different types vary in key characteristics:
  - Nominal cell voltage
  - Self-discharge rate
  - Number of charge cycles (life)
  - Max safe charge/discharge current
  - Weight for given capacity
  - Safety
  - Cost

Common Battery Technologies

- Lead Acid:
  - Flooded, aka “wet”
  - Sealed Lead Acid: AGM and Gel
- NiCd and NiMH
- Lithium-Ion
  - $LiCoO_2$ aka “LCO”
  - $LiNiMnCoO_2$ aka “NMC”
  - $LiFePO_4$ aka “LFP”

Lead Acid

- Cheap capacity
- Heavy compared to other batteries
- Slower to charge than others
- If stored for weeks or months with cell voltage much below 2.1V, *sulfation* occurs, which reduces battery life. Sometimes it can be fixed with a 24hr overcharge… other times it is permanent.

Lead Acid

- Flooded, aka “wet”
  - More dangerous than sealed.
    - Can spill acid
    - Corrosion issues
    - Generates hydrogen.. Boom!
    - Environmental concerns

Lead Acid

- Different construction types:
  - Car batteries designed for short duration, large discharge rate. But don't like deep discharging
  - Deep-Cycle batteries can't provide as much discharge current… but tolerate deep discharges

Lead Acid

- Construction types (Cont'd):
  - Marine: usually a hybrid. Generally shouldn't discharge below 50%
  - Golf cart batteries are typically "semi deep cycle". Usually can be discharged to 25-30%. Typically economical

Lead Acid

- Sealed lead acid
  - Safer than flooded but more sensitive to overcharging
  - Two to three times as expensive as flooded
  - Typical charge voltage: 2.37 to 2.40V/cell
  - Typical float voltage: 2.20 to 2.22V/cell

Lead Acid

- Sealed lead acid (Cont'd)
  - Gelled type
    - Can tolerate more discharges below 50% than starter batteries… deep-cycle better
    - Must be charged slower than AGM or flooded and at lower voltage
    - Don't function well below 32˚

Lead Acid

- AGM= Absorbed Glass Mat
  - Like gel, low self-discharge
  - Can discharge farther and charge faster than gel
  - Less likely to sulfate at low cell voltages (<2.05V/cell) than other lead acid batteries
  - For max battery life, don't discharge more than 50%

NiCd and NiMH

- NiCd= Nickel-Cadmium
  - Nominal cell voltage of 1.2V
  - High self-discharge rate
  - Supports high discharge rate
  - Long life… with an intelligent charger..
  - Much lighter than lead acid
  - More $ than lead acid
  - Cadmium= Bad

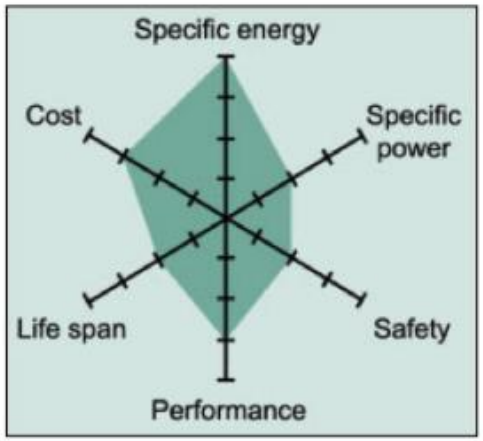
NiCd and NiMH

- NiMH=Nickel Metal Hydride
  - Similar to NiCd, but…
  - Safer for environment
  - Higher capacity
  - Cheaper
  - Tolerates deep discharge
  - Higher self-discharge rate
  - Trickier charger design than NiCd. Shouldn't use trickle chgr.

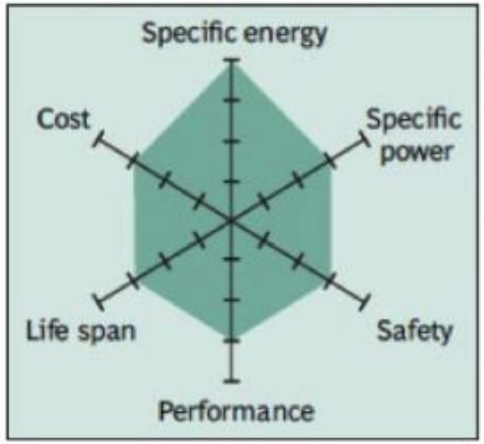
Lithium-Ion

- Lithium-Ion
  - $LiCoO_2$ aka “LCO”
  - $LiNiMnCoO_2$ aka “NMC”
  - $LiFePO_4$ aka “LFP”

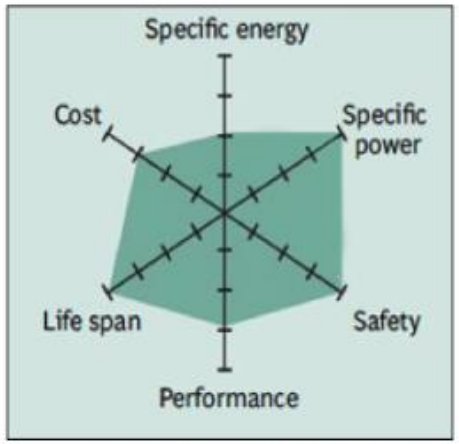
Lithium Cobalt
$LiCoO_2$



Lithium Nickel-Manganese Cobalt Oxide (NMC)
$LiNiMnCoO_2$



Lithium Iron Phosphate
$LiFePO_4$ (LPF)



Source: Battery University

Lithium-Ion

- $LiCoO_2$ aka “LCO”
  - Lithium Cobalt Oxide.. cobalt oxide is the “ion” part..
  - What is usually meant when we refer to “lithium” batteries
  - Nominal cell voltage of 3.6V (don’t discharge below 2V)
  - Relatively low lifespan and limited load capacity (<C)

Lithium-Ion

- $LiCoO_2$ aka “LCO” (Cont’d)
  - Can explode!
    The industry prefers “rapid disassembly” ☺
  - Batteries often designed to limit charge/discharge current to C.
  - Shouldn’t be charged below 32°

Lithium-Ion

- $LiNiMnCoO_2$ aka “NMC”
  - Lithium Nickel Manganese Cobalt Oxide
  - Low internal resistance allows high charge/discharge current
  - Improved longevity
  - Used in Chevy Volt, Nissan Leaf, e-bikes, power tools, etc
  - Safer and cheaper than LCO

Lithium-Ion

- $LiFePO_4$ aka “LFP”
  - Lithium Ferrophosphate
  - Higher self-discharge rate than other lithium-ion batteries
  - Supports high charge/discharge rates and has long life
  - Often used to replace lead acid starter batteries
  - Tolerant of abuse

Lithium-Ion

- $LiFePO_4$ aka “LFP” (Cont’d)
  - Nominal cell voltage of 3.3V
  - Typically supports 2 to 4 times as many charge cycles as AGM
  - LFP batteries can be discharged 80% (compared to only 50% for AGM)

Lithium-Ion

- $LiFePO_4$ aka “LFP” (Cont’d)
  - At high discharge rates, has significantly higher usable capacity than AGM with same Ah rating
  - BEWARE: Some LFP vendors cite a PbEq Ah or Lead acid equivalent Ah. Others use the term “Lithium Ah”… all to triple the true Ah rating in specs!

Lithium-Ion

- $LiFePO_4$ aka “LFP” (Cont’d)
  - Safest current type of Lithium battery. It generates only 5.5% of the heat of LCO batteries and the thermal runaway temperature is a 270˚ (vs 130˚ C for LCO).
  - Typically half the weight of AGM

Lithium-Ion

- $LiFePO_4$ aka “LFP” (Cont’d)
  - Shouldn’t discharge a “12V” battery below 10V
  - Don’t use a “battery minder” type of battery charger (one that tries to de-sulphate with periodic high current pulses).
  - Chargers not designed for LFP may overcharge a deeply discharged battery.

Misc Tips and Info

- "C" equals Ah capacity. For AGM batteries, typical recommended charge rate is 0.2C. For instance, a 10Ah battery should be charged at a 2Amp charge rate. For a Lithium battery, typical recommended charge rate is 0.5C, though it can tolerate 2.5C (with reduced cycle life).

Misc Tips and Info

- Deep cycle batteries are rated in ampere-hours (Ah). Typically based upon max current draw for 20 hours to 10.5V (for 12V battery). Sometimes 6 and 100 hour rates are given for different applications. The faster a battery is discharged, the LOWER the Ah capacity.

Misc Tips and Info

- Unlike other battery types, lead acid battery *state of charge* can be determined fairly reliably off of the cell voltage (after resting for 3 hours). For a 12V battery:
  - 12.7V 100% charged
  - 12.4V 70% charged
  - 12.1V 50% charged
  - 11.9V 40% charged (minimum recommended)

Misc Tips and Info

- If a battery is rated in CCA (cold cranking amps) or MCA (marine cranking amps), it may not be a deep cycle battery, regardless of that term being used by manufacturer.

Misc Tips and Info

- Avoid using a fast/rapid charger in low or high temperatures. Also avoid using with aged/low performing batteries
- Your chance of being struck by lighting in your life is 1 in 13,000. Lithium-ion battery failure rate is 1 in 1 million (1 in 10 million for quality batteries).

For More Info on Batteries

- www.wikipedia.com — for quick research
- www.batteryuniversity.com — for more in depth information