Rechargeable Batteries and Temperature

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Inspiration

I noticed a big disparity in the performance I would get from the same batteries when flying in the winter versus the summer.

Inspired by what I noticed flying RC quadcopters, I wanted to find out more about the effect temperature has on batteries and to be able to visualize the relationships.
Objectives

I wanted to measure three criteria using the same procedure across multiple temperatures.

- Measuring Voltage and Amperage output from the battery while its under a load
- Measuring the time to fully discharge the battery
Lithium Polymer Batteries

Lithium Polymer (LiPO) batteries are known for their continuous high amperage output, with the specific ones I used for this experiment capable of 35 Amps.

LiPO batteries have an average cell voltage of 3.7 Volts.

This high amperage output and energy density make them a great choice for remote control quadcopters.
Nickel Metal Hydride (NiMH) Batteries often come in the size of AA or AAA batteries. NiMH batteries’ similar attributes to the traditional AA or AAA batteries make them a common rechargeable option for batteries in that form factor.

NiMH batteries have an average cell voltage of 1.2 Volts.

Traditional AA or AAA batteries have a nominal cell voltage of 1.5 Volts.
First Circuit Prototype

Very simple circuit. A plug for batteries on the right and the light as the load on the left. The alligator clips allowed for easy installment of the current and voltage multimeters.
Test Trial

The first test trial showed very low amperage output using a single LED panel.

It took nearly 10 hours at room temp to fully drain the NiMH batteries at this amperage, way too long with the way I was collecting data.
Circuit Revision

I soldered another LED panel in parallel with the other one to double the load on the battery. This almost exactly doubled the amperage output and halved the discharge time, just as I had hoped.
Due to the coronavirus shutdown, I had to change my data collection method from what I had initially planned.

For a substitute, I opted for using a multimeter for voltage and one for amperage. I then used my camera to take pictures on a 5 minute interval for the duration of the battery’s discharge.
Data Collection Downfalls

This method of collecting data was far from optimal. With it being a phone it was prone to having its battery die, or taking dark pictures with hard to read data, or falling over.

All of these events, while annoying, only seemed to lead to easily identifiable outliers in the data and did not seem to cause systematic error.
Testing at different Temperatures

Testing for both battery chemistries was done at room temperature, in our fridge at 41 Fahrenheit, and our freezer at 1 Fahrenheit.

Unfortunately due to the coronavirus we did not have the equipment to reliably do trials at other temperatures, limiting the scope of the data to these 3 temperatures.
LiPO Results

The room temperature and fridge trial show a very interesting steep voltage drop off compared to the more linear freezer trial.
NiMH Results

The NiMH did not have as much of a dramatic voltage drop off as seen in the LiPO graph.

The NiMH batteries I used here seemed to discharge at a significantly lower current than the LiPO batteries.
Room Temperature (75°F) Comparison

This comparison at room temperature really shows the major difference in how the different battery chemistries operate and potential uses that would derive from each.
Fridge Temperature (41° F) Comparison

The Fridge trials showed very similar trends as the room temperature.

Both batteries seemed to have a longer discharge time at this temperature but the NiMH’s change was more dramatic
Freezer Temperature (1° F) Comparison

Stepping down to the freezer temperature, the two curves start to look more and more alike.

The LiPOs steep drop off seen at the end of its discharge in the two previous temps is almost nonexistent at this temperature.
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How to Expand?

➔ Expand data collection to include more temperatures and different battery chemistries.
➔ Ensure reproducibility.
➔ Test at different amperage loads to see if the results and trends seen change.
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