

**Problem 1.1)**

C Rate	Q at T=25°C (Ah)	Q at T=45°C (Ah)
0.05	2.22	2.20
1	1.97	2.10
2	1.90	2.05
5	1.84	1.98
15	1.26	1.76

**Problem 1.3) Observations**

For this problem, I utilized the `fit()` function in MATLAB, using the `power1` fit type. This function found the best-fit curve of the form  $Q = k * I^n$ , where Q is the capacity in Amp-hours and I is the current in Amps. However, the desired form of the equation is  $Q = k * I^{1-n}$ , so the values reported below for the parameter n were obtained by multiplying the value obtained from MATLAB by -1 and adding 1.

Peukert Equation Coefficients		
	T = 25°C	T = 45°C
k	1.968	2.088
n	1.070	1.033
RMSE	0.216	0.087

The values of k are close to the nominal capacity of the battery, which implies that the nominal capacity of the battery is based on a C-rate which corresponds to roughly a 1A constant discharge current. The value of n for the 25°C trials was higher than that of the 45°C trials, which suggests that the effects modeled by the Peukert equation are not as strong at higher temperatures – at higher temperatures, battery capacity is diminished less by a higher discharge current. The RMSE for each of these curve fits seemed relatively high. Upon further examination, it seemed that the 0.05 C-rate trials yielded results that did not quite match the Peukert equation, so the fit was performed again while leaving out the 0.05 C-rate trials. The results can be seen below.

Peukert Equation Coefficients – Excluding 0.05C trial		
	T = 25°C	T = 45°C
k	2.02	2.11
n	1.041	1.021
RMSE	0.005	0.023

### Problem 1.5) Observations

These plots make it apparent that the data from the 25°C trial appears to be missing most of the charging cycle. However, the 45°C trial clearly shows both the constant-current and constant-voltage portions of the charging cycle. There is also a long period of time (at least 1 hour) between charging and discharging for each battery. The voltage and current profiles are similar for each trial over time, though the discharge for the 45°C trial had a slightly longer duration due to the increased capacity of the battery with temperature. The voltage fell quite quickly in both trials due to the high current needed to discharge the battery in 12 minutes.

### Problem 1.6)

Coulometric Efficiencies		
C Rate	T=25°C	T=45°C
1	43.6%	55.4%
2	35.2%	43.6%
15	0.0%	0.0%

Energy Efficiencies		
C Rate	T=25°C	T=45°C
1	43.1%	55.0%
2	34.5%	43.1%
15	0.0%	0.0%

The first thing that struck me about these results were that the efficiencies were all incredibly low. This is likely because most of the charging occurs at or above 3.65V, while a significant amount of the battery capacity cannot be discharged without the voltage dropping below 3.65V. The efficiencies decreased as the C-rate increased. This can be understood by considering a simple equivalent circuit model for the battery with a voltage source and series resistor – the higher the discharge current, the higher the resistive losses and the greater the voltage drop across the resistor, which results in a lower voltage at the terminals. This is why the 15C discharge has efficiencies of 0 - the battery cannot be discharged at a current this high without the voltage dropping below 3.65V. The efficiencies were higher for the higher temperature trials, which is interesting.