You want to investigate the practicality of a plug-in hybrid car that can go some distance, say 30 miles, on stored electrical energy before having to switch on a liquid fuel powered engine. You know that it takes about 0.2 kW-hr/mile to power the car. You want to know what the parameters would be if the electrical power source is a bank of capacitors arranged in parallel. Suppose that you are told that a realistic voltage for a capacitor is 400V. What is the required total capacitance of the bank of capacitors?

Since it is not at all unusual for electric cars to use a very large number of individual 3.7 V LiIon batteries (hundreds or thousands), suppose that you can use 500 individual capacitors. Think up some parameters (total plate area, separation, dielectric constant) for an individual capacitor in the bank that do not seem too crazy. Could this bank alone maintain a constant 400 V as it discharges, or would some additional circuitry be needed?

**Solution.** The energy needed to travel 30 miles is given by

\[(0.2 \text{ kW-hr/mile}) \times (30 \text{ miles}) = 6 \text{ kW} \times 3600 \text{ s} = 21.6 \times 10^6 \text{ J}.

Since the energy stored in a capacitor is \(U = CV^2/2\), the total capacitance required to store the necessary energy is

\[C = \frac{2U}{V^2} = 270 \text{ F}\]

Note that this is the capacitance needed to deliver the necessary amount of energy when initially charged to the required voltage, but the voltage will decrease as the capacitor is discharged, to below the value we’ve required. Not a good sign for this concept working out.

Let’s make some generous estimates on the capacitance \(C = \epsilon A/d\). Take the dielectric constant \(\epsilon/\epsilon_0\) to be 3, the plate area to be 1 m\(^2\), and the separation to be 10\(^{-5}\) m. Then the capacitance is

\[C = \frac{\epsilon A}{d} = 2.66 \times 10^{-6} \text{ F}\]

Since the capacitors are connected in parallel, the total capacitance would be \(C_T = 500C = 1.33 \times 10^{-3} \text{ F}\). This is nowhere near 270 F, so the car won’t be able to maintain 400 V very long, certainly not the whole trip.