Homework 2: Batteries and electric vehicles

Kevin J. Kircher, Purdue ME 597

Directions:

- Students may work individually or in groups, but each student must upload their own solutions to Gradescope by **11:59 PM ET on Saturday, February 3**.
- Use any outside resources you want, but **cite your sources**. (If you really want to learn the material, I recommend seriously attempting the problems yourself before looking for outside help.)
- The TA will grade each problem quickly on a three-tier scale:
  - Zero points for a solution that's mostly unreadable or missing.
  - One point for a serious attempt that's not easy to read or is substantially incorrect.
  - Two points for a solution that's clearly readable and nearly or completely correct.

Problems:

1. (Refer to 'Linear dynamical systems' lecture slides.)
   (a) Show that with uniform time step Δt and piecewise constant $p^{\text{chem}}(t)$, the continuous-time battery model
   $$\frac{\mathrm{d}x(t)}{\mathrm{d}t} = -\frac{x(t)}{\tau} + p^{\text{chem}}(t).$$
   can be written in discrete time as
   $$x(k+1) = ax(k) + (1-a)\tau p^{\text{chem}}(k),$$
   where $a = e^{-\Delta t/\tau}$.
   (b) In the special case of a battery with no self-dissipation, the continuous-time model simplifies to
   $$\frac{\mathrm{d}x(t)}{\mathrm{d}t} = p^{\text{chem}}(t).$$
   Show that with uniform time step Δt and piecewise constant $p^{\text{chem}}(t)$, a discrete-time version of this model is $x(k+1) = x(k) + \Delta t p^{\text{chem}}(k)$.
2. (Refer to 'Batteries and electric vehicles' lecture slides.) The charge state of a battery, initially at 80% of its energy capacity, drops to 50% of its energy capacity after 30 days unplugged and unused. What is the battery's self-dissipation time constant?
3. (Refer to 'Batteries and electric vehicles' lecture slides.) Download the Matlab files in the Github repository electric-vehicles. Fill in the missing code from the functions `simulatePolicy1` and `simulatePolicy2`. Given the inputs in the `simulateEV` script, these functions should return trajectories of the EV battery's stored chemical energy and charging electrical power. Show the missing lines of code here. Show the graphs here that `simulateEV` draws in figures 1 through 3.
4. (Extra credit, graded 0 or 1.) Repeat problem 3 for the function `simulatePolicy3`. Show the missing lines of code and the graph that `simulateEV` draws in figure 4.