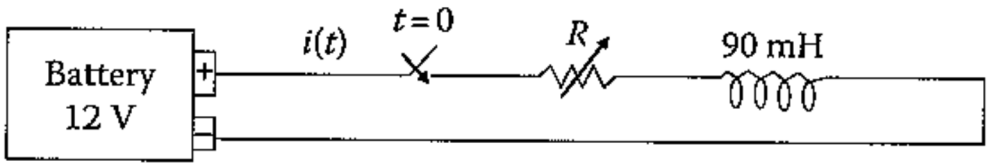
ME 50105 Hybrid and Electric Transportation

Home Work Set 3

1. A 12V battery is connected to a series RL load as shown below. The battery is rated at 80 Ah. At t=0, the switch is closed and battery begins to discharge.



   (a) Calculate and plot the battery discharge current, i(t), if the steady-state discharge rate is C/3 in Ah/h (C is battery rated capacity). Neglect battery voltage drop.
   (b) Derive and plot SoD(t) in Ah for $0<t<2$h.
   (c) Derive and plot SoC(t) assuming that at t=0, the battery is charged to the rated capacity. Assume also that the rated capacity is the practical capacity.
   (d) Calculate the time corresponding to 70% DoD.

2. Given below are constant power discharge characteristics of a 12V lead-acid battery:

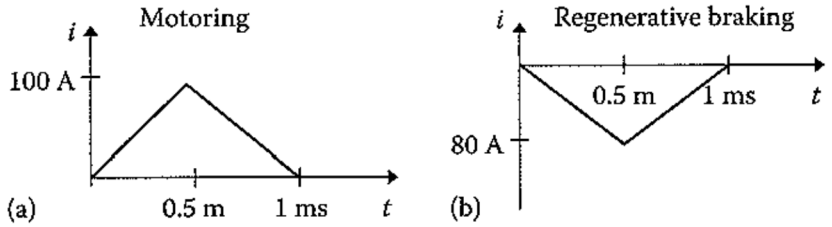
SP (W/kg)	SE (W h/kg)
10	67.5
110	8

   The battery characteristics are to be expressed in terms of Peukert's equation, which as the following from:

   $(SP)^n(SE) = \lambda$ (n and λ are curve fitting constants)

   (a) Derive the constants n and λ, assuming a linear relationship between log(SP) and log(SE).
   (b) Find the capacity Q_T of the battery if the theoretical energy density is SE_T = 67.5 Wh/kg, given the battery mass is 15kg.

3. An EV battery pack consists of four parallel sets of 6 series connected 12V, 120Ah lead-acid batteries. One steady-state motoring (discharge) cycle of battery current is show in the figure below (a). The steady-state regenerative braking (charge) cycle is also show below (b).



(a) Suppose no regenerative braking is employed. How much time does it take to reach 80% DoD?

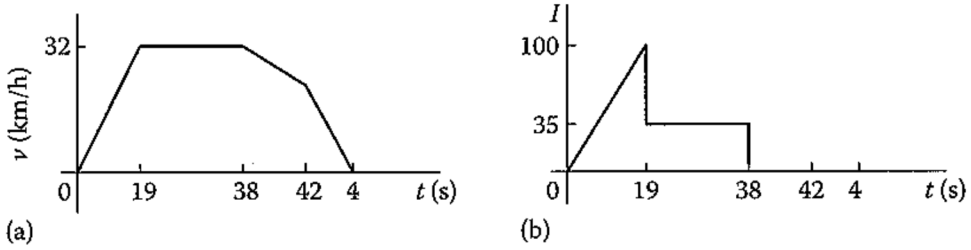
(b) If regenerative braking is employed such that for every 100 motoring cycle there is 1 regenerative braking cycle, how much time does it take to reach 80% DoD?

(Note: You may neglect variation of capacity with discharge rate. Assume that the practical capacity is equal to the rated capacity.)

4. Given a lead-acid battery having the following empirical characteristics:

$$(SP)^{0.9}(SE) = 2{,}160{,}000$$

Where SP = specific power and SE = specific energy. The EV parameters are:
$m = 700kg$, $M_B = 150$ kg, $C_D = 0.25$, $A_F = 2$ m^2, $C_0 = 0.01$, $C_1 = 0$, $\rho_{air} = 1.16$ kg/m^3, $g = 9.8$ m/s^2.



Calculate the EV range based on SAE J227a schedule B driving cycle using the power density approach of fractional depletion model (FDM). You assume that there is no regenerative braking. The drive cycle and current profile of the EV is shown in the above figure.

TABLE 3.5

SAE J227a Standard Driving Schedules

Test Parameter	SAE J227a Schedules		
	B	C	D
Max. speed, km/h (mi/h)	32	48	72
Acceleration time, t_a (s)	19	18	28
Cruise time, t_{cr} (s)	19	20	50
Coast time, t_{co} (s)	4	8	10
Brake time, t_{br} (s)	5	9	9
Idle time, t_i (s)	25	25	25
Total time (s)	72	80	122
Approximate number of cycles per mile	4–5	3	1