The Materials Science of Rechargeable Batteries

HW #3

1. You came back from a nice relaxing weekend and you find on your workbench three carefully labelled electrochemical cells: cell (I) which is a full cell with cathode, h_c, separator, h_s, and anode, h_a, layers; cell (II) which is a cathode half cell with cathode, h_c, and separator, h_s, layers only; and cell (III) which is an anode half cell with anode, h_a, and separator layers, h_s, only. Your manager has determined the tortuosity of each cell. So, cell (I) has a tortuosity $\tau_I = 5/2$, cell (II) has a tortuosity $\tau_{II} = 5/2$, and cell (III) has a tortuosity $\tau_{III} = 3$. She also left a nice sticky note where she reports the thickness of each layer: $h_c = 200\mu\mathrm{m}$, $h_a = 100\mu\mathrm{m}$, and $h_s = 25\mu\mathrm{m}$.

i) Please determine the tortuosity of each of the individual layers.

(a) $\tau_c = 2, \tau_s = 5, \tau_a = 3$

(b) $\tau_c = 5, \tau_s = 2.2, \tau_a = 2$

(c) $\tau_c = 1.7, \tau_s = 1.5, \tau_a = 9$

(d) $\tau_c = 2.2, \tau_s = 5, \tau_a = 2.5$

(e) $\tau_c = 1.75, \tau_s = 1.5, \tau_a = 2.5$

ii) (10/**60 points**) Estimate the porosity of each layer assuming a Bruggeman-type model for the electrode layers.

(a) $\epsilon_c = 0.3, \epsilon_s = 0.1, \epsilon = 0.5$

(b) $\epsilon_c = 0.32, \epsilon_s = 0.44, \epsilon = 0.11$

(c) $\epsilon_c = 0.21, \epsilon_s = 0.04, \epsilon = 0.16$

(d) $\epsilon_c = 0.44, \epsilon_s = 0.35, \epsilon = 0.012$

(e) $\epsilon_c = 0.04, \epsilon_s = 0.2, \epsilon = 0.25$

2.**(40 points)** For a Bruggeman-type porous electrode, propose a measure of performance that simultaneously minimizes the tortuosity and maximizes the reactivity area per unit volume of a battery as a function of average porosity of particle size, r_p. Based on this proposed measure, what is the optimal porosity value, ϵ?

(a) $\epsilon = 1/2$ and $R = 3/r_p$

(b) $\epsilon = 2/3$ and $R = 1/r_p$

(c) $\epsilon = 1/3$ and $R = 3/r_p$

(d) $\epsilon = 1/4$ and $R = 4/r_p$

(e) $\epsilon = 1/3$ and $R = 2/r_p$