Heat Transfer - 1

A battery pack is discharged by drawing an electric current through the pack to an external electric load. The internal electric resistance of the battery pack causes the pack to heat up. After discharging the available energy capacity of the pack, the battery pack needs to cool down before recharging. Battery packs are generally constructed from high thermal and electrical conductivity materials. The battery pack thermal and electrical properties are given below.

Internal electrical resistance = 0.1 ohm
Heat capacity = 100 kJ/ ^{o}C
Surface area of pack exposed to ambient air = 1 m^2

The battery is initially at the ambient air temperature = 25 ^{o}C. The battery pack reaches a steady temperature of 35 ^{o}C when a current load of 50 A is applied to the terminals of the battery.

a) (20 pts) Draw a diagram, label all of the symbols used, and formulate a steady state energy balance when internal heat generation is caused by the electric current flow. Find the heat generation in the battery pack when the current is 50 A.

b) (15 pts) From the steady state temperature of 35 ^{o}C, find the convective heat transfer coefficient for the outer surface of the battery pack.

c) (20 pts) Starting from Tinit = the steady initial condition temperature in b), the load current then experiences a step change from the steady 50 A to a higher, short-term constant peak current of 200 A. Draw a detailed diagram that includes ***all*** of the symbols used in the solution, and formulate a transient energy balance for this scenario. State any assumptions you make.

d) (10 pts) Demonstrate that this transient energy balance correctly reproduces the steady state result for b) if a current of 50 A continues for a long time.

e) (20 pts) When the battery pack reaches 50 ^{0}C, the load current of 200 A is removed and the pack begins to cool. Find the time that the pack takes to cool from the initial temperature of 50 ^{o}C back down to 35 ^{o}C in the 25 ^{o}C ambient air.

f) (15 pts) Sketch the time history of the battery temperature for the entire 50 A – 200 A – 0 A process described above. Show the correct relative heating and cooling times.

After completing b) thru f), revisit c) and check that you put ***all*** symbols used in your solution on your diagram; redraw it if you started too small and can't fit all of the symbols legibly.