1 Battery pack cooling

1.1 problem statement

A battery pack composed of 21700 lithium ion batteries needs to be designed for a small electric vehicle. The pack must supply 225 amps of maximum current at 28 volts. The pack is to be air cooled using a 140 mm diameter fan with a maximum flow rate of 270 $\mathrm{m^3/h}$ and a maximum static gauge pressure of 65 Pa. Each cell has a maximum safe operating current of 45 amps and a maximum safe operating temperature of 75°C. The pack operates in air at 25°C. Your objective is to design a battery pack that satisfies the above criteria while maximizing volumetric power density, defined as:

$$\rho_{\mathrm{e,pack}} = \frac{P}{L \times W \times H} \left(\frac{\mathrm{W}}{\mathrm{m}^3}\right) \tag{1.1}$$

where P is the electrical power provided by the pack. When calculating the dimensions of the enclosure, the minimum spacing between the outside cells and the enclosure wall must not be less than the spacing between cells: $S_{\mathrm{T}} - D$, where D is the cell diameter.

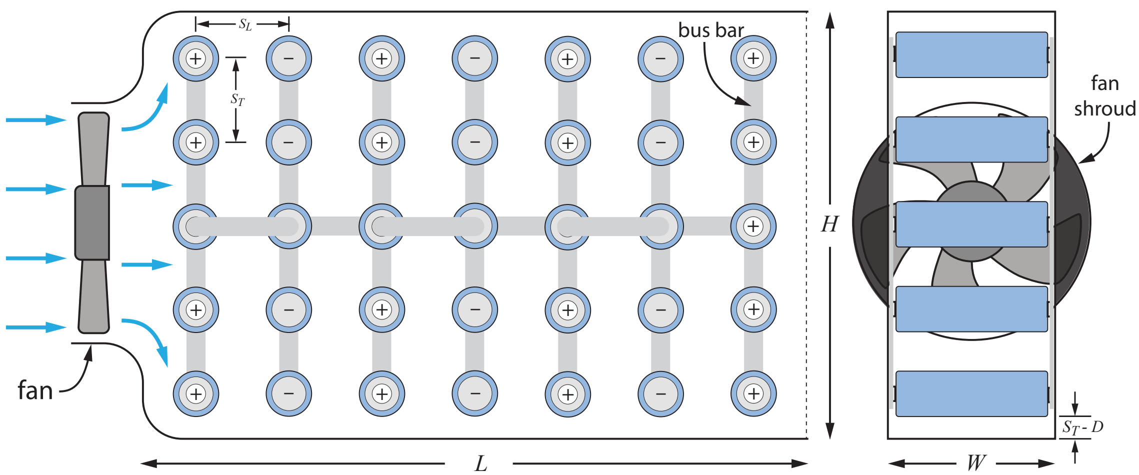


Figure 1.1: Battery pack housing and cell arrangement. The above pack is a 7s5p (seven rows in series and five cells in parallel) and would provide a voltage of $V_{\mathrm{pack}} = 4.0\ \mathrm{V} \times 7 = 28$ volts and a maximum cell current of $I_{\mathrm{cell}} = 225/5 = 45\mathrm{A}$.

Table 1: 21700 battery specifications

diameter (mm)	length (mm)	mass (g)	voltage (V)	resistance (Ω)
21.55	70.15	70	4.0	0.015

Pressure drop and flow rate

The pressure drop through your pack is related to the maximum air velocity using Eq. 7.65 in your text:

$$\Delta p = N_L \chi \left(\frac{\rho V_{\mathrm{max}}^2}{2}\right) f \tag{1.2}$$

where the friction factor, f, and the correction factor, χ, are plotted in Figures 7.14 and 7.15 in your text.

1.2 submission requirements

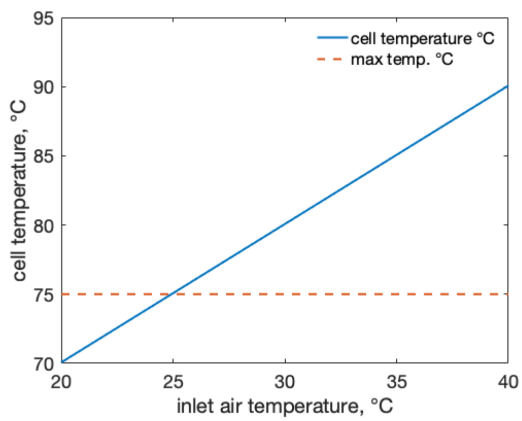
Submit a single pdf writeup of your solution that includes the following:

1. (5 pts) Problem statement
2. (5 pts) List of assumptions
3. (5 pts) Description of your chosen approach to the problem
4. (5 pts) A figure illustrating your design. This should show the placement of the fan, flow direction, and cell arrangement (i.e. something like Fig. 1.1, but it doesn't need to be that detailed)
5. (20 pts) A table listing the following values for your solution:

Table 2: Battery pack dimensions and performance

H (m)	L (m)	V_{pack} (V)	I_{cell} (A)	$\rho_{\text{e,pack}}$ $\left(\frac{\text{W}}{\text{m}^3}\right)$	$\dot{V}_{\text{air}}$ (m^3/h)	Δp (Pa)	$T_{\text{m,o}}$ °C	T_{cell} °C

6. (5 pts) Plot of cell temperature vs inlet air temperature for 20 °C $\leq T_{\text{m,i}} \leq$ 40 °C. Also plot the maximum allowable operating temperature (see example below).



7. (5 pts) Discussion. Describe your chosen design and summarize your pack's performance. Identify trade-offs in your design and justify your choices. State the maximum inlet air temperature your pack can handle and discuss how you might design a battery pack for an air temperature of 40 °C.

You must append your code at the end of your writeup.

Note: If you choose to use MATLAB publishing tool or Python Jupyter Notebook, you can either input a table of your solutions or you can print each answer sequentially.