Convective Heat Transfer Assignment 5 — External Convection

Due on Wednesday May 9th at 17:00. Do Questions #1, #2, and #3a.

Question #1

A tube bank uses an in-line arrangement with $S_p = S_n = 1.9$ cm and 6.33-mm-diameter tubes. The tube bank is 6 rows deep and 50 tubes high. The surface temperature of the tubes is constant at 90° C, and air at a pressure of 1 atmosphere, a temperature of 20° C, and a speed of 4.5 m/s is forced across them. Calculate the total heat transfer per unit length for the tube bank as well as the outlet temperature of the air.

Question #2

A flat plate 10 cm long and 1 m wide is placed in a wind tunnel where the air properties in the test section are $u = 2500$ m/s, $P = 1/40$ atm, and $T = -40^\circ$ C. Assuming the flow is laminar throughout, how much cooling must be used to maintain the plate temperature at 700° C?

Question #3

A solid sphere made of a radioactive material is cooled by natural convection in an inert gas: $T_\infty = 20^\circ$ C. The diameter of the sphere is 0.02 m, and there is a constant rate of heat generation per unit volume, S, inside it. Under steady-state conditions, measurements indicate that the surface temperature of the sphere is $T_\text{w} = 100^\circ$ C. Radiation heat transfer may be considered negligible. The thermal conductivity k_s of the radio-active material is of 0.49 W/m$^\circ$C. The thermophysical properties of the inert gas can be taken as $k = 0.025$ W/m$^\circ$C, $c_p = 1000$ J/kg$^\circ$C, $\mu = 2 \times 10^{-5}$ kg/ms, $\rho = 1.0$ kg/m^3, and $\beta = 0.003$ K^{-1}. Perform the following tasks:

(a) Calculate the volumetric rate of heat generation, S, inside the sphere.

(b) Calculate the maximum temperature inside the sphere.

Answers

1. 54.9 kW/m, 30.6° C.
2. 34.8 kW.
3. 0.24 MW/m^3, 108.2° C.