Heat Transfer Assignment 6 — Flat Plate Flow

Instructions

ξ is a parameter related to your student ID, with ξ_1 corresponding to the last digit, ξ_2 to the last two digits, ξ_3 to the last three digits, etc. For instance, if your ID is 199225962, then $\xi_1 = 2$, $\xi_2 = 62$, $\xi_3 = 962$, $\xi_4 = 5962$, etc. Keep a copy of the assignment — the assignment will not be handed back to you. You must be capable of remembering the solutions you hand in.

Question #1

Consider the wing of an aircraft as a flat plate of 2.5 m length in the flow direction. The plane is moving at 100 m/s in air that is at a pressure of 0.7 bar and a temperature of -10° C. If the top surface of the wing absorbs solar radiation at a rate of 800 $\mathrm{W/m^2}$, estimate its steady-state temperature with and without the effect of viscous dissipation. Assume the wing to be of solid construction and to have a single, uniform temperature. Ignore incident radiation on the bottom surface and take $\epsilon = 0.4$ on the top and bottom surfaces of the wing.

Question #2

A thin, flat plate of length $L = 1$ m separates two airstreams that are in parallel flow over opposite surfaces of the plate. One airstream has a temperature of $T_{\infty,1} = 200^\circ$C and a velocity of $u_{\infty,1} = 60$ m/s, while the other airstream has a temperature of $T_{\infty,2} = 25^\circ$ C and a velocity of $u_{\infty,2} = 10$ m/s. The pressure in both streams corresponds to 1 atm. What is the temperature at the midpoint of the plate?

Question #3

Consider liquid water flowing over a flat plate of length $L = 1$ m. The water has the following properties:

$\rho = 1000\ \mathrm{kg/m^3}, \quad c_p = 4000\ \mathrm{J/kgK}, \quad \mu = 10^{-3}\ \mathrm{kg/ms}, \quad k = 0.6\ \mathrm{W/m \cdot^\circ C}$

Midway through the plate at $x = 0.5$ m, you measure a heat flux to the surface of:

$q''_{x=0.5\ \mathrm{m}} = 3181\ \mathrm{W/m^2}$

You also measure an average heat flux to the surface over the length of the plate of:

$\overline{q''} = 4500\ \mathrm{W/m^2}$

Knowing the latter, and knowing that the plate temperature is equal to 20° C do the following:

(a) Is the flow laminar or turbulent, or a mix of both? You must provide proof of this using the data provided.

(b) What is the possible range of the freestream velocity U_∞?

(c) Find a relationship between T_∞ and U_∞

Answers

1. -3.66° C, -8.13° C.
2. 460.8 K.
3. $T_\infty = 20^\circ\mathrm{C} + 6^\circ\mathrm{C m^{0.5} s^{-0.5}} U_\infty^{-0.5}$.

Due on Wednesday May 22nd at 9:00. Do all questions.