

# Heat Transfer Assignment 6 — Flat Plate Flow

## Instructions

$\xi$  is a parameter related to your student ID, with  $\xi_1$  corresponding to the last digit,  $\xi_2$  to the last two digits,  $\xi_3$  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  $-10^\circ\text{C}$ . If the top surface of the wing absorbs solar radiation at a rate of  $800\text{ W/m}^2$ , 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  $L = 1\text{ m}$  separates two airstreams that are in parallel flow over opposite surfaces of the plate. One airstream has a temperature of  $T_{\infty,1} = 200^\circ\text{C}$  and a velocity of  $u_{\infty,1} = 60\text{ m/s}$ , while the other airstream has a temperature of  $T_{\infty,2} = 25^\circ\text{C}$  and a velocity of  $u_{\infty,2} = 10\text{ m/s}$ . 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  $L = 1\text{ m}$ . The water has the following properties:

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

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

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

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

of:

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

Knowing the latter, and knowing that the plate temperature is equal to  $20^\circ\text{C}$  do the following:

- Is the flow laminar or turbulent, or a mix of both? You must provide proof of this using the data provided.
- What is the possible range of the freestream velocity  $U_\infty$ ?
- Find a relationship between  $T_\infty$  and  $U_\infty$ .

## Answers

- $-3.66^\circ\text{C}$ ,  $-8.13^\circ\text{C}$ .
- 460.8 K.
- $T_\infty = 20^\circ\text{C} + 6^\circ\text{Cm}^{0.5}\text{s}^{-0.5}U_\infty^{-0.5}$ .

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