

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 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°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. $T_\infty = 20^\circ \text{C} + 6^\circ \text{Cm}^{0.5}\text{s}^{-0.5}U_\infty^{-0.5}$.

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