METU, Department of Aerospace Engineering

AEE 331 Heat Transfer HW 4

Due 12 Dec. 2018 to Course Assistants : Zeynep Ünal / Özcan YIRTICI

(1 -to be submitted) 2-D, steady-state, incompressible, viscous flow equations are given by

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$$
$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\nu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)$$
$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)$$

where the first two equations are momentum equations and the last one is the energy equation with negligence of heat generation due to viscous action.

These equations can be solved over a flat plate that has a temperature of T_s to find the convection heat transfer from or into it directly. Assume you are about to do so, and before you start, you need to make these equations dimensionless.

Then, non-dimensionalize these equations using length of the plate L as the length scale, free-stream velocity V_∞ as the velocity scale, free-stream pressure p_∞ as the pressure scale, and $T_s - T_\infty$ as the temperature scale. Do you see any non-dimensional numbers in these equations? What are they?

(2 -to be submitted) Consider the cylindrical rod part of the landing gear of an aircraft. This rod is made up of stainless steel. It has a radius of 5 cm. Before it is put in service, it is thermally treated in a furnace to 800 K, and then left cool down in a large room with ambient air of 300 K. Assume the average convection coefficient over the surface of the rod throughout the entire cooling process is 15 W/m^2 K. The rod also radiates to surrounding which is at 300 K. The surface emissivity of the rod is 0.85. Assume during the cooling the radiative heat transfer may be taken constant at its average value. You may obtain properties of stainless steel from the properties tables given in the appendix of the text book.

(a) Calculate the convection heat flux from the rod at the beginning of cooling.
(b) Calculate the radiation heat flux from the rod at the beginning of cooling.
(c) Calculate the convection heat flux from the rod at 400 K.
(d) Calculate the radiation heat flux from the rod at 400 K.
(e) Calculate the time in which the centerline of the rod reaches 400 K.

Include all relevant assumptions you make.