Adv. Heat Transfer / Thermal Science
Fall 2009
Final Exam
12/07/09
Due Wednesday Dec. 9 by 5:00 p.m.

Name ________________________

ID#__________________________

Instructions:

1. This is a take home exam, which means you can use your book for the exam. Any other reference should be completely referenced on your exam (e.g. another book or the web). Be careful about sources you may consult.
2. The work on the exam must be performed by you not in consultation with any one else. If you need to ask a question you can send Dr. Lemley an e-mail.
3. The exam will be due by noon on Monday Dec. 8, 2008.
4. You will need to sign the statement below before turning the exam.
5. You MUST NOT consult any other person regarding the solution to this exam.
6. You MUST submit work that is yours only and not taken from another source. It is acceptable to consult heat transfer textbooks for basic equations, tables, and graphs, but if you find a very similar problem you MUST NOT use the solution to the problem.

VVI
Print this out and place worked problems in order of the problems in the exam. Staple the worked problems after the printed exam before submitting the exam.

I have read and understand the rules above and also understand that violation of these rules may result in a decreased grade for the exam or other academic action.

____

Sign Here

Problem One

For a boundary layer on a flat plate one can derive a useful integral equation by considering mass and momentum equations, which gives:

$$\rho \frac{d}{dx}\int_0^{\delta}(u_\infty - u)\,u\,dy = \mu\left(\frac{\partial u}{\partial y}\right)_{y=0}$$

Equation 1

For use in the above equation a velocity profile u is needed of the form

$$u = C_1 + C_2 y + C_3 y^2 + C_4 y^3$$

By applying appropriate boundary conditions in the boundary layer, find the constants C_1 through C_4. Note that the $\frac{\partial p}{\partial x} = 0$ which is required to find the constants.

Problem Two

Assuming the velocity profile found in Problem One (using the constants you found C_1 through C_4) find an expression (using Eq. 1) that relates the boundary layer thickness, δ, to the distance measured along the plate x.

Problem Three

Air at 27˚C and 1 atm flows over a flat plate at a speed of 2 m/s. The viscosity of the air is 1.85 x 10^{-5} kg/m/s. Using the relationship for δ as a function of x from Problem Two, find the boundary layer thickness at x = 10 cm and x = 25 cm.

Problem Four

Another useful integral equation can be derived by considering a thermal boundary layer

$$\frac{d}{dx}\left[\int_0^{\delta_t}(T_\infty - T)\,u\,dy\right] + \frac{\mu}{\rho C_p}\left[\int_0^{\delta_t}\left(\frac{du}{dy}\right)^2\right] = \alpha\left(\frac{\partial T}{\partial y}\right)_{y=0}$$

Equation 2:

It has been assumed that $\delta_t/\delta << 1$.

For use in the above equation a temperature profile T is needed of the form

$$\frac{\theta}{\theta_\infty} = \frac{T - T_s}{T_\infty - T_s} = function(y/\delta_t)$$

Equation 3:

By applying appropriate boundary conditions in the thermal boundary layer, find a *<u>cubic</u>* expression in Eq. 3 . Note you will need to assume there is no viscous heating (equivalent to $\frac{\partial^2 T}{\partial y^2} = 0$). Also what Prandtl numbers would this expression work for?

Problem Five

Using the distribution found in Problem Four and using Eq. 2 find an expression that relates) that relates δ_t/δ to the distance measured along the plate x.

Problem Six

Engine oil enters a 5.0-mm tube at 120°C. The tube wall is maintained at 50°C, and the inlet Reynolds number is 1000. Calculate the heat transfer, average heat transfer coefficient, and exit oil temperature for tube lengths of 10, 20, and 50 cm.

Problem Seven

Water at an average temperature of 300 K flows at 0.7 kg/s in a 2.5-cm-diameter tube that is 6 m long. The pressure drop is measured as 2 kPa. A constant heat flux is imposed, and the average wall temperature is 55°C. Estimate the exit temperature of the water.

Problem Eight

Steel balls 12 mm in diameter are annealed by heating to 1150 K and then slowly cooling to 400 K in an air environment for which $T_\infty = 325$ K and $h = 20\ W/(m^2 - K)$. Assuming the properties of steel to be as follows

k = 40 W/m•K
$\rho = 7800\ kg/m^3$
c = 600 J/kg•K

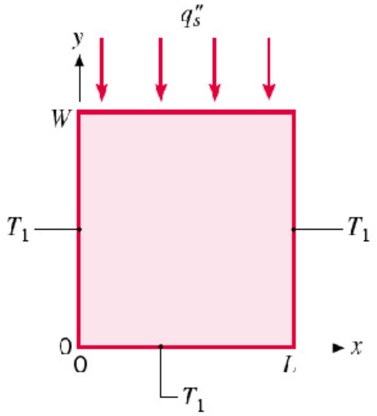
Estimate the time for the cooling process. Justify your approach by stating the assumptions made in solving the problem.

Problem Nine

Aluminum fins of rectangular profile (1.5 cm wide and 1.0 mm thick) are placed on a 2.5-cm diameter tube to dissipate heat. The tube surface is 170 degrees C, and the ambient air temperature is 25 degrees C. Calculate the heat loss per fin for h = 130 W/m^2/K. Assume that k = 200 W/m/K for aluminum.

Problem Ten

A two-dimensional plate is subjected to the B.C.'s shown. Derive an expression for the temperature in the plate.



Problem Eleven

A long aluminum cylinder 5.0 cm in diameter and initially at 200 degrees C is suddenly exposed to a convection environment at 70 degrees C and *h* = 525 W/m^2/K. Calculate the temperature at a radius of 1.25 cm and the heat lost per unit length 1 minute after the cylinder is exposed to the environment.