ta3220 Final Examination
Spring 2012 - 17 April 2012

Write your solutions *on your answer sheet*, not here. In all cases ***show your work***.
To avoid any possible confusion,
state the equation numbers and figure numbers of equations and figures you use.
Beware of unnecessary information in the problem statement.

1. A pipe 0.05 m in diameter contains water (properties given below). The pipe is 100 m long; its outlet is at atmospheric pressure (1.01×10^5 Pa), and rests 4 m lower than the inlet. The desired flow rate Q through the pipe is 0.002 m^3/s (2 liter/s). The height of the roughness in the pipe is estimated at 0.0005 m. What is the minimum absolute pressure p required at the inlet to maintain this flow rate?

(20 pts)

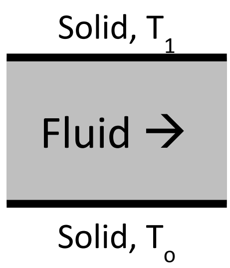
<u>properties of water</u>

$\rho = 1000\ kg/m^3$ $\mu = 0.001$ Pa s $k = 0.680$ W/(m K) $C_p = 4190$ J/(kg K)

2. Water (properties given in problem 1) flows with velocity 0.5 m/s through a slit-shaped conduit of gap width D = 0.02 m between two smooth surfaces that are maintained at fixed temperature. What is the heat-transfer coefficient h for heat transfer between water and the slit walls?

(10 pts)

3. A liquid (with properties μ, ρ, C_p, and k) flows in a slit-shaped gap between two metal surfaces that are maintained at two different temperatures, T_0 and T_1. The gap width is D and the liquid velocity V. The heat-transfer coefficient on the two surfaces is assumed to be the same value, h. What is the overall heat-transfer coefficient U for heat transfer between the two surfaces in terms of the parameters given for this problem?



(7 pts)

4. In the scientific literature, one can find ketchup described as either a Bingham plastic or a power-law fluid. Describe an experiment you could design that would determine whether a fluid is a Bingham plastic or a power-law fluid. Describe how the fluid would behave if it were a Bingham plastic, and how it would behave if it were a power-law fluid, and how in your experiment you could easily tell which kind of fluid it is from this difference in behavior.

(8 pts)

5. For certain situations in oil-well drilling it is important to know the shear stress τ_{rz} at the surface of a cylindrical hole. Suppose a horizontal cylindrical pipe of diameter 10 cm carries liquid in highly turbulent flow with a pressure gradient ($\Delta\mathcal{P}/L$) along the pipe of 2×10^4 Pa/m. What is the shear stress τ_{rz} at the wall in this case? (Strictly, shear stress would fluctuate in time in turbulent flow; I'm asking for the time-average value.) (Hint: consider a macroscopic momentum balance on fluid in the pipe.)

(5 pts)

6. A cylindrical wire of radius R is heated by electrical conduction as in *BSL* section 9.2. The outer surface, at R, is maintained at temperature T_o, as in *BSL* section 9.2. In this case, however, the rate of thermal energy production is not uniform but varies with radial position as follows:

   $S_e = S_{eo} + B\, r$

   where r is radial position in the wire and S_{eo} and B are a constants. There is no variation of temperature in the z direction (along the axis of the wire). Solve for the steady-state temperature distribution T(r) within the wire. You don't have to repeat any part of the derivation in *BSL* that applies here, but, if you use that derivation, state which equation you begin with. Note the relevant pages from *BSL* attached to the end of this exam.

(20 pts)

7. A solid cube 0.2 m on a side is placed into a well-stirred tank of water containing 0.03 m^3 water. The outside walls of the tank are well insulated, so there is no interaction with the surroundings outside the tank. Properties of water are given with Problem 1. The cube is initially at 100°C and the water initially at 0°C. After 10 min., precise measurement indicates that temperature of the water has risen to 7.500°C. After a very long time (2 hr), during which the cube and tank have come to the same temperature, the temperature of the water is 8.200°C.
   a. How much heat (in Joules) did the cube lose during the two hours?
   b. Based on your answer to part (a), what is ($\rho\ C_p$) for the cube?
      If you don't have an answer to part (a), assume a value for the heat loss from the cube and make clear what value you are assuming.
   c. What was the average temperature of the cube after 10 min.?
      If you didn't get an answer to part (b), for this part assume the same values of ($\rho\ C_p$) for the cube as for water. If you use this assumption because you didn't finish part (b), state so clearly. (This is not the correct answer to part (b), but Ok for working this part if you can't figure out part (b).)

(15 pts)

8. A solid **sphere** (not a cube) 0.2 m in diameter is placed into a well-stirred tank of water that is **maintained at** 0°C. The sphere is initially at 100°C. After 10 min., precise measurement indicates that average temperature of the sphere has decreased to 8.00°C.
   (Please note this is not exactly a continuation of problem 7. The shape of the solid, and some other aspects, have changed.)
   a. Assuming that the only resistance to heat transfer is internal conduction within the sphere, what is the thermal conductivity $\alpha = k/(\rho\ C_p)$ [or $a = \lambda/(\rho\ C_p)$ in the *FT* text] of the sphere?
   b. Given that you made an assumption in part (a), is the true value of α larger or smaller than the value you compute in part (a)? Briefly explain your answer.

(15 pts)