GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2004

Heat Transfer

EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

* Please sign your **name** on the back of this page —

Question 1

Consider a wire (radius r_w, length l, thermal conductivity k, density ρ, heat capacity C). The nearby air flows over the wire – it has a temperature T_0, and there is a heat transfer coefficient from the wire to the air, h.

The temperature rise in the wire can be written $\Theta(x) = T(x)-T_0$

Initially, the wire is at a uniform temperature $\Theta(x) = 0$. *At time=0* an electrical current flows through the wire. The power generated in the wire per unit length is uniform, given as P'.

Please do the following:

(a) Assuming the temperature does not vary in the r direction; write the governing equation for $\Theta(x)$.

(b) If $\Theta(0) = \Theta(l) = 0$, sketch Θ vs. x immediately after current in the wire is turned on, after the wire has reached steady state, and at some intermediate time. Sketch these in chronological order.

(c) If the boundary condition at the ends of the wire is specified not as a temperature (previous case) but rather as a given thermal resistance R_B, sketch Θ vs. x immediately after current in the wire is turned on, after the wire has reached steady state, and at some intermediate time. Sketch these in chronological order.

(d) For part (c), let's say that the wire comes to steady state and then current is turned off. About how long will it take for the wire to cool down to its initial temperature T_0?

Question 2

A viscous fluid flows through a parallel plates channel whose walls are separated by a distance $2l$. Each wall is subjected to a uniform wall heat flux of q_w''.

1. (30%) Describe what is meant by fully hydrodynamically and thermally developed conditions, respectively. Starting with the appropriate energy balances, write down how the local fluid temperature T, the wall temperature T_w, and the bulk fluid temperature T_b vary with the downstream distance x.
2. (30%) For the case described in Part 1, write down a set of equations and boundary conditions that can be used to determine the temperature distribution in the fluid.
3. (20%) Assuming the fully developed velocity profile is given by:

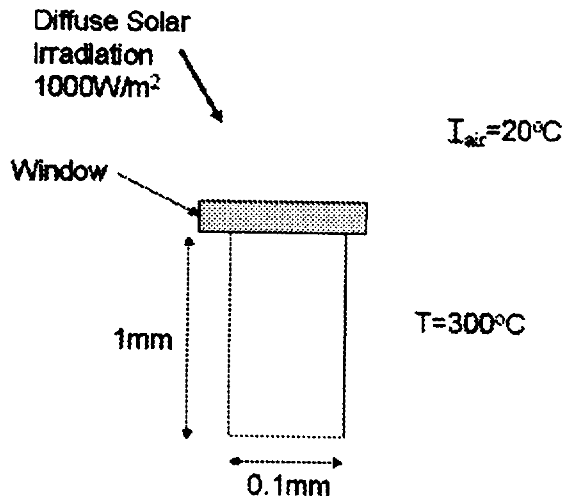
$$u/U = \frac{3}{2}\left(1-\eta^2\right)$$

where U is the mean fluid velocity, and $\eta = y/l$ is measured from the centerline, find out the temperature profile under thermally fully developed conditions.

4. (20%) Write an expression for the Nusselt number. Evaluate this expression to find the Nusselt number using the temperature profile for the thermally fully developed flow (see previous question 3).

Question 3

A 1 mm deep cylindrical cavity 0.1 mm diameter can be used to approximate a blackbody and is maintained at 300°C while exposed to solar irradiation of 1000 W/m^2 and surroundings and ambient air at 20°C. A thin window of spectral transmissivity 0.9, and reflectivity and 0, for the spectral range 0.2 to 4 μm is placed over the cavity opening. In the spectral range beyond 4 μm the window behaves as an opaque diffuse, gray body of emissivity 0.9. Assuming the convection coefficient on the upper surface of the window is 10 W/m^{2}K determine the temperature of the window and the power required to maintain the cavity at 300°C.



Blackbody Fractional Spectral Emissive Power

λT (μmK)	F(0-λ)
1000	0.00032
1200	0.00213
1400	0.00779
1600	0.01972
1800	0.03934`
2000	0.06673
2200	0.10089
2400	0.14026
2600	0.18312
2800	0.22790
3000	0.27323
3200	0.31810
3400	0.36174
3600	0.40361
3800	0.44338
4000	0.48088
5000	0.63375
6000	0.73782
7000	0.80811
8000	0.85630
9000	0.89003
10000	0.91420
11000	0.93189
12000	0.94510
13000	0.95514
14000	0.96290
15000	0.97000