M.E. Ph.D. Qualifier Exam
Fall Semester 1999

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 1999

Heat Transfer
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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

Problem 1

The temperature distribution for a fin of uniform cross section is given by

$$\frac{\theta}{\theta_o} = \frac{t - t_\infty}{t_o - t_\infty} = \frac{\cosh\left[m\left(L_c - x\right)\right]}{\cosh\left[mL_c\right]}$$

where $m^2 = (hP/kA)$. The cross sectional area is A, P is the perimeter, L is the length of the fin, and L_c is the corrected length.

a) Show that fin efficiency is

$$\eta_f = \tanh\,(mL_c)/(mL_c)$$

b) A plate fin made out of anodized aluminum (k = 200 W/m-°C, thickness 2 mm and length 100 mm) is used to enhance heat transfer. The convective heat transfer coefficient is 10 W/m^{2}C. Determine the rate of heat transfer per meter of width for this fin when θ_o = 80C. Estimate the Biot number.

c) Sketch the temperature distribution as a function of position along the length of the fin.

d) Suppose that this fin is attached to a copper plate and that the thermal contact resistance between the fin and the plate is 20 percent of the fin thermal resistance. Estimate the new value for the heat transfer rate from the fin. Sketch the temperature distribution for this case. Comment on the magnitude of fin efficiency for this case.

Problem 2

Liquid mercury at 300K flows over a smooth 0.5m long by 0.25m wide flat plate at a rate of 0.15m/s. The flow direction is parallel to the longer dimension. The plate is maintained at a constant temperature of 400K. What is the minimum value of the local surface convective heat flux, q"? What is the total power dissipated from the surface by convection?

Some flat plate heat transfer correlations which you may use:

Local Nusselt number for laminar flow:

$$Nu_x = 0.565 \mathrm{Re}_x^{1/2} \mathrm{Pr}^{1/2}$$

Local Nusselt number for turbulent flow:

$$Nu_x = 0.0296 \mathrm{Re}_x^{4/5} \mathrm{Pr}^{1/3}$$

The properties of mercury at 350K are:

Kinematic viscosity

$$\nu = 0.0976x10^{-6} m^2/s$$

Thermal conductivity

$$k = 9.18 W/mK$$

Thermal diffusivity

$$\alpha = 4.975x10^{-6} m^2/s$$

Assume that the critical Reynolds number for transition from laminar to turbulent flow is 500,000.

Problem 3

A gray plate (emissivity known) is mounted on a spacecraft and placed normal to incident radiation from the sun. The plate is insulated on its back surface. The sun is a distance D_s from the spacecraft and the diameter of the sun is D. The sun may be assumed to be a blackbody at a temperature T_s. Incident radiation from other parts of the spacecraft are negligible and the surroundings can be assumed to be at O degrees K. Set up sufficient equations to calculate the equilibrium temperature of the plate in terms of known information. State all assumptions that you make. How would you modify your analysis if the plate is non-gray with a known emissivity in the IR of ε_I and an emissivity of ε_S in the solar wavelength range.