GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1996

HEAT TRANSFER
EXAM AREA

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

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

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Please **print** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

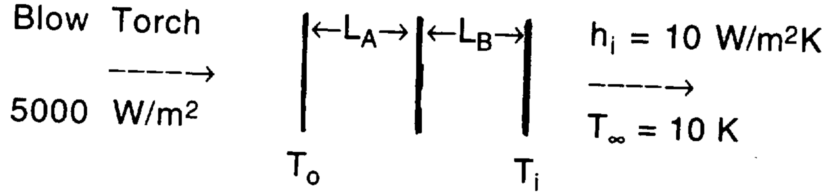
Ph.D. Qualifying Exam
Heat Transfer
Spring Quarter 1996

1) A liquid nitrogen dewar is made from two concentric spheres separated by a vacuum. The inner sphere has a diameter of 1 m. and the outer sphere has a diameter of 2 m. Both are gray surfaces with $\varepsilon = 0.2$. The saturation temperature for nitrogen at one atmosphere is 80K and its latent heat of vaporization is 200 kJ/kg. Estimate the nitrogen boil-off rate when the inner sphere is full of liquid N_2 and the outer sphere is at 30°C.

Suggest ways in which you can change the design of the dewar and reduce the nitrogen boil-off rate.

PROBLEM

A blow torch is directed at a wall which is made up of two layers. The outer layer towards which the blow torch is directed is 0.05 m thick and has the following properties: $k = 5$ W/m·K, $c = 1000$ J/Kg·K, and $\rho = 2000$ Kg/m^3. The inner part of the wall is 0.10 m thick and has the following properties: $k = 500$ W/m·K, $c = 400$ J/Kg·K, and $\rho = 10{,}000$ Kg/m^3. The blow torch provides a heat flux at the surface of the outer part of the wall of 5000 W/m^2. The inner part of the wall is cooled at its backside by room temperature air, i.e. $T_\infty = 10$ K, with a natural convection coefficient of $h_i = 10$ W/m^{2}K.



(a) Assuming steady state conditions have been reached and the problem can be treated as plane wall heat conduction, determine the temperature distribution across the wall by calculating the temperature at key points.

(b) If the contact resistance between the two parts of the wall is $R_c = 6 \times 10^{-4}$ m^2·K/W, determine how the temperature distribution across the wall as calculated in Part (a) is altered.

(c) Estimate how much time is required (from when the blow torch is turned on) for steady state conditions to be reached(i.e. within 5% of steady state temperatures).

It is desired to find an expression for the thermal boundary layer thickness as a function of axial distance for an incompressible, steady laminar fluid flow between infinitely long stationary parallel plates with a fully developed velocity profile and a second order temperature profile for the following two cases:

i) Both plates are at the same uniform temperature that is different from the inlet fluid temperature.

ii) The top plate is at the uniform temperature as in part (a), but there is a uniform heat flux externally imposed on the bottom plate.

For each case, separately

1.) sketch qualitatively the temperature profiles in the thermally developing and the thermally fully developed domains

2.) perform an energy balance for an integral control volume in the thermally developing domain and obtain the algebraic equation for the thermal boundary layer thickness

3.) repeat part 2 for the thermally fully developed region.