# GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

**Ph.D. Qualifiers Exam - Spring Semester 2003**

Heat Transfer
EXAM AREA

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

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

Please **p r i n t** your name here.

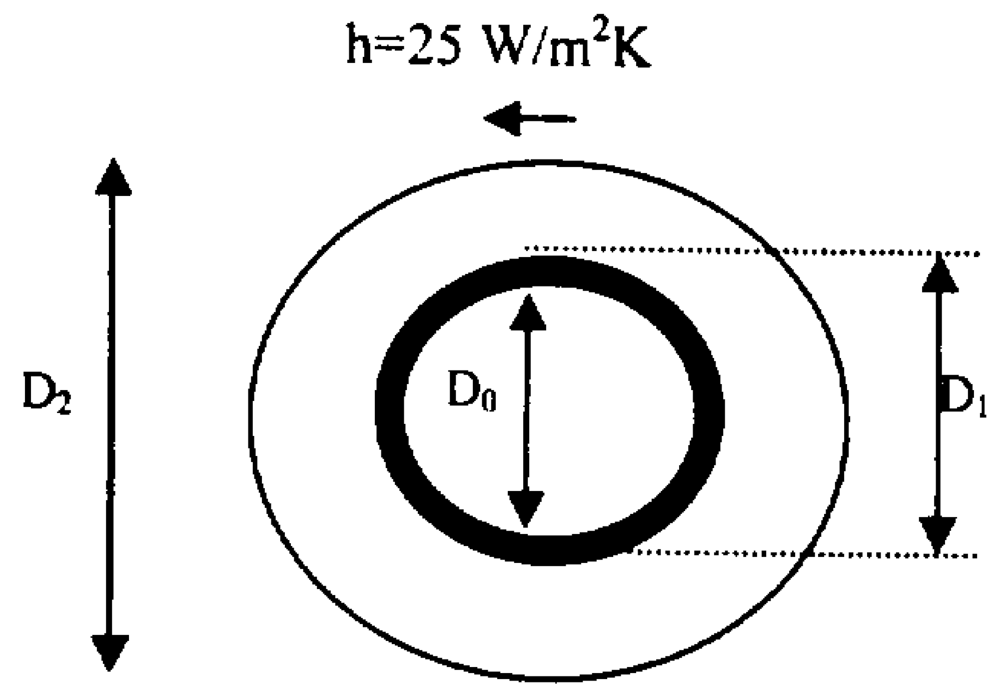
**The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.**

**Ph.D. Qualifying Examination, Spring 2003**
**Heat Transfer**

1. A hot water pipe of length L traverses a basement where the air temperature is $T_a$. The water enters the pipe (inside diameter $D_I$ and outside diameter $D_o$) at temperature $T_H$ and mass flow rate $\dot{m}$.

Draw a sketch depicting the average water temperature as a function of axial position. Begin **with basic principles** and develop an appropriate analysis to determine an expression for the average water temperature as a function of axial position and the temperature ($T_C$) of the water leaving the pipe. State and justify your assumptions.

2.




The electrical wire, of diameter $D_I$=10 mm, has an insulating core of diameter $D_0$ = 6 mm, shown above. It is carrying a current of 100 amperes. The insulation of thickness 5 mm ($D_2$ = 20 mm). Given that the forced convection coefficient from the external surface is 25 $W/m^2K$ and the ambient temperature is 20 °C, calculate the maximum internal temperature of the wire.

The insulation material has a thermal conductivity of 0.1 W/mK and emissivity of unity. Thermal conductivity of the aluminum conductive layer is 200 W/mK and its electrical resistivity is 0.01 micro-ohms-m.

Assume that radiation can be neglected and then determine and discuss if this assumption is justified. Clearly state any other assumptions that you make.

3. The schematic shows a conical ceramic bowl with known radiative and thermophysical properties, which was used by the ancient Greeks to heat up water during the sunny and warm days. At noon, 1 kilogram of water at initial temperature $T_0$ = 20 °C is poured into a bowl and placed outside under the sun. At noon, the solar irradiation is 800 $W/m^2$ and the environment air temperature $T_e$ (e.g., 40 °C) and humidity (e.g., 30%) are known.

Assume that the water surface is a diffuse emitter and reflector of thermal radiation but spectrally selective (for example, its spectral directional emissivity is 0.1 for $\lambda<1$ μm and 0.9 for $\lambda>1$ μm).

Assume that all other relevant thermophysical, radiative and transport properties of the bowl, water, and atmosphere/sky are known. Also, all required geometrical parameters and view factors are available. If you think that there is some missing information in the problem statement, feel free to make appropriate assumptions but provide appropriate justification.

**Find**:

*(1) How long would it take to heat the water to certain temperature $T_f$ (e.g., 30°C)?*
*(2) What would be the steady-state temperature of the water $T_{ss}$?*
*(3) What can you suggest to improve the efficiency of the water heating process?*

Don't attempt to obtain the closed-form solution of the problem!!! Only (i) identify all important modes of heat transfer, (ii) formulate the problem in terms of relevant parameters and clearly define them, (iii) make appropriate assumptions and justify them, (iv) state the boundary and initial conditions, and (v) discuss how you'll go about finding the solution (in a few words).

**Words of wisdom**: Don't freak out!!! Spend a few minutes just thinking about the problem and key phenomena that need to be accounted for, and only then proceed to writing! Remember, this problem can be solved in many possible ways depending upon the assumptions you make...so be sure to support every step of your analysis by appropriate assumptions/observations.