GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1996

HEAT TRANSFER
EXAM AREA

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

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

Ph.D. Qualifying Exam
Heat Transfer
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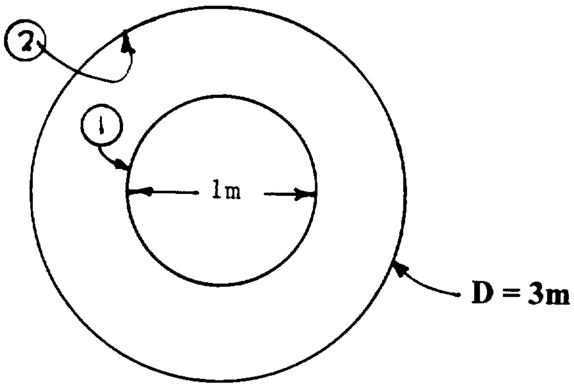
All problems are equal credit.

1) Two infinitely long concentric cylinders have temperatures and properties as shown in the figure. Calculate the net radiative heat gain (q_{net}) of both surfaces when

   a. both surfaces are diffuse emitters and diffuse reflectors

   b. both surfaces are diffuse emitters while surface 1 is a diffuse reflector and surface 2 is a specular reflector



$T_1 = 1000K$
$T_2 = 2000K$

$\epsilon_1 = 0.5$
$\epsilon_2 = 0.1$

2)

a) The temperature profile at a point in the thermal boundary layer is given by;

$$\frac{\theta}{\theta_e} = \frac{3}{2}\left(\frac{y}{\delta_t}\right) - \frac{1}{2}\left(\frac{y}{\delta_t}\right)^3 ; \theta = t - t_w \ \& \ \theta_\infty = (t_\infty - t_w)$$

Determine the rate of heat transfer and the Nusselt number at this location.

Use the following additional information given here, $t_\infty = 100°F$, $t_w = 400°F$, velocity boundary layer thickness = 0.2 inch and the forms of profiles are similar.

Temperature °F	Thermal Conductivity B/hr. ft. F	Dynamic Viscosity lbm/hr.-ft.	Prandtl Number
100	0.364	1.65	4.53
400	0.384	0.33	1.00

b) Sketch the velocity and temperature profiles in the boundary layer region at this location. Properly label the sketch.
c) Sketch the shape of the local heat transfer coefficient as a function of x from the leading edge.
d) Is the flow turbulent or laminar for the data of part (a)? If the plate is very long redraw the sketch you have drawn in part (c). Explain the engineering significance.
e) State the relationship between the local heat flux of part (a) and the average value up to that point from the leading edge. How will you obtain this result? Express it in evaluation form.
f) Using applicable anologies and based on your solution development, state additional information you can obtain to solve engineering problems.

3) Copper tubing is joined to an aluminum solar collector plate of thickness t and the working fluid maintains the temperature of the plate above the tubes at T_o. There is a uniform **net** radiation heat flux q''_{rad} to the top surface of the plate, while the bottom surface is well-insulated. The top surface is also exposed to a fluid at T_∞ that provides for a uniform convection coefficient h.

(a) Begin with an energy balance on an appropriate volume and develop an expression for the temperature distribution in the plate. Clearly state and justify all assumptions and boundary conditions.

(b) Sketch the temperature distribution.

(d) What would you say are reasonable values for q''_{rad}, h, and k (for copper and for aluminum) in SI units?