GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1997

Heat Transfer
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

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Mechanical Engineering
Ph.D. Qualifying Exam
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1. The wall of a house consists of three materials. The inner material is 0.5" thick plaster board (k = 0.15 W/m·K, ρ = 800 kg/m3, c_p = 1200 J/kg·K), the middle material is a 2" thick insulating material (k = 0.050 W/m·K, ρ = 15 kg/m^3, c_p = 1000 J/kg·K), and the outer material is 1" thick wood siding (k = 0.10 W/m·K, ρ = 500 kg/m^3, c_p = 1500 J/kg·K).

a. If the temperature within the house is 25°C and the outside air temperature is -10°C, calculate the energy lost across the wall in W/m^2. Assume that steady state conditions exist and that the heat transfer coefficient between the inside air and the inner wall is h = 10 W/m^2 ·K and the heat transfer coefficient between the outer surface of the house and the outside air is h = 50 W/m^2 ·K.

b. A high school student as a prank turns a blow torch on the outside surface of the house. The heat flux from the blow torch is 100 W/m^2. Other conditions are as in part (a). Assuming steady state conditions are reached, estimate the outside surface temperature of the wood siding and the inside wall temperature of the plaster board.

c. For part (b) estimate the time required to reach steady state conditions.

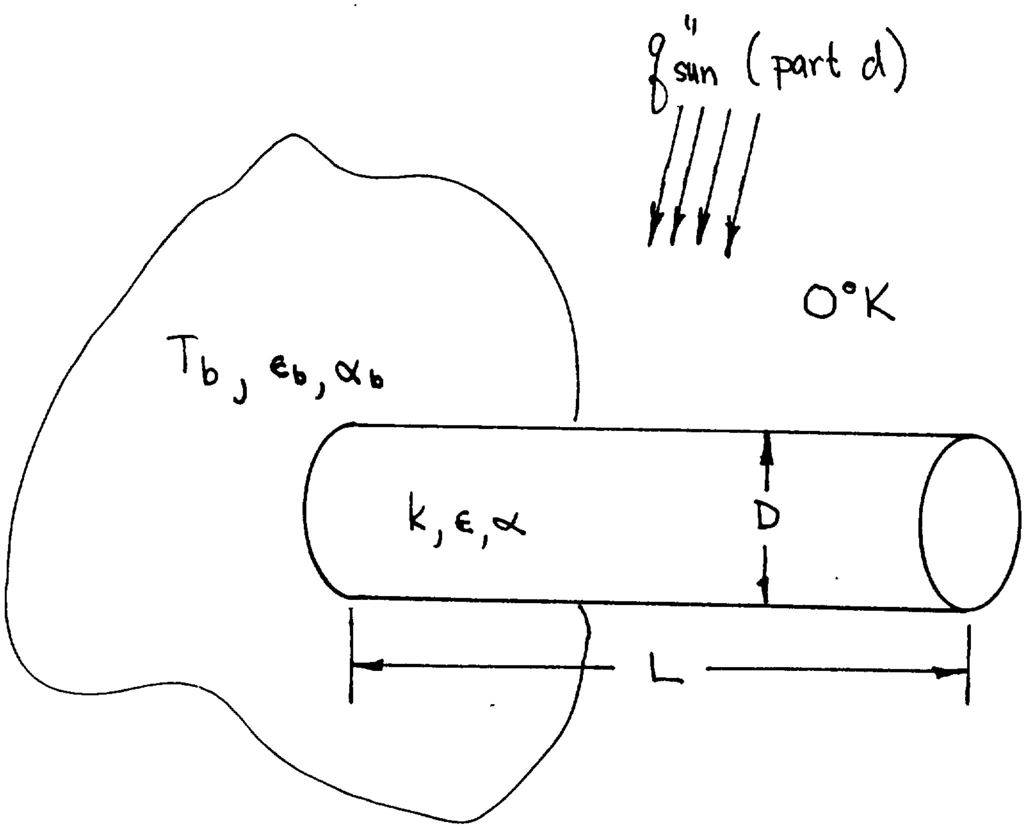
2. The outer surface of a space probe has a circular, metallic rod (length L, diameter D) extending from its external surface as shown in the sketch. The surroundings may be considered to be at 0°K for radiation purposes. The thermal properties of the rod (k, ε, α) are known. The rod is assumed to be gray and diffuse. The rod is attached to an isothermal (T_b), diffuse and gray, plane surface.

a. Write a differential equation that can be used to determine the local, steady temperature T (x) in the rod assuming no solar input.

b. State sufficient boundary conditions that will allow you to solve your differential equation in part (a) assuming no solar input.

c. Write an expression for the heat transfer rate from the rod to the surroundings assuming no solar input.

d. Modify parts (a), (b) and (c) as necessary, if the rod is subjected to a known incident heat flux from the sun q''_{sun}.



3. In a concentric tube heat exchanger, liquid is cooled as it flows through the inner tube while a gas flows through the annulus between the tubes.

a. Sketch the axial variation of the bulk temperature of each fluid for

i. a parallel-flow arrangement, and

ii. a counter-flow arrangement

b. Comment on your choice for a Nusselt number correlation for heat transfer calculations on the liquid side, if the flow Reynolds number is (i) 1,000; (ii) 10,000; (iii) 100,000; (iv) 500,000.

c. If fins are added to enhance the heat transfer, then on which surface should the fins be attached (i.e., the liquid side or the gas side)?

d. If N fins are attached to the chosen side in part (c), with finned surface area A_f per fin, fin efficiency η_f, heat transfer coefficient h_f, and with the unfinned portion having area A_{uf} and heat transfer coefficient h_{uf}, develop an expression for the overall heat transfer coefficient for the annular tube heat exchanger.