THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF MECHANICAL ENGINEERING

EXAMINATION FOR THE DEGREE OF B.E.

#9900: HEAT TRANSFER
JUNE 2000

TIME: THREE HOURS

Candidates are also allowed 10 minutes to read the paper before the examination begins.

Candidates are required to answer **FIVE** of the six questions in this paper.

Each question is worth 20 marks.

The use of notes, prescribed textbook and calculators is permitted. The textbook will be necessary to solve some of the problems.

Marks are assigned within each question for problem layout and especially for comments both through the solution and concerning the significance of the answer.

Question 1:

(a) Two concentric 20 cm diameter disks, 10 cm apart, have facing sides at 1000 K and 700 K, and insulated backs. For gray disk surfaces with emissivity ε_1=0.4, and black surrounding at 0 K, determine:

(i) the net radiation exchange between the disks
(ii) the heat loss from each disk.

(b) If we to insert two concentric and equally spaced *thin* disks of the same size (20 cm diameter) between the insulated disks above, what would the net radiation exchange between the outer disks be then?

Question 2:

(i) Air flow through a long rectangular heating duct that is 0.75 m wide and 0.3 m high. The outer duct surface temperature is maintained at 45°C. If the duct is un-insulated and exposed to air at 15°C in the crawlspace beneath a home, what is the heat loss from the duct per meter of length?

Note: You can treat the horizontal and vertical surfaces separately.

(ii) Discuss briefly the effect of surface roughness on your solution and how does it affect skin friction.

Question 3:

A 15 cm diameter, 30 cm long 18-8 (AISI 302) stainless steel billet at 20°C is placed in an oil bath at 300°C. The heat transfer coefficient may be taken to be 400 W/m^2 K. Determine the center temperature after 500 s have lapsed:

(i) Using the lumped thermal capacity model
(ii) Assuming the billet is long compared to its diameter
(iii) Accounting for the finite length of the cylinder

Question 4:

Hot oil is to be cooled by water in a 1-shell-pass and 8 tube-passes heat exchanger. The tubes are thin-walled and are made of copper with an internal diameter of 1.4 cm. The length of each tube pass in the heat exchanger is 5 m, and the overall heat transfer coefficient is 310 W/m^2 °C. Water flows through the tubes at a rate of 0.2 kg/s, and the oil through the shell at a rate of 0.3 kg/s. The water and the oil enter at temperatures of 20°C and 150°C, respectively. Determine:

(i) the rate of heat transfer in the heat exchanger
(ii) the outlet temperatures of the water and the oil.

Question 5:

Consider the flow of Engine oil (SAE 50) at 20°C in a 30 cm diameter pipeline at an average velocity of 2 m/s. A 200 m long section of the pipeline passes through icy waters of a lake at 0°C. Measurements indicate that the surface temperature of the pipe is very nearly 0°C. Disregarding the thermal resistance of the pipe material, determine:

(i) The temperature of the oil when the pipe leaves the lake

(ii) The rate of heat transfer from the oil

(iii) The pumping power required to overcome the pressure losses and to maintain the flow of the oil in the pipe.

Note: evaluate oil properties initially at 20°C and comment on the accuracy of this assumption.

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Question 6:

A sphere with a diameter of 10 mm is initially in a furnace with a uniform temperature of 400°C. The sphere is suddenly removed from the furnace and subjected to two stage cooling process.
Stage 1: Cooling in air at 20°C for a period of time t_a until the center temperature reaches a critical value of 335°C. In this stage the convective heat transfer is 10 W/m^2 K.
Stage 2: Cooling in a well-stirred water bath at 20°C, with a convective heat transfer coefficient of 6000 W/m^2 K.
The thermophysical properties of the sphere material are ρ = 3000 kg/m^3, k = 20 W/m K, c = 1000 J/kg and α=6.66E-06 m^2/s.

(i) Calculate the time t_a required for stage 1 of the cooling process to be completed.

(ii) Assuming that the temperature is uniform at the end of stage 1, Calculate the time t_w required, during stage 2 of the process, for the center of the sphere to cool from 335°C to 50°C.

End of Examination paper