2009 Heat Transfer Midterm Exam

April 23rd 2009
19:00 — 21:20

NO NOTES OR BOOKS; USE HEAT TRANSFER TABLES THAT WERE DISTRIBUTED; ANSWER ALL 4 QUESTIONS; TOTAL POINTS: 100 PTS.

Question #1

25 pts. Fins are frequently installed on tubes by a press-fit process. Consider a circumferential aluminum fin having a thickness of 1.0 mm to be installed on a 3.0-cm-diameter aluminum tube. The fin length is 1.5 cm, and the contact conductance may be taken from the tables for a 100-μinch ground surface. The convection environment is at 30° C, and $h = 140$ W/m$^2 \cdot ^\circ$C.

(a) Calculate the heat transfer for each fin for a tube wall temperature of 200°C.

(b) What percentage reduction in heat transfer is caused by the contact conductance?

Question #2

25 pts. A plate of stainless steel (18% Chrome, 8% Nickel) has a thickness of 4.0 cm and is initially uniform in temperature at 500°C. The plate is suddenly exposed to a convection environment on both sides at 80° C with $h = 250$ W/m$^2 \cdot ^\circ$C.

(a) Calculate the time for the center temperature to reach 100°C.

(b) Calculate the time for the face temperatures to reach 100°C.

Question #3

30 pts. A solid sphere of radius $r_0 = 1.0$ m is buried in earth. The center of the sphere is at a distance of 5.0 m below the earth's surface. The thermal conductivity of the earth is $k_{\text{earth}} = 1.2$ W/m $\cdot ^\circ$C, and its surface temperature is 25°C. Inside the sphere, there is a volumetric rate of heat generation given by $S = S_0[1 - (r/r_0)^2]$ with $S_0 = 3750$ W/m^3 = constant. The thermal conductivity of the sphere material is $k_{\text{sphere}} = 25$ W/m $\cdot ^\circ$C. At the interface between the earth and the solid sphere, there is a thermal contact conductance coefficient of $h_c = 500$ W/m$^2 \cdot ^\circ$C. Assuming that the temperature distribution *inside the sphere* is essentially 1-D radial, calculate the following for steady-state conditions:

(a) the temperature *of the earth* at the interface between the earth and the sphere;

(b) the surface temperature of the sphere;

(c) the maximum temperature inside the sphere.

Question #4

20 pts. A solid cube is heated to a uniform temperature of 520° C. It is then exposed to a convective cooling environment: $h = 1000$ W/m$^2 \cdot {}^\circ$C and $T_\infty = 20^\circ$ C. The length of each side of the cube is 0.05 m. The properties of the cube material are the following: $\rho = 8000$ kg/m^3, $c = 1000$ J/kg $\cdot {}^\circ$C, and $k = 25$ W/m $\cdot {}^\circ$C.

(a) How long does it take for the *centre* of each *face* of the cube to cool down to a temperature of 68.4° C?

(b) At $t = 200$ s into the cooling process, the cube is wrapped *completely* in excellent insulation. Calculate its equilibrium temperature.

Answers

1. 64.5 W, 26.4 %
2. 939 s, 879 s
3. 400 C, 401 C, 418.5 C
4. 200 s, 75.5 C