Examination Heat Transfer

code: 4B680
date: 2 February 2007
time: 14.00 - 17.00 hours

Note:

There are 4 questions in total. The first one consists of independent sub-questions. If possible and necessary, guide numbers are given for the answers.

Good luck

<u>Question 1</u> (all sub-questions can be solved independently)

a) A 10 cm thick slab of aluminum at a uniform temperature of 200 ^{0}C is submerged in a bath of oil at a temperature of 70 ^{0}C. The heat transfer from the slab to the oil can be described by a convection coefficient which is assumed to be infinitely large. One is interested in the temperature distribution in the slab as a function of time. Give an estimation of the time interval over which the temperature distribution in the slab can be calculated using the semi-infinite solid approach. Errors large than 5 ^{0}C are not allowed. Aluminum has the following properties: ρ = 2707 kg/m^3; c_p = 896 J/kg.K; k = 204 W/m.K.

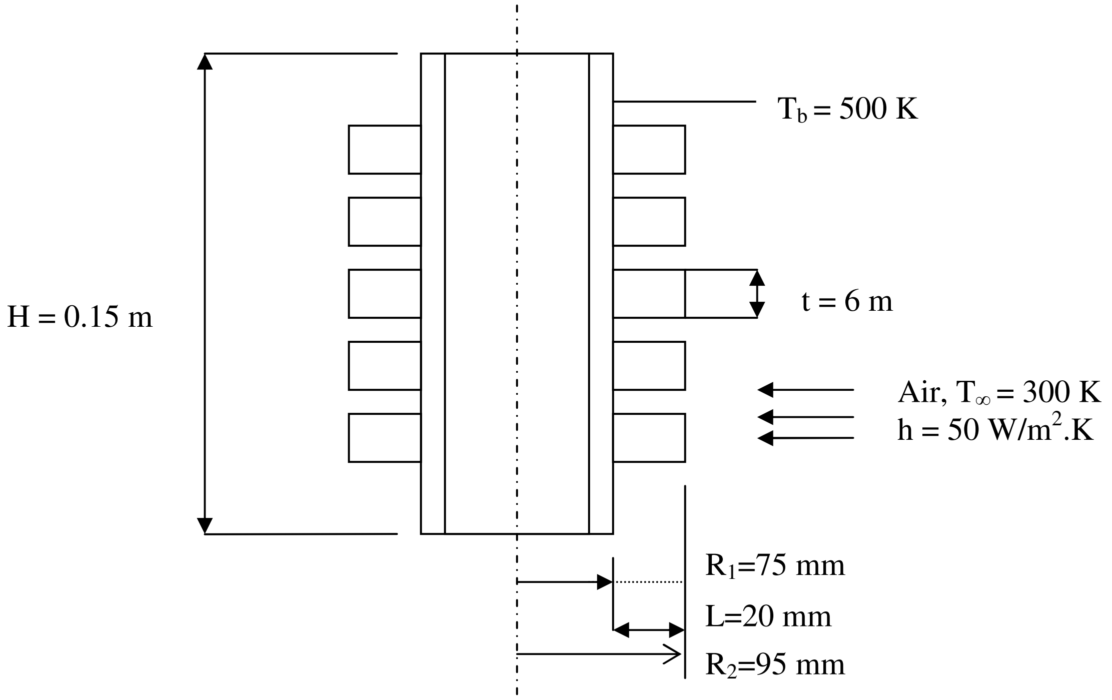
b) Water at 20 ^{0}C and a mass flow rate of 0.1 kg/s enters a pipe with an inner diameter of 2 cm and a length of 2 m. A constant heat flux is imposed on the tube wall of 5000 W/m. Calculate the exit temperature of the water and the wall. The water properties can be evaluated at a temperature of about 20 ^{0}C. The flow is supposed to be hydrodynamically and thermally fully developed.

c) Water at a mass flow rate of 68 kg/min is heated from 35 to 75 ^{0}C by oil having a specific heat of 1.9 kJ/kg.^{0}C. The fluids are used in a shell-and-tube heat exchanger with the water making one shell pass and the oil making two tube passes. The oil enters the exchanger at 110 ^{0}C and leaves at 75 ^{0}C. The overall heat transfer coefficient is 320 W/m^2.K. Calculate the heat exchanger area.

Question 2 (all sub-questions can be solved independently)

The engine of a motorcycle consists of a metal cylinder with a heat conduction coefficient equal to k = 186 W/m.K. The cylinder has a height of H = 0.15 m and an outside diameter of D = 150 mm. Under typical operating conditions the outer surface of the cylinder is at a temperature of 500 K and exposed to ambient air at 300 K and a convection coefficient of 50 $W/m^2.K$. Circumferential fins with a rectangular cross section are applied to increase the heat transfer rate to the surroundings. Consider five such fins, which are equally spaced and have a thickness of t = 6 mm and a length of L = 20 mm. Because the cylinder diameter is relatively large compared to the length of the fins, the fins may supposed to be straight with an equivalent width equal to the perimeter of the cylinder.

a) Calculate the efficiency of the rectangular fins. ($\eta_e = 0.8$)
b) Calculate the convection heat transfer rate using fins. ($q_{fins} = 500\ W$)
c) What is the increase in heat transfer rate by using fins?
d) Is a value of 50 $W/m^2.K$ for the convection heat transfer coefficient realistic if assumed that the cylinder is freely exposed to the surroundings at a cruising speed of 100 km/h.



Question 3 (all sub-questions can be solved independently)

To increase the contribution of green energy an electricity company considers the construction of a solar panel field in a dessert. A disadvantage of solar cells is that their efficiency is inversely proportional to their temperature. A part of the total incident solar energy is converted to electricity, a part is reflected and a part is absorbed as heat by the solar cells. The latter quantity amounts $q''_{zon} = 500\ \text{W/m}^2$.

The solar panels have dimensions of 1.0m × 0.5m × 0.01m (Length × Width × Thickness). It can be assumed that the solar cells are made of pure silicon (high heat conduction coefficient) and that the rear side of the panels is perfectly insulated. The properties of air can be determined at a temperature of 350 K.

a) On a windless, sunny day ($v_{air} = 0$ m/s) the air temperature equals $T_{air} = 32\ ^0$C. Assume that heat transfer is only taking place by natural convection to the environment and that the solar panels are positioned perfectly horizontal.

   What is the mean surface temperature in steady state?

b) At a certain moment wind starts blowing at a speed of $v_{air} = 8$ m/s in the width direction of the solar panels (B = 0.5 m). From now on natural convection can be disregarded.

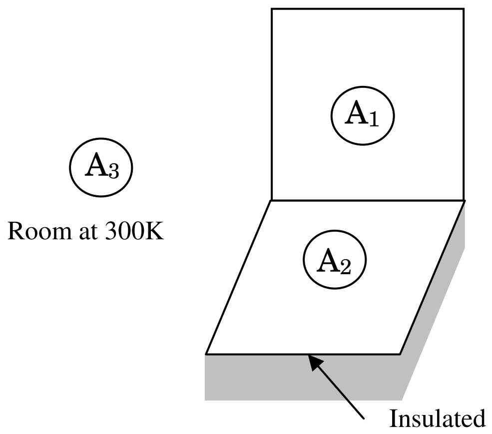
   How thick are the hydrodynamic (δ) and thermal (δ_t) boundary layers at he end of the panel?

c) What is the maximum surface temperature for the forced convection case? Assume that there is no conduction heat transfer in the panel due to temperature differences.

d) Does it matter for the mean heat transfer coefficient $\bar{h}_L$ if the solar panels are positioned in length (L = 1.0 m) or width direction (B = 0.5 m) with respect to the wind direction? Substantiate your answer.

Question 4 (the sub-questions a), b) and d) can be solved independently)

Two flat plates are placed perpendicularly with one common edge, see figure. Surface 1 is at a temperature of T_1 = 1000 K and has an emissivity of ε_1 = 0.6. Surface 2 is insulated at its bottom and is in thermal equilibrium with surface A_1 and with a large surrounding room at temperature T_3 = 300 K. Both surfaces have dimensions 50 × 50 cm.



a) Calculate the radiation view factors F_{12}, F_{13}, F_{21} and F_{23}.
   (*If you don't succeed than estimate the values and use those further on*)
b) Consider the enclosure consisting of the surfaces A_1, A_2 and A_3 and sketch the electrical analogy for this enclosure indicating all resistances non-equal to zero. Try to simplify the system as much as possible.
c) Determine the heat lost by surface A_1. (q_1 = *10 kW*)
d) Determine the temperature of surface A_2.