CH EN 3453 – HEAT TRANSFER – FALL 2014

HOMEWORK #6

Due Friday, October 10 at 4:00 PM

Turn in to the CH EN 3453 basket at the main desk of the Chemical Engineering offices (MEB 3290)

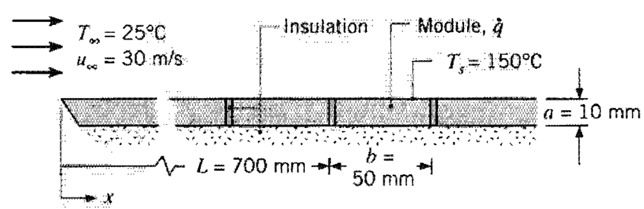
Help session Wednesday, October 8 at 4:30 p.m. in MEB 2325

For this assignment, you must…
- *show your work*
- *write legibly and not in micro-font*
- *circle or put a box around your final answer*

1. (20 pts) What are the velocity, thermal, and convection boundary layers? Under what conditions do they develop?

2.* (10 pts) An object of irregular shape has a characteristic length of of L = 1 m and is maintained at a uniform surface temperature of T_s = 400 K. When placed in atmospheric air at a temperature of T_∞ = 300 K and moving with a velocity of V = 100 m/s, the average heat flux from the surface to the air is 20,000 W/m^2. If a second object of the same shape, but with a characteristic length of L = 5 m, is maintained at a surface temperature of T_s = 400 K and is placed in atmospheric air at T_∞ = 300 K, what will the value of the average convection coefficient be if the air velocity is V = 20 m/s?

3.* (10 pts) A flat plate of width 1 m is maintained at a uniform surface temperature of T_s = 150°C by using independently controlled, heat-generating rectangular modules of thickness a = 10 mm and length b = 50 mm. Each module is insulated from its neighbors, as well as on its back side. Atmospheric air at 25°C flows over the plate at a velocity of 30 m/s. The thermophysical properties of the module are k = 5.2 W/m·K, c_p = 320 J/kg·K and ρ = 2300 kg/m^3.



(a) Find the required power generation, $\dot{q}$ (W/m^3), in a module positioned at a distance 700 mm from the leading edge.

(b) Find the maximum temperature T_{max} in that heat generating module.

4.* Consider a rectangular fin that is used to cool a motorcycle engine. The fin is 0.20 m long and at a uniform temperature of 250°C, while the motorcycle is moving at 80 km/hr in air at 27°C. The air is in parallel flow over both surfaces of the fin, and turbulent flow conditions may be assumed to exist throughout (over the entire length of the fin).

(a) What is the rate of heat removal per unit width of the fin?

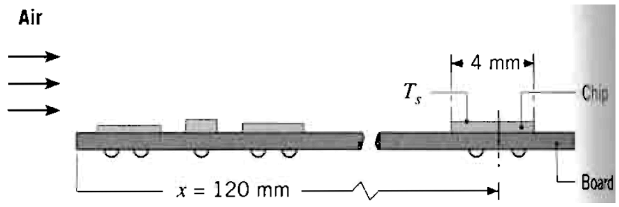
(b) Determine the heat removal rate for various speeds between 10 and 100 km/hr and generate a plot of this behavior.

More problems on the other side…

* Solutions for these problems are available on the course website: www.chen3453.com

5.* Forced air at 25°C and 10 m/s is used to cool electronic elements mounted on a circuit board. Consider a chip of length 4 mm and width 4 mm located 120 mm from the leading edge. Because the board surface is irregular, the flow is disturbed and the appropriate convection correlation is of the form:

$$Nu = 0.04\,\mathrm{Re}_x^{0.85}\,\mathrm{Pr}^{0.33}$$



Estimate the surface temperature of the chip, T_s, if its heat dissipation rate is 30 mW.

6. (20 pts) In his analysis of near-surface fluid flow, Paul Richard Heinrich Blasius determined that the velocity boundary layer thickness, δ, for laminar flow over a flat plate can be determined by the following relation (introduced in Chapter 7):

$$\frac{\delta}{x} = \frac{5}{\sqrt{\mathrm{Re}_x}}$$

where *x* is the distance from the edge of the plate. Suppose nitrogen at 23°C and 1 atm pressure is flowing at 8 meters/sec across a 0.25 m wide, 1 m long flat plate which is kept at 131°C. Using the Blasius correlation above and relations in the book, determine:

(a) δ halfway down the length of the plate

(b) δ at the trailing edge

(c) δ_t halfway down the length of the plate

(d) δ_t at the trailing edge

(e) h_x halfway down the length of the plate

(f) h_x at the trailing edge

(g) $\bar{h}$

(h) total heat transfer from the plate

7. (20 pts) A fancy hillside house has a sunken hot tub built into the patio. When not in use, the hot tub is covered by square, 8 cm thick piece of foam insulation (k = 0.3 W/m·K), which is 3 meters on a side. Estimate heat loss through the cover if the outside air temperature is 15°C and blows across the cover at 5 meters/sec. Assume that the air space between the water surface and the underside of the cover is 40°C and the heat transfer coefficient on the underside of the cover is 10 W/m^2·K.

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