CH EN 3453 – HEAT TRANSFER – FALL 2014

HOMEWORK #9

Due Friday, November 7 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, November 5 at 4:30 p.m. in MEB 2325

1. (12 pts) With respect to free convection:

(a) What is an extensive, quiescent fluid?
(b) What are the two major physical considerations or forces for free convection?
(c) What is the Grashof number in words (ratio of forces) and mathematically?
(d) What is the Rayleigh number in words and mathematically?

2. (8 pts) A single-pass, cross-flow heat exchanger uses hot exhaust gases (mixed) to heat water (unmixed) from 30 to 80°C at a rate of 3 kg/s. The exhaust gases, having thermophysical properties similar to air, enter and exit the exchanger at 225 and 100°C, respectively. If the overall heat transfer coefficient is 200 W/m^2·K, estimate the required surface area.

PROPERTIES: *Table A-6*, Water ($\overline{T}_c$ = (80 + 30)°C/2 = 328 K): c_p = 4184 J/kg·K; *Table A-4*, Air (1 atm, $\overline{T}_h$ = (100 + 225)°C/2 = 436 K): c_p = 1019 J/kg·K.

3. (8 pts) A cross-flow heat exchanger consists of a bundle of 32 tubes in a 0.6-m^2 duct. Hot water at 150°C and a mean velocity of 0.5 m/s enters the tubes having inner and outer diameters of 10.2 and 12.5 mm. Atmospheric air at 10°C enters the exchanger with a volumetric flow rate of 1.0 m^3/s. The convective heat transfer coefficient on the tube outer surfaces is 400 W/m^2·K. Estimate the fluid outlet temperatures.

PROPERTIES: *Table A-4*, Air ($T_{c,i}$ = 10°C = 283 K, 1 atm): ρ = 1.2407 kg/m^3; *Table A-4*, Air (assume $T_{c,o} \approx$ 40°C, $\overline{T}_c$ = (10 + 40)°C/2 = 298 K, 1 atm): c_p = 1007 J/kg·K; *Table A-6*, Water (assume $T_{h,o} \approx$ 140°C, $\overline{T}_h$ = (140 + 150)°C/2 = 418 K): $\rho = 1/v_f = 1/1.0850 \times 10^{-3}$ m^3/kg, c_p = 4297 J/kg·K, $\mu_f = 188 \times 10^{-6}$ N·s/m^2, k_f = 0.688 W/m·K, Pr_f = 1.18.

4. (8 pts) Determine the average convective heat transfer coefficient for the 2.5-m high vertical walls of a home having respective interior air and wall surface temperatures of (a) 20 and 10°C and (b) 27 and 37°C. (Note that the wall temperature is cooler in part a, hotter in part b.)

For T_f = 15°C: $\nu = 14.82 \times 10^{-6}$ m^2/s, k = 0.0253 W/m·K, $\alpha = 20.9 \times 10^{-6}$ m^2/s, Pr = 0.710
For T_f = 32°C: $\nu = 16.39 \times 10^{-6}$ m^2/s, k = 0.0267 W/m·K, $\alpha = 23.2 \times 10^{-6}$ m^2/s, Pr = 0.706

More problems on the other side…

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

5. (8 pts) A sphere of 25-mm diameter contains an embedded electrical heater. Calculate the power required to maintain the surface temperature at 94°C when the sphere is exposed to a quiescent medium at 20°C for (a) air, (b) waer and (c) ethylene glycol.

	$\nu \cdot 10^6$, m^2/s	$k \cdot 10^3$, W/m·K	$\alpha \cdot 10^6$, m^2/s	Pr	$\beta \cdot 10^3$, K^{-1}
Table A-4, Air (1 atm)	18.91	28.5	26.9	0.711	3.03
Table A-6, Water	0.497	650	0.158	3.15	0.504
Table A-5, Ethylene glycol	5.15	260	0.0936	55.0	0.65

6. (8 pts) A building window that is 1.2 m high and 0.8 m wide is separated from the ambient air by a storm window of the same height and width. The air space between the two windows is 0.06 thick. If the building and storm windows are 20 and –10°C, respectively, what is the rate of heat loss by free convection across the air space?

7. (16 pts) Water flowing at a rate of 3.8 kg/s is heated from 38 to 55°C in the tubes of a shell-and-tube heat exchanger. The shell side is one-pass with water flowing at 1.9 kg/s entering at 94°C. The overall heat transfer coefficient is 1420 $W/m^2 \cdot K$. The average water velocity in the 1.905-cm ID tubes is 0.366 m/s. Because of space limitations, the tubes may not exceed 2.44 m in length. Determine:

(a) the required number of tube passes
(b) the number of tubes per pass
(c) the length of the tubes (per pass), keeping in mind the space restriction

8. (16 pts) A cylindrical fluorescent light bulb, 35 mm diameter and 0.8 m long, is rated at 100 Watts. When the light bulb, which is oriented horizontally, is on in a warehouse with an air temperature of 25°C, its surface temperature is 140°C.

(a) Estimate the rate of heat transfer (Watts) from the bulb by natural convection.
(b) Why does the result not equal 100 Watts?

9. (16 pts) A solar energy collector on a rooftop is 6 x 6 meters and mounted in a horizontal position. The incident solar energy flux is 630 W/m^2. If the surface of the collector is 65°C and surrounding air is stagnant and at 10°C, what fraction of the incident energy is lost by convection to the surrounding air?

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