ID number: Heat Transfer

Name: 1^{st} Semester, 2008

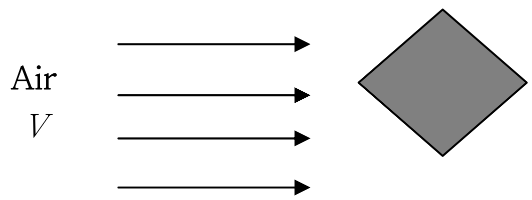
Problem	1	2	3	4	5	Total
Points						

Final Exam

(June 11)

1. Experimental measurements of the convection heat transfer coefficient for a square bar in cross flow yielded the following values (length of one side L = 0.5 m):

$\bar{h}_1 = 50$ W/m^2·K when $V_1 = 20$ m/s, $\bar{h}_2 = 40$ W/m^2·K when $V_2 = 15$ m/s



Assume that the functional form of the Nusselt number is $\overline{\mathrm{Nu}} = C\,\mathrm{Re}^m\,\mathrm{Pr}^n$, where C, m, n are constants (5 pts each, 20 pts in total).

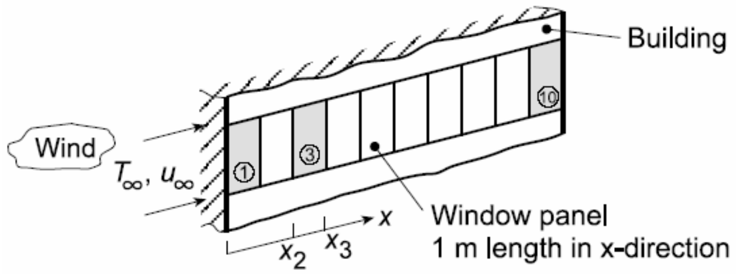
(a) What is the value of m?

(b) What will be the convection heat transfer coefficient for a similar bar with L = 1 m when V = 15 m/s?

(c) What will be the convection heat transfer coefficient for a similar bar with L = 1 m when V = 30 m/s?

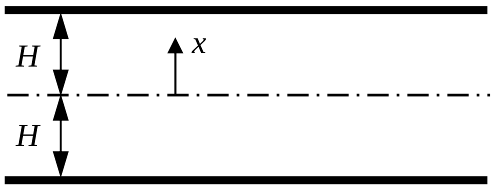
(d) Would your results be the same if the diagonal of the bar, rather than its length of one side, were used as the characteristic length?

2. Consider weather conditions for which the prevailing wind blows past the penthouse tower on a tall building. The tower length in the wind direction is 10 m and there are 10 window panels. For simplicity, it is assumed that material properties of air at a film temperature of 300 K can be used: $\nu = 16 \times 10^{-6}$ m^2/s, $k = 26 \times 10^{-3}$ W/m·K, Pr = 0.7. The critical Reynolds number for turbulent transition is $Re_{x,c} = 5 \times 10^5$. (20 pts)



(a) Predict at which window the air flow transits from laminar to turbulent when the wind speed is $u_\infty = 5$ m/s.
(b) Calculate the average convection coefficient for the first and third window panels.

3. For a liquid metal flow between two parallel plates (two-dimensional channel) as shown below, the velocity and temperature profiles at a particular axial location may be approximated as being uniform and parabolic, respectively. That is, $u(x) = C_1$ and $T(x) - T_s = C_2\left\{1 - (x/H)^2\right\}$, where C_1 and C_2 are constants and H is the half height of the channel. Determine the corresponding value of the mean (or bulk) temperature T_m and the Nusselt number Nu_H (= hH/k) at this axial position. (20 pts)



4. The feedwater heater for a boiler supplies 10,000 kg/h of water at 65°C. The feedwater has an inlet temperature of 20°C and is to be heated in a single-shell, two-tube pass heat exchanger by condensing steam at 1.30 bars. The overall heat transfer coefficient is 2000 W/m^2·K. Using both the LMTD and NTU methods, determine the required heat transfer area. What is the steam condensation rate? Assume correction factor $F = 1$.

Properties: Steam (1.3 bar, saturated): $T_h = 380.3$ K, $h_{fg} = 2238 \times 10^3$ J/kg·K; Water ($T =$ 316 K): $c_p = 4179$ J/kg·K, $\mu = 725 \times 10^{-6}$ N·s/m^2, $k = 0.625$ W/m·K, Pr = 4.85.
<u>Note that some properties are necessary, while some are not.</u>

For single-shell and two tube passes,

$$\text{NTU} = -\left(1+C_r^2\right)^{-1/2} \ln\left(\frac{E-1}{E+1}\right), \quad E = \frac{2/\varepsilon - \left(1+C_r\right)}{\left(1+C_r^2\right)^{1/2}} \quad (C_r = C_{\min}/C_{\max})$$

5. A concentric tube heat exchanger for cooling lubricating oil is comprised of a thin-walled inner tube of 20-mm diameter carrying water and an outer tube of 40-mm diameter carrying the oil. The exchanger operates in counterflow with an overall heat transfer coefficient of 50 W/m^2·K. The inlet temperatures are 100°C and 30°C for oil and water, respectively and the flow rates are the same at 0.1 kg/s for both fluids. The material properties are given below (20 pts)

Properties	**Water**	**Oil**
ρ (kg/m^3)	1000	800
c_p (J/kg·K)	4200	1900
ν (m^2/s)	7×10^{-7}	1×10^{-5}
k (W/m·K)	0.64	0.134
Pr	4.7	140

(a) If the outlet temperature of the oil is 60°C, determine the total heat transfer rate and the outlet temperature of the water.

(b) Determine the length (L) required for the heat exchanger.

Table. Summary of convection heat transfer correlations for external flow.

Correlation	**Geometry**	**Condition**
$\mathrm{Nu}_x = 0.332\,\mathrm{Re}_x^{1/2}\,\mathrm{Pr}^{1/3}$	Flat plate	Laminar, local, T_f, $0.6 \le \mathrm{Pr}$
$\overline{\mathrm{Nu}}_x = 0.664\,\mathrm{Re}_x^{1/2}\,\mathrm{Pr}^{1/3}$	Flat plate	Laminar, average, T_f, $0.6 \le \mathrm{Pr}$
$\mathrm{Nu}_x = 0.0296\,\mathrm{Re}_x^{4/5}\,\mathrm{Pr}^{1/3}$	Flat plate	Turbulent, local, T_f, $\mathrm{Re} \le 10^8$ $0.6 \le \mathrm{Pr} \le 60$
$\overline{\mathrm{Nu}}_L = (0.037\,\mathrm{Re}_L^{4/5} - 871)\,\mathrm{Pr}^{1/3}$	Flat plate	Mixed, average, T_f, $\mathrm{Re} \le 10^8$ $0.6 \le \mathrm{Pr} \le 60$