Name_______________

Circle one:

Div. 1 (12:30 pm, Prof. Choi) **Div. 2 (9:30 am, Prof. Xu)**

School of Mechanical Engineering
Purdue University
ME315 Heat and Mass Transfer

Exam #2

April 3, 2014

Instructions:

- Write your name on each page
- Write on one side of the page only
- Keep all the pages in order
- <u>You are asked to write your assumptions and answers to sub-problems in designated areas. Only work in its designated area will be graded.</u>

Performance

1	**25**	
2	**25**	
3	**25**	
4	**25**	
Total	**100**	

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Problem 1 (25 points)
Consider a tiny drop of water of diameter of *D* floating very slowly in air with a velocity *u*. The temperature of air is T_{air}. The relative humidity of air is ϕ.

It is known that the average Nusselt number is 2 for such a small spherical object. Assume that the Sherwood number also equals 2 according to the Reynolds analogy.

(a) Express the average heat transfer coefficient $\overline{h}$ in terms of given parameters and properties of water and/or air. **For each property used, clearly list it and state what it represents in the table below.** An example for the Prandtl number *Pr* is given in the table.

(b) Perform an energy balance analysis, and derive an expression for the steady-state temperature of the water droplet, and briefly discuss how the temperature of water droplet will be solved. Assume the evaporation rate is very small so the change of the diameter of the water droplet can be neglected. **List properties you used, what they represent in the same table below.**

Assumptions [2 pts] - **List assumptions here**

Table of the Properties used in Your Answer, identify it is air or water properties or both, and at what temperature they are evaluated [6 pts]

Pr	Prandtl number ***of air***

Start your answer to question (a) here [5 pts]:

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Problem 1. - cont'd

Start your answer to question (b) here [12 pts]:

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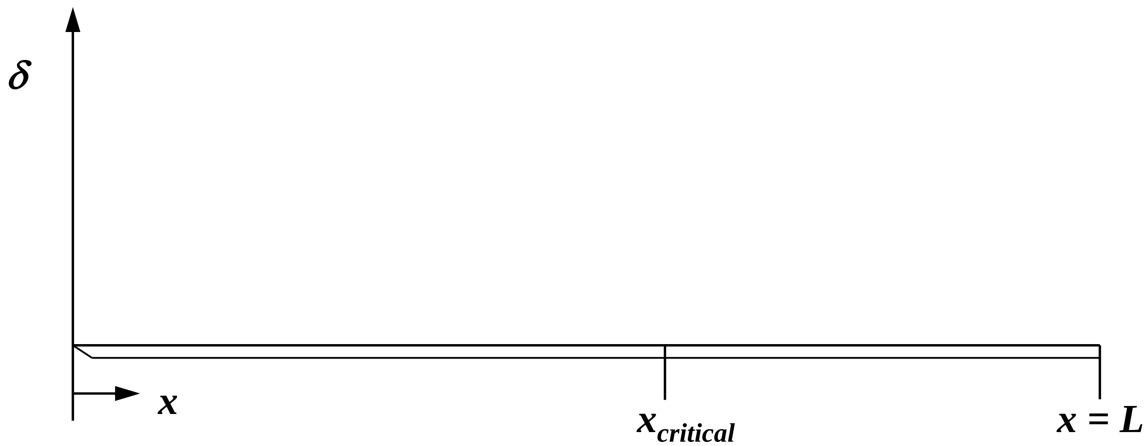
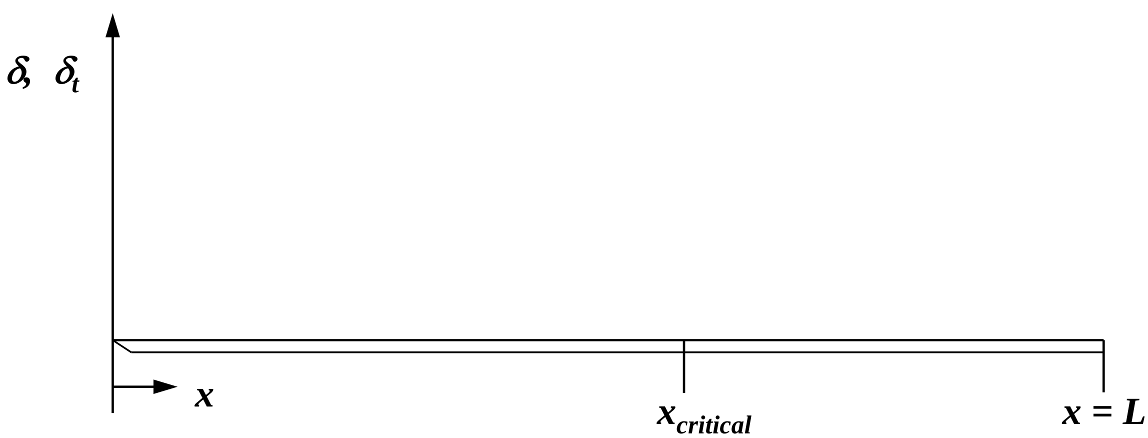
Problem 2 (25 points)
Consider a parallel air flow (u_∞, T_∞, and $C_{A\infty}$) over a very long, flat plate where $Re_L = 5\times10^6$ and transition from laminar to turbulent flow occurs, at $x_{critical}$. You are asked to examine velocity, thermal, and species *A* concentration boundary layers. Plot the following quantities as a function of *x*. <u>You need to provide your reasoning</u>.

(a) Velocity boundary layer thickness, δ [6 pts]:



(b) Compare the relative growth of velocity and thermal boundary layers (i.e. δ versus δ_t). You are given Pr = 4. [7 pts]



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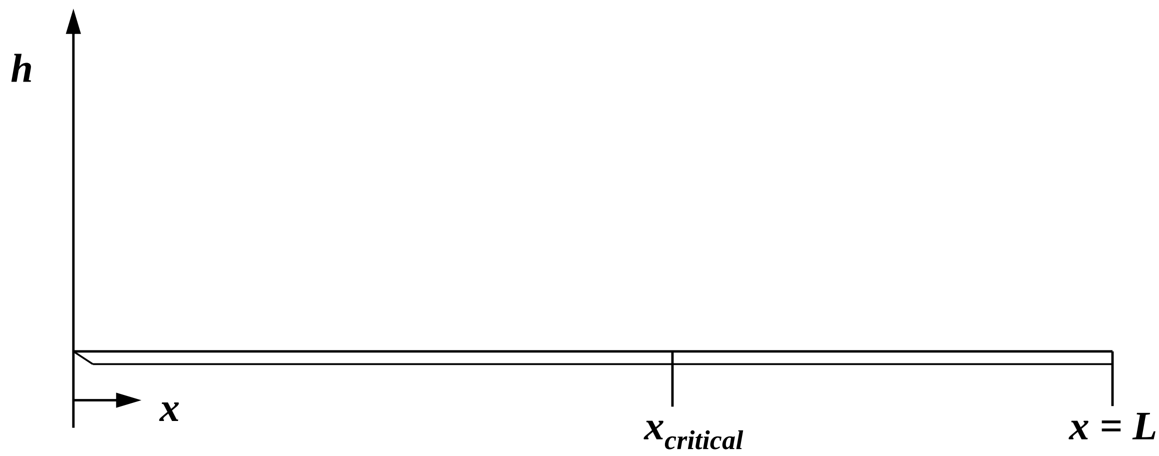
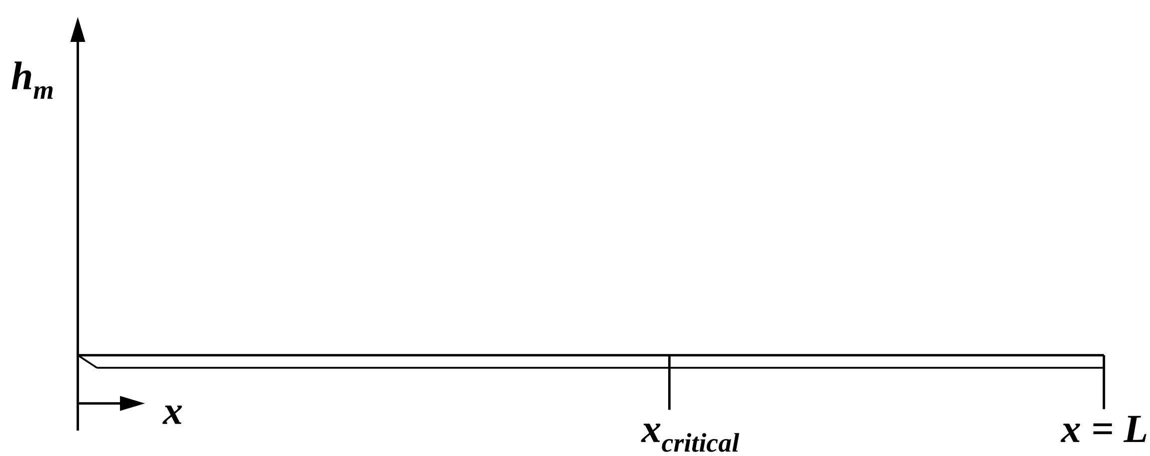
(c) Heat convection coefficient, *h* [6 pts]:



(d) Mass transfer coefficient, h_m [6 pts]:



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Problem 3 [25 points]
Consider a constant surface temperature thin-walled tube of length 1 m and diameter 10 mm, used to route a hot fluid coming from a processing plant. The tube is subjected to cross flow of air at constant temperature 25°C at 25 m/s. The hot fluid has a mass flow rate of 20 kg/hour. The mean temperature of hot fluid at inlet is $T_{m,i}$ = 90°C.

Air properties at 25°C are as follows: ρ = 1.1614 kg/ m^3, c_p = 1.007 kJ/kg·K, μ=184.6 ×10^{-7} N·s/m^2, k=0.0263 W/m·K, Pr=0.707

Hot fluid properties can be assumed as follows: ρ = 1100 kg/ m^3, c_p = 2.65 kJ/kg.K, μ=0.0035 N·s/m^2, k=0.27 W/m·K, Pr=2

(a) Calculate the heat transfer coefficient for the air flow outside the tube. [5 pts]
(b) Calculate the heat transfer coefficient for the internal hot fluid flow inside the tube assuming fully developed flow. [5 pts]
(c) Calculate the mean temperature $T_{m,o}$ of hot fluid at outlet. [5 pts]
(d) Calculate the constant surface temperature T_s of the thin-walled tube. [5 pts]
(e) If the mass flow rate of hot fluid increased to 80 kg/ hour (i.e. 4 fold increase), and viscosity is decreased to 0.0007 N.s/ m^2 (i.e. 5 fold decrease) what will be the mean temperature at outlet? [5 pts]

Please answer the individual parts in the space dedicated to that part.

Start your answer to part (a) here [5 pts]:

Start your answer to part (b) here [5 pts]:

Name________________

Problem 3 continued.

Start your answer to part (c) here [5 pts]:

Start your answer to part (d) here [5 pts]:

Start your answer to part (e) here [5 pts]:

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Problem 4 [25 points]
Consider a heat exchanger with the surface area of $A = 100$ m^2, which is operating under the con ditions listed in the table below:

	Hot fluid	Cold fluid
Heat capacity rate (kW/K)	4	8
Inlet temperature (°C)	80	40
Outlet temperature (°C)	--	58

(a) Calculate the overall heat transfer rate or q in Watt. [5 pts]
(b) Determine the outlet temperature of the hot stream (T_{ho}) in °C. [7 pts]
(c) Find the type of this heat exchanger: choose one from the following multiple choices and state the reason. [4 pts]
  (i) Parallel-flow heat exchanger
  (ii) Counter-flow heat exchanger
  (iii) You cannot determine the type with given information.
(d) Determine the overall heat transfer coefficient, U, in W/m^{2}K. [7 pts]

List your assumptions here (2 points):

Start part (a) here [5 pts]:

Start part (b) here [7 pts]:

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Problem 4 – cont'd

Start part (c) here [4 pts]:

Start part (d) here [7 pts]: