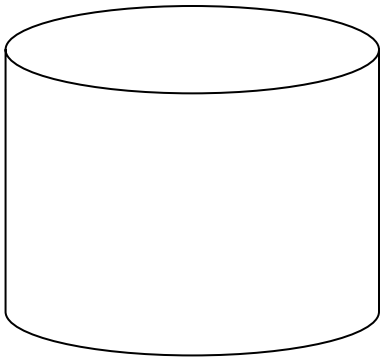
NAME

ChE 306: HEAT TRANSFER
FALL 2009 EXAM 3
(40 POINTS)
MONDAY, NOVEMBER 16, 2009

CLOSED BOOK / CLOSED NOTES / CLOSED HOMEWORK / NO CALCULATORS

1. (6 pts) For a fluid stored in an upright cylindrical tank with heated walls, **draw a sketch** to show the general shape of the thermal boundary layer in free convection.



Add & clearly label two arrows on this diagram:
Arrow 1: indicate the direction of heat transfer; Arrow 2: indicate the direction of fluid flow.

2. (8 pts) TRUE/FALSE

_____ The variable F in the equation $q = U\ A\ F\ \Delta T_{LM,CF}$ is a correction factor used in shell and tube heat exchangers to account for flow patterns that are not truly counter-flow.

_____ Surface tension, σ, is an important factor in heat transfer with phase change.

_____ For free convection problems with no phase change, the Nusselt number is a function of Reynolds number and Prandtl number.

_____ Radiation should be included in equations for heat transfer rates for film boiling.

3. (4 pts) List 2 things that may cause fouling in a heat exchanger.

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4. (6 pts) MULTIPLE CHOICE:

_____The SI units of the overall heat transfer coefficient, U, are:
(A) W/m (B) W (C) J/kg (D) W/m^2-K (E) W/m^2 (F) None of the above

_____In which equation would a fouling factor be included:
(A) an equation for heat transfer rate (q),
(B) an equation for internal energy change (ΔU),
(C) an equation for energy loss to the environment (q_{loss})
(D) an equation for fin efficiency (η)

_____ A difference in what fluid property drives fluid motion for free convection?
(A) viscosity (B) Prandtl number (C) surface tension
(D) density (E) thermal diffusivity (F) thermal conductivity

5. (4 pts) Briefly explain the difference between a DESIGN problem and a RETROFIT problem for heat exchangers.

6. (12 pts). A. Draw the temperature vs. x profile for a counter flow double pipe heat exchanger with ethylene glycol heating from 52 ^oF to 93 ^oF using saturated steam at 280 ^oF that exits the annulus as subcooled water at 190 ^oF.

B. Using variables, write the equations for internal energy change for both the ethylene glycol and steam entering the heat exchanger.

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OPEN BOOK / OPEN NOTES / OPEN HOMEWORK / CALCULATORS ALLOWED

1. (30 pts) A counterflow double pipe heat exchanger is used to heat a reactant stream (mass flow rate = 15 kg/s, heat capacity 4.5 J/kg-K) with an inlet temperature of 28 ^{o}C. Hot water flows through the annulus, entering at 95 ^{o}C, with a mass flow rate of 22 kg/s and heat capacity of 4.18 J/kg-K. The heat exchanger has a length of 5 m, and the inside pipe is made of steel, with d_i = 3.5 cm and d_o = 4.0 cm. The overall heat transfer coefficient for the heat exchanger, U_o, is 475 W/m^2-K.

What is the temperature of the reactant stream when it exits the heat exchanger?

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2. A large cylindrical tank equipped with a heater on the flat bottom surface is used to boil saturated liquid water at atmospheric pressure by keeping the bottom (circular) surface at 103 ^{o}C. The tank has a 2 m diameter and is 4 m tall. The sides of the tank are insulated.

Assuming all of the energy entering the water goes to form vapor, **what is the rate of vapor production from this tank?**

Heat of Vaporization, h_{fg}	2257 kJ/kg
Liquid Heat Capacity, c_p	4217 J/kg-K
Liquid Kinematic Viscosity, ν	2.91×10^{-7} m^2/s
Liquid Density, ρ_f	957.8 kg/m^3
Vapor Density, ρ_g	0.596 kg/m^3
Liquid Thermal Expansion Coefficient, β	7.501×10^{-4} K^{-1}
Surface Tension, σ	0.0589 N/m
Liquid Thermal Diffusivity, α	1.683×10^{-7} m^2/s
Prandtl Number, Pr	1.76
Liquid Thermal Conductivity, k_f	0.680 W/m-K
Vapor Thermal Conductivity, k_g	0.0248 W/m-K

Other fluid properties can be found in Appendix A.6