DEPARTMENT OF CHEMICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Name:——————————

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WINTER SEMESTER 2014-15

Test 2

CH2006 HEAT TRANSFER

Duration: 1 hour | Date :09.04.2015 | Maximum Marks: [20]

Instructions: "Answer *all* questions. Any missing data may be suitably assumed"

1. Answer the following in two or three lines
   a) A hot horizontal plate is exposed to air by keeping,
   (i) the hot surface facing up (ii) the hot surface facing down
   Heat transfer to the ambient air is primarily by natural convection. In which of the above cases, is the heat transfer coefficient higher and why? **[1]**
   b) Give the physical significance of Biot number. **[1]**
   c) There are two fluids, one with a larger coefficient of volume expansion and the other with a small one. In what fluid will a hot surface initiate stronger natural convection currents? Why? Assume the viscosity of the fluids to be the same. **[1]**

2. (i) Using lumped capacitance method, derive an expression for temperature of solid at any time and heat transfer up to time t, where the solid initial temperature is less than the surrounding fluid temperature. **[2.5]**
   (ii) During a picnic on a hot summer day, all the cold drinks disappeared quickly, and the only available drinks were those at the ambient temperature of 30°C. In an effort to cool a 350 mL drink in a can, which is 13 cm high and has a diameter of 6.5 cm, a person grabs the can and starts shaking it in the iced water of the chest at 0°C. The temperature of the drink can be assumed to be uniform at all times, and the heat transfer coefficient between the iced water and the aluminum can is 170 W/m^2. K. Using the properties of water for the drink, estimate how long it will take for the canned drink to cool to 4°C.
   The density and specific heat of water at room temperature are $\rho = 1000$ kg/m^3, and $C_p =$ 4.18 kJ/kg.°C **[2.5]**

3. To prevent ice formation on the wings of a small, aircraft, it is proposed that the electric heating elements to be installed within the wings. To determine the representative power requirements, consider nominal flight conditions for which the plane moves at 100m/s in air that is at a temperature of -23°C and has properties of thermal conductivity 0.022 W/m. K, Pr = 0.72, kinematic viscosity = 16.3×10^{-6} m^2/s. If the characteristic length of the air-foil is L=2m and wind tunnel measurements indicate an average friction coefficient of 0.0025 for the nominal conditions, what is the average heat flux needed to maintain a surface temperature of 5°C. **[3.5]**

4. Copper tubes 25 mm in diameter and 0.75 m long are used to boil saturated water at 1 atm. If the tubes are operated at 75% of the critical heat flux, how many tubes are needed to provide a vapour production rate of 750 kg/h? What is the corresponding tube surface temperature?
   Saturated water (100°C): $\rho_l = 957.9$ kg/m^3, $C_{p,l} = 4217$ J/kg. K, $\mu_l = 279 \times 10^{-6}$ $N.s/m^2$, $Pr_l = 1.76$, latent heat of vapourisation = 2257 kJ/kg, surface tension = 58.9×10^{-3} N/m, $\rho_v = 0.5955$ kg/m^3, $C_{s,f}=0.013$, n=1 **[3.5]**

5. You are designing a heat exchange device to cool blood (bypassed from a patient) from 40 to 30°C by passing the fluid through a coiled tube placed in vessel of water-ice mixture. The volumetric flow rate is 10^{-4} m^3/min; the tube diameter is 2.5 mm; and $T_{m,i}$ and $T_{m,o}$ represent the inlet and outlet temperatures of blood. **[0.5+0.5+1.5+1+1.5]**
   a) At what temperature would you evaluate the fluid properties in determining **h** for the entire length?
   b) If the properties of blood evaluated at the temperature for part (a) are ρ=1000 kg/m^3, ν=7x10^{-7}m^2/s, k=0.5 W/m. K, and c_p=4 kJ/kg. K, what is the Prandtl number of the blood?
   c) Neglecting all entrance effects and assuming fully developed conditions, calculate the value of **h** for heat transfer from the blood.
   d) What is the total heat rate loss from the blood as it passes through the tube?
   e) When the convection effects on the outside of the tube are included, the average overall heat transfer coefficient U between the blood and ice-water mixture can be approximated as 300 W/ m^2. K. Determine the tube length L required to obtain the outlet temperature $T_{m,o}$.

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EQUATIONS

$$q_s'' = \mu_l h_{fg}\left[\frac{g(\rho_l-\rho_v)}{\sigma}\right]^{1/2}\left(\frac{c_{p,l}\Delta T_e}{C_{s,f}h_{fg}\Pr_l^n}\right)^3$$

$$q_{\max}'' = 0.149 h_{fg}\rho_v\left[\frac{\sigma g(\rho_l-\rho_v)}{\rho_v^2}\right]^{1/4}$$

$$q_{\min}'' = 0.09 h_{fg}\rho_v\left[\frac{\sigma g(\rho_l-\rho_v)}{(\rho_l+\rho_v)^2}\right]^{1/4}$$

$$Nu = 0.62\left[\frac{g(\rho_l-\rho_v)h_{fg}D^3}{\nu_v k_v(T_S-T_{sat})}\right]^{1/4}$$