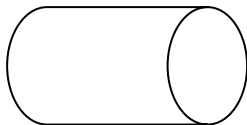


ChE 306: HEAT TRANSFER
FALL 2010: Homework #6
Ch 9 & 10: Free Convection & Boiling/Condensation
(70 points)
DUE: WEDNESDAY, OCTOBER 26

1. Work Incropera and DeWitt Problem 9.13
2. Verify the following news report as true or false (you must show numerical work to get credit):
Hypothermia research at the University of North Dakota claims that a person who falls into cold (stagnant) water at 10 °C will experience 30 times the heat loss rate as a person standing in air at 10 °C. Model the person as a nude, vertical cylinder. $T_{\text{skin}} = 34$ °C.
3. A continuous crystallization process is carried out by passing an aqueous salt solution at 90 °C through a large cylindrical horizontal tube, and collecting the product at 30 °C. There is no additional mixing in the reactor, but the fluid passes through the tube at 45 cm/s.

CRYSTALLIZING TUBE

Length = 10 m; Diameter is 1 m.
Surface temperature of walls = 15 °C.



SALT SOLUTION (assume constant)

Density = 0.989 kg/m³
Thermal conductivity = 0.657 W/m-K
Heat capacity = 4189 J/kg-K
Prandtl Number = 2.81
Kinematic Viscosity = 4.73 x 10⁻⁴ m²/s
Volumetric Thermal Expansion Coefficient = 543 x 10⁻⁶ K⁻¹
Thermal Diffusivity = 1.59 x 10⁻⁴ m²/s
Viscosity = 468 x 10⁻⁶ N-s/m²

- a. What **temperature** would be used to estimate the physical properties of the salt solution?
 - b. Using Gr_D and Re_D , determine if the heat transfer from the salt solution to the tank walls is by **free or forced convection, or both**?
 - c. Using the known change in internal energy of the fluid and log-mean temperature difference for the heat transfer equation, **estimate the average convective heat transfer coefficient, h**, for convection heat transfer with the tank walls. (Note: Nusselt number correlations are not necessary)
4. A disk-shaped horizontal heater is placed below a large tank filled with engine oil. The disk and tank both have a diameter of 400 mm, but the tank is much taller. The bulk oil temperature is 5 °C. **Estimate the power (W) required** for the heater to maintain the surface temperature at the bottom of the tank at 70 °C. (You may ignore the thermal resistance of the metal tank.) Use the characteristic length $L_c = A_s/P$ for a horizontal flat plate.
 5. Two cans of your favorite beverage are initially at room temperature (27 °C) and are placed in the refrigerator at 4 °C: one standing up, and the other laid horizontal. Which will cool to a drinkable temperature fastest?

To get an approximate answer, you may ignore the circular ends of the cans, and only calculate heat loss by free convection from the curved sides; you may also ignore any conduction from the can to the shelf (i.e., assume the cans levitate without touching a surface). The cans may be approximated as cylinders with $D = 60$ mm and $L = 150$ mm.

6. Water at its saturation point is heated in a small cylindrical copper tank that has a diameter of 15 cm. At atmospheric pressure, the bottom surface of the tank is kept at $115\text{ }^{\circ}\text{C}$.

A. How much energy must be added to the pan to boil the water? (Watts)

B. What is the rate of evaporation of water from the pan?

C. What fraction of the maximum heat flux for nucleate boiling is required for this surface temperature?

7. A small aluminum sphere at a temperature above the Leidenfrost point is dropped into saturated liquid water at 1 atm and $100\text{ }^{\circ}\text{C}$. Draw the temperature profile that you would expect to observe as the sphere cools from its initial temperature to $100\text{ }^{\circ}\text{C}$. (This is a thought problem requiring a qualitative answer, so a rough hand-drawn sketch of the temperature profile is expected, not calculations).