NAME: ________________________ STUDENT #___________

TN4780ta and AESB2320, 2014-15
Part 2 Examination - 3 July 2015

This exam can count toward the Part 2 score for either TN4780ta or AESB2320.
Circle here which course you wish the exam to count toward:

AESB2320 TN4780ta

<u>Turn in this exam with your answer sheet.</u>
Write your solutions *on your answer sheet*, not here. In all cases ***show your work***.
To avoid any possible confusion,
state the equation numbers and figure numbers of equations and figures you use.
Beware of unnecessary information in the problem statement.

1. Derive the differential equation for steady-state temperature as a function of position (T(z)) for a cooling fin where heat transfer at the surface is governed by radiation, instead of convective heat transfer as in the example worked in class. That is, heat flux to the surroundings at the surface of the fin is [C (T^4 - T_o^4)], where C and T_o are constants.
   This problem has some similarities to the solution for the cooling fin in BSL Section 9.7 (1st edition; Section 10.7 in second edition), as worked in class. All the assumptions of that problem apply, but with a different mechanism of heat transfer at the surface. I am looking for an equation corresponding to Eq. 9.7-3, but which applies to this problem.
   You do not need to solve the resulting differential equation.
   (20 points)

2. Consider a design for a heat-exchanger pipe.
   a. Water flows through a steel pipe of inner diameter 2 cm, outer diameter 3 cm. The flow rate of water is 200 cm^3/s (2 x 10^{-4} m^3/s). The heat-transfer coefficient on the outside of the pipe is 25 W/(m^2 K). What is the overall heat-transfer coefficient between the fluid and its surroundings?
   b. The heat exchanger is not efficient enough. What should be done to address this problem most directly: pump water faster through the tube, replace the pipe with one with greater thermal conductivity, or increase convection on the outside of the pipe? (Choose one.) Briefly justify your answer.
   (30 points)

<u>properties of water</u>

ρ = 1000 kg/m^3 μ = 0.001 Pa s k = 0.680 W/(m K) C_p = 4190 J/(kg K)

<u>properties of steel</u>

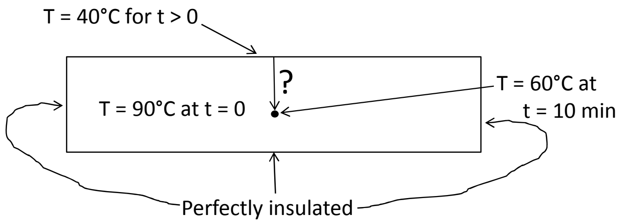
ρ = 7820 kg/m^3 k = 42.9 W/(m K) C_p = 473.3 J/(kg K)

3. A cylindrical bowl of soup is 15 cm in diameter and 5 cm thick. Initially the soup is at 90°C. Assume the radial and bottom surfaces of the soup are perfectly insulated, but evaporation maintains the top surface of the soup at 40°C. The soup is so viscous that there is no convection within the soup.
   a. Consider the central axis of the bowl (equidistant from the radial edges). After 10 minutes, how far down this axis from the top surface has the temperature fallen to 60°C?
   b. If the soup were less viscous, and we allowed for convection in the soup, would the rate of cooling of the soup be greater or less than with no convection? Briefly justify your answer.

   (20 points)

<u>properties of soup (approximate)</u>

μ = (very large) $k = 0.60$ W/(m K) $C_p = 4180$ J/(kg K) $\rho = 1008$ kg/m^3



4. A solid slab of copper has a rectangular cross-section, 20 cm x 10 cm, and is semi-infinite in the vertical (z) direction. The vertical sides of the solid are perfectly insulated. The solid is initially at 50°C. At time t=0, the bottom side at z = 0 is suddenly raised in temperature to 150°C. After 2 minutes, the temperature is raised again, to 200°C. What is the temperature at a point along the central axis of the slab, 20 cm from the surface at z = 0, 3 minutes after the second change in temperature (i.e., 5 after the first change in temperature)?

   (30 points)

<u>properties of copper</u>

$k = 386$ W/(m K) $C_p = 385.4$ J/(kg K) $\rho = 8890$ kg/m^3