tn4780ta Physical Transport Phenomena 2013-14
Part 2 Final Examination - 25 June 2014

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. A cylinder of wax (a candle) is 60 cm long and 5 cm in diameter. It is initially at a uniform temperature of 0°C. Starting at time t = 0 the cylinder is placed in air at 35°C. Assume that the candle stays at a uniform temperature at all times as it warms. How long does it take until the candle temperature reaches 25°C? Assume a heat-transfer coefficient h = 10 W/(m^2 K) and the properties of wax given below.
(15 points)

properties of wax

k = 0.25 W/(m K) ρ = 900 kg/m^3 C_p = 2500 J/(kg K)

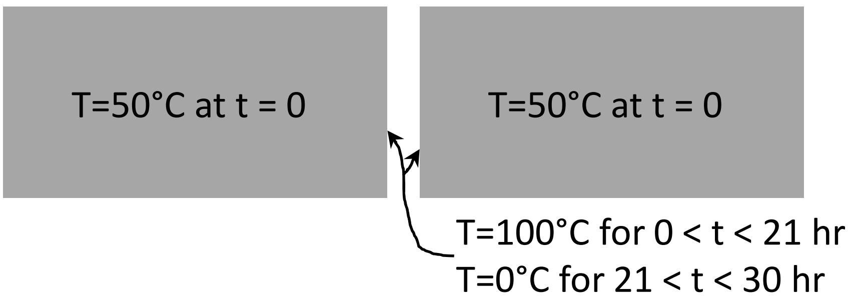
2. Now reconsider the problem in part 1, but assume that the surface is immediately heated to 35°C, and allow for nonuniform temperature in the candle. How long does it take until the center of the candle is at a temperature of 25°C?
(12 points)

3. Based on your answer to questions 1 and 2, which is the best estimate of the time it would take a candle to warm to 25°C? Briefly justify your answer. If you were unable to obtain numerical answers to questions 1 and 2, explain clearly how you would answer this question if you did have numerical answers to those questions.
(8 points)

4. A very thick layer of stone, which extends radially outward for a very large distance, has a hole, 5 cm in diameter, drilled through its center. The stone is initially at a uniform temperature of 50°C. The top and bottom surfaces of the stone are perfectly insulated. At time t = 0 the surface of the hole is heated to and maintained at 100°C. Then, after 21 hours, the surface of the hole is reduced to and maintained at 0°C. What is the temperature in the rock at a radial distance 25 cm from the center of the hole after 30 hours, i.e. 9 hours after the second change in temperature?
(20 points)

Properties of sandstone

C_p=726 J/(kg K) k = 0.831 W/(m K) ρ = 2008 kg/m^3



5. One way to heat bitumen in order to produce it or convert it to lighter hydrocarbons is to fracture the formation and pump very hot fluids through the fracture. Suppose a fracture were a slit with gap width 2 cm, and water (under pressure to keep it liquid) were pumped at a velocity of 1 m/s through the fracture. The water is at 250°C. Suppose the fracture wall is maintained at 100°C. Use the properties of water below, and treat the fracture as a rectangular slit.
   a. What would be the rate of heat transfer in W/m^2 between the water and the rock face, as long as the water is maintained at 250°C and the rock face at 100°C?
   b. Suppose the water cools off as it gives up its heat but the rock race is maintained 100°C. How far would the water flow before it had fallen in temperature to 200°C?

   (25 points)

<u>properties of water (250°C, 50 bar)</u>

μ = 0.000106 Pa s ρ = 800 kg/m^3 k = 0.62 W/(m K) C_p = 4851 J/(kg K)

6. A thin, long wire of radius R and length L is heated by an electrical current, with a release of heat at a uniform rate within the wire S (in W/m^3). The wire has density ρ, thermal conductivity k and heat capacity C_p. One end of the wire (x = 0) is maintained at temperature T_o. The other end (x = L) is perfectly insulated. At the radial surface of the wire, there is convective heat transfer with the surrounding air (which is at temperature T_a), governed by a heat-transfer coefficient h. The wire is so thin that one can neglect radial temperature variations within the wire.

   Derive a differential equation for the steady-state temperature distribution T(x) along the wire. Give two boundary conditions on T that apply to this problem.

   You do not need to solve the differential equation.

   (20 points)