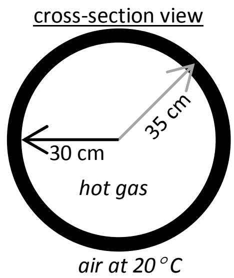
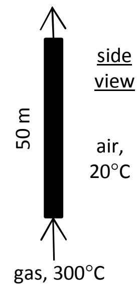
AESB2320, 2016-17
Part 2 Re-Examination - 5 July, 2017

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
along with the text you are using (BSL2 or BSLK).
Beware of unnecessary information in the problem statement.

1. A smokestack is cylindrical, 50 m tall, with inner radius 30 cm and outer radius 35 cm. Hot gas flows up inside the smokestack with velocity 2 m/s. The gas enters the smokestack at temperature 300°C. Outside the smokestack is air at temperature 20°C. The heat-transfer coefficient of air on the outer surface of the smokestack is h = 50 W/(m^{2}K).
   a. At what temperature does the gas leave the smokestack? (30 points)
   b. I'm not very confident of the value of heat-transfer coefficient on the outside of the pipe, h; the value of h=50 for the outside of the smokestack might be incorrect by a modest amount. How important is this value of h to the overall process of heat transfer between hot gas inside the smokestack and the surrounding air? Be as quantitative as you can be. If you are unable to finish part (a), explain how you *would* answer the question if you had completed part (a). (10 points)

   (40 points total)





Properties of gas inside smokestack

μ = 3 x10^{-5} Pa s   k = 0.025 W/(m K) ρ = 1.1 kg/m^3 C_p = 1006 J/(kg K)

Properties of smokestack wall

k = 0.5 W/(m K) C_p = 920 J/(kg K) ρ = 1500 kg/m^3

2. A very long steel wire of radius R starts at a uniform temperature T_o at time t = 0. The wire has properties thermal conductivity k, density ρ, and heat capacity per unit mass C_p. Starting at t = 0, electricity passes through the wire and releases energy at a uniform and constant rate S (in units W/m^3). The main means of heat transfer at the wire surface is radiation, which produces a heat flux at the surface q_r that depends on the temperature of the wire:

   $$q_r|_{r=R} = A\,(T-T_o)^4$$

   where A is a constant. Derive a differential equation for the temperature of the wire as a function of time, T(t). Assume the wire is at a uniform temperature at all times. You do not need to solve this differential equation.
   (20 points)

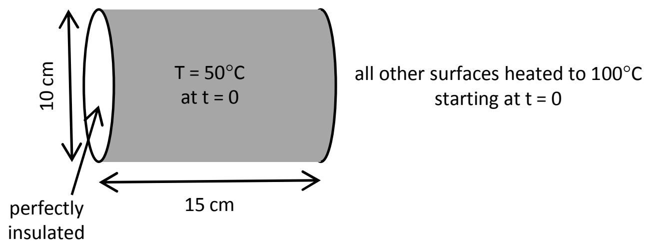
3. A solid with properties listed below extends from x = 0 to x = ∞; it is very wide (infinite) in the other two directions. The solid is at an initial temperature 100°C. Starting at time t = 0 the temperature of the surface at x = 0 is reduced to 20°C. After 1 hr, the heat flux q_r at the surface is determined to be -7000 W/(m^2 K). (The heat flux $q_r < 0$ because heat flows to the surface, out of the solid.) What is the thermal conductivity of the solid?

<u>Properties of solid material</u>

C_p = 130 J/(kg K) ρ = 11,000 kg/m^3

(15 points)

4. A solid steel cylinder is 15 cm long and 10 cm in diameter. At time t = 0 it is at a uniform temperature of 50°C. Starting at time t = 0 one flat surface and the radial surface are raised to, and maintained at, 100°C. (See diagram below.)
   a. What is the location in the solid that is slowest to heat up? Describe this location clearly, perhaps using a drawing.
   b. What is the temperature at this location after 1 minute?
   c. This question assumes that internal conduction is the important step in the heat-transfer process. An engineer does a separate calculation assuming instead that convective heat-transfer to the surface is the controlling step; he assumes that the temperature of the solid stays uniform as it warms. He estimates that after 1 minute the temperature of the solid is 90°C. Which estimate is more accurate for the overall process, your answer in part (b), or this other estimate? Briefly justify your answer. If you were unable to complete part (b), explain clearly how you *would* answer this question if you had an answer to part (b).



<u>properties of steel</u>

ρ = 7820 kg/m^3 C_p = 461 J/(kg K) k = 23 W/(m K)

(25 points)