American University of Beirut
Faculty of Engineering Architecture
Department of Mechanical Engineering

MECH 412 Heat Transfer –
Closed Book Exam – 1.5 Hour5:00 – 6:30 pm

N. Ghaddar and K. Ghali Tuesday, March 18, 2008

Answer all questions

Problem (1) (30%)

Steam at Temperature $T_{\infty 1}$=320 °C flows in a cast iron pipe (k=80 W/m·K) whose inner and outer diameters are d_1 =5 cm and d_2 =5.5 cm, respectively. The pipe is covered with 3 cm thick glass wool insulation (k = 0.05W/m·K). Heat is lost to the surroundings at temperature $T_{\infty 2}$ = 5 °C by natural convection and radiation with a combined heat transfer coefficient h_2 = 18 W/m^2·K. Taking the heat transfer coefficient inside the pipe to be h_1 = 60 W/m^2·K, determine:

a) The rate of heat loss of the steam per unit length of the steam pipe.
b) The temperature drop across the pipe shell and across insulation.

Problem 2 (35%)

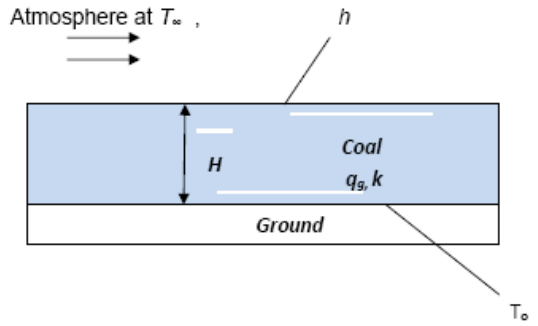
The coal powder is piled in a layer of constant thickness H = 2m. This layer is heated volumetrically at a rate of q_g = 50 W/m^3, which is due to chemical reaction. The effective thermal conductivity of the coal layer is k =0.2 W/m·K, and the heat transfer coefficient is at the upper surface is h =2 W/m^2·K. The temperature of the lower surface of the coal layer equals the ground temperature T_o = 25 °C. The atmospheric temperature is at T_∞=25 °C.

a) Show that the maximum temperature registered inside the coal layer is

$$T_{\max} = T_o + \frac{q_g H^2}{2k}\left(\frac{1+(Bi/2)}{1+Bi}\right)^2 \qquad (1)$$

Where Bi is the Biot number hH/k. Find the horizontal plane where this temperature is located from the ground.

b) Calculate the numerical values of maximum temperature and the position of the maximum hottest plane relative to the ground level.

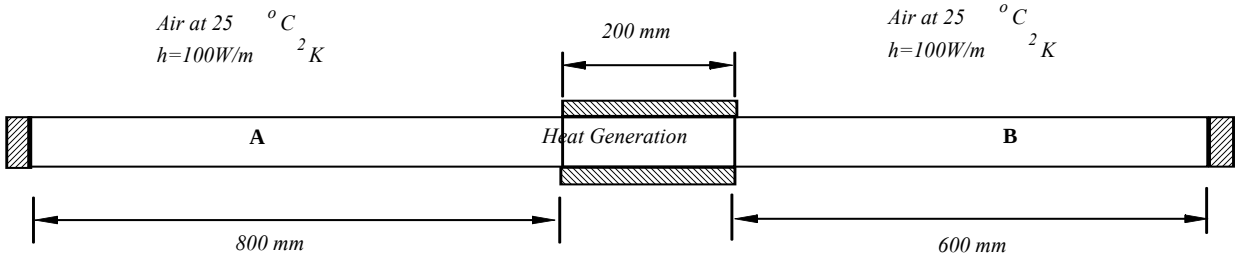


Problem 3 (35%)

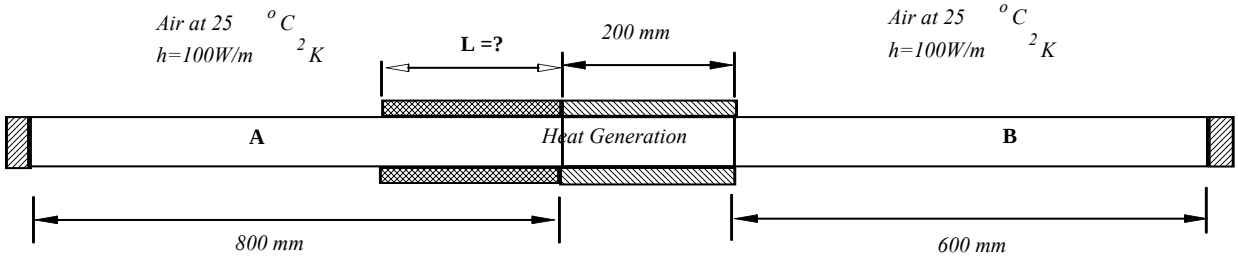
A 200-mm length piece of metal having a heat generation q_g = 4.00 x 10^3 W/m^3 and a conductivity, k, 15 W/m·k is well insulated from its top surfaces while its sides are connected to two different rods, A and B. Rod A has a length of 800 mm and a conductivity, k_A, of 25 W/m·K while rod C has a length 600 mm and conductivity, K_C, of 50 W/m °K. All rods have equal diameter of 20 mm and are subjected to air at a temperature of 25 °C and convective heat transfer coefficient, h, of 100 W/m^2 K. Assume heat loss is negligible at the tips of the rods A and B.

a) Find the temperature at the joining ends between the heat generating piece of metal and the two rods A and B.

b) It is requested to cover part of rod A by insulation thickness L. Find the thickness L so that the highest temperature of exposed part of the rod found in part (a) is reduced by 10 °C. In other words, the temperature of the rod at the end of insulation should be the temperature of the joining end of part (a) minus 10 °C.



(a)



(b)