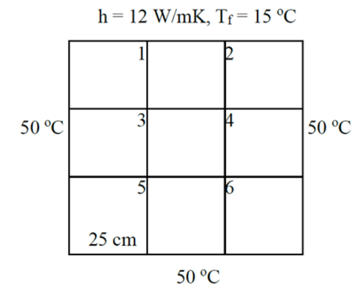
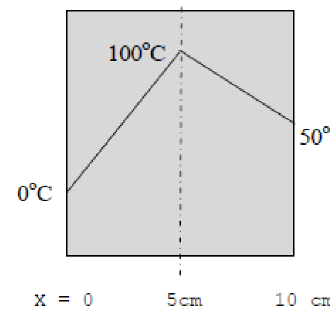
ENGR 55500/G5300 REACTOR THERMAL-HYDRAULICS

Assignment #2 (due March 18, 2024)

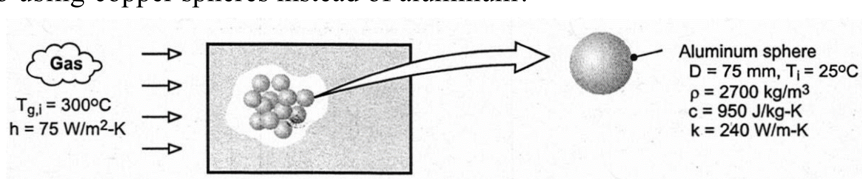


Q1. For the square solid without any heat generation shown on the right, numerically solve the steady state 2-D heat conduction equation for the temperatures $T_1 - T_4$. Thermal conductivity is k = 15 W/mK and each square mesh is 25 cm wide. The upper surface is subjected to convection to a fluid at T_f = 15 ºC with a heat transfer coefficient of h = 12 W/mK. To simplify the analysis, lateral symmetry in the temperature profile can be assumed.



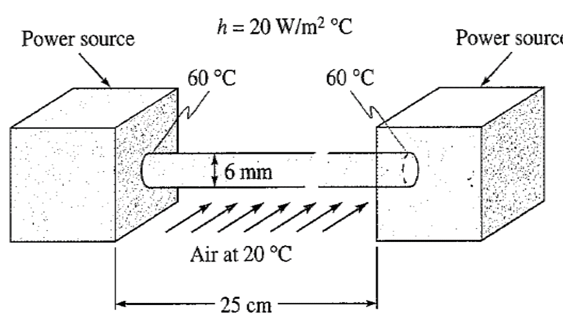
Q2. Consider a slab with an initial temperature profile as shown on the right. Calculate the unsteady temperature profiles numerically as done in class, using $\alpha\Delta t/(\Delta x)^2 = 0.1$ and 0.6. Tabulate all the temperatures up to 10 time steps and plot the temperature profiles for each case.

Q3. Thermal energy storage systems for a high temperature gas reactor would involve a packed bed of solid spheres, through which a hot gas flows if the system is being charged to store heat, or a cold gas if heat is being discharged. In a charging process, heat transfer from the hot gas increases the thermal energy stored within the colder spheres; during discharge, the stored energy decreases as heat is transferred from the warmer spheres to the cooler gas. Consider a packed bed of 75-mm-diameter aluminum spheres (ρ=2,700 kg/m^3, c_p= 950 J/kgK, k = 240 W/mK) and a charging process for which a hot gas enters the storage unit at a temperature of T_g=300°C. If the initial temperature of the spheres is T_i=25°C and the convection heat transfer coefficient is h = 75 W/m^{2}K, how long does it take the sphere near the inlet of the system to accumulate 90% of the maximum possible thermal energy? What is the corresponding temperature at the center of the sphere? Is there any advantage to using copper spheres instead of aluminum?



Q4. A 0.6 cm diameter steel rod at 38 ºC is suddenly immersed in a hot liquid at 93 ºC with a heat transfer coefficient of h = 11 W/m^{2}ºC. The length of the rod is L and it has the following thermophysical properties: k = 43 W/mºC, C_p = 473 J/kgºC, ρ = 7,801 kg/m^3 and $\alpha = k/\rho C_p = 1.172\times10^{-5}$ m^2/s. Determine the time required for the rod to warm to 88 ºC.

Q5. Two power sources contain radioisotopes that generate heat. The power sources are at 60 ºC and connected by a cylindrical metal rod with k = 60.5 W/mºC. The convective heat transfer coefficient between the rod and air that flows over it is 20 W/m^{2}ºC. The air temperature is 20 ºC. Estimate the heat transfer rate from the rod to the surrounding air if the diameter of the rod is 6 mm and the length is 25 cm.



Q6. Nitrogen gas at 30 ºC and atmospheric pressure enters a **triangular duct** 0.02 m on each side at a rate of 4.0 x 10^{-4} kg/s. If the duct wall temperature is uniform at 200 ºC, estimate the bulk temperature of the nitrogen at 2 m and 5 m downstream of the inlet.