City College of New York

ENGR 55500/G5300 REACTOR THERMAL-HYDRAULICS

Assignment #1 (due February 26, 2024)

1. To build a containment wall for a nuclear reactor, concrete has been poured to form a 1.2m thick slab. The hydration of the concrete results in the equivalent of a constant heat source of q_o'''= 100 W/m^3. If both surfaces of the concrete slab are kept at 16 °C, determine the maximum temperature, T_{max}, that would be reached, assuming a steady state condition. The thermal conductivity of the wet concrete may be taken as 0.84 W/mK.

2. A nuclear fuel element of thickness, 2L, is covered with a steel cladding of thickness b. Heat generated within the nuclear fuel at a rate q_o'''(W/m^3) is removed by a coolant at T_∞, which flows past the surface at x = L+b and is characterized by a heat transfer coefficient h. The other surface at x = -L-b is well insulated, and the fuel and steel have thermal conductivities of k_f and k_s, respectively.
   a) Obtain an expression for the temperature distribution T(x) in the nuclear fuel. Express your answer in terms of q_o''', k_f, L, b, k_s, h and T_∞.
   b) Sketch the temperature distribution T(x) for the entire system from x = -L-b to x = L+b. At what x does the maximum temperature occur?

3. Consider steady, one-dimensional heat conduction in a solid wall of thickness 15 cm without any internal heat generation. The thermal conductivity is not constant and varies with temperature as k = 2.0 +0.005T (W/mK), where T is in degrees Kelvin. If one surface of this wall is maintained at 150 °C and the other at 50 °C, determine the rate of heat conduction per square meter (W/m^2). Sketch the temperature distribution through the wall. Is it linear or non-linear?

4. Consider a shielding wall of thickness L for a nuclear reactor. The wall receives gamma-rays such that heat is generated within the wall according to the relation,
$$q''' = q_o''' e^{-\mu x}$$
where q_o''' is incident radiation flux (constant), μ is a gamma attenuation coefficient, and x is the distance from the inner surface. Using this relation, derive expressions for the temperature distribution in the wall,
(a) if both the inner and outer temperatures are maintained at T_1 at x = 0 and x = L,
(b) if the inner and outer temperatures are maintained at T_i at x = 0 and at T_o at x = L, respectively.
(c) For the temperature distribution obtained in (b), at what distance from the inner surface would the temperature be at a maximum?

5. Consider a nuclear fuel shaped as a long slab of thickness, 7.5 cm, and with k = 12 W/m°C. The fuel generates heat internally at a rate of 10^5 W/m^3. One side of the wall at x = 0 is insulated and the other side at x = 7.5 cm is exposed to a convection environment with a heat transfer coefficient of h = 500 W/m^2°C and a fluid temperature of 90 °C. Determine the temperature profile in the slab and calculate the maximum temperature in °C assuming steady one-dimensional heat conduction.

6. 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 = 1.5 W/mK and each square mesh is 2 cm wide. The four surfaces are kept at constant temperatures as shown.