Name: ______________________________ A#: ______________________________

MAE 3440: HW #3

Due January 23, 2019

1. Two stainless steel plates 10 mm thick are subjected to a contact pressure of 1 atm under vacuum conditions for which there is an overall temperature drop of 100°C across the plates. What is the heat flux through the plates? What is the temperature drop across the contact plane? Hint: Use the contact conductance value in Table 2.1.

2. A stainless steel (AISI 304) tube used to transport a chilled pharmaceutical has an inner diameter of 36 mm and a wall thickness of 2 mm. The pharmaceutical and ambient air are at temperatures of 6°C and 23°C, respectively, while the corresponding inner and outer convection coefficients are 400 W/m^2-K and 6 W/m^2-K, respectively.

   (a) What is the heat gain per unit length [W/m]?

   (b) What is the heat gain per unit length if a 10 mm thick layer of calcium silicate insulation (k_{ins} = 0.05 W/m-K) is applied to the outside of the tube?

Name: ______________________________ A#: ______________________________

3. Steam at a temperature of 250°C flows through a steel pipe (AISI 1010) of 60 mm inner diameter and 75 mm outer diameter. The convection coefficient between the steam and the inner surface of the pipe is 500 W/m^2-K, while that between the outer surface of the pipe and the surroundings is 25 W/m^2-K. The pipe emissivity is 0.8, and the temperature of the air and surroundings is 20°C. What is the heat loss per unit length of pipe?

Name: ______________________________ A#: ______________________________

4. A spherical shell of inner and outer radii of r_i and r_o, respectively, is filled with a heat-generating material that provides for a uniform volumetric generation rate ($\mathrm{W/m^3}$) of $\dot{q}$. The outer surface of the shell is exposed to a fluid having a temperature T_∞ and a convection coefficient h. Obtain an expression for the steady-state temperature distribution $T(r)$ in the shell, expressing you results in terms of r_i, r_o, $\dot{q}$, h, T_∞, and the thermal conductivity k of the shell material.

Name: ______________________________ A#: ______________________________

5. The exposed surface ($x = 0$) of a plane wall of thermal conductivity k is subjected to microwave radiation that causes volumetric heating to vary as

$$\dot{q}(x) = \dot{q}_o \left(1 - \frac{x}{L}\right) \tag{1}$$

where $\dot{q}_o$ (W/m^3) is a constant. The boundary at $x = L$ is perfectly insulated, while the exposed surface is maintained at a constant temperature T_o. Determine the temperature distribution $T(x)$ in terms of x, L, k, $\dot{q}_o$, and T_o.

Name: ____________________ A#: ____________________

6. A long cylindrical rod of diameter 200 mm with thermal conductivity of 0.5 W/m-K experiences uniform volumetric heat generation of 24,000 W/m^3. The rod is encapsulated by a circular sleeve having an outer diameter of 400 mm and a thermal conductivity of 4 W/m-K. The outer surface of the sleeve is exposed to a cross flow of air at 27°C with a convection coefficient of 25 W/m^2-K.

   (a) Find the temperature at the interface between the rod and sleeve and on the outer surface.

   (b) What is the temperature at the center of the rod?

Name: ______________________________ A#: ______________________________

7. Radioactive waste ($k_{rw} = 20$ W/m-K) is stored in a spherical, stainless steel ($k_{ss} = 15$ W/m-K) container of inner and outer radii of $r_i = 0.5$ m and $r_o = 0.6$ m, respectively. Heat is generated volumetrically within the waste at a uniform rate of $\dot{q} = 10^5$ W/m^3, and the outer surface of the container is exposed to a water flow for which $h = 1000$ W/m^2-K and $T_\infty = 25$°C.

   (a) Evaluate the steady-state outer surface temperature of the container, $T_{s,o}$.

   (b) Evaluate the steady-state inner surface temperature of the container, $T_{s,i}$.

   (c) Obtain an expression for the temperature distribution, $T(r)$ in the radioactive waste. Evaluate the temperature at $r = 0$.