1. Explain the following terms in detail: (10 pts)
   (a) boundary layer (b) contact thermal resistance (c) azeotropic distillation (d) Leva equation (e) thermal diffusivity

2. Air is flowing upward through a 1000-ft-long vertical heated tube. The air enters at 80 °F and at a velocity of 20 ft/s. It leaves the tube at 230 °F and 50 ft/s. The average specific heat of air is 0.24 Btu/(lb °F). How many Btus per pound of air are transferred through the walls of the tube? (9 pts)

3. A Newtonian fluid is confined between two broad parallel vertical plates, separated by a distance L. The plate on the left is stationary; that on the right is moving vertically upward at a constant velocity v₀. Assume that the flow is laminar.
   (a) List the two boundary conditions in solving the above system. (2 pts)
   (b) Draw a figure to show your system and find the equation for the steady-state velocity profile in the fluid. (10 pts)

4. A tank contains 800 gal of water in which 200 lb salt is dissolved. Two gallons of fresh water runs in per minute, and 2 gal of the mixture in the tank, kept uniform by stirring, runs out of per minute.
   (a) Find the amount of salt in the tank at any time t. (10 pts)
   (b) How much salt is left in the tank after 5 hours? (2 pts)

5. (a) What is the Wien's displacement law? (2 pts)
   (b) By the use of Planck distribution to prove the Wien's displacement law. (10 pts)

(Hint): The Planck distribution equation \( C_1 = 3.742 \times 10^4 W \cdot \mu m^4 / m^2; C_2 = 1.439 \times 10^4 \mu m \cdot K \)

\[
E_{\lambda\phi} = \frac{C_1}{\lambda^5 \left( \exp \left( \frac{C_2}{\lambda T} \right) - 1 \right)}
\]

6. Starting with the steady-state heat diffusion equation in cylindrical coordinates

\[
\frac{1}{r} \frac{\partial}{\partial r} \left( kr \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + q = 0
\]

A solid cylinder (radius = \( r_0 \), length = \( L \)) with uniform internal energy generation is considered long enough so that only radial conduction occurs. Determine the temperature distribution and the energy flux based on the following two boundary conditions: (i) the temperature gradient is zero at the central line. (ii) the temperature at the surface is \( T_s \). (12 pts)

7. A furnace wall is constructed from 0.30-m-thick brick \( k = 3.40 W/m K \). The inner and outer surface temperatures are 1200 and 1000 K, respectively. What is the heat flux loss through a wall that is 2.0 m² in area? (5 pts)

8. (a) What are the definitions of the following dimensionless groups: Reynolds number, Schmidt number, and Sherwood number? (6 pts)
   (b) By the use of the dimensional analysis theory to show that \( \text{Sherwood number} = f(\text{Reynolds number, Schmidt number}) \) in natural convective mass transfer. (12 pts)

9. A continuous fractionating distillation column is used to separate 37.8 kg/s of 40 mass % benzene\( C_6H_6 \) and 60 mass % toluene\( C_9H_8CH_3 \) into an overhead product containing 97 mass % benzene and a bottom product containing 98 mass % toluene. Find the amounts of feed, top and bottom products in kg moles/s. (10 pts)