1. Answer the following questions:

   (a) Show and explain the relative positions of the operation lines and the system equilibrium curve for an absorber and a stripper.　(5%)

   (b) What are the differences in the operating principles between the rectification and gas absorption?　(5%)

   (c) Define thermal diffusivity for a conductive medium and state the importance of this physical quantity. Also, point out which one in the following materials has the highest thermal diffusivity at room temperature: iron oxide, stainless steel, and PTFE.　(5%)

   (d) What are the characteristics of heat transfer?　(5%)

   (e) Define Reynolds number (Re), Nusselt number (Nu) and Sherwood number (Sh).　(5%)

2. A mixture of ammonia and air is scrubbed in a plate column with fresh water.　The rates of water and air are 0.04 and 0.02 kmol/(m^2·s), respectively.　If the ammonia concentration is reduced from 5 mol% to 0.1 mol%, how many theoretical plates are required?　The equilibrium relation between the gas phase and liquid phase is $Y = X$, where Y is the molar ratio between NH_3 and air in the gas phase and X is the molar ratio between NH_3 and water in the liquid phase.　(25%)

3. A double-pipe counter-flow heat exchanger is designed to cool oil from 433 K to 413 K using water, which is supplied to the inner tube at 293 K and discharged at 353 K. The thin-walled inner tube has a diameter of 0.02 m, and the overall heat transfer coefficient is 450 W/(m^2·K). The design condition calls for a total heat transfer rate of 3500 W.

   (a) What is the effectiveness (ε) and number of transfer unit (*NTU*) of this heat exchanger?　(16%)

   (b) What is the length of the heat exchanger?　(9%)

4. A horizontal tube with 0.24 in. in diameter and 50 ft in length is used to transport an oil. The oil has a kinematic viscosity of 0.08×10^{-3} ft^2/s, a density of 57 lb$_m$/ft^3 and a rate of 1.5 ft^3/h.

   (a) Is the flow inside the tube laminar or turbulent?　(5%)

   (b) Calculate the corresponding Fanning friction factor.　(10%)

   (c) Determine the total pressure drop in the tube.　(10%)