1. (25 points)
A counter-current heat exchanger is used to cool the hot oil from 400K to 350K. The hot oil has a specific heat of 2.3 kJ/kg K at a flow rate of 3600 kg/hr. A cooling water with a specific heat of 4.2 kJ/kg K enters at a flow rate of 1400 kg/hr and 278K. The overall heat transfer coefficient U of the heat exchanger is 360 $W/m^2 K$. Please determine (a) the exit temperature of the cooling water; (b) LMTD (logarithmic mean temperature difference); (c) the required heat-transfer area; (d) re-calculate the required heat-transfer area if the heat exchanger is a co-current type. **[(a)～(c): 5points each , (d): 10 points]**

2. (25 points)
We consider the steady-state, laminar flow of an incompressible fluid of constant density ρ and viscosity μ in a horizontal tube of radius R. The liquid flows under the influence of a constant pressure difference, $\partial p/\partial x$. Neglect the entrance and exit effects. Please write down the main equation and boundary conditions to develop the velocity profile and the maximum velocity.

3. (20 Points)
Steam is condensed on the outer surface of a **thin-wall** circular tube of 5-cm diameter and 5-m length. The outer surface of the tube is maintained at a uniform temperature of 100 °C. Water (with c_p = 4000 J/kg·K) flows through the tube at a rate of 0.2 kg/s, and its inlet and outlet temperatures are 15 °C and 55 °C.

(a) Obtain **the expression** relating the total heat transfer rate, Q, to the average convection heat-transfer coefficient associated with the water flow, $\bar{h}$. **(5 pts.)**

(b) Calculate the values of Q and $\bar{h}$. **(10 pts)**

(c) What exit water temperature will result if the water flow rate is decreased to 0.1 kg/s? **(5 pts.)**

4. (15 points)
The Froessling equation is a convective mass transfer correlation. Three dimensionless groups: Sherwood number (N_{Sh}), Reynolds number (N_{Re}), and Schmidt number (N_{Sc}) are related by

$$N_{Sh} = 2.0 + 0.552\, N_{Re}^{1/2}\, N_{Sc}^{3/1}$$

(a) For what kind of mass transfer system you can this equation for correlating the data? **(4 pts.)**
(b) Define the Sherwood number (also called the **mass transfer Nusselt number)** and Schmidt number. **(4 pts.)**
(c) What is the meaning of "2.0" in this equation? **(4 pts.)**
(d) Explain how the flow velocity can influence the mass transfer rate. **(3 pts.)**

5. (15 points)
For each of the following 5 separation terms, select **a proper definition** from the pool of definitions (a) to (f) and **a proper equilibrium involved** in that separation from the pool of equilibrium from (K) to (O). (不要抄題，依序挑出答案的英文代號即可) [3 points each]

(1) Distillation
(2) Absorption
(3) Adsorption
(4) Leaching
(5) Liquid extraction

Definitions:
(a) Soluble material is dissolved from its mixture with an inert solid by means of a liquid solvent.
(b) A solute is removed from either a liquid or gas through contact with a solid adsorbent, the surface of which has a special affinity for the solute.
(c) A soluble vapor is removed from its mixture with an inert gas by means of a liquid.
(d) A mixture of liquid is treated by a solvent that preferentially dissolves one or more of the components in the mixture.
(e) A liquid, usually water, is separated by the use of hot gas.
(f) To separate, by vaporization, a liquid mixture of miscible and volatile substances into individual components or, in some cases, into groups of component

Equilibrium:
(K) Gas-liquid equilibrium
(L) Liquid-liquid equilibrium
(M) Gas-gas equilibrium
(N) Liquid-solid equilibrium
(O) Equilibrium between fluid (liquid or gas) and solid (or liquid on the solid)