1. Explain the following terms in detail: (18 pts)
   (a) Bernoulli equation
   (b) adsorption
   (c) Hagen-Poiseuille equation
   (d) thermal diffusivity
   (e) flash distillation
   (f) Murphree efficiency

2. In the steady, incompressible flow through a horizontal sudden enlargement, \( A_1 < A_2 \). The process variables are \( u \) (internal energy), \( v \) (velocity), \( \rho \) (fluid density), \( P \) (pressure), and \( A \) (cross-sectional area). Use conservation of mass, momentum, and energy to show that the change in internal energy between section 1 and section 2 is (neglect shear stresses at walls) \( (10 \) pts) \[
\frac{u_2 - u_1}{u_2} = \frac{1}{2} \left( 1 - \frac{A_1}{A_2} \right) \]

3. The water at the rate of 68.0 kg/min, having a mean specific heat of 4.2 kJ/(kg K), is heated from 308 to 348K. The fluids are used in a parallel double-pipe heat exchanger. The oil, having a mean specific heat of 1.9 kJ/(kg K), enters the heat exchanger at 383K and leaves at 353K. The overall heat transfer coefficient is 320 W/m²K. Calculate the heat-exchanger area. \( (10 \) pts)

4. Water (\( \mu = 1.005 \text{cP}, \rho = 998 \text{kg/m}^3 \)) passes through a packed column with 50 \( \mu \text{m}-\text{diameter} \) spheres (porosity = 0.4). The packed column is 5mm in diameter and 2.0 m in length. The superficial velocity is 3.0 m/hour. Predict the pressure drop in Pa. \( (10 \) pts) \[
\frac{(-Ap)}{L} = \frac{\varepsilon D_p}{1 - \varepsilon} \rho \frac{\varepsilon}{\nu} = \frac{150}{Re_{j(1-\varepsilon)}} + 1.75
\]

5. A given gas \( A \) can diffuse through the solid wall of a tube in which it flows. Find the rate of gas diffusion in terms of the tube dimensions (inside wall radius \( R_0 \), outside radius \( R_w \), tube length \( L \)), the gas-solid diffusivity, and the gas concentrations at the walls. \( (10 \) pts) \[
\frac{\partial N_A}{\partial t} + \frac{1}{r} \frac{\partial (rN_A)}{\partial r} + \frac{1}{r} \frac{\partial N_A}{\partial r} + \frac{\partial N_A}{\partial z} = R_d
\]

6. (a) What are the definitions of the following dimensionless groups: Reynolds number, Prandtl number, Biot number, and Grashof number. \( (8 \) pts)

   (b) By the use of the dimensional analysis theory to show that \( Nu = f(Re, Gr) \) in natural convective heat transfer. \( (9 \) pts)
7. Consider a 0.8-m-high and 1.5-m-wide double-pane window consisting of two 4-mm-thick layers of glass \( k = 0.78 \text{ W/m K} \) separated by a 10-mm-wide stagnant air space \( k = 0.026 \text{ W/m K} \). Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be \( h_i = 10 \text{ W/m}^2\text{K} \) and \( h_o = 40 \text{ W/m}^2\text{K} \). If the room is maintained at 293K while the temperature of the outdoors is 263K, determine the steady rate of heat transfer through this double-pane window and the temperature of its inner surface. (10 pts)

8. The flow of a liquid down an inclined flat plate of length \( L \) and width \( W \), as shown in Figure. For small flow rates we expect that the velocity profile \( v_z \) will become independent of \( z \). (15 pts)
   (a) What is the velocity distribution, \( v_z(x) \) ?
   (b) Show that the mass flow rate is \( (\rho g W \delta^2 \cos \beta) / \mu \).
   (c) An oil has a kinematic viscosity of \( 2 \times 10^{-4} \text{ m}^2/\text{s} \) and a density of 800 kg/m³. If the falling film thickness is 1.5 mm on a vertical wall, What is the value of Reynolds number?