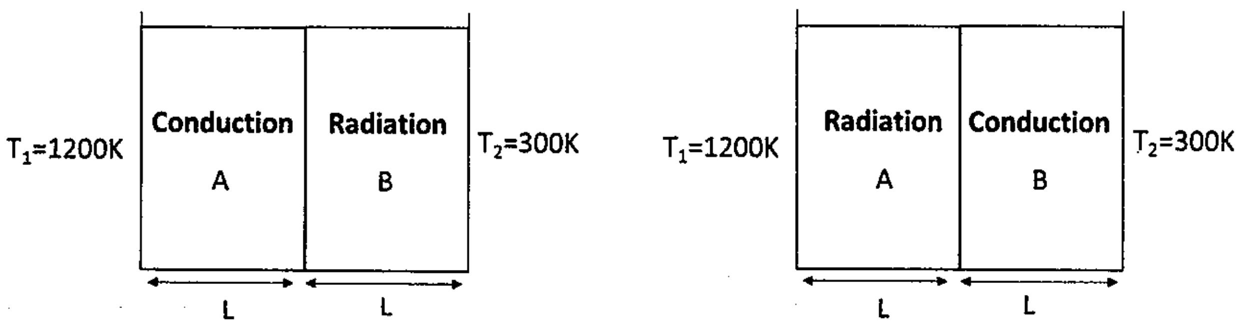
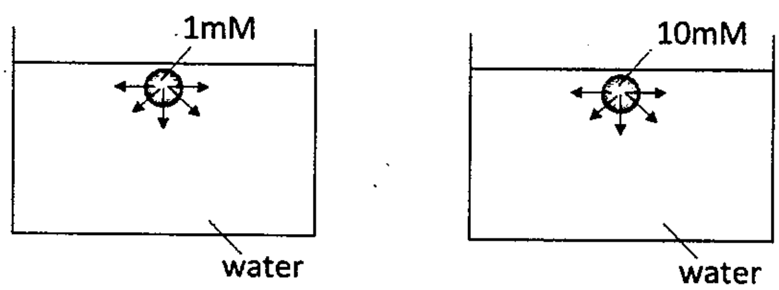
1. From the following descriptions, provide the name of dimensionless numbers. (15%)
   (a) Ratio of the internal thermal resistance of a solid to the boundary layer thermal resistance.
   (b) Ratio of inertial forces to viscous forces within a fluid.
   (c) Ratio of the heat conduction rate to the rate of thermal energy storage in a solid.
   (d) Ratio of the momentum and mass diffusivities.
   (e) Ratio of the momentum and thermal diffusivities.

2. Consider a heat transfer process consisting of one conduction and one radiation in series, as shown in the Figure below. The temperature on the left surface T_1 and right surface T_2 are 1200K and 300K, respectively. The dimensions of region A and B are identical. Toward higher rate of heat transfer at steady state, should the region A or B be the radiation process? Why? (5%)

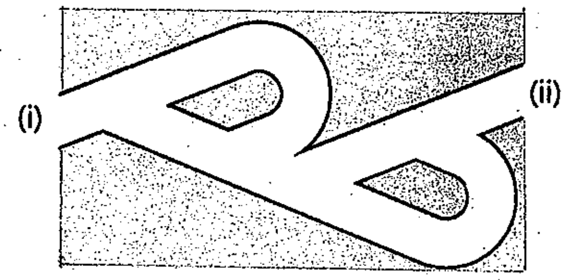


3. The thermal conductivity of metals is often higher than that of alloys. Provide the reason in terms of the conduction mechanism (5%)

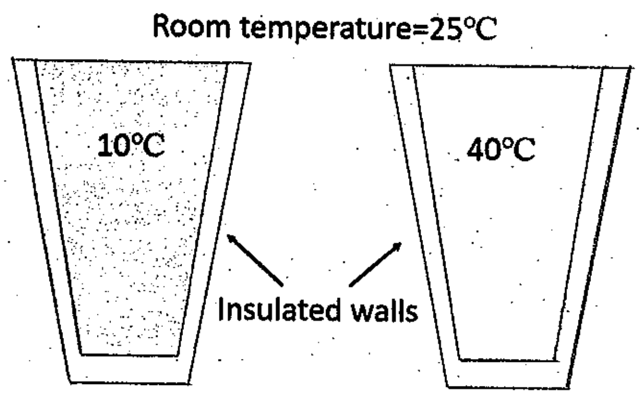
4. A drop of dye is injected into a cup of water, which leads to the diffusion of dye in water. Consider two experiments: the concentration of the dye drop is (a) 1mM and (b) 10mM. For simplicity, the diffusivities are the same in both experiments. In which case, the dye concentration is faster to become uniform in the water? Why? (5%)



5. The following is the geometry of a "Tesla valve" that works like a check valve but has no moving parts. The white places are the channel where fluid can flow.
   (a) Draw the flow pattern for the case that fluid enters from (i). Use arrows to represent the flow direction. (3%)
   (b) Draw the flow pattern for the case that fluid enters from (ii). (3%)
   (c) Give the reason why the Tesla valve can be used as a check valve. (3%)



6. The figure on the right illustrates two identical cups holding water of 10°C and 40°C, respectively. The cups have perfectly insulated walls but have no caps. The room temperature is 25°C. For which case will the water temperature reach the room temperature earlier? Why? (5%)

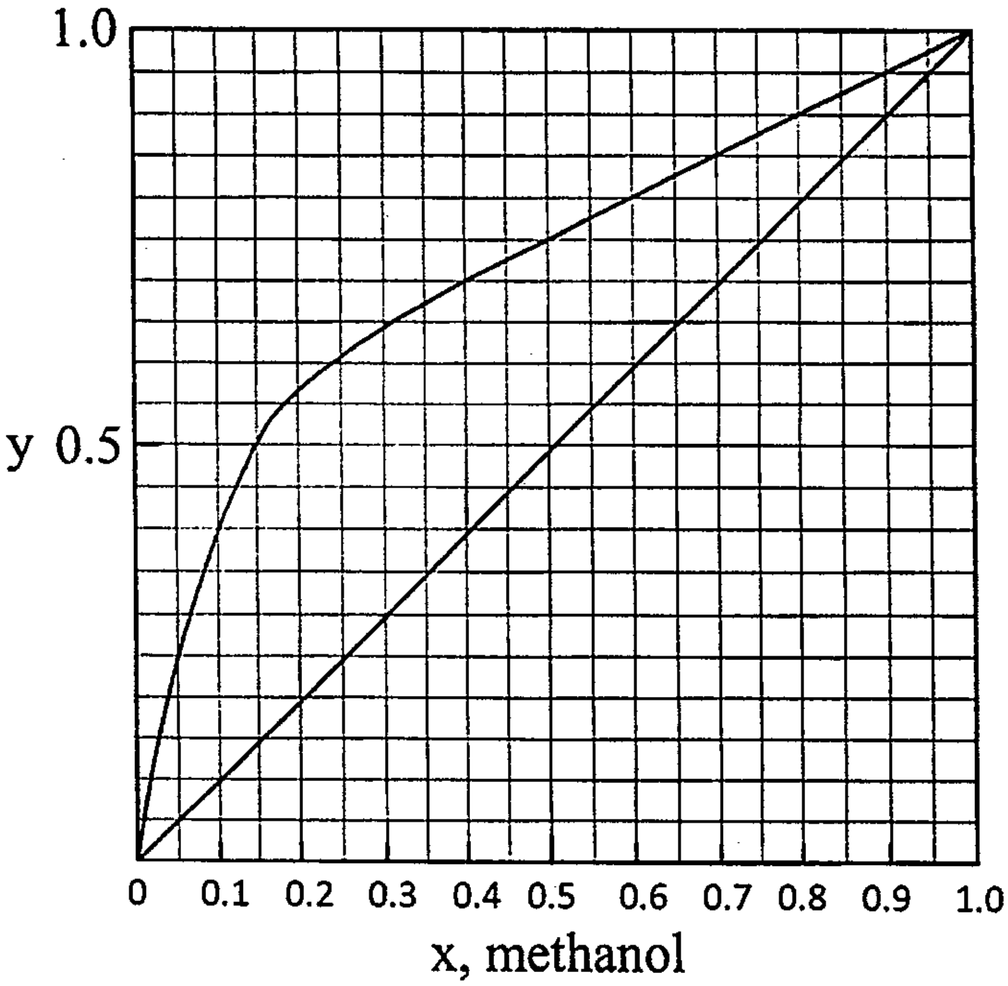


7. A stainless-steel sphere of 1 mm in radius is originally at 95°C, and it is suddenly placed at 30°C in a gas flow. The heat capacity, thermal conductivity, and density of the sphere are 500 J/(kg-K), 15 W/(m^2-K), and 7500 kg/m^3, respectively. If the average heat transfer coefficient is 200 W/(m^2-K), estimate the temperature for the sphere after 1 second. (10%)

8. An oxygen bubble originally of 1 mm in radius is injected into excess stirred water. After 10 minutes, the bubble size is observed to be 0.5 mm in radius. The saturation concentration of oxygen in water is 40 mg/L at 27°C and the experiment is carried out under 1 atm. For simplicity, we only consider the mass transfer effects and ignore other effects such as buoyancy and surface tension.
   (a) What is the mass balance relation for the change of bubble size? (4%)
   (b) From the change of bubble size with time, estimate the mass transfer coefficient. (6%)

接次頁

9. A methanol-water mixture containing 30 mol% of methanol is to be distilled at 1 atm. A column with a total condenser and a reboiler is used. The top product contains 95 mol% methanol and the bottom product contains only 5% methanol. The feed is a saturated liquid (at its boiling point). Using the McCabe-Thiele method to answer the following questions:
   (a) Determine the minimum reflux ratio R_m. (3%)
   (b) If the reflux ratio is 2, determine the optimum feed plate (3%), the number of theoretical stages needed (3%) and the composition at the fifth plate (x_5, y_5). (3%)
   (c) At the same situation of case (b), if the feed rate is 1000 mole/hr, evaluate the liquid molar flux L_m and vapor molar flux V_m in the stripping section. (5%)



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10. We consider a flow between two concentric spherical shells. The space between two shells is filled with a Newtonian and incompressible fluid at constant temperature. The radii of the inner and outer wetted surfaces are κR and and R, respectively. The outer shell is fixed and the inner shell rotates at an angular velocity Ω in ϕ direction. The flow can be assumed to be a creeping flow. We also postulate that $v_r=v_\theta=0$, $v_\phi=v_\phi(r,\theta)$ and $p=p(r,\theta)$.

(a) Simplify the ϕ-component of the Navier-Stokes equations. (5%)

(b) List the boundary conditions necessary for solving the velocity field. (4%)

(c) Since the equation in (a) is a PDE, a student tries to solve the problem by first making a guess of the form of the velocity profile. He guesses $v_\phi=rf(\theta)$. Here $f(\theta)$ is a function of θ to be determined. Please explain whether his guess is reasonable or not. (5%)

(d) Assuming the velocity profile v_ϕ has been solved. List the formula to obtain the torque needed to hold the outer shell stationary. (5%)

Spherical coordinates (r, θ, ϕ):

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_r}{\partial \phi} - \frac{v_\theta^2+v_\phi^2}{r}\right) = -\frac{\partial p}{\partial r} + \mu\left[\frac{1}{r^2}\frac{\partial^2}{\partial r^2}(r^2 v_r) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial v_r}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_r}{\partial\phi^2}\right] + \rho g_r$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_\theta}{\partial \phi} + \frac{v_r v_\theta - v_\phi^2\cot\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} + \mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial v_\theta}{\partial r}\right) + \frac{1}{r^2}\frac{\partial}{\partial\theta}\left(\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}(v_\theta\sin\theta)\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_\theta}{\partial\phi^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial\theta} - \frac{2\cot\theta}{r^2\sin\theta}\frac{\partial v_\phi}{\partial\phi}\right] + \rho g_\theta$$

$$\rho\left(\frac{\partial v_\phi}{\partial t} + v_r\frac{\partial v_\phi}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\phi}{\partial \theta} + \frac{v_\phi}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi} + \frac{v_\phi v_r + v_\theta v_\phi\cot\theta}{r}\right) = -\frac{1}{r\sin\theta}\frac{\partial p}{\partial \phi} + \mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial v_\phi}{\partial r}\right) + \frac{1}{r^2}\frac{\partial}{\partial\theta}\left(\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}(v_\phi\sin\theta)\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_\phi}{\partial\phi^2} + \frac{2}{r^2\sin\theta}\frac{\partial v_r}{\partial\phi} + \frac{2\cot\theta}{r^2\sin\theta}\frac{\partial v_\theta}{\partial\phi}\right] + \rho g_\phi$$

試題隨卷繳回