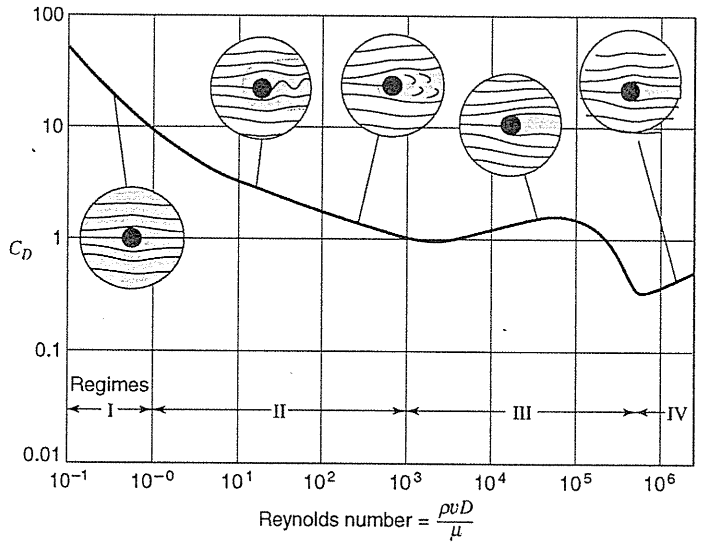
※ 考生請注意：本試題可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. The drag coefficient (C_D) for circular cylinders moving through a viscous fluid as a function of Reynolds number (Re) is shown below. Please answer the following questions.

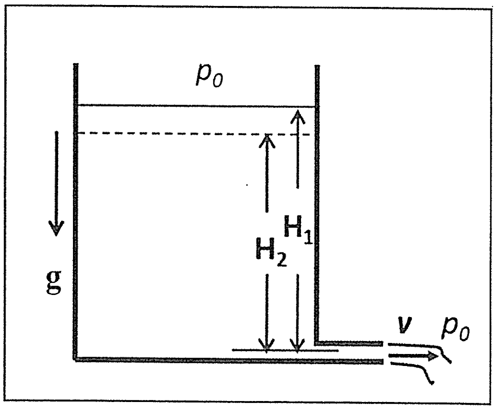


(a) Write down the physical meaning of Reynolds number. (4%)

(b) Please specify the predominating forces in regime I and IV, respectively. (6%)

(c) Please explain why the drag coefficient is inversely proportional to Reynolds number. (4%)

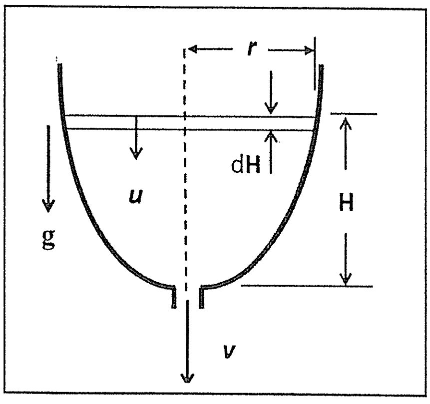
2. Water is discharged from a small hole on the side of a cylindrical tank with fixed radius as shown on the right. The surface area of the tank is much larger than that of the hole. Assume that the fluid flow is in the laminar regime, the energy loss due to friction is neglected, and no work was done on or by the system.



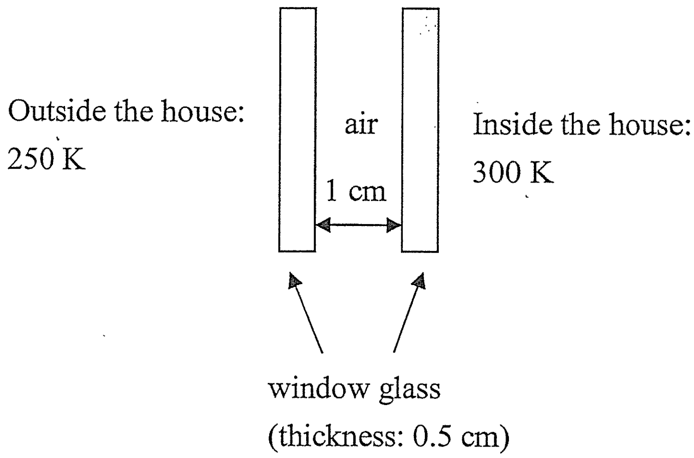
(a) Please determine the fluid velocity (***v***). (5%)

(b) Please determine the time for the water surface level descending from $\mathbf{H_1}$ to $\mathbf{H_2}$. (5%)

(c) An engineer wants to design a tank with varied radius (***r***) that can render the water discharging from a small hole on the bottom of a tank with constant descending velocity (***u***) of the water surface level as shown on the right. The information regarding the geometry of the tank is required. The fluid velocity (***v***) is calculated to be $Ca\sqrt{2gH}$, where C is a constant and a is the surface area of the hole. Please help the engineer to determine the geometry by deriving the height of the water in the tank (**H**) in terms of ***g***, ***u***, and ***r***. (6%)

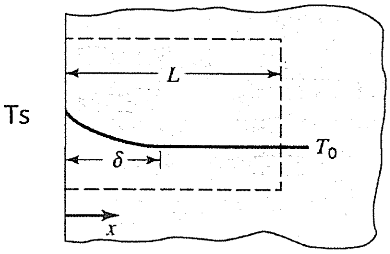


3. The following shows the cross section of a storm window. Determine the heat loss through the window measuring 2 m by 4 m. The convective coefficients on the inside and outside surfaces of the window are 25 and 20 $W/m^2 \bullet K$, respectively. The conductivity of glass and air are 0.78 and 0.026 $W/m \bullet K$, respectively. (7%)



4. For a one-dimensional, semi-infinite wall with initially uniform temperature To, the surface is maintained at temperature Ts for t > 0. If the temperature is assumed to be parabolic, i.e. $T=A+Bx+Cx^2$ within the penetration depth, δ
   (a) Write down the 3 boundary conditions. (3%)
   (b) Find T(x). (2%)
   (c) Show that the heat flux at the wall (q_x/A) is as follows: (8%)

$$\frac{q_x}{A} = \frac{d}{dt}\int_0^{\delta} \rho C_p T dx - \rho C_p T_0 \frac{d\delta}{dt}$$



   where ρ: density of the wall, *Cp*: specific heat of the wall

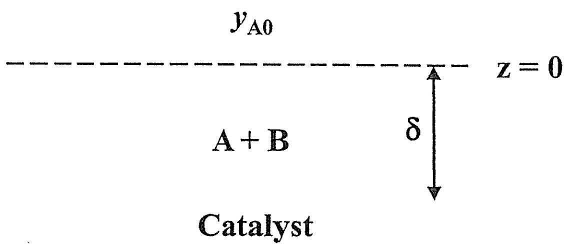
   (d) Determine the penetration depth, δ(t). (5%)
   k: conductivity of the wall, α: thermal diffusivity

5. Component A diffuses through a stagnant film containing only A and B. Upon reaching the catalytic surface, it is instantaneously converted into species B by the reaction A → B. When B diffuses back into the stagnant film, it begins to decompose by the first-order reaction B → A. The rate of formation of component A with the film is equal to $R_A = k_1 y_B$, moles A produced/(time)(volume), where y_B is the concentration of B expressed in mole fraction.
   (a) Find the concentration profile of component B in the stagnant film if this is a steady-state process. (8%)
   (b) Determine the rate at which A enters the gas film. (4%)

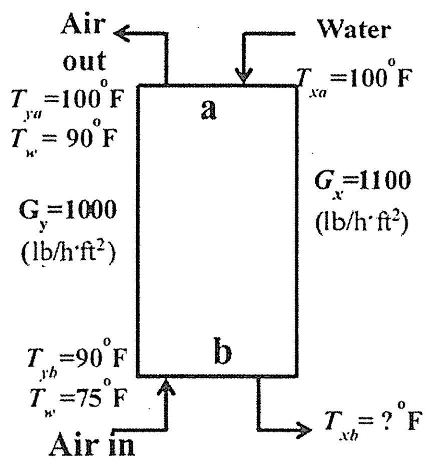
(c) Reconsider the problem and determine the concentration profile of component A in the stagnant film if in the film B decomposes to form A and if A reacts to form B, both by first-order reactions:

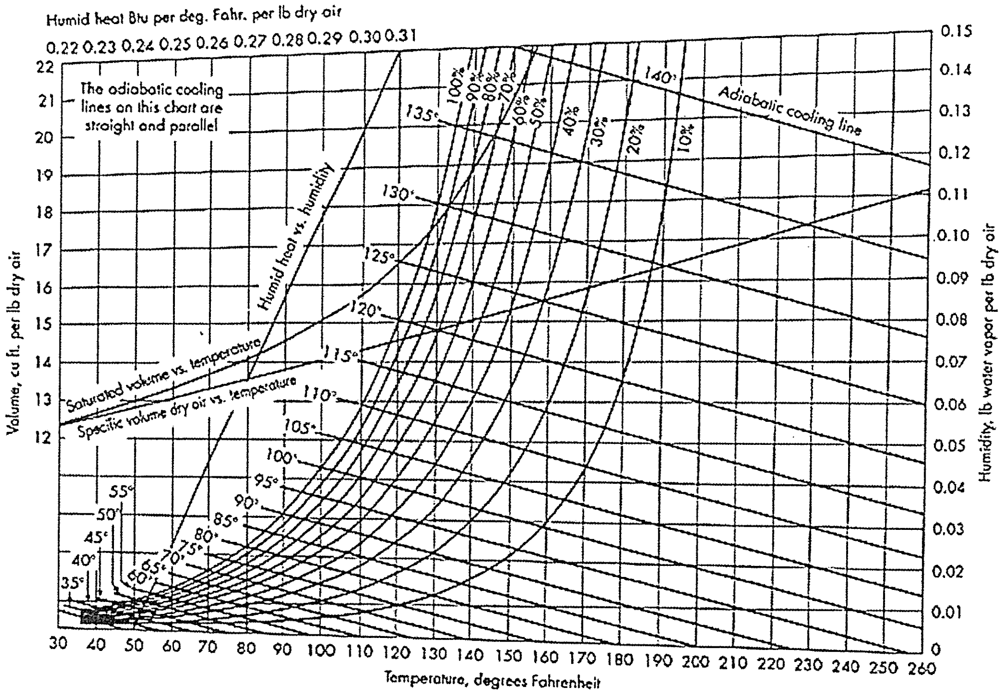
$$\mathrm{A} \underset{k_1}{\overset{k'_1}{\rightleftarrows}} \mathrm{B}$$

Simultaneously, A is instantaneously reacting to form B in the flat catalytic surface. (8%)



6. A counterflow cooling tower was used to cool a water stream (as shown in the figure attached). The water has inlet temperature of 100 °F and flow rate of G_x = 1100 lb/h–ft². The inlet air has dry–bulb and wet–bulb temperatures of 90 and 75 °F, respectively. The dry–bulb and wet–bulb temperatures of the outlet air were measured to be 100 and 90 °F, respectively.
   (a) If the flow rate of dry air is G_y=1000 lb/h–ft², determine the outlet temperature of the water (assume constant water flow rate)? (the latent heat of water at 32 °F is λ=1075 Btu/lb) (12%)
   (b) If the water flow rate (G_x) changes, but the air flow rate, the input and output conditions of gas, and the temperature of the input water (T_{xa}) are kept constant, what is the minimum temperature the water can be cooled, and the corresponding flow rate of water at this condition? (5%)





7. (a) In a two-components fractionation column, the flow rates of feed (F) and distillate (D) are kept constant, and the concentrations of feed (X_F), distillate (X_D), and bottom product (X_B) are known. If the feed is a **saturated liquid**, please describe how to determine the minimum reflux ratio. (3%)

   (b) When the column is operated at a normal and constant reflux ratio, please evaluate the variation (**<u>increase, decrease, or kept constant</u>**) of the following items when the feed is cooled **<u>from saturated to a sub-cooled liquid</u>**. (i) number of ideal plate; (ii) the required cooling water in condenser; (iii) the required steam in the reboiler; (iv) In a factory, the feed was always pre-heated to the saturation state, please explain the reason. (describe your answer with a help of drawing figures) (5%)