Problem 1 (39 points)

(1) (10 points)

Please give the SI units of the following physical quantities:

(a) rate of strain (b)thermal diffusivity (c) NPSH (d)Fanning friction factor (e) Reynolds stress

(2) (9 points)

The Navier-Stokes equation can be written as

$$\rho\frac{\partial\vec{v}}{\partial t}+\rho\vec{v}\bullet\nabla\vec{v}=\mu\nabla^2\vec{v}-\nabla p+\rho\vec{g}$$

where $\vec{v}$ represents the fluid velocity, p is pressure, $\vec{g}$ is the gravitational acceleration, t stands for time, ρ the fluid density and μ the fluid viscosity.

(a) For a steady velocity field, which term(s) in the above equation can be neglected? (1 point)

(b) For a flow with very small Reynolds number, which term(s) in the above equation can be neglected? (2 points)

(c) For an ideal flow, which term(s) in the above equation can be neglected? (2 points)

(d) Can the Navier-Stokes equation be used to describe the flow of compressible fluid? (2 points)

(e) Can the Navier-Stokes equation be used to describe the turbulent flow of water? (2 points)

(3) (6 points)

The fish concentration distribution in a lake is given by C=5t+3x+2y+z, where C represents the fish concentration (number of fish per cubic meter), t the time (min), and x,y,z the spatial coordinates (m). What is the $\partial C/\partial t$ for an observer fixed on a boat travelling on the lake with a velocity of V_x=5 (m/min), V_y=2 (m/min) and V_z=0.

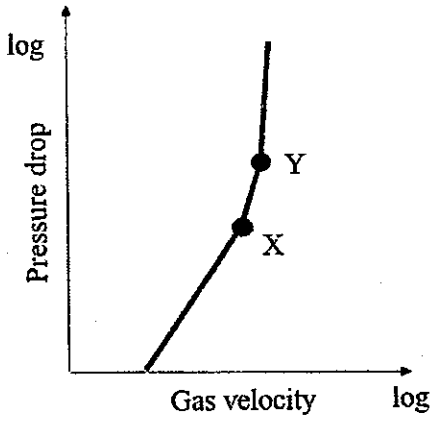
(4) (8 points)

(a) Give the definition of the "selectivity ratio" and "distribution coefficient" in extraction? (6 points)

(b) Which property in distillation has the same significance as the distribution coefficient? (2 points)

(5) (6 points)

The following figure shows the relationship between the pressure drop and the gas velocity in a packed column where the liquid flows downwards and the gas stream goes upwards. What are the names and the meanings of point X and Y?



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Problem 2 (16 points)

For a binary mixture of A and B with the average velocity v. The velocity and concentration of component i is v_i and c_i, respectively. i=A or B.

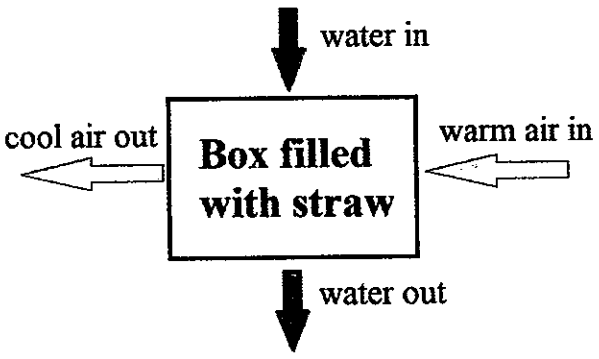
(1) Derive the Fick's first law for the absolute molar flux N_A. (6 points)

(2) Show $D_{AB}=D_{BA}$. (5 points)

(3) If B is stagnant, show that the absolute molar flux N_A is always pointing from higher C_A to lower C_A. (5 points)

Problem 3 (20 points)

In India, water coolers are a common alternative to air conditioners. The simplest version of such a cooler, as illustrated in the right figure, is by forcing the warm air through a box filled with straw wetted by water. The temperature of air passing through the box can be lowered for more than 10°C at appropriate condition.



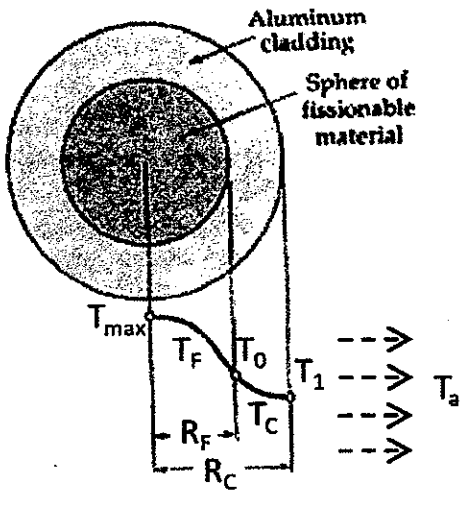
(1) Please explain the working principle of this cooler. (5 points)

(2) A psychometric chart can be used to estimate the maximum temperature drop of the air obtainable with such cooler. Sketch the chart with the marks on important properties (8 points) and describe how to estimate the maximum temperature drop using the chart. (4 points).

(3) Is this type of cooler suitable for use in Taiwan? Why? (3 points)

Problem 4 (25 points)

Consider a spherical nuclear fuel element as shown in the following figure. It consists of a sphere of fissionable material with radius R_F, surrounded by a spherical shell of alumina cladding with outer radius of R_C. The thermal conductivity of the fissionable material is k_F and that of the alumina cladding is k_C. Inside the fuel element, the fissionable material generates heat with a rate per unit volume S_n, which is constant. Outside the element, heat is lost to the ambient environment with a constant temperature T_a and the heat flux can be described by the Newton's law of cooling with a heat transfer coefficient h. The heat transfer process has reached the steady state and the temperature in the element is a function of r (the radial coordinate) only.



(1) Find T_1 (the temperature at $r=R_c$) without solving any differential equations. (8 points) (Hint: overall heat balance may help)

(2) Write down the differential equation and the boundary conditions needed to solve T_C, the temperature in the cladding. Find T_0-T_1, the temperature drop across the cladding. You are asked to find the answer without solving T_F, the temperature in the sphere of fissionable material. (10 points)

(3) Write down the differential equation and the boundary conditions needed to solve T_F, the temperature in the sphere of fissionable material. Find T_{max}, the maximum temperature in the sphere. (7 points)

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