(1) (20%) A section of the curved tube is attached to the mid-portion of a straight tube to form a "D" configuration, as shown in Figure 1. An excised (割下來的) bovine (牛的) heart valve membrane is installed across the entrance to the curved section, as indicated by the short line drawn at S. Fluid flow was directed down the straight tube into a water-filled tank. Please describe what will happen to the bovine heart valve membrane if

(a) the velocity U in the straight tube is accelerated;
(b) U is constant; and
(c) U is decelerated.

The motion of the fluid in the straight tube can be described as

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} = -\frac{1}{\rho}\frac{\partial p}{\partial x}$$

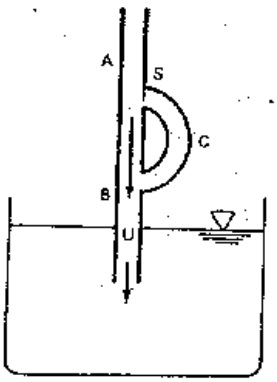

Figure 1

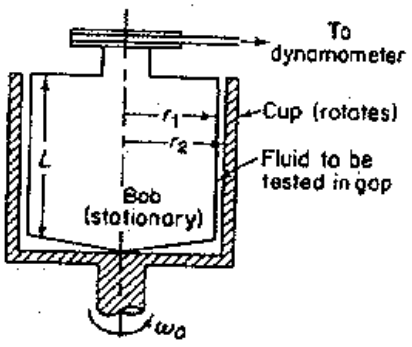

Figure 2

(2) (15%) Determine the velocity distribution of the fluid to be tested in the annular region and the torque acting on the inner cylinder for a Couette viscometer as shown in Figure 2. The viscosity of the fluid to be tested in the viscometer is μ.

) (20%) The temperature distribution across a wall 0.3 m thick at a certain instant of time is $T(x) = a + bx + cx^2$, where T is in degrees Celsius and x is in meters, $a = 200^\circ C$, $b = -200^\circ C/m$, and $c = 30^\circ C/m^2$. The wall has a thermal conductivity of 1 W/m K.

(a) On a unit surface basis, determine the rate of heat transfer into and out of the wall and the rate of change of energy stored by the wall. (15%)

(b) If the cold surface is exposed to a fluid at $100^\circ C$, what is the convection coefficient? (5%)

4) (15%) For flow of a liquid metal through a circular tube, the velocity and temperature profiles at a particular axial location may be approximated as being uniform and parabolic, respectively. That is, $u(r) = C_1$ and $T(r) - T_s = C_2[1-(r/r_0)^2]$, where C_1 and C_2 are constants. What is the value of the Nusset number Nu_D at this location? (The mean temperature is $T_m = \frac{1}{Au_m}\int_A uTdA$)

(5) (20%) Find the rate of transfer of oxygen into a fermentation broth under the following conditions. Air bubbles at 1 atm pressure and having diameters of d = 100 μm are injected into water at 37 °C. The water has no dissolved oxygen initially. The solubility of O_2 from air is 2.26×10^{-7} g-mole O_2/cm^3 H_2O, in water at 37°C. The diffusivity of O_2 in water at 37°C is D = 3.25×10^{-9} m^2/s.
(a) Find the flux of oxygen, in units of kg-mole O_2/m^2·sec. (15%)
(b) What is the Reynolds number characteristic of the bubble motion ? Define and give its value. For a convective mass transfer coefficient k_L, use $Sh = Pe^{1/3}$. (5%)
Hint: Sherwood number $Sh = k_L \cdot d/D$ and Peclet number $Pe = U \cdot d/D$. $\mu(H_2O)$ = 0.01 g/cm·sec.

6) (10%) Several models have been presented for prediction of the convective mass transfer coefficient external to a sphere moving through a fluid. Examples include

[6.1] $Sh = (4 + 1.21\ Pe^{2/3})^{1/2}$

and

[6.2] $Sh = Pe^{1/3}$

both of which have a theoretical basis. Calderbank and Jones (1961) correlate data for mass transfer to bubbles rising in a liquid, using

[6.3] $k_L = 0.38\ Sc^{-2/3}\ (g\mu\Delta\rho/\rho^2)^{1/3}$.

(a) What limitation of Eq [6.2] is accounted for by Eq [6.1] ? (5%)
(b) Show how an equation nearly identical to Eq [6.3] may be derived from Eq [6.2]. (5%)
Hint: Schmidt number Sc = ν/D.