一、Please from definition of “shear stress” to identify “momentum flux”? (5%)

二、Please from Reynolds number ($N_{Re}$) discuss creeping flow and potential flow? (5%)

三、What is the Newton’s law of viscosity? And from the viscosity to discuss the kind of fluid? (10%)

四、An incompressible fluid is flowing in a horizontal pipe by steady laminar, please prove the friction factor ($f$) is linear of Reynolds number ($N_{Re}$)? (10%)

五、An incompressible fluid is steady laminar flow in the annular region between two coaxial circular cylinders of outer radius (inner pipe) $kR$ and inner radius (outer pipe) $R$, please calculate the hydraulic radius? (10%)

六、For the case of laminar flow over a flat plate, the von Karm’an momentum integral equation is described as follows

$$\frac{\tau_0}{\rho} = \frac{d}{dx} \int v_y (v_\infty - v_x) dy$$

where $v_\infty$ and $\delta$ respectively mean free-stream velocity and boundary thickness which is a function of $x$, $\tau_0$ stands for the shear stress at wall

$$\tau_0 = \mu \frac{\partial v_x}{\partial y} \big|_{y=0}$$

Suppose the velocity profile for the laminar boundary layer can be represented by the following second order function

$$v_x = a + by + cy^2$$
Where $a$, $b$ and $c$ are undetermined coefficients. Please determine

(1) The above velocity profile. You have to list the related boundary conditions.

(2) The boundary layer thickness, $\delta(x)$

(3) The local skin-friction coefficient, $C_f$

七、A tri-effect evaporator concentrates steadily a constant boiling point (bp) solution at a constant heat transfer area. The inlet temperature of steam at first-effect evaporator is 108 $^\circ$C, the bp of solution at third-effect evaporator is 52 $^\circ$C, the overall heat transfer coefficient of first-, second- and third-effect are 2500, 2000, 1000, respectively. Please calculate the bp of solution in both the first- and second-effect evaporator? (10%)

八、A water drop (radius $R_1$, point 1) is steadily evaporated in a stagnant air, the air pressure and temperature are constant, assume the diffusion thickness of gas film is very large (radius $R_2$, point 2), water content in the air is scarce and all gas are ideal, please derive the molar flux of water evaporation, $N_{A2}$ is

$$N_{A2} = \frac{D}{R_1 KT} (P_{A1} - P_{A2})$$

Where
- $D$: diffusivity of water in air
- $K$: ideal gas constant
- $T$: temperature
- $P_{A1}, P_{A2}$: partial pressure of water gas at point 1, point 2

(20%)