1. A sphere of density ρ, and diameter D is dropped from rest in a fluid of density ρ and viscosity μ. Assuming a constant drag coefficient $C_{d_s}$, derive a differential equation for the fall velocity V(t) and show that the solution is

$$V = \left[\frac{4gD(S-1)}{3C_{d_s}}\right]^{1/2} \tanh C$$

$$C = \left[\frac{3gC_{d_s}(S-1)}{4S^2D}\right]^{1/2}$$

where $S=\rho_s/\rho$ is the specific gravity of the sphere material.

(* $\int \frac{dx}{a^2-x^2} = \frac{1}{a}\tanh^{-1}\frac{x}{a}$ ) (15%)

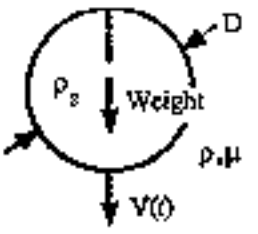


Fig.1

2. A horizontal air jet having a velocity of 50 m/s and a diameter of 20mm strikes the inside surface of a hollow hemisphere as indicated in Fig.2. How large is the horizontal anchoring force needed to hold the hemisphere in place? The magnitude of velocity of the air remains constant. (20%)

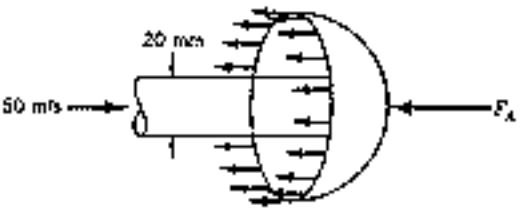


Fig.2

3. A circular disk can be lifted up by blowing on it with the device shown in Fig.3. Explain why this happens. (15%)

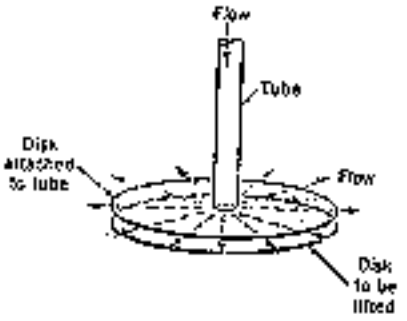


Fig.3

4. A flat plate of length L and height δ is placed at a wall and is parallel to an approaching boundary layer, as in Fig.4. Assume that the flow over the plate is fully turbulent and that the approaching flow is a one-seventh power law

$$u(y) = U_0\left(\frac{y}{\delta}\right)^{1/7}$$

Using strip theory, derive a formula for the drag coefficient of this plate. Compare this result with the drag of the same plate immersed in auniform stream $U_0$. (20%)

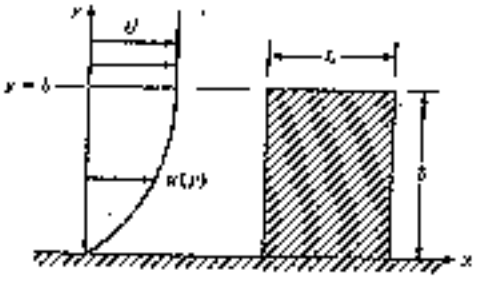


Fig.4

(背面仍有題目,請繼續作答)

5. Answer as indicated

(a) The temperature at a section in water flowing over a flat surface of length $0.5\ m$ is experimentally measured to be $T(^{\circ}C) = 25 + 75e^{-300y}$, where $y$ is the distance in $m$ measured normal to the surface with $y = 0$ corresponding to the surface. Assume that the thermal conductivity of water is $0.62\ W/m\cdot K$. What is the local Nusselt number? (4 %)

(b) List at least four important characterizing factors that influence the convection heat transfer process. (4 %)

(c) Define the following dimensionless parameters and state their physical significance: Stanton number, Rayleigh number, Prandtl number, and Jacob number. (12 %)

6. Consider a fluid flow at a rate $\dot{m}$ through a concentric tube annulus of length $L$. The inner and outer radii of the tube annulus are $r_i$ and $r_o$, respectively. The outer surface of the annulus is well insulated while the surface heat flux on the inner tube is known to vary sinusoidally with distance along the annulus, which is of the form $q_i''(x) = q_{i,m}'' \sin(\pi x / L)$. The maximum flux $q_{i,m}''$ is a known constant, and the fluid enters the annulus at a known temperature $T_{m,i}$. The flow is assumed to be hydrodynamically and thermally fully developed. Obtain an expression for the variation of the fluid mean temperature $T_m(x)$ with distance $x$ along the annulus. (10 %)