國立中山大學 101 學年度碩士暨碩士專班招生考試試題

科目：流體力學及熱對流【機電系碩士班甲組】

題號：4097

Fluid Mechanics: (65%)

1. (7%) Consider a balloon filled with gas of density ρ_b ($\rho_b < \rho_{air}$) in a stationary car, and then the car accelerates suddenly in the x direction with a constant acceleration a_x.
   (a). Neglect the viscous effect and relative fluid motion, and then draw a suitable control volume to derive the equation of motion in the x direction:
   $$\frac{dp}{dx} = -\rho_{air} \cdot a_x$$
   where p is the static pressure and ρ_{air} is the density of air in the car . (3%)
   (b). When the car suddenly accelerates in x direction, your body will move backward. Will the balloon move forward or backward? Why? (4%)

2. (13%) The tank shown in the Figure problem 2 rolls with negligible resistance along a horizontal track. It is to be driven from rest by a liquid jet of velocity V and cross-sectional area A that strikes the vane at the edge of the tank and is deflected into the tank. Assume themass of the tank is $M(t)$, and the velocity of the tank is $U(t)$. Use Reynolds transport equation to derive the (a) continuity (5%) and (b) momentum equation (8%) as $t \geq 0$. (You don't need to solve the equations)

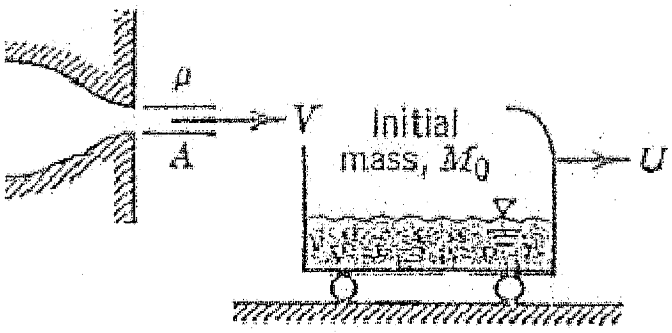

Figure Problem 2

3. (15%) Consider a uniform airflow $U=5\ m/s$ past a horizontal flat plate. Assume the critical Reynolds number = 1.25×10^6, and the kinetic viscosity of air $\nu = 1.6\times10^{-5}\ m^2/s$. You will also need the following equation for boundary layer thickness:
   For laminar : $\delta_L = 5x/\sqrt{Re_x}$
   For turbulent: $\delta_T = 0.37xRe_x^{-0.2}$
   (a)(5%) Decide the transition location x_{crit} that separates the laminar and turbulence on the flat plate.
   (b)(10%) Compute the boundary layer thickness at $x = 4\ m$ on the flat plate.

4. (15%) Many flying and swimming animals rely on an oscillating motion for propulsion through air or water. Assume the average travel speed, U, depends on the oscillation frequency f, the amplitude of the motion a (unit of length), the characteristic length scale of the animal L, the gravity g, the density of the animal ρ_a, the density of the fluid ρ, and the viscosity of the fluid μ.

(a) (6%) Formulate a dinsion1ess scaling law for U involving all the other parameters by using ρ, g and **L** as the repeating parameters

(b)(3%) Simplify your answer for (a) for high Reynolds numbers where μ is no longer a parameter. (Hint: drop the dimensionless parameter regarding viscosity μ directly from (a))

(c)(6%) While swimming submerged, fish and marine mammals are usually neutrally buoyant or very nearly so. Thus, simplify your answer for (b) so that g drops out. For this situation, determine how the speed U depends on the frequency f. (Hint: try to cancel the gravity g by manipulating the dimensionless parameters regarding g from (b))

5. (15%)

(a) (3%) Write down the Navier-Stokes equation in vector form. (Which is a momentum equation including body force, viscous force, pressure force and inertia force.)

(b) (3%) What are the conditions for the Navier-Stokes equations valid?

(c) (3%) What are the major difficulties in solving the Navier-Stokes equations.

(d) (3%) Write the Navier-Stokes equations in Cartesian coordinates for x, y and z components.

(e) (3%) Simplify the equation in (d) for solving steady laminar flow between fixed parallel plates, and solve the velocity profile u(y) corresponding to the figure given below.

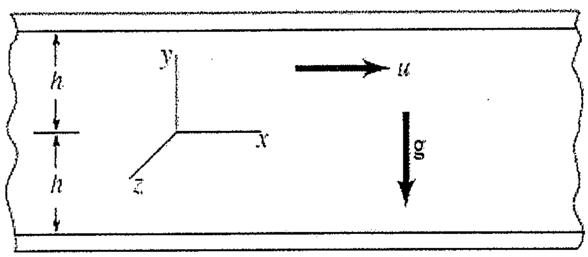

Figure Problem 5

Convection: (35%)

6.(10%, 2% each)

(a) Define the convection heat transfer coefficient, h, and write down its unit in SI.

(b) Define the Nusselt number and write its physical interpretation.

(c) Define the Prandtl number and write its physical interpretation.

(d) Define the Grashof number and write its physical interpretation.

(e) How to determine if a convection problem is forced convection dominant, free convection dominant.

7. (10%) Typical values for the convection heat transfer coefficient are given in the following table for processes of free convection, forced convection, and convection with phase change. Write possible process for (a) to (e). (2% each)

h ($W/m^2 \cdot K$)	
2–25	← (a)
50–1000	← (b)
25–250	← (c)
100–20,000	← (d)
2500–100,000	← (e)

8. (9%, 3% each) For a uniform flow over a flat plate,

(a) draw a diagram to show the profile of local convection heat transfer coefficient, h(x), varies along the flow direction x and explain the profile.

(b) write down the boundary layer momentum and energy equations for steady laminar flow situation.

(c) non-dimensionalize the equations of (b) and gives all dimensionless dependent variables for dimensionless temperature.

9. (6%, 2% each) For laminar flow in a circular tube with constant fluid properties：

(a) What is a thermally fully-developed flow?

(b) What are the values of Nu for fully-developed flows with constant wall temperature and constant wall heat flux, respectively?

(c) Draw a diagram to show how the heat transfer coefficient (h) varying along the flow direction (x) from the tube entrance to fully-developed.