國立清華大學 100 學年度碩士班入學考試試題

系所班組別：動力機械系（所）甲 組

考試科目（代碼）：熱流學(二) (1001)

 *請在【答案卷、卡】作答

Boundary Layer Flow & Creeping Flow (15%)

1.(a) It is often stated that the boundary layer approximation "bridges the gap" between the Euler equation and the Navier–Stokes equation. Explain. (5%)

(b) We usually think of boundary layers as occurring along solid walls. However, there are other flow situations in which the boundary layer approximation is also appropriate. Name three such flows, and explain why the boundary layer approximation is appropriate. (5%)

(c) Write a one-word description of each of the five terms in the incompressible Navier–Stokes equation,

$$\underbrace{\rho \frac{\partial \vec{V}}{\partial t}}_{\text{I}} + \underbrace{\rho(\vec{V} \cdot \vec{\nabla})\vec{V}}_{\text{II}} = \underbrace{-\vec{\nabla} P}_{\text{III}} + \underbrace{\rho \vec{g}}_{\text{IV}} + \underbrace{\mu \nabla^2 \vec{V}}_{\text{V}}$$

When the creeping flow approximation is made, only two of the five terms remain. Which two terms remain, and why is this significant? (5%)

Compressible Flow (20%)

2.(a) What is dynamic temperature? In air-conditioning applications, the temperature of air is measured by inserting a probe into the flow stream. Thus, the probe actually measures the stagnation temperature. Does this cause any significant error? (5%)

(b) Consider a converging nozzle with sonic speed at the exit plane. Now the nozzle exit area is reduced while the nozzle inlet conditions are maintained constant. What will happen to the exit velocity and the mass flow rate through the nozzle? Please provide the reasons for your answers. (10%)

(c) Can a shock wave develop in the converging section of a converging–diverging nozzle? Explain. (5%)

Heat Radiation (10%)

3.(a) What is the Kirchhoff's law in its most basic sense (with no restrictions)? Please also explain the physical base of its validity. (b) What is the form of Kirchhoff's law for a gray surface? Describe how this relation can be used in applications.

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Heat Transfer (25%)

4. A slender metal cylinder, with length L, diameter D, and thermal conductivity k_s, is heated with Q at one end (Fig. 1). All other surface is subjected to convection with a heat transfer coefficient h.
   (a) If the steady-state temperature distribution can be considered one-dimensional, $T(x)$, derive the energy equation and boundary conditions in terms of $T(x)$.
   (b) What is the criterion for T to be 1-D, a function of x only?
   (c) Schematically draw two curves of $T(x)$ respectively for the situations when the cylinder is heated with Q and $2Q$. Also explain for your answer.
   (d) Consider the following transient process. Initially the cylinder is at T_∞, and its one end is suddenly subjected to heating of Q at t=0. Rewrite the energy equation in terms of $T(x, t)$. Also draw a few $T(x, t)$ curves from t=0 to t=∞.

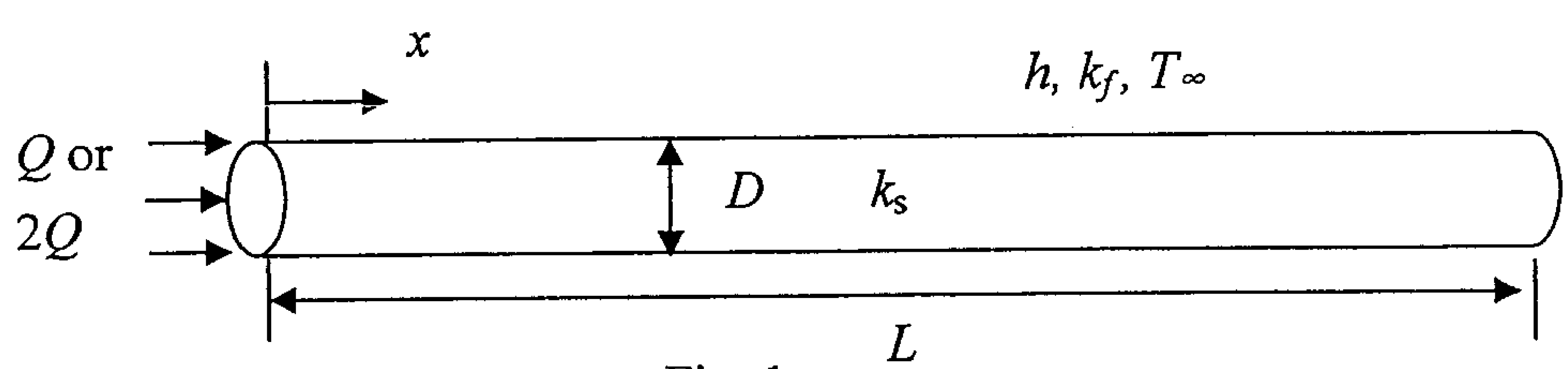

Fig. 1

Heat Convection (30%)

5. The local Nusselt number for a laminar heat convection flow parallel to a flat plate is expressible as

$$Nu_x = 0.332\,\mathrm{Re}_x^{1/2}\,\mathrm{Pr}^{1/3}$$

The free stream velocity and temperature are u_∞ and T_∞, respectively. The flat plate has a length L (i.e. $0 \le x \le L$) as well as a uniform wall temperature T_w.

(a) Determine the average heat flux over the flat plate $\bar{q}$ in terms of the relevant thermophysical properties of the fluid, i.e. thermal conductivity k, kinematic viscosity ν, and Prandtl number Pr. (20%)

(b) Which fluid does provide a better heat transfer under the same free stream velocity? water or SAE 30 Engine oil?

Water: $k = 0.6\,W/mK$, $\nu = 0.8\times10^{-6}\,m^2/s$, Pr = 5.3

SAE 30: $k = 0.3\,W/mK$, $\nu = 440\times10^{-6}\,m^2/s$, Pr=5300 (10%)