Nov. 28/17

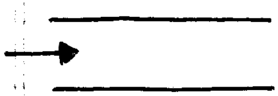
THERMAL

Reynolds number :

$$Re = \frac{\text{Inertia Force}}{\text{Viscous Force}} = \;\Rightarrow \frac{\rho V L_c}{\mu} \quad \text{OR} \quad \Rightarrow \frac{V L_c}{\nu}$$

ρ : Density, μ : Dynamic viscosity, ν : Kinematic viscosity $\left(\nu = \mu/\rho\right)$

Internal Flow



$$\begin{cases} Re \leq 2000 \rightarrow \text{Laminar} \\ Re > 10000 \rightarrow \text{Turbulent} \end{cases}$$

External Flow :

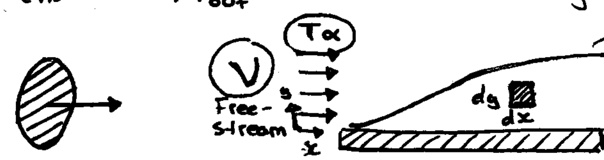
$Re_{cr} = 5 \times 10^5$

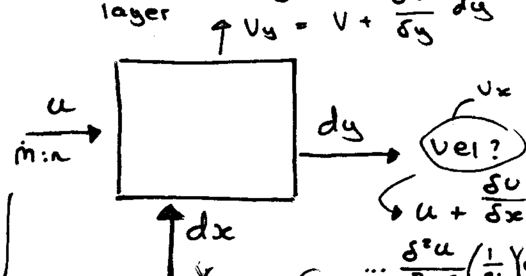
$Re < 5 \times 10^5 \rightarrow$ laminar

$Re > 5 \times 10^5 \rightarrow$ turbulent

For a control volume

$\dot{m}_{in} = \dot{m}_{out}$ ⟶ continuity $\qquad \dot{m} = \rho V A$





$u + \frac{\delta u}{\delta x} dx + \ldots$

$\ldots \frac{\delta^2 u}{\delta x^2}\left(\frac{1}{2!}\right)(dx)^2 \ldots$ etc.

neglect higher-order terms

$\Rightarrow u + \frac{\delta u}{\delta x} dx$

TAYLOR SERIES EXPANSION

(1) $\dot{m}_{in} = \rho u (dy \cdot 1) + \rho V (dx \cdot 1)$

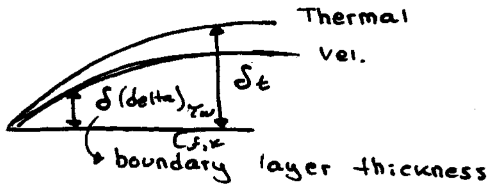
(2) $\dot{m}_{out} = \rho\left(u + \frac{\delta u}{\delta x} dx\right)(dy \cdot 1) + \rho\left(V + \frac{\delta V}{\delta y} dy\right)(dx \cdot 1)$

$\dot{m}_{in} = \dot{m}_{out}$

$$\Rightarrow \boxed{\frac{\delta u}{\delta x} + \frac{\delta V}{\delta y} = 0}$$

x-momentum : $\rho\left(u \frac{\delta u}{\delta x} + V \frac{\delta u}{\delta x}\right) = \mu \frac{\delta^2 u}{\delta y^2} - \underbrace{\frac{\delta P}{\delta x}}_{\text{pressure gradient}}$

Energy eq'n : $\rho C_p\left(u \frac{\delta T}{\delta x} + V \frac{\delta T}{\delta y}\right) = k\left(\frac{\delta^2 T}{\delta x^2} + \frac{\delta^2 T}{\delta y^2}\right)$



$$\frac{\delta}{x} = \frac{4.91}{\sqrt{Re_x}}$$

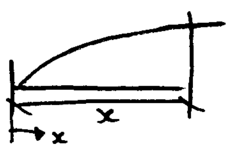
$$C_{f,x} = \frac{\tau_w}{\rho(V^2/2)} = \underline{\underline{0.664\ Re_x^{-1/2}}}$$

$$C_f = 2C_{f,x}$$

$$\boxed{h = 2h_x} \qquad \boxed{Nu = 2Nu_x}$$

avg — local

$$Nu_x = \frac{h_x \cdot x}{k} = \boxed{0.332\ P_r^{1/3} Re^{1/2}}$$



$$\underline{\underline{h_x}} \ \left\{ \ \dot{q}_x = h_x (T_s - T_\infty) \right.$$

$$\delta_t = \frac{\delta}{Pr^{1/3}} \qquad \frac{\delta}{x} = \frac{4.91}{\sqrt{Re_x}}$$

$$= \frac{4.91 \cdot x}{Pr^{1/3}\sqrt{Re_x}}$$

$$C_{f,x} \frac{Re_L}{2} = Nu_x\ Pr^{-1/3}$$

<u>Stanton number</u> : $St = \frac{h}{\rho c_p V} = \frac{Nu}{Re_L \cdot Pr}$

$$\boxed{h = \frac{C_f \rho V c_p}{2\,Pr^{2/3}}}$$

(Homework Example 6-2):

<u>Example 6-3</u> (Air property table)

@20°C, 1 atm : $\rho = 1.204\ kg/m^3$

$W = 2m$ $\qquad c_p = 1.007\ kJ/kg \cdot K$

$L = 3m$ $\qquad P_r = 0.7309$

A_s = both sides area

$= 2 \times 2 \times 3 = 12 m^2$

$$F_f = C_f A_s \frac{\rho V^2}{2}$$

$$\therefore C_f = \frac{F_f}{A_s (\rho V^2/2)} = \frac{0.86}{12 \times 1.204 \times (7^2/2)}$$

$$= 0.00243$$

$$h = \frac{C_f \rho V c_p}{2 \, Pr^{2/3}}$$

$$\therefore h = 12.7 \ W/m^2.K$$

Review for Final Exam:

Two Sections → A: Theory – 30%
- MC, TF, definitions and derivations
  - $\dot{Q}_{cond}$ for cylinder
  - $\dot{Q}_{cond}$ for sphere
  - Critical radius of insulation
  - Differential continuity eq'n.

B: Problems – 70%

7 → 8 problems

Covering chapters: Thermal – 5 (mass + energy analysis of control volume)

Heat Transfer –
- 1 Intro. and basic concepts
- 3 Steady heat conduction
- 6 Fundamentals of convection
- 12 Fundamentals of thermal radiation
- 13 Radiation heat transfer

↳ In-class problems

↳ assignments *

↳ D2L (my course link)