Indian Institute of Technology, Department of Chemical Engineering,

Mid Semester Examination, 2017

Transport Phenomena (CH30012)

Open Book Examination

Only the following two textbooks are allowed: i) Fox & McDonald and ii) Bird, Stewart & Lightfoot

Any other book(s), photocopies of text books and class notes are not allowed

There may be handwritten notes on the pages of the book, but sharing of books is NOT allowed.

Assume and clearly write any information and data that you feel are missing.

1. (a) A crude approximation for the x component of velocity in a laminar boundary layer is a linear variation from $v_x = 0$ at the surface ($y = 0$) to the freestream velocity, U, at the boundary layer edge ($y = \delta$). The equation for the profile is given below (where C is a constant). Evaluate the maximum value of the ratio v_y / v_x at a location $x = 0.5$ m and $\delta = 5$ mm. **3**

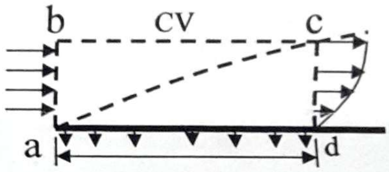
$$v_x = C\,U\,\frac{y}{x^{1/2}}$$

1. (b) A sailboard is gliding across a lake at a speed of 20 mph (9 m/s). The sailboard is 3 m long, 0.75 m wide and represents a smooth, flat surface. Assume laminar flow. Kinematic viscosity of water is 9.8×10^{-7} m^2/s
i) What is the average friction factor for the sailboard?, ii) What is the average shear stress on the sailboard? iii) How much power must the wind provide to propel the sailboard? **3**

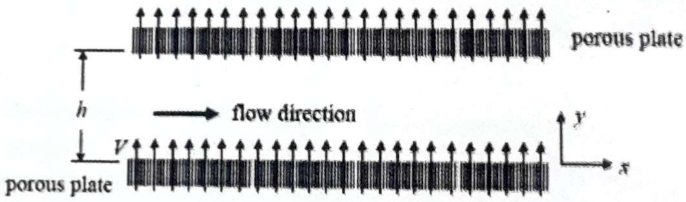
1. (c) Consider the steady flow of water past a porous plate with a constant suction velocity of 0.2 mm/s (i.e., V = - 0.2j mm/s). A thin boundary layer grows over the flat plate and the velocity profile at section cd is

$$\frac{u}{U_\infty} = \frac{3}{2}\frac{y}{\delta} - 2\left(\frac{y}{\delta}\right)^{1.5}$$

, where U_∞ is the velocity of approach at section ab and is equal to 3 m/s. Find the mass flow rate across section bc. Given: width of the plate = 1.5m, length = 2m **4**



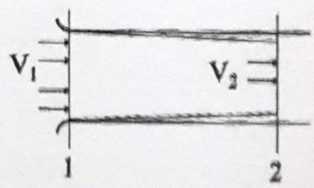
2. An incompressible fluid flows between two porous, parallel flat plates as shown in the figure. An identical fluid is injected at a constant speed V through the bottom plate and simultaneously extracted from the upper plate at the same velocity. Assume the flow to be steady, fully-developed, the pressure gradient in the x-direction is a constant, and neglect body forces. Determine appropriate expressions for the y component of velocity. Show that the x component of velocity can be expressed as



$$u_x = \frac{h}{\rho V}\left[\frac{\partial p}{\partial x}\right]\left[\left\{\frac{1-\exp\left(\frac{\rho V y}{\mu}\right)}{1-\exp\left(\frac{\rho V h}{\mu}\right)}\right\} - \frac{y}{h}\right]$$

10

3. Air enters a 0.076m diameter circular duct through a smoothly contoured duct. The flow is steady and the duct area is constant. The velocity is uniform at section 1, where the static pressure is - 0.0144 m of water. At section 2 (downstream from section 1), the velocity varies linearly, from 0 at the wall to V_2 at a distance of 3.81 mm from the wall. Determine (a) the volume flow rate of air through the duct ($\rho_{air} = 1.23$ kg/m^3), (b) the core velocity at section 2, and (c) the displacement thickness at section 2 (Note for (c): the thickness of the boundary layer is small compared to the radius). **10**



$\frac{\dot m}{\rho}$ $\dot m = \rho A u$ $\frac{\rho A u}{\rho}$

$= \frac{kg}{m^3}\cdot\frac{m^3}{s}$

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