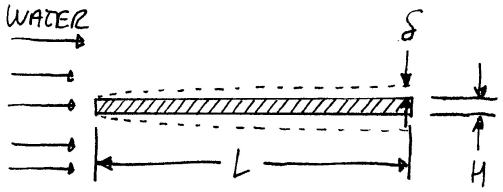
Fundamentals of Fluid Mechanics B
Assignment 7 — Boundary Layer

Instructions

Write your solutions in single column format, with one statement following another vertically. Write your solutions neatly so that they are easy to read and verify. Don't write one line with two equal signs. Highlight your answers using a box. Failure to do this will result in a lower score and fewer comments on my part.

Question #1

You perform an experiment in which liquid water at a temperature of 27°C flows on a flat plate as follows:



The flat plate has a length L of 2 meters, a height H of 2 mm, and a depth D of 1 meter. Knowing that the boundary layer thickness at the trailing edge of the plate is of $\delta = 2.76$ cm, estimate as well as possible the total drag force on the plate caused by the flowing water. Please use the following data for liquid water: density $\rho = 1000$ kg/m^3, viscosity $\mu = 10^{-3}$ kg/ms, heat capacity $c = c_p = c_v = 4200$ J/kgK, conductivity $k = 0.6$ W/mK.

Question #3

Consider a cone with its tip being sawed off. The tip radius is of R_0 and the radius of the cone corresponds to $as + R_0$ with a a constant and s a coordinate parallel to the cone surface. Starting from the Mangler's transform:

$$\hat{s} = \int_0^s \frac{R^2}{L^2} ds \quad , \quad \hat{n} = \frac{R}{L} n \quad , \quad \hat{v}_s = v_s \quad , \quad \hat{v}_n = \frac{L}{R}\left(v_n + \frac{n}{R} v_s \frac{dR}{ds} \right)$$

and the expressions previously derived for a planar boundary layer using a polynomial fit for the velocity:

$$\frac{\delta}{x} = 4.64 \mathrm{Re}_x^{-0.5} \quad , \quad \frac{u}{U_\infty} = \frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

do the following:

(a) Derive an expression for the characteristic length L applicable to this

problem.

(b) Derive an expression for v_s as a function of n and δ through the axisymmetric boundary layer.

(c) Derive an expression for the skin friction coefficient of the axisymmetric boundary layer.

(d) Find an expression for the ratio between the axisymmetric C_f and the planar C_f. Show that this ratio depends on only one non-dimensional parameter.

Answers

1. 0.0246 N.

Due on Tuesday April 9th at 11:00 am. Do Problems #1 and #3 only.