Mansoura University
Faculty of Engineering
Mech. Power Eng. Dept.

Total 100 Marks
Boundary Layer Theory

M. Sc. Courses
September 2013
Time: 3 Hrs.

Answer all questions - Assume reasonable values for ungiven data:

1- a) Specify important characteristics of laminar flow. Give examples where such flow is encountered. (5 Marks)

b) For the laminar boundary layer on a flat plate at zero incidence derive the values of $c_f\sqrt{R_x}$, $C_F\sqrt{R}$, $\frac{\theta}{x}\sqrt{R_x}$, $\frac{\delta^*}{x}\sqrt{R_x}$, $\frac{\delta}{x}\sqrt{R_x}$ and H for the velocity distribution:

$$\frac{u}{U_\infty}=2\left(\frac{y}{\delta}\right)-2\left(\frac{y}{\delta}\right)^3+\left(\frac{y}{\delta}\right)^4$$

where U_∞ is the free stream velocity, y is the distance measured normal to the wall, u is the velocity at the distance y and δ is the boundary layer thickness. (20 Marks)

2-a) Drive an expression for pressure drop for a steady two-dimensional laminar flow between two fixed parallel plates. (5 Marks)

b) Asmooth flat plate with a sharp leading edge is placed at zero incidence in a free stream of water flowing at 3.5 m/s. Determine the distance from the leading edge where the transion from laminar to turbulent may commence. The viscosity of water is 1 centipoise. (1 centipoise $= 10^{-3}$ Pa.s)
Calculate the boundary layer thickness at the transion point. (20 Marks)

3-a) Sketch the boundary layer separation in a diverging chanel by showing at least three different velocity profiles. (5 Marks)

b) Water approaches an infinitely long and thin flat plate with uniform velocity U.

i-Determine the velocity distribution $u(y)$ in the boundary layer given by:

$$u(y)/U = a\,y^2 + b\,y + c\ .$$

ii- Boundary layer displacement thickness.
iii- Boundary layer momentum thickness.
iv- What is the flux of mass (per unit length of plate) across the boundary layer?
v- Calculate the magnitude and the direction of the force needed to keep the plate in place. (20 Marks)

4-a). Differentiate between the characteristics of laminar and turbulent boundary layers. (5 Marks)

b) Air at 20°C and 1 atm ($\upsilon = 10^{-5}$), flows past the flat plate in Fig. P4, under laminar conditions. There are two equally spaced pitot stagnation tubes, each placed 2 mm from the wall. The manometer fluid is water at 20°C. Let the known data be $U = 15\ m/s$ and $h_1 = 8\ mm$ of water. Use this information to determine (a) L, in cm, (b) h_2, in mm. (10 Marks)

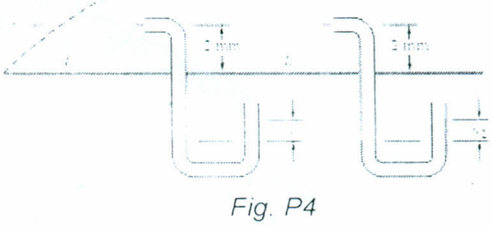

Fig. P4

من فضلك اقلب الصفحة

c) The one-seventh-power law could approximate the turbulent boundary layer profile:

$$\left(\frac{u}{U}\right)_{turb} = \left(\frac{y}{\delta}\right)^{1/7}$$

For the above velocity profile, find:

i) The displacement thickness δ, momentum thickness θ and shape factor *H*.

ii) The skin friction coefficient C_f and drag coefficient C_D. (10 Marks)

GOOD LUCK *Prof. Dr. M. Safwat*

$y[U/(\nu x)]^{1/2}$	u/U	$y[U/(\nu x)]^{1/2}$	u/U
0.0	0.0	2.8	0.81152
0.2	0.06641	3.0	0.84605
0.4	0.13277	3.2	0.87609
0.6	0.19894	3.4	0.90177
0.8	0.26471	3.6	0.92333
1.0	0.32979	3.8	0.94112
1.2	0.39378	4.0	0.95552
1.4	0.45627	4.2	0.96696
1.6	0.51676	4.4	0.97587
1.8	0.57477	4.6	0.98269
2.0	0.62977	4.8	0.98779
2.2	0.68132	5.0	0.99155
2.4	0.72899	∞	1.00000
2.6	0.77246		

The Blasius Velocity Profile.

Equations of motion

Continuity Equation:

$$\frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

x-momentum:

$$\rho g_x - \frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) = \rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right)$$

y-momentum:

$$\rho g_y - \frac{\partial p}{\partial y} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right) = \rho\left(\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right)$$

z-momentum:

$$\rho g_z - \frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right) = \rho\left(\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right)$$