



Allowed Tables and Charts: None

Answer all the Following Questions

(100 Marks for all)

Question (1)

(50 Marks)

- A. The polynomial velocity profile of a laminar boundary layer over a smooth flat plate (length L) immersed parallel to the flow stream can be approximated by a third degree equation as follows:

$$\frac{u}{U_{\infty}} = a_0 + a_1\left(\frac{y}{\delta}\right) + a_2\left(\frac{y}{\delta}\right)^2 + a_3\left(\frac{y}{\delta}\right)^3$$

- (I) Compute the unknown constants. (8 Marks)  
 (II) Determine the local boundary layer thickness, the displacement thickness and the momentum thickness. (8 Marks)  
 (III) Compute the drag coefficient of the plate,  $C_d$ . (4 Marks)
- B. Discuss the different regions in the boundary layer. Write the law of the wall, from which how do you derive the Clauser's plot relation? (10 Marks)
- C. Give a brief outline of the Blasius solution of laminar boundary layer for flow over a flat plate in the form:  $f f'' + 2 f''' = 0$ . What are the boundary conditions from which the analytical solution can be developed. Write the function of the boundary layer and displacement thicknesses developing in streamwise direction. (20 Marks)

Question (2)

(50 Marks)

- A. For 3-dimensional incompressible flow develop the continuity and Navier-Stokes equations in Cartesian coordinates. Reduce the final forms to steady incompressible flow. (20 Marks)
- B. Explain how to develop the turbulent Reynolds-stresses tensor matrix in three-dimensional turbulent flow. (15 Marks)
- C. To close the system of Reynolds-averaged Navier-Stokes equations (RANS) given in question (2-B), we must find enough equations to solve for our unknowns. Describe how to develop a simple linear turbulence model for solving the RANS equations ( $k$ - $\epsilon$  turbulence model). Define all terms in the developed equations. (15 Marks)

Question	1	2
ILOs	KU4.2 , KU6.1 , KU6.2 , I4.1 , I8.1 , PP4.2 , PP3.2	I4.1 , I8.2 , KU1.1, KU1.2, KU1.3, KU1.4, KU1.5, KU4.1, KU4.3, KU6.1

*Best wishes*

*Professor Wageeh El-Askary*