Indian Institute of Space Science and Technology
AE721/AE480 Boundary Layer Theory
End Semester Exam

(May 13, 2025)

Duration: 180 min **Total marks: 100**

General Instructions:

- **Draw schematic diagram wherever possible and label clearly**
- **State the assumptions clearly wherever required**
- **Assume suitable value for parameter if required and mention it clearly with units**

Questions:

1. Write brief answer
   (a) Compare the boundary layer thickness and wall shear stress of a laminar boundary layer with turbulent boundary layer for a given Reynolds number. [3]
   (b) Compare adiabatic wall temperature and stagnation temperature. [3]
   (c) Reference temperature method in compressible boundary layer and its merits. [3]
   (d) What is Reynolds analogy? [3]
   (e) What is stationary and non-stationary flow in a turbulent flow? [3]
   (f) What is RANS, LES and DNS? [3]
   (g) How to reduce the pressure drag of a bluff body? [3]
   (h) What is logarithmic layer in a turbulent layer? [3]
2. Explain briefly the types transition from laminar to turbulent flow in a boundary layer. [6]
3. Explain the swing of a cricket ball with a seam. [6]
4. Derive the relation of energy defect and energy thickness for a laminar compressible boundary layer. [8]
5. Explain the following
   (a) State the condition (value of m) for which the boundary layer thickness is (i) growing and (ii) decreasing with flow direction. Also comment about the pressure gradient in the above cases. Assume Falker-Skan flow. [6]
   (b) Explain the connection between the inflection point in the incompressible boundary layer velocity profile and the pressure gradient in the outer flow. [4]
6. Explain the following
   (a) What is 'cold', 'hot', and 'adiabatic' wall in the laminar compressible boundary layer over a flat plate. Also, compare the static temperature variation across the boundary layer in a single figure for the above cases. [7]
   (b) Compare the stagnation enthalpy profile across the laminar compressible boundary layer over an adiabatic flat plate for (i) $Pr < 1$, (ii) $Pr > 1$, and $Pr = 1$ and explain the reason for their behavior. [5]
7. Write the boundary layer equations (no need to derive the equations) and its boundary conditions for the following cases (i) incompressible laminar flow, and (ii) incompressible turbulent flow. Discuss the static pressure distribution across the boundary layer (along y - direction). [12]

8. Derive the Reynolds averaged Navier-Stokes equation (RANS) for an incompressible flow and discuss its implications. Also explain the Boussinesq turbulent viscosity hypothesis. [12]

9. Using Thwaites method, calculate $\delta^*(x)$, $\theta(x)$ and $c_f(x)$ for an incompressible flow over a flat plate. [10]

Useful relations:

$$\frac{d\theta}{dx} + \frac{1}{u_e}\frac{du_e}{dx}(H+2)\theta = \frac{c_f}{2}$$

$$\frac{d}{dx}(u_e^6\,\frac{\theta^2}{\nu}) = 0.45\,u_e^5$$

$$\bar{\tau}(\lambda) = 0.220 + 1.52\lambda - 5\lambda^2 - (0.072\lambda^2/(\lambda+0.18)^2)$$

$$\bar{H}(\lambda) = 2.61 - 4.1\lambda + 14\lambda^3 + (0.56\lambda^2/(\lambda+0.18)^2)$$

⋆ *End of Paper* ⋆

$$\frac{D}{Dt}(\rho v e) + \rho e\,\frac{\partial v_i}{\partial x_j} = -k\frac{\partial T}{\partial x_j}$$