

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

Midterm Exam
(March 05, 2026)

Duration: 120 min

Total marks: 60

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. Give brief answer

- (a) Write continuity equation for (a) steady incompressible flow, (a) unsteady incompressible flow, and (c) steady compressible flow. [3]
- (b) What is dissipation in energy equation and its meaning? Write the term in indicial and symbolic notation. [3]
- (c) Write the constitutive equations for Newtonian fluid and Fourier heat conduction. [3]
- (d) What is baroclinic torque? and express this in indicial and symbolic notation. At what condition, this torque is zero? [3]
- (e) What is the physical meaning of $\nabla \cdot \underline{\underline{\sigma}} \cdot \underline{\underline{u}}$? and write the term in indicial notation. [3]
- (f) Write the y -component of integral momentum equation. [3]
- (g) How a third order tensor transform when coordinate system is rotated. Clearly mention the relation between new and old coordinate system. [3]
- (h) Explain vorticity tilting using material line. [3]

✓ 2. Write brief answer [6]

- (a) Which part of the Navier-Stokes equation gives nonlinearity? and discuss the implications of nonlinearity.
- (b) Explain the reason behind use of superposition of elementary solution to compute lift in an airfoil.

✓ 3. Using tensor indicial notation, derive the following: $\underline{\underline{a}} \times (\underline{\underline{b}} \times \underline{\underline{c}}) = (\underline{\underline{a}} \cdot \underline{\underline{c}})\underline{\underline{b}} - (\underline{\underline{a}} \cdot \underline{\underline{b}})\underline{\underline{c}}$. [6]

4. Derive the relation of energy thickness for a laminar compressible boundary layer. [6]

✓ 5. For the two-dimensional steady flow having velocity components $u = ky$ and $v = 0$, determine the following when k is a positive real constant having units of inverse time. [8]

- (a) equations for the streamlines with a sketch of the flow pattern
- (b) the components of the rotation tensor and vorticity tensor
- (c) the components of the dilation and deviatoric strain rate tensor

6. Write brief answer [10]

- (a) What is thin shear layer? and its assumption
- (b) Reference scales used to derive Prandtl's boundary layer equation and its justification
- (c) Discuss the characteristics of Prandtl's boundary layer equation compared to Navier-Stokes equations

★ End of Paper ★