

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

End Semester Exam

(May 06, 2026)

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

- no change
1. (a) What is Galilean invariance and Objectivity. Give examples. [3]
- (b) What is barotropic flow? Give two examples. [3]
- oriented to pressure
- (c) Necessary conditions for flow separation. [3]
- (d) What is recovery factor? [3]
- how much actually goes through
- (e) What is rough wall in the context of incompressible turbulent boundary layer? [3]
- (f) What is bypass transition in boundary layer? and when this will happen? [3]
- (g) Static pressure distribution across the flat plate boundary layer (along y- direction) for (i) incompressible laminar flow and (ii) incompressible turbulent flow. [3]
2. (h) What is the physical meaning of (a) $\frac{d\sigma_{ij}}{dx_j}$, (b) $\sigma_{ij} \frac{du_i}{dx_j}$? [3]
- (i) What is ensemble average and time average? [3]
- (j) What is energy cascade in turbulent flow? [3]
- (k) What is shear production term and its role in turbulent mean kinetic energy equation as well as in turbulent kinetic energy equation. [3]
- (l) What is y^+ in turbulent boundary layer and its significance. [3]
2. Explain the inverse Robin-Magnus effect in rotating ball. [6]
3. Calculate the Kolmogorov length scale and velocity scale of a free air jet which exhausts from 100 mm nozzle with velocity 30 m/s. What happens to Kolmogorov length scale if velocity is doubled?. Assume kinematic viscosity of air is $10^{-5} \text{ m}^2/\text{s}$. [6]
- Inviscid - Viscous
4. Derive the relation for mass defect, momentum defect, displacement thickness and momentum thickness for compressible boundary layer and explain its physical meaning. [12]
5. Derive Prandtl boundary layer equation and state its assumption, consequences and boundary conditions. [12]
6. Give brief answer [12]
- (a) Discuss the effect of shear stress gradient on the development of boundary layer.
- (b) Plot shear stress profile as well as total pressure profile (along y- direction) in the laminar incompressible boundary layer over a flat plate.
- (c) Compare velocity profile and temperature profile (along y- direction) in 'hot wall' and 'adiabatic wall' of laminar compressible boundary layer over a flat plate.

7. Give brief answer

[16]

- (a) Derive the Reynolds averaged Navier-Stokes equation (RANS) for an incompressible flow and its implications
- (b) Boussinesq turbulent viscosity hypothesis.
- (c) Inertial subrange in incompressible turbulent boundary layer over a flat plate.
- (d) Difference between RANS, LES and DNS.

★ End of Paper ★