B. Tech.

(SEM. VIII) EXAMINATION. 2006-07

ADVANCED FLUID MECHANICS

Time : 3 Hours] [Total Marks : 100

Note : Attempt all questions.

1. Attempt any four parts of the following :
   (a) An idealized flow is given by
       \[ \mathbf{V} = 2x^3 \mathbf{i} - 3x^2y \mathbf{j} \]
       is this flow steady or unsteady? Make calculation for the velocity and local acceleration of a fluid particle in this flow field at point P(2,1,3).
       5
   (b) Explain Reynold’s transport theorem.
       5
   (c) Differentiate between uniform and non-uniform flow.
       5
   (d) Express the wall shear stress and wall friction coefficient
       5
   (e) A two dimensional incompressible flow in cylindrical polar co-ordinates is given by
       \[ V_r = -2r \sin \theta \cos \theta; \quad V_\theta = -2r \sin^2 \theta \]
       5
Check whether these velocity components represent a physically possible flow field.

(f) Starting with the momentum and continuity equation, derive the velocity profile for the flow between two parallel plates? One of which is at rest and other moving with a velocity V parallel with the fixed plate.

2 Attempt any four parts of the following:
   (a) Analyse the flow past a source:
       Sink pair in a uniform flow. Extend the analysis to steady the limiting case of doublet in a uniform flow.
   (b) Derive continuity equation in Cartesian co-ordinates. State the assumptions made.
   (c) Consider the area of one side of moving van to be 55m². Determine the resultant force acting on the side of the van when the wind is blowing at 4.5 m/s normal to the area (i) when the van is at rest (ii) when the van is moving at 13.5 m/s normal to the direction of wind in (i) use CD 1.30 and in (ii) use CD = 0.25 and CL = 0.6 (\(e_\alpha = 1.22 \text{ kg/m}^3\))
   (d) Explain magnus effect in brief.
   (e) Differentiate between form and surface drag. What measures are taken to reduce form drag on bodies?
   (f) Explain flow past a Rankine’s half body with the help of a neat sketch.

3 Attempt any two parts of the following:
   (a) Explain briefly the boundary layer theory.
(b) Obtain an expression for the thickness of the boundary layer for laminar flow assuming the velocity distribution law as

\[
\frac{u}{U} = 2 \left( \frac{Y}{\delta} \right) - \left( \frac{Y}{\delta} \right)^2
\]

where \( U \) = approach velocity of the stream,
\( u \) = velocity of the stream in the boundary layer at a distance \( y \) from the boundary.
\( \delta \) = thickness of the boundary layer.

(c) Water of kinematic viscosity \( \nu = 1 \times 10^{-6} \text{m}^2/\text{s} \) is following steadily over a smooth flat plate at zero angle of attack with a velocity of 2 m/s. The length of the plate is 1.6 m. Calculate (i) the thickness of the boundary layer of 20 cm from the leading edge (ii) the boundary layer rate of growth at 20 cm from the leading edge.

4 Attempt any two parts of the following:

(a) Discuss with a diagram the design and off-design performance of a convergent–divergent nozzle explaining clearly the terms ‘over-expanding’ and ‘under-expanding’.

(b) Explain the terms mach number, mach cone, mach angle and mach wedge. What are subsonic, supersonic and hypersonic flows?
(c) An air plane flies at an altitude of 15,000 m with a velocity of 800 km/hr. Calculate (i) the maximum possible temperature at the airplane skin, (ii) the maximum possible pressure intensity on the airplane body, (iii) the critical velocity of the air relative to the airplane and (iv) the maximum possible velocity of the air relative to the airplane.

5 Attempt any two of the following:

(a) Define ‘strength of shock wave’ and explain its significance.

(b) Air available at standard atmospheric conditions flow through a heated constant area pipe. If the flow is decelerated from mach number 1.5 to mach number 1.0. Determine (i) the change in temperature (ii) the heat addition to air.

(c) Establish from first principles the fanno equation and sketch on T-s plane, characteristic “fanno line” for a duct of constant area section. Mark the subsonic and supersonic parts and the sonic point.