EX/PG/ME/T/111C/2018

M.E. Mechanical Engineering First Year First Semester Examination, 2018

Subject: Advanced Fluid Mechanics – I

Time : Three hours **Full Marks: 100**

*Answer any **FIVE** QUESTIONS*
taking atleast TWO from each group

GROUP A

1. (a) Using the continuum concept and an arbitrarily shaped control volume in a Lagrangian frame of reference, derive the equation for *Reynold's Transport Theorem.*
(b) For a Newtonian fluid, what are the four conditions that the stress tensor is supposed to follow? Show that following these four conditions, the 81 unknown parameters in the relationship between stress tensor and deformation rate tensor are reduced to 2 unknown parameters. [12+8]

2. Using incompressible Navier-stokes's equation and suitable assumptions, obtain the governing equations for *flow between two rotating cylinders* with appropriate boundary conditions. Obtain expressions for velocity and pressure distribution. [20]

3. Define *Stokes' Second Problem.* Using incompressible Navier-stokes's equation and suitable justifications obtain the governing equations and state the boundary conditions. Justify why this problem allows similarity transformation. Using a suitable similarity variable obtain the velocity profile. Give a typical sketch of the profile. [20]

4. (a) Using 2D incompressible *Navier-Stokes equations* use *Prandtl's order of magnitude analysis* to obtain the boundary layer equations. Using suitable similarity transformations, obtain the *Blasius' equation* for boundary layer over a flat plate. State the suitable boundary conditions.
(b) **Write** the *Falkner-Skan Equations.* Under what choice of parameters, this equation reduces to the *Blasius' Equation*? What are the values of the *Falkner-Skan* parameters for boundary layer flow over a wedge of angle θ? [14+6]

GROUP B

5. a) State and proof Kelvin's circulation theorem.
b) Solve continuity equation for the case of flow past a solid sphere using the method of separation of variables and find
   i) velocity potential function,
   ii) velocity components, and
   iii) pressure distribution on the surface of the sphere. [5+15]

6. a) Define source and doublet, and derive their complex potential functions.
b) Using method of superposition and the complex potential, analyze an ideal flow past a-solid cylinder in terms of streamlines and equipotential lines. [10+10]

7. a) Using complex potential, establish the flow structures (streamlines) for corner flow and the flow over a wedge of 120°. How to find out velocity components?
b) Discuss Cauchy-Riemann conditions in connection with complex potential. [14+6]

8.a) Explain the use of stream function and velocity potential function and prove that they intersect each other at 90°.
b) Derive three-dimensional continuity equation in spherical coordinates for incompressible flow. [8+12]