M.E. MECHANICAL ENGG 1st YR. 1st SEM. EXAM - 2025

Advanced Fluid Mechanics

Time: 3 Hours **Full Marks: 100**

*Assume any relevant data, if necessary, with **appropriate justifications.***
Symbols carry their usual meanings unless otherwise specified.
***For full credit of Marks**, suitable **sketches**, **assumptions**, and physical **reasons** must be included in the answers.*

Use a Separate ANSWER SCRIPT for EACH PART.

Part A (50 Marks)

1. a) State and prove Kelvin's circulation theorem.

   b) Briefly explain the method of separation of variables, and using it, analyze the case of flow past a solid sphere in terms of the velocity potential function and velocity components. **[20]**

2. a) Explain the complex potential function along with its advantages.
   b) Formulate complex potential expressions for source flow, a source-sink pair, and doublet flow with neat sketches. **[20]**

OR

3. a) Using the method of separation of variables, analyze the flow in a lid-driven square cavity in terms of the velocity potential function and velocity components.
   b) Write down the complex potential function for an ideal flow over a solid wedge of 120°, and draw streamlines and equipotential lines. **[20]**

4. Using the method of superposition of complex potential, analyze the case of flow past a solid cylinder in terms of the stream function, and velocity components. **[10]**

OR

5. What is conformal mapping? Discuss different types of conformal transformations. [10]

Part B (50 Marks)

Answer Question [6] and ANY TWO from the rest

Use a separate ANSWER SCRIPT for Part B

[6] (a) State *Orr-Sommerfeld* equation. Draw the stability curve showing stable and unstable zones.
(b) Give an expression of Reynolds stress tensor for two-dimensional turbulent flow.
(c) For a Newtonian fluid, what are the four conditions that the stress tensor is supposed to follow? [3+3+4=10]

[7] 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. Estimate the distance away from the moving boundary within which the fluid is influenced by the motion of the boundary. [20]

[8] Using the Boundary Layer equations, apply suitable similarity transformations to obtain the *Falkner-Skan* Equations. State the suitable boundary conditions. Hence obtain solutions for Stagnation Point Flow. [20]

[9] 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]