ADVANCED FLUID MECHANICS
(MECH 3233)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The flow of liquid through the hole in the bottom of the washbasin is an example of
(a) forced vortex flow (b) free vortex flow
(c) uniform flow (d) steady flow.

(ii) The velocity potential and stream function are mutually
(a) parallel (b) perpendicular
(c) inclined at 60° (d) inclined at 30°.

(iii) An isentropic process can be
(a) adiabatic and irreversible (b) adiabatic and reversible
(c) reversible and isothermal (d) any adiabatic process.

(iv) For a plane Poiseuille flow, the nature of shear stress distribution between the plates is
(a) linear (b) parabolic
(c) hyperbolic (d) logarithmic.

(v) The tangential velocity component of ideal fluid flow on the surface of a cylinder is given by
(a) U sinθ (b) 2U sinθ (c) 3U sinθ (d) 4U sinθ.

(vi) An airplane is cruising at a speed of 800 km/h at an altitude where the air temperature is 0^0C. Assuming $\gamma = 1.4$ for air, Mach number of the airplane at this speed is
(a) 0.50 (b) 0.67 (c) 0.25 (d) 2.4.

(vii) Flow pattern around a nosed bridge pier can be represented by
(a) a doublet in a uniform flow (b) a source and sink of equal strength
(c) a source and sink in a uniform flow (d) a source in a uniform flow.

(viii) Fluid is flowing through a duct with a Mach number equal to 1.2. An increase in cross-section area in the downstream will cause
(a) decrease in velocity (b) increase in velocity
(c) increase in static pressure (d) chocked flow situation.

(ix) Using Stokes law the property of fluid that is determined is
(a) density (b) specific gravity
(c) viscosity (d) compressibility.

(x) In fluid flow within boundary layer, a negative pressure gradient is called a
(a) adverse pressure gradient (b) unstable pressure gradient
(c) separation pressure gradient (d) favorable pressure gradient.

Group- B

2. (a) In a two dimensional incompressible flow, the fluid velocity components are given by u = x −4y and v = −y −4x. Show that the velocity potential exists and determine its form as well as stream function. [(CO1)(Evaluate/HOCQ)]
(b) Discuss the orthogonality of streamlines and equipotential lines. [(CO1)(Understand/LOCQ)]

6 + 6 = 12

3. (a) In a two-dimensional incompressible flow over a solid plate, the velocity component perpendicular to the plate is $v = 2x^2y^2 + 3y^3x$, where, x is the coordinate along the plate and y is perpendicular to the plate. Hence find out (i) the velocity component along the plate, and (ii) an expression for stream function and verify whether the flow is irrotational or not. [(CO1)(Evaluate/HOCQ)]
(b) An open cylindrical tank of diameter 0.4 m and height 2 m contains water up to a depth 1.4 m. If the cylinder rotates about its vertical axis at a speed of 240 rpm, then determine the height of the paraboloid formed at the free surface. Also determine the speed of rotation required for the water to start spilling. [(CO1)(Analyze/IOCQ)]

6 + 6 = 12

Group - C

4. (a) Show that in case of Couette flow, the shear stress at the horizontal mid-plane of the channel is independent of the pressure gradient imposed on the flow. [(CO2)(Analyze/IOCQ)]
(b) An oil of viscosity 0.5 Poise flows between two stationary parallel plates 100 cm wide maintained 2 cm apart. If the velocity midway between the plates is 2.5 m/s, then determine the pressure gradient along the flow, the average velocity and the discharge of the oil. [(CO2)(Analyse/IOCQ)]

6 + 6 = 12

5. (a) Velocity profile of laminar boundary layer is given by $\frac{u}{U_\infty} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$. Determine the expressions for boundary layer thickness (δ), shear stress (τ_0), skin friction coefficient (C_f) and coefficient of drag (C_D) in terms of Reynolds number. [(CO4)(Analyze/IOCQ)]

(b) A laminar flow of an oil of dynamic viscosity 25 Poise is maintained between two horizontal parallel fixed plates kept at a distance of 15 cm apart. If maximum velocity of the oil is 2.5 m/s, then determine the pressure gradient, the shear stress at the plates and the discharge per metre width for the flow of oil. [(CO2)(Analyse/IOCQ)]

6 + 6 = 12

Group - D

6. (a) An aircraft flying at an altitude where the static pressure was 35 kPa (abs) and the temperature is -38^{0}C. The stagnation pressure measured was 70 kPa (abs). Calculate the speed of the aircraft. [(CO3)(Analyse/IOCQ)]

(b) Find the speed of propagation of a small disturbance through a compressible fluid in terms of change in pressure and change in density. [(CO3)(Remember/LOCQ)]

6 + 6 = 12

7. (a) For compressible, isentropic flow through a converging duct, find the value of Mach number for maximum discharge. [(CO3)(Understand/LOCQ)]

(b) A nozzle is designed to expand air isentropically to atmosphere pressure from a large tank in which properties are held constant at temperature 5^{0}C and pressure 304 kPa (abs). The desired flow rate is 1 kg/s. Determine the exit area of the nozzle. [(CO3)(Analyse/IOCQ)]

6 + 6 = 12

Group - E

8. (a) A man, descends to the ground from an aeroplane with the help of a parachute against the resistance of air with an uniform velocity of 25m/s. The total mass of the man and the parachute is 80 kg. The shape of the parachute is hemispherical. Find the diameter of the parachute. Assume C_d = 0.5 and ρ_{air} = 1.25 kg/m^3. [(CO5)(Analyse/IOCQ)]

(b) A doublet of strength 20 m^2/s is in the line of the uniform flow having a velocity of 15 m/s. Determine the stream function and the resultant velocity in the flow field at a point P (0.5 m, 30°). [(CO6)(Analyse/IOCQ)]

6 + 6 = 12

9. (a) A source flow between two flat parallel plates originates from a small hole of diameter 0.05 m in the lower plate, 1.5 m distance apart with the water particles move radially outwards between the plates. If water enters the space between the plates at a rate of 1.2 m^3/s, then determine (i) the strength of the source and

velocity at a radius of 0.4 m from the centre of the plate, (ii) pressure at the given location if water pressure at the inlet is 225 kPa and (iii) stream function for the streamlines at 30° and 90° from the streamline with $\psi_0 = 0$.

[(CO6)(Analyse/IOCQ)]

(b) A source and a sink of equal volume flow rate 10 m^3/s are located 2 m apart. If a uniform flow of 5 m/s is superimposed, find out the location of the stagnation points. [(CO6)(Analyse/IOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	18.75	68.75	12.5

Course Outcome (CO):

After the completion of the course students will be able to

CO 1	Explain the fundamental principles for solving kinematics of fluid flow.
CO 2	Analyze standard bench mark problems like Couette flow, Poiseuille flow.
CO 3	Apply the fundamental laws to solve problems of compressible fluid flow in engineering systems.
CO 4	Relate different flow parameters for boundary layer flow over flat plate.
CO 5	Evaluate the effects of drag and lift force on submerged bodies.
CO 6	Explain various phenomena for ideal fluid flow.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question