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) Simple Couette flow is
(a) purely pressure driven flow.
(b) purely shear driven flow.
(c) combination of pressure and shear driven flow.
(d) vortex flow.

(ii) In case of forced vortex flow, the height of free surface, which is a parabola varies with
(a) fourth power of radius. (b) cubic power of radius.
(c) square of radius. (d) directly proportional to radius.

(iii) Pressure drag is _____ and chance of flow separation is _____ for a streamlined body.
(a) less, more (b) more, less (c) less, less (d) more, more

(iv) An equipotential line
(a) has constant dynamic pressure
(b) is same as streamline
(c) has no velocity component tangent to it
(d) has velocity component tangent to it.

(v) If we reverse the direction of velocities of a sink flow, it becomes
(a) counter sink flow (b) source flow
(c) a free vortex (d) a forced vortex.

(vi) The dimension of stream function is
(a) LT^{-1} (b) L^2T^{-1} (c) L^3T^2 (d) L^2T^{-2}.

(vii) When a body is immersed in a flow field, the component of the resultant force acting on it in the direction normal to the relative velocity is called
(a) lift force (b) gravity force (c) buoyant force (d) drag force.

(viii) Flow separation is caused by
(a) reduction of pressure to vapour pressure
(b) a negative pressure gradient
(c) a positive pressure gradient
(d) the boundary layer thickness reducing to zero.

(ix) In a laminar flow between two stationary parallel plates, the ratio of maximum velocity to average velocity is equal to
(a) 1 (b) 1.5 (c) 2 (d) 2.5.

(x) A streamlined body is one in which the
(a) skin friction drag is zero
(b) skin friction drag is minimum
(c) thickness of the body is minimum
(d) separation point occurs on the far downstream of the body.

Group- B

2. (a) The velocity field in a fluid medium is given by $\overline{V} = 3xy^2\hat{i} + 2xy\hat{j} + (2zy + 3t)\hat{k}$. find the magnitude of rotational velocity at (1,2,1) and at time t=3.
[(CO1)(Evaluate/HOCQ)]

(b) What are the differences between free and forced vortex?
[(CO1)(Understand/LOCQ)]
6 + 6 =12

3. (a) What do you mean by free and forced vortex? Give some practical examples of it.
[(CO1)(Understand/LOCQ)]

(b) In the free cylindrical vortex water flow at a point 0.2 m radius, the velocity and pressure are 7.5 m/s and 155 kPa, respectively. Determine the pressure at a radius of 0.3 m.
[(CO1)(Analyze/IOCQ)]
6 + 6 =12

Group - C

4. (a) For general Couette flow, where the upper plate is moving with constant velocity U and the gap between the fixed and moving plate is H, show that the discharge per unit width of the plate is given by $q = U\frac{H}{2} - \frac{H^3}{12\mu}\left(\frac{dp}{dx}\right)$. All symbols have usual meanings.
[(CO2)(Analyze/IOCQ)]

(b) A viscous oil flows steadily between parallel plates. The fully developed velocity profile is given by $u = -\frac{h^2}{8\mu}\left(\frac{\partial p}{\partial x}\right)\left[1 - \left(\frac{2y}{h}\right)^2\right]$ where the total gap between the plates h = 3 mm and y is the distance from the centre line. The viscosity of the oil is 0.5 Ns/m^2 and the pressure gradient is -1200 N/m^2 /m. Find the magnitude and direction of the shear stress on the upper plate, and the volumetric flow rate per metre width of the channel.
[(CO2)(Evaluate/HOCQ)]
6 + 6 =12

5. (a) Velocity profile of laminar boundary layer is given by $\frac{u}{U_\infty} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$. Determine the expressions for boundary layer thickness (δ), shear stress (τ_0), in terms of Reynolds number. *[(CO4)(Analyze/IOCQ)]*

(b) Water at 60° C flows between two large flat plates. The lower plate moves to the left at speed of 0.3 m/s. The plate spacing is 3 mm and the flow is laminar. Determine the pressure gradient required to produce zero net flow at a cross section ($\mu = 4.7\times10^{-4}$ kg/m-s at 60° C). *[(CO2)(Analyze/IOCQ)]*

6 + 6 =12

Group - D

6. (a) A duct conveys an isentropic flow of air. At section 1, velocity, pressure and temperature are 100m/s, 200 kPa (abs) and 70°C respectively. At another downstream section (section 2) the velocity is 250 m/s. At section 2, determine (i) the temperature of air (ii) Mach number and (iii) static pressure of air. (For air, γ= 1.4 and R= 287 J/kg-K). *[(CO3)(Evaluate/HOCQ)]*

(b) A supersonic plane flies at 1900 km/hr in air having a pressure of 28.5 kPa (abs) and density of 0.439 kg/m^3. Calculate the (i) temperature (ii) pressure and (iii) density of air at the stagnation point on nose of the plane. (For air, γ = 1.4 and R = 287 J/kg-K). *[(CO3)(Analyze/IOCQ)]*

(2 + 2 + 2) + 6 = 12

7. (a) Air at 40^{0}C flows isentropically from a large tank through a converging nozzle of 40 mm diameter at nozzle exit. The tank contains air at 150 kPa (abs) and the discharge is to atmosphere of pressure 95 kPa (abs). Calculate the mass flow rate through the nozzle. (For air, γ = 1.4 and R = 287 J/kg-K). *[(CO3)(Evaluate/HOCQ)]*

(b) A rocket is found to have a speed of 2100 km/hr in air at a temperature of (- 40^{0}C). Calculate the Mach number and the Mach angle. (For air, γ = 1.4 and R = 287 J/kg-K). *[(CO3)(Evaluate/HOCQ)]*

8 + 4 = 12

Group - E

8. (a) A man descends to the ground with the help of a parachute from an aeroplane against the resistance of air with a uniform velocity of 10m/s. The parachute is negligible in weight and hemispherical in shape and is having diameter of 5m. Find the weight of the man if C_d = 0.5 and ρ_{air} = 1.25 kg/m^3. *[(CO5)(Evaluate/HOCQ)]*

(b) If the strength of a doublet is 15 m^2/s, then determine the velocity at point P (1,2) and the value of stream function passing through it by using Cartesian coordinate systems. *[(CO6)(Analyse/IOCQ)]*

6 + 6 =12

9. (a) If a circular cylinder of diameter 1 m rotates at 300 rpm in a uniform stream of 10 m/s, then locate the stagnation point and determine the minimum rotational speed for detached stagnation points. *[(CO6)(Analyse/IOCQ)]*

   (b) Obtain the equation of the dividing streamline for the flow resulting from a superposition of a uniform flow at 10 m/s on a two-dimensional source with strength of 10 m^2/s. Also sketch the flow pattern. *[(CO6)(Analyse/IOCQ)]*

6 + 6 =12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*12.5*	*50*	*37.5*

Course Outcome (CO):

After the completion of the course students will be able to

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

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