FLUID MECHANICS
(CHEN 2102)

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) A Newtonian fluid (density = ρ, viscosity = μ) is flowing with an average velocity ν in a tube of diameter 'D'. Let Δp be the pressure drop across the length 'L'. For laminar flow, Δp is proportional to
(a) $L \rho \nu^2/D$ (b) $L \mu \nu / D^2$
(c) $\mu \nu/L$ (d) $D \rho \nu^2/L$.

(ii) A streamline is a line in flow field,
(a) along which a fluid particle travels
(b) such that at every point on it, the velocity is tangential to it
(c) that is traced by all the fluid particles passing through a given point
(d) none of these.

(iii) Sewage sludge is an example of _____ fluid.
(a) Newtonian (b) Pseudoplastic
(c) Bingham plastic (d) Dilatant.

(iv) For uniform laminar flow (in the x-direction) past a flat plate at high Reynold's number, the local boundary layer thickness (δ) varies with the distance along the plate (x) as
(a) $\delta \alpha x^{\frac{1}{4}}$ (b) $\delta \alpha x^{\frac{1}{3}}$ (c) $\delta \alpha x^{\frac{1}{2}}$ (d)) $\delta \alpha x$

(v) _____ is an example of dilatant fluid
(a) paper pulp (b) milk (c) tooth paste (d) butter.

(vi) The equivalent diameter for fluid flow through a square cross-section channel of side x is given by
(a) 4x (b) 2x (c) x (d) 0.5x.

(vii) Pitot tube measures
(a) point velocity (b) average velocity
(c) bulk velocity (d) maximum velocity.

(viii) In case of an open channel super-critical flow, Froude number (F_r) is
(a) <1 (b) 0 (c) =1 (d)) >1.

(ix) During free fall of an object through a fluid medium, the terminal velocity becomes
(a) accelerating (b) decelerating
(c) zero (d) constant.

(x) The particle Reynolds number (Re_p) for a critical flow of fluid in a fluidised bed condition is
(a) $Re_p < 10$ (b) $2000 < Re_p > 10$
(c) $Re_p > 2000$ (d) $2000 < Re_p < 4000$.

Group – B

2. (a) A velocity field is given by $\mathbf{V} = 0.3 x \mathbf{i} - 0.3 y \mathbf{j}$.
(i) Find the streamline passing through the point (2, 8, 0)
(ii) If the particle passes through the point (2, 8, 0) at time $t_0 = 0$, determine the location and velocity of the particle at time t = 6 sec.

(b) For fluid flow in a smooth circular tube with radius, R, at a Reynolds number of about 10^5, the velocity profile varies according to:

$$V = V_{max}\left(\frac{R-r}{R}\right)^{1/7}$$

where r is the radial distance from the centre and V_{max}, the maximum velocity at the centre. Find out the relationship between average velocity V_{avg} and V_{max} for an incompressible fluid.

(3 + 3) + 6 = 12

3. (a) Define streak line.
The velocity components in a flow field are given as follows: u = x (1 + 2t), v = y and w = 0. A coloured dye is injected at the point A (1, 1) in the flow field at t = 0. Find the equation of streak line passing through the point A at t = 1.

(b) A manometer is used to measure the pressure drop across an orifice. The manometric liquid is mercury (density 13,590 kg/m³). The fluid flowing through the orifice and filling the manometer leads is brine (density 1,260 kg/m³). When the pressure at the taps are equal, the level of the mercury in the manometer is 0.92 m below the orifice taps. Under the operating conditions, the gauge pressure at the upstream

tap is 0.135 bar; the pressure at the downstream tap is 240 mm Hg below atmospheric. What is the reading of the manometer in cm?

(2 + 4) + 6 = 12

Group – C

4. (a) A kerosene storage tank drains by gravity to a tank truck. The length of the pipeline between the tank and truck is 61 m and its internal diameter is 25 mm. Kerosene has a viscosity of 0.0005 Pa s and a density of 800 kg/m^3. Both tank and truck are open to the atmosphere, and the flow rate is 0.81 lit./s. Calculate the difference between the level in the tank and that in the truck.
(Given: $f = 0.079\mathrm{Re}^{-0.25}$, where f is friction factor.)

(b) Define 'momentum correction factor'.

(c) Derive an expression of the velocity profile in case of Coutte flow with pressure gradient.

7 + 1 + 4 = 12

5. (a) A Newtonian fluid is confined between two broad, parallel, vertical plates separated by a distance B. The plate on left is stationary, that on right is moving vertically upward with a constant velocity u_0. Assuming that the flow is laminar, find the steady-state velocity profile in the fluid.

(b) Obtain an expression of frictional head loss due to sudden expansion of cross section for a fluid flowing through a conduit in turbulent condition.

(c) A nozzle of cross-sectional area A_2 is discharging to the atmosphere and is located at the side of a large tank, in which the open surface of the liquid in the tank is H metre above the centreline of the nozzle. Calculate the velocity v_2 at the outlet of the nozzle and the volumetric rate of discharge if no frictional losses are assumed.

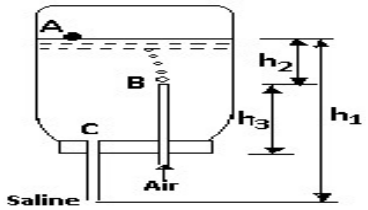
5 + 3 + 4 = 12

Group – D

6. (a) Derive an expression for the volumetric flow rate of a fluid flowing through an orifice meter.

(b) Explain that pressure drop due to fluid flow through a rotameter is invariant.

(c) Consider the saline drip bottle shown in the following figure. If ρ is the density of saline, find (i) pressure at A (ii) the velocity of flow of saline through the tube.



(Neglect the viscous losses in the tube. Atmospheric pressure is $P_{atm.}$)

4 + 4 + 4 = 12

7. (a) What is "Drag Coefficient"?

(b) Explain the term Stokes flow and terminal velocity.

(c) Show that the terminal velocity of a spherical particle with Stokes flow is given by the expression $\frac{d^2 g (\rho_s - \rho_f)}{18\mu}$. Also, show that $C_d = \frac{24}{Re}$ for drag coefficient in a fluid flow past a sphere where, C_d stands for drag coefficient, R_e is Reynolds number, d is the diameter of the pipe, ρ_s is the density of the solid, ρ_f is the density of the fluid & μ is the viscosity of the fluid.

2 + 4 + 6 = 12

Group – E

8. (a) Explain with neat sketches the working of a centrifugal pump. What are the merits and demerits of such a pump?

(b) Plot a graph to explain the characteristics of a centrifugal pump.

(c) The rotor of a centrifugal pump is 170 mm diameter and runs at 1450 rev/min. It is 15 mm deep at the outer edge and swept back at 30^0. The inlet flow is radial. The vanes take up 10% of the outlet area. 65% of the outlet velocity head is lost in the volute chamber. The pump delivers 15 dm^3/s of water. Calculate: the head produced; the efficiency and power consumed.

5 + 2 + 5 = 12

9. (a) Derive an expression for minimum fluidization velocity. Also give its physical significance.

(b) The report of observations made by an engineer in the plant for the fluidisation operation is as follows:
Data: Air: Density of the gas ρ_g = 1.2 × 10^{-3} g/cm^3, Viscosity of the gas $\mu = 1.8 \times 10^{-4}$ g/cm. s; Sand: $\overline{d_p}$ = 160 μm, φ_s = 0.67, ρ_s = 2.60 g/cm^3.
Calculate minimum fluidisation velocity (u_t) for sharp irregular sand particles used by the engineer for the fluidisation operation in the plant.

6 + 6 = 12