CHEMICAL ENGINEERING 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) To determine the height of an aeroplane in flight, we can use
(a) Fanning equation (b) Navier-Stokes equation
(c) Barometric equation (d) Bernoulli's equation.

(ii) Momentum diffusivity is also known as
(a) Dynamic viscosity (b) Kinematic viscosity
(c) Eddy viscosity (d) Bulk viscosity.

(iii) Chocolate is an example of _____ fluid.
(a) Dilatant (b) Pseudo-plastic
(c) Thixotropic (d) Bingham Plastic

(iv) The value of kinetic energy correction factor for laminar flow within a pipeline is
(a) 2 (b) 1 (c) 0 (d) ∞.

(v) Stokes equation is applied for analysing _____ flow.
(a) rotational (b) viscous (c) creeping (d) potential

(vi) In case of a pressure-driven laminar flow of a Newtonian fluid of viscosity μ through a horizontal pipe, the velocity of the fluid is proportional to
(a) $\mu^{-0.5}$ (b) μ^{-1} (c) μ (d) $\mu^{0.5}$.

(vii) Purpose of relief valve in a reciprocating pump is to
(a) protect the pump against developing excessive pressure
(b) facilitate unidirectional flow of liquid
(c) reduce the discharge pressure
(d) control the rate of discharge.

(viii) Which of the following facilitates control of flow of fluids in a large diameter pipe?
(a) Gate valve (b) Globe valve (c) Butterfly valve (d) Check valve.

(ix) Minimum fluidization velocity in case of very small particles is proportional to
(a) μ (b) μ^{-1} (c) μ^{-3} (d) μ^{-2}.

(x) For calculation of pressure drop for flow of fluids through packed beds, if viscous forces predominate over inertial forces, _____ equation can be used as a simplification.

(a) Burke-Plummer (b) Kozeny-Carman
(c) Ergun (d) Darcy

Group- B

2. (a) A 3-D velocity field is given by $V = 5x^2yi + Cyj - 10xyzk$, where i, j and k are the unit vectors in x,y and z directions respectively. The coefficient C is a constant. If flow is incompressible, find the value of C. [(CO3)(Apply/IOCQ)]

(b) Consider an incompressible flow of a constant property fluid over a smooth, thin and wide flat plate. The free stream flows parallel to the surface of the plate along its length and its velocity is constant. Value of Reynold's number at a distance of 2m from the leading edge of the plate is 8000. Determine the nature of the flow (Laminar/turbulent/transitioning/inviscid) within the boundary layer at a distance of 1m from the leading edge of the plate. [(CO3)(Analyse/IOCQ)]

(c) Give examples of dilatant and thixotropic fluids. [(CO1)(Remember/LOCQ)]

5 + 5 + 2 = 12

3. (a) The instantaneous velocity component in the x-direction for a turbulently flowing fluid is given as:
$u_i = 8 + 4(Sin5t + Cos(-4t))$. Estimate the intensity of the turbulence after t = 10s. [(CO3)(Analyze/IOCQ)]

(b) Why doesn't boundary layer separation take place for flow over a flat plate? [(CO3)(Understand/LOCQ)]

8 + 4 = 12

Group - C

4. (a) A Newtonian fluid of viscosity μ flows between two parallel plates due to the motion of the bottom plate, which is moved with a velocity V along the x direction. The vertical gap between the two plates (y-direction) is **2b**. The top plate is stationary. Determine the steady state shear stress distribution of the fluid, considering laminar flow, and represent the qualitative trend of the profile through a diagram. [(CO3)(Apply/IOCQ)]

(b) "For estimating the air velocity profile 2m above the wings of an aeroplane, Stokes equation can be used". Evaluate the correctness of the statement. [(CO3)(Evaluate/HOCQ)]

(c) "Shear Stress and Momentum flux are analogous". Justify. [(CO3)(Evaluate/HOCQ)]

6 + 3 + 3 = 12

5. (a) Water with a density of 998kg/m^3 is flowing at a steady mass flow rate through a uniform diameter pipe. The entrance pressure of the fluid is 72kN/m^2 absolute in the pipe, which connects to a pump which actually supplies 167J/kg of fluid flowing in the pipe. The exit pipe from the pump is the same diameter as the inlet pipe. The exit section of the pipe is 3.4m higher than the entrance and the exit pressure is

136kN/m² absolute. The flow in the pipe is turbulent. Calculate the frictional loss in the system. [(CO3)(Apply/IOCQ)]

(b) What do you mean by "Roughness parameter"? [(CO3)(Understand/LOCQ)]

(c) Differentiate between static pressure, dynamic pressure and stagnation pressure. [(CO3)(Analyze/IOCQ)]

6 + 2 + 4 = 12

Group - D

6. (a) Benzene at 37.8°C is pumped from a reservoir at the rate of 9.09m³/hour. The reservoir is at atmospheric pressure. The gauge pressure at the end of the discharge line is 345kN/m². The discharge is 10ft and the suction is 4ft from the reservoir level. The frictional loss in the suction line is estimated to be 3.5kN/ m² and in the discharge line to be 37.9kN/ m². Density of benzene is 865kg/m³ and the vapour pressure at the given temperature is 26.2kN/ m². If the pump manufacturer specifies a NPSHR of 3.05m, will the pump be suitable for this service? [(CO4)(Apply/IOCQ)]

(b) When do we require series operation of centrifugal pumps? Under such situation, whether we connect pumps in series or we use a different configuration? [(CO4)(Understand/LOCQ)]

8 + 4 = 12

7. (a) An orifice meter with orifice diameter 10cm is inserted in a pipe of 20cm diameter through which an oil of density 860kg/m³ is flowing. The differential manometer, connected to the two sides of the orifice meter showed a deflection of 21cm. If the coefficient of discharge for the orificemeter is 0.61, find the discharge through the pipe. [(CO4)(Apply/IOCQ)]

(b) What is the utility of the operating characteristic curve and the system resistance curve in centrifugal pump operation? Explain with a diagram. [(CO4)(Analyze/IOCQ)]

8 + 4 = 12

Group - E

8. (a) A low-pressure separation operation has to be carried out in a packed bed. Two beds are available: one with voidage 0.4, another with 0.7. Which bed will you suggest for carrying out the operation? Justify your recommendation. [(CO5)(Evaluate/HOCQ)]

(b) A rigid solid sphere is falling with a constant velocity in a fluid. The viscosity of the fluid is 0.1Pa.s, g = 10ms^{-2}, particle density = 1180kg m^{-3} and fluid density = 1000kg m^{-3}. Calculate the diameter of the largest sphere that settles in the Stokes' Law regime ($Re_p < 0.1$). [(CO5) (Apply/IOCQ)]

5 + 7 = 12

9. (a) Differentiate between particulate and bubbling fluidization. Which is predominant for fluidization with a gas? [(CO5)(Analyze/IOCQ)]

(b) Differentiate between free settling and hindered settling. In which case is the drag coefficient higher and why? [(CO5)(Analyze/IOCQ)]

(c) "For an exothermic reaction, a fluidised bed reactor is more suitable than a packed bed reactor". Justify. [(CO5)(Evaluate/HOCQ)]

4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	12.5	71.9	15.6

Course Outcome (CO):

After the completion of the course students will be able to

1. Analyze the rheological behavior of fluids and classify them as Newtonian or non-Newtonian fluids.
2. Determine force on submerged bodies and apply the working principle of manometric devices for pressure-drop measurement.
3. Apply continuity equation, momentum balance equation, Bernoulli's equation to solve engineering problems on fluid flow.
4. Categorize different flow measuring devices/fluid moving devices and determine the optimum operating conditions for pumps/blowers/compressors based on the given requirements.
5. Estimate pressure drop in a packed bed as well as minimum fluidization velocity for a given fluidized bed.

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