CHEMICAL ENGINEERING FLUID MECHANICS
(CHEN 2102)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The flow behaviour index is less than 1 for
(a) Newtonian fluids (b) Bingham Plastic fluids
(c) Dilatant fluids (d) Pseudoplastic fluids.

(ii) Navier Stoke's equation deals with the law of conservation of
(a) mass (b) momentum (c) energy (d) none of these.

(iii) 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 a laminar flow, Δp is proportional to
(a) $L \rho \nu^2/D$ (b) $L \mu \nu/ D^2$ (c) $\mu \nu/L$ (d) $D \rho \nu^2/L$

(iv) In case of turbulent flow of fluid in a pipe, kinetic energy correction factor is approx.
(a) (1/2) (b) 1 (c) (3/2) (d) 2

(v) Eddy diffusivity of momentum is proportional to
(a) ρ (b) ρ^{-1} (c) ρ^2 (d) $\rho^{0.5}$

(vi) Priming is required in a centrifugal pump to prevent
(a) prevent air binding (b) increase discharge pressure
(c) decrease cavitation (d) decrease hydraulic loss.

(vii) Which of the following is the most common pump for pumping either raw sewage or sludge?
(a) Magnetic pump (b) Centrifugal pump
(c) Reciprocating pump (d) Gear pump.

(viii) Which valve is used for very fine flow control?
(a) Globe valve (b) Ball valve
(c) Needle valve (d) Diaphragm valve.

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

(x) Fluidization with liquids mostly leads to
(a) Fast fluidization (b) Bubbling fluidization
(c) Particulate fluidization (d) Pneumatic conveying.

Fill in the blanks with the correct word

(xi) The equivalent diameter of an annulus of inner and outer radii R_i and R_0 respectively is _____.

(xii) In case of laminar flow of a Newtonian flow in a smooth tube, the ratio of average velocity to maximum velocity is _____.

(xiii) _____ is an example of a thixotropic fluid.

(xiv) The line joining the fluid elements that have moved past a fixed point is called _____.

(xv) For pumping viscous liquids, we should use a _____ pump.

Group - B

2. (a) Experimental data on a fluid is tabulated below:

Log τ	1.2	1.4	2	2.5	3	3.5	3.75	4	4.5
Log ($\delta u/\delta y$)	0.05	0.08	1	1.4	1.75	1.9	2.1	2.3	2.5

Determine the flow consistency index of this fluid. *[(CO1)(Analyse/IOCQ)]*

(b) A 2-D velocity field is given by the expression $V = 5xi - 3yj$. Here i and j are the unit vectors along the x and y directions respectively. Determine the equation for the streamlines in this flow-field . *[(CO1)(Apply/IOCQ)]*

(c) Give two examples of a Dilatant fluid. *[(CO1)(Remember/LOCQ)]*

5 + 5 + 2 = 12

3. (a) The difference in the two arms of an U-tube manometer is 30 cm. The manometric fluid is mercury (density 13.2 g/cc) and the other fluid is air with a density of 1.225 kg/m^3. What is the pressure difference measured by the manometer? *[(CO2)(Apply/IOCQ)]*

(b) Justify the statement that "Boundary layer separation doesn't occur for flow over a flat plate". *[(CO3)(Evaluate/HOCQ)]*

(c) Explain the concept of "Turbulence intensity". *[(CO3)(Understand/LOCQ)]*

5 + 4 + 3 = 12

Group – C

4. (a) A pump (efficiency 55%) draws a solution (sp. Gravity 1.84) from a storage tank through a pipe of 75 mm inside diameter. The velocity in the suction line is 0.9 m/s. The pump discharges through a pipe having 50 mm inside diameter. The end of discharge pipe is 14.5 m above the level of solution in the storage tank. Friction losses in the entire system are 29 J/Kg.

(i) What is the power of the pump?
(ii) What pressure must the pump develop? *[(CO3)(Evaluate/HOCQ)]*

(b) Derive an expression of the velocity profile in case of Coutte flow without pressure gradient. *[(CO3)(Analyze/IOCQ)]*

(6 + 3) + 3 = 12

5. (a) Water at 25^0C is pumped at a constant rate of 11 m^3/h from a large reservoir resting on the floor to the open top of an experimental absorption tower. The point of discharge is 5.6 m above the floor, friction losses in the 52 mm pipe from the reservoir to the tower is 2.6 J/Kg. At what height in the reservoir must the water level be kept if the pump can deliver only 0.12 kW.
Given data: Density of water = 997 Kg/m^3, viscosity of water = 0.89 cP.
[(CO3)(Evaluate/HOCQ)]

(b) Obtain the equivalent diameter of an annulus of inner and outer radii R_i and R_O respectively. *[(CO3)(Apply/IOCQ)]*

9 + 3 = 12

Group – D

6. (a) Air at 80^0C is forced through a long, circular flue (900 mm diameter). A pitot tube reading is taken at the centre of the flue (assume normal velocity distribution). The pitot-tube reading is 12 mm of H_2O and the static pressure at the point of measurement is 360 mm of H_2O. The coefficient of the pitot tube is 0.98. Calculate the flow of air measured at 30^0C temperature and 1 atm pressure.
Assume the ratio of average to maximum velocity of flowing air is 0.86.
Viscosity of air at 80^0C is 2.00 x10^{-5} Kg/(m.s). *[(CO3)(Evaluate/HOCQ)]*

(b) Discuss the advantages and disadvantages of orifice meter and venturi meter. What is 'vena contracta'? *[(CO4)(Remember/LOCQ)]*

8 + (3 + 1) = 12

7. (a) Justify the reasoning behind expressing centrifugal pump characteristics in terms of head and not in terms of absolute pressure. *[(CO4)(Evaluate/HOCQ)]*

(b) What is the reason for using multi-stage compressors with intercoolers? *[(CO4)(Analyse/IOCQ)]*

(c) What do you understand by the terms "compressor surge" and "compressor stall"? *[(CO4)(Analyse/IOCQ)]*

4 + 4 + 4 = 12

Group - E

8. (a) For a packed bed of porosity 0.35, sphericity 0.9, average diameter of packing 0.01m and density of packing material 5000 kg/m^3, determine the minimum fluidization velocity for fluidization with water. Assume laminar flow. *[(CO5)(Apply/IOCQ)]*

(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 = 1180 kg m^{-3} and fluid density

= 1000 kg 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) A bed of spherical glass beads (density 3000 kg/m^3, diameter 1 mm, void fraction 0.5) is to be fluidized by a liquid of density 1000 kg/m^3 and viscosity 0.1 Pa.s. If the particle Reynolds number is small compared to 1, then find the minimum velocity required to fluidize the bed. *[(CO5)(Apply/IOCQ)]*

(b) Why are fluidized bed reactors more suitable for carrying out catalytic reactions which are exothermic? *[(CO5)(Analyse/HOCQ)]*

(c) Define Drag Coefficient. *[(CO5)(Remember/LOCQ)]*

6 + 4 + 2 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	11.45	48.95	39.58

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.*