FLUIDIZATION ENGINEERING
(CHE3241)

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 void fraction of a fixed bed is defined as _____.
(a) Ratio of particle density to bulk density
(b) Fraction of bed volume not occupied by solids
(c) Ratio of bed height to particle size
(d) Ratio of fluid velocity to minimum fluidization velocity

(ii) When average particle size is equal to dimensionless particle size in fluidized bed then (F_c is the inter-particle cohesive force and F_d is drag force on the particle) _____.
(a) $F_c/F_d<1$ (b) $F_c/F_d>1$
(c) $F_c/F_d = 1$ (d) $F_c/F_d = 0$

(iii) In Geldart classification, Group D particles are characterized by _____.
(a) Small size and low density (b) Fine, cohesive nature
(c) Large size and/or high density (d) Uniform bubbling behavior

(iv) The pressure drop curve for a fluidized bed as gas velocity increases typically shows _____.
(a) Linear increase throughout (b) Sudden decrease after fluidization
(c) Linear rise followed by a plateau (d) Constant value at all velocities

(v) In the bubbling fluidization regime, the average pressure drop across the bed _____.
(a) increases proportionally with gas velocity
(b) decreases due to bed expansion
(c) remains approximately constant
(d) becomes zero

(vi) For a system of seven components and two phases the degrees of freedom to solve the system is equal to _____.
(a) 7 (b) 5
(c) 4 (d) 6

(vii) The ratio between pressure drop at the orifice and the bed pressure drop is equal to _____.

(a) 0.1to 0.3 (b) 0.2 to 0.4
(c) 0.4 to 0.6 (d) 0.6 to 0.8

(viii) The upflow of gas is progressively increased through a 50 cm deep bed of particles in a 30 cm ID vessel. At u_0=3 cm/s the slug will appear at a height from the distributor is _____.

(a) 3.4 cm (b) 2.4 cm
(c) 4.4 cm (d) 5.4 cm

(ix) If freeboard height is less than TDH, according to freeboard-entrainment model complete reflux is _____ the solid density.

(a) equal to (b) more than
(c) less than (d) independent of

(x) The mass transfer coefficient for the exchange between bubble and cloud can be approximated with _____.

(a) surface renewal theory (b) Higbie's penetration theory
(c) Fick's first law (d) Davidson model

Fill in the blanks with the correct word

(xi) Fluidized bed combustion is mainly used for _____ fuel combustion with better heat transfer and lower emissions

(xii) Spouted beds are especially suitable for handling _____ particles.

(xiii) Large or very dense particles that require high gas velocities for fluidization are classified as Geldart Group _____.

(xiv) Typical value for mass transfer coefficient from bubble to cloud is _____.

(xv) The discharge coefficient is equal to _____ for flow (Re>4000) through orifices in tuyere on the distributor of a fluidized bed.

Group - B

2. (a) What is the physical significance of Archimedes number? Mention its importance in a fluidized bed. *[(CO1)(Understand/LOCQ)]*

(b) What is zeta potential of a particle in fluid? Discuss the role played by zeta potential in fluidized bed operation. *[(CO1)(Remember/LOCQ)]*

(c) Air at 300 K is flowing through a fixed bed of spheres having a diameter of 12 mm. The void fraction of the bed is 0.38 and bed has a diameter of 0.6 m and height of 2.5 m. The air enters the bed at 1.1 atm pressure at a rate of 0.36 kg/s. Determine the pressure drop of the bed under steady state condition. Given, viscosity of air 1.85×10^{-5} Pa-s. *[(CO1)(Evaluate/HOCQ)]*

(2 + 2) + (2 + 2) + 4 = 12

3. (a) With schematic diagram show the various contacting pattern between solid and fluid used industrially for fluidized bed operation. *[(CO1)(Remember/IOCQ)]*

(b) With the increase of gas velocity from the bottom distributor of a fixed bed how flow pattern of the solid changes as the bed is fluidized? Discuss with schematic diagram. *[(CO1)(Understand/IOCQ)]*

(c) A fixed bed of 10 cm diameter is filled with spherical particle of 10 kg mass. The bed is fluidized with air at 30°C and 1.2 bar pressure. The particle density is 2500kg/m^3. Predict the pressure drop across the bed at the onset of fluidization. *[(CO1)(Apply/HOCQ)]*

3 + 4 + 5 = 12

Group - C

4. (a) What is minimum fluidization velocity? Explain how the Ergun equation is used to estimate minimum fluidization velocity for given particle-fluid system. *[(CO2)(Explain/IOCQ)]*

(b) A fluidized bed contains spherical sand particles with density ρ_s=2500 kg/$m^3$and mean diameter d_p=200 μm. Air at 20°C has density ρ_f=1.2 kg/$m^3$and viscosity $\mu=1.8\times10^{-5}$ Pa-s. Assume the voidage at minimum fluidization ε_{mf}=0.40. Estimate the minimum fluidization velocity and pressure drop at minimum fluidization. *[(CO2)(Apply/HOCQ)]*

(2 + 5) + 5 = 12

5. (a) For gas-solid fluidized bed how do you determine total pressure drop in the riser. Determine expression for each term separately contributing to toal pressure drop. *[(CO2)(Analyse/IOCQ)]*

(b) A bubbling fluidized bed of height 1.6 m and diameter 0.08 m, is operated with air at air superficial velocity 0.11 m/s with sand particle effective diameter 110 μm. Given that the air density is 1.2 kg/m^3viscosity of air is 1.84×10^{-5} Pa-s and the density of sand is 2600 kg/m^3. The voidage of the bed is 0.55. Consider the particle is circulating with its terminal velocity in the bed. The sphericity of the sand particle is 0.85. Calculate the friction pressure drop between particle and bed wall and friction pressure drop between gas and bed wall. Take the particle friction factor 0.02. *[(CO4)(Apply/IOCQ)]*

6 + (3 + 3) = 12

Group - D

6. (a) A perforated plate distributor is to be designed for a fluidized bed. Determine the fraction of open area needed and the relationship between orifice diameter and number of orifices per area.
Given:
ρ_S=2000 kg/m^3, ρ_g=2 kg/m^3, ε_{mf}=0.48, L_{mf}=3 m, $\mu=2x10^{-5}$ Pa-s, u_0=0.6 m/s, d_t=6 m, $\Delta p_d=0.3\Delta p_b$. *[(CO4)(Apply/IOCQ)]*

(b) Elaborate on different types of distributors through sketches only with proper labelling. *[(CO4)(Remember/LOCQ)]*

6 + 6 = 12

7. (a) During distribution of gas through distributor inside a fluidized bed, what do you understand by dead zone? How do you eliminate dead zone for a particular classification of particle? *[(CO1)(Remember/LOCQ)]*

(b) The upflow of gas is progressively increased through a 0.5-m-deep bed of particles vessel. At u_0 = 0.03 m/s, the bed just fluidizes.

(i) What will be the ID of the vessel for which the minimum superficial velocity to have slug formation is 0.15 m/s?

(ii) At what height in the bed will slugs just appear?

Given:

$$u_{ms} = 0.136\left(\frac{d_p}{d_t}\right)^{0.6324}\left(\frac{d_t}{h}\right)^{0.044}\left(\frac{\rho_s}{\rho_f}\right)^{0.6559}$$

Slug appearance at a height (h) = $1.3d_t^{0.175}$

Fluidized bed porosity (ε_{mf}) = 0.5; spherical particle size (d_p) =0.001 m; density of the particle (ρ_s) =2000 kg/m^3; density of the fluid (ρ_f)=2 kg/m^3; viscosity of the fluid (μ_f) =1.8x10^{-5} Pa-s. *[(CO3)(Apply/IOCQ)]*

(3 + 3) + (4 + 2) = 12

Group - E

8. (a) State the assumption of Kunii-Levenspiel model. *[(CO3)(Remember/LOCQ)]*

(b) Based on the assumption of Kunii-Levenspiel model show that bubble volume fraction =$\delta = \frac{u_0 - u_{mf}}{u_b - u_{mf}(1+f_w)}$, where δ=bubble volume fraction, u_0 is the superficial velocity, u_{mf} is the minimum fluidization velocity, u_b is the bubble velocity and f_w is the wake parameter. *[(CO5)(Evaluate/HOCQ)]*

6 + 6 = 12

9. (a) Based on the Kunii-Levenspiel model find out the unsteady state equation for the mass transfer between bubble and emulsion. *[(CO2)(Remember/LOCQ)]*

(b) For adsorbed hydrocarbon tracer in a 0.9 m ID fluidised bed of cracking catalyst, k_{be}=0.028-0.05 m/s. Compare this result with the interchange rate for nonadsorbed tracer gas (m=0).

Given:

u_0=0.3 m/s; d_b=0.13 m; m=7 (for adsorbed tracer gas); ε_{mf}=0.5; u_{mf}=0.0018 m/s; D_g=9-22x10^{-6} m^2/s

For adsorbed trace: $K_{be} = \frac{6}{d_b}k_{be}$

$$K_{bc} = 4.5\frac{u_{mf}}{d_b} + 5.85\left(\frac{D_g^{0.5}g^{0.25}}{d_b^{1.25}}\right); \quad K_{ce} = 6.77\left(\frac{0.711 D_g \varepsilon_{mf}\sqrt{g d_b}}{d_b^3}\right)^{0.5}$$

[(CO2)(Evaluate/HOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	33.33	39.58	27.09