Name: **Enrolment No:**	UPES UNIVERSITY WITH A PURPOSE

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End-Semester Examination, December 2021

Course: Heterogeneous Catalysis and Catalytic Reactors **Semester: I**

Program: Chemical Engg with Spl. in Process Design Engineering **Time : 3 hrs**

Course Code: CHPD7023 **Max. Marks: 100**

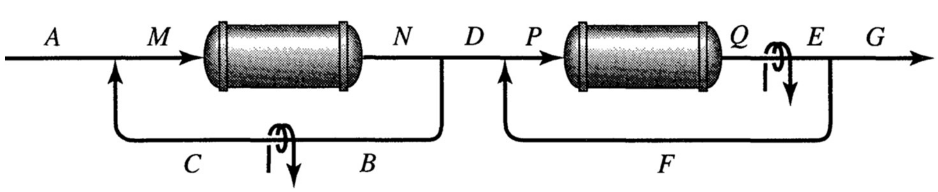
Instructions: The exam is closed book and closed notes. Use of unfair means will be severely dealt with.

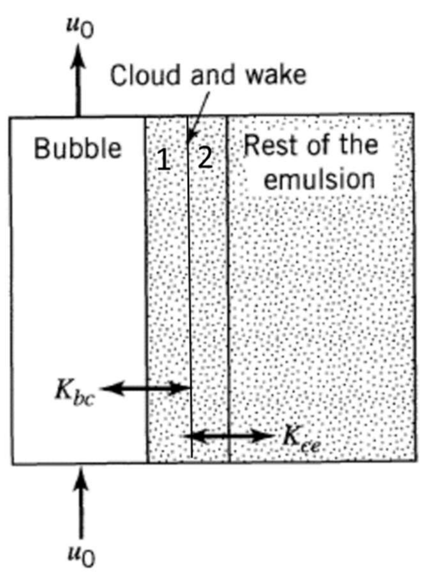
ATTEMPT ALL QUESTIONS

SECTION A

S. No.		**Marks**	**CO**
1	Distinguish between homogeneous and heterogeneous catalysts.	**4**	**CO1**
2	What are the different steps in a heterogeneous catalytic reaction?	**4**	**CO2**
3	What are the limitations of the Langmuir-Hinshelwood kinetics mechanism?	**4**	**CO2**
4	How is the design equation of reaction engineering modified for the case of suspended bed reactors?	**4**	**CO4**
5	State the primary difference between a bubbling fluidized bed reactor and a fast fluidized bed reactor.	**4**	**CO3**

SECTION B

S. No.		**Marks**	**CO**
1	Derive an expression for a Langmuir-type adsorption isotherm where the heat of adsorption decreases linearly with the surface coverage.	**10**	**CO2**
2	What is cold shot cooling? How is the technique used to eliminate the need for inter-stage coolers?	**10**	**CO2**
3	Sketch the X_A vs. T diagram for the two-reactor configuration shown in the figure below. The reaction is exothermic and the following conditions hold. • Conversion in first reactor is two-thirds that in the second reactor • Recycle ratio of first reactor is 1.5 and that in the second reactor is 3.0 • Heat exchangers all cool the reacting fluid 	**10**	**CO3**
4	Derive the population balance equations for the production of catalyst particles with respect to the liquid phase reaction A(aq) +B(aq) → C(s) in a batch reactor. Assume the nucleation rate to be I and the growth rate to be G, which is a function of the particle volume V. Also assume the particle agglomeration kernel to be equal to β.	**10**	**CO4**

SECTION C			
1	The reaction 2A(g) + B(g) ↔ 2D(g) is catalyzed by a heterogeneous catalyst and the reaction proceeds via the following elementary steps. A(g) + S ↔ A.S (1) (Adsorption of A) B(g) + 2S ↔ 2C.S (2) (Dissociative adsorption of B) A.S+C.S ↔ D.S + S (3) (Formation of D) D.S ↔ D(g) + S (4) (Desorption of D) Obtain the expression for the reaction rate if step (2) is the rate limiting step. Take k_i to be the forward rate of the ith reaction and K_i to be the equilibrium constant for the ith reaction. Also let P_α be the partial pressure of the αth reactant in the gas phase and assume ideal gas law to be valid.	**20**	**CO3**
2	Re-derive the expression for the conversion in the Kunii-Levenspiel model for a first-order reaction occurring in a bubbling fluidized bed (BFB) reactor assuming that the cloud + wake layer consists of two separate regions having different properties with cloud layer (1) being in contact with the bubble and cloud layer (2) being in contact with the emulsion. Take δ to be the volume fraction of the bed, f_b, f_{c1}, f_{c2} and f_e to be the volume fraction of solids in bubble, cloud layer 1, cloud layer 2 and emulsion respectively, K_{bc1}, K_{c1c2} and K_{c2e} to be the mass transfer coefficient between bubble and cloud layer 1, cloud layer 1 and cloud layer 2, and cloud layer 2 and emulsion respectively, k''' to be the rate constant of the reaction taken per unit volume of catalyst, H_{BFB} to be the bed height of the bubbling fluidized bed and u_0 to be the superficial velocity of the gas phase.  	**20**	**CO4**