BIOREACTOR DESIGN AND ANALYSIS
(BIOT 3202)

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.
Symbols are of usual significance
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) Damkohler number (Da) is a measure of
(a) pore diffusion (b) film diffusion
(c) combination of (a) and (b) (d) none of (a), (b) & (c).

(ii) The approximate doubling time of a microbial culture where specific growth rate is 0.35/hr. is
(a) 1 hr (b) 3 hr (c) 2 hr (d) 6 hr.

(iii) The best method of control Bioreactor system is
(a) P I control system (b) PID control system
(c) PD control system (d) none of (a), (b) & (c).

(iv) Thiele parameter predicts the effect of
(a) molecular diffusion (b) chemical reaction
(c) pore diffusion (d) combination of (a) and (b).

(v) Monod model follows
(a) zero order kinetics (b) 1st order kinetics
(c) shifting order kinetics (d) 2nd order kinetics.

(vi) Immobilized cell reactors for waste water treatment have the advantage of having/being
(a) higher cell concentration
(b) more stable prevents washout
(c) higher dilution rate before the cells washout
(d) all of the above.

(vii) The kinetics of monoclonal antibodies are described by the type
(a) growth associated (b) non-growth associated
(c) Monod model (d) combination of (a) and (b).

(viii) A batch reactor is characterised by
(a) residence time distribution
(b) variation in extent of reaction and properties of the reaction mixture with time
(c) variation in reactor volume
(d) very low conversion.

(ix) Air-lift fermenter may be design on the basis of
(a) plug flow (b) plug flow with dispersion
(c) completely mixed system (d) segregated model.

(x) A bubble column used for aerobic fermentation is best modelled by
(a) plug flow (b) CSTR
(c) dispersion model (d) plug flow with axial dispersion.

Group – B

2. (a) Describe the method of K_La measurement in a fermenter by dynamic method.
[(CO2) (Illustrate/IOCQ)]

(b) The growth of microorganism is given by the following kinetics:
$\mu = \mu_{max} (1 - e^{-S/K})$
where $\mu_{max} = 0.4\ hr^{-1}$, $K = 6.0\ kg/m^3$, $Yx/s = 0.5$
The microorganism is cultivated in $10\ m^3$ chemostat with a flow rate of $3\ m^3/hr$. Initial substrate concentration is $10\ kg/m^3$. What will be the steady state concentration of substrate and biomass at the exit of the chemostat?
[(CO1) (Evaluate/IOCQ)]

6 + 6 = 12

3. *Pseudomonas sp* has minimum doubling time of 2.4 hrs when grown on acetate (in a chemostat operation that follows the Monod model). Given, Ks=1.3 g/L, Yx/s=0.46 g cell/g acetate, and So= 38g/L.
(i) Find S and X when D=1/2 of Dmax.
(ii) Find cell mass productivity at 0.8 Dmax.
(iii) Find Dwashout.
[(CO2) (Evaluate/HOCQ)]

4 + 4 + 4 = 12

Group - C

4. (a) Derive nth. Order rate equation. *[(CO1) (Remember/LOCQ)]*

(b) An aqueous feed of A and B (400 liter/min, 100 m mol A/lit , 200 m mol B/lit) is to be converted to product in a plug flow reactor. The kinetics of the reaction is represented by
$$A + B \rightarrow R, \qquad -r_A = 200\ C_A C_B\ [\text{mol/lit min}]$$
Find the volume of the reactor for 98.5% conversion of A to product.
[(CO4) (Understand/IOCQ)]

2 + 10 = 12

5. A mixed flow reactor (2 m^3) processes an aqueous feed (100 liter/min) containing Reactant A (C_{A0} = 100 m mol/lit) . The reaction is reversible and represented by $A \rightarrow R$ (reversible), $-r_A = 0.04\ C_A - 0.01\ C_R$ [mol/ lit min]
What is the equilibrium conversion and the actual conversion in the reactor?

[(CO4) (Remember/IOCQ)]

2 + 10 = 12

Group - D

6. The concentration reading given below represents a continuous response to a pulse input into a closed vessel which is to be used as a chemical reactor. Calculate the mean residence time of the fluid in the vessel and construct C- curve and E - curve (calculate area under the curve).

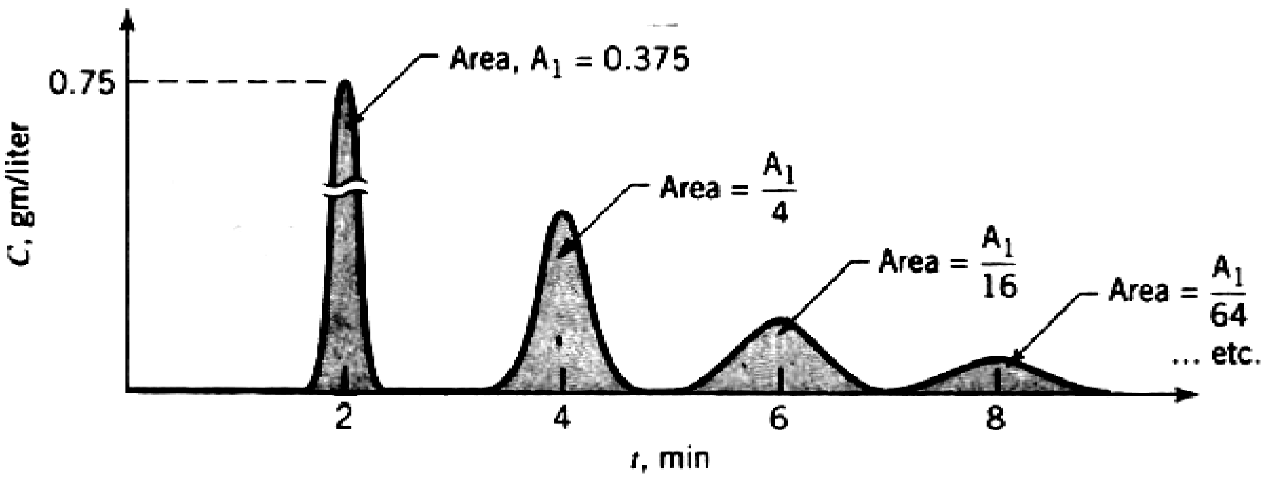
Time t (min)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	infinite
C_{pulse} (gm/lit)	0	3	5	6	7	8	6	5	4	3	2	1	0.5	0.25	0.0

[(CO5) (Analyze/HOCQ)]

2 + 4 + 6 = 12

7. (a) Explain the significance of C –curve and E - curve. *[(CO5) (Remember/LOCQ)]*

(b) A large tank (860 liters) is used as a gas-liquid contactor. Gas bubbles up through the vessels and out from the top, liquid flows in at one part and out the other at 5 lit./sec to get an idea of the flow pattern of liquid in this tank a pulse of tracer (M = 150 gm) is injected at the liquid inlet and measured at the outlet, as shown below.



(i) Is this a properly done experiment ?
(ii) If so, find the liquid fraction in the vessel
(iii) Determine the "E" curve for the liquid. *[(CO5) (Analyse/HOCQ)]*

3 + 9 = 12

Group – E

8. (a) Define enzyme. *[(CO1) (Remember/LOCQ)]*

(b) Substrate A and enzyme E flow through a M F R (V= 6 lit.). From the entering and leaving concentrations and flow rate find a rate equation to represent the action of enzyme on substrate.

C_{E0} (mol/lit.)	C_{A0} (mol/lit.)	C_A (mol/lit.)	v (lit./min)
0.02	0.2	0.04	3.0
0.01	0.3	0.15	4.0
0.001	0.69	0.60	1.2

[(CO3) (Understand/IOCQ)]

2 + 10 = 12

9. (a) Explain the operating principles of the following :
Membrane bioreactor, Fed batch system. *[(CO3) (Remember/IOCQ)]*

(b) A → product
Derive the first order and second order rate equation and show the result graphically in terms of C_A and X_A. *[(CO1) (Remember/IOCQ)]*
[(CO1) (Remember /IOCQ)]

(3 + 3) + (3 + 3) = 12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*7.29*	*58.33*	*34.37*

Course Outcome (CO):

After completing the course, the students will be able to:
1. Develop basic concept of reaction engineering.
2. Understand basic concepts of bioreactor design and analysis.
3. Understand the basic operating principles of bioreactors.
4. Interpret batch reactor data with reference to basic reactor design for a single reaction ideal reactor.
5. Analyze non-ideal flow pattern with reference to residence time distribution (RTD) and dispersion numbers (D/UL)
6. Analyze basic cell growth data to verify Monod model.

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