BIOREACTOR DESIGN AND ANALYSIS
(BIOT 3203)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.
Symbols are of usual significance

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) Which type of reactor, aeration is generally accomplished in a separate vessel?
(a) Fluidised bed (b) Trickle bed
(c) Packed bed (d) Stirred and air-driven reactor.

(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) PI control system (b) PID control system
(c) PD control system (d) none of these.

(iv) A chemostat can be operated at dilution rate which is
(a) higher than the specific growth rate
(b) lower than the specific growth rate
(c) equal to the specific growth rate
(d) not related to the specific growth rate.

(v) In which of the following bioreactors, the particles are not immersed in liquid?
(a) Airlift bioreactor (b) Stirred vessel
(c) Packed bed (d) Trickle bed .

(vi) The volumetric mass transfer coefficient is related to
(a) oxygen transfer (b) packed bed absorption
(c) diffusion rate (d) none of the above.

(vii) Immobilized cell reactors for wastewater treatment have the advantage of having/being
(a) higher cell concentration
(b) more stable and prevent washout
(c) higher dilution rate before the cells washout
(d) all of the above.

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

(ix) If the reaction rate doubles as the concentration of the reactant A increases by a factor of 2, what is the order of the reaction with respect to A?
(a) First order (b) Zero order
(c) Pseudo first order (d) none of these.

(x) The rate limiting step in the movement of oxygen from the gas phase in a bubble to the medium is the movement of oxygen molecules through
(a) gas-liquid interface (b) bulk liquid
(c) gas phase (d) none of these.

Group – B

2. (a) Consider a culture of bacteria that secrete a product in a chemostat operated at steady state. The specific growth rate of biomass is described by the Monod equation satisfactorily. Rate of product formation is described by Luedeking-Pirate kinetics.

$$\frac{dP}{dt} = (\alpha\mu + \beta)X$$

This system is well characterized. Values of the different constants are as follows:

$Y_{X/S}$ = 0.4 g/g, μ_{max} = 0.7 h^{-1}, K_S = 0.2 g/L, α = 0.2 g/g, β = 0.3 g/g.h,

$Y_{P/S}$ = 0.8 g/g, S_0 = 10 g/L, F = 15 L/hr, V = 500L.

If the system is operated at steady state and the liquid feed to the chemostat is sterile, then calculate the following:
(i) Steady state substrate concentration.
(ii) Biomass concentration at steady state.
(iii) What is the productivity of the process?
(iv) If the volume of the reactor is kept constant, what value of the flow rate would cause washout of the reactor?

(b) What is the significance of dispersion number and Sherwood number?

8 + 4 = 12

3. (a) What are the parameters that affect the volumetric mass transfer coefficient?

(b) A fermentor has to attain k_{La} = 25 hr^{-1}. With its maximum agitator speed at 0.5 m^3 gas/min. *E. Coli* with specific oxygen consumption rate, q_{o_2} = 10 moles of O_2/kg dry wt cells are to be cultured. The critical dissolved oxygen concentration is 0.2 g/m^3. The solubility of oxygen from air in the fermentation broth is 8 g/m^3 at 30°C.

(i) What maximum concentration of *E.Coli* can be sustained in the reactor?

(ii) What concentration of *E.Coli* can be attained if pure oxygen is used?

5 + 7 = 12

Group – C

4. (a) Find the overall order of the irreversible reaction — $2H_2 + 2NO \rightarrow N_2 + 2H_2O$ from the following constant-volume data using equimolar amounts of hydrogen and nitric oxide:

Total pressure, mm H_g	200	240	280	320	360
Half-life, sec	265	186	115	104	67

(b) Derive first order rate equation from Michaelis-Menten equation

10 + 2 =12

5. A mixed flow reactor (2 m^3) processes an aqueous feed (100 liter/min) containing reactant A (C_{AO} = 100 m mol/liter). The reaction is reversible and presented by

A ← → R, $-r_A = 0.04C_A - 0.01C_R$ mol / liter. min.

What is the equilibrium conversion and the actual conversion in the reactor?

12

Group – D

6. (a) The concentration readings given below represent a continuous response to a pulse input into a closed vessel.

t (min.)	0	5	10	15	20	25	30	35
C_{pulse} (gm/lit)	0	3	5	5	4	2	1	0

This vessel is to be used as a reactor for the decomposition of a liquid "A".

A→ Products, $-r_A = K C_A$, $K = 0.307 min^{-1}$

Estimate the fraction of the reactant unconverted in the real reactor and compare this with the fraction unconverted in a P F R of same size.

3 + 9 = 12

7. (a) Substrate A and enzyme E flow through a mixed flow reactor (V = 6 liter). From the entering and leaving concentrations and flow rate find a rate equation to represent the action of enzyme on substrate.

C_{E0}, mol/liter	C_{A0}, mol/liter	C_A, mol/liter	v, liter/hr
0.02	0.2	0.04	3.0
0.01	0.3	0.15	4.0
0.001	0.69	0.60	1.2

(b) Define dispersion number.

9 + 3 = 12

Group – E

8. (a) What are the limitations of cell immobilization? What is active and passive cell immobilization?

(b) What is membrane fouling? What are the two important configurations of membrane bioreactor?

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

9. (a) In a fed-batch culture operating with intermittent addition of glucose solution, values of the following parameters are given at time t= 2 h, when the system is in quasi-steady state.

V = 1000 ml, $F = \frac{dV}{dt}$ = 00 ml/h, S_0 = 100 g glucose/l, μ_{max} = 0.3 h^{-1}, K_S = 0.1 g glucose/l, $Y^M_{X/S}$ = 0.5 gdw cell/ g glucose, X^t_0 = 30 g

(i) Find initial volume of the culture (V_0).

(ii) Determine the concentration of growth-limiting substrate in the vessel at quasi steady state.

(iii) Determine the concentration and total amount of biomass in the vessel at t = 2 h (at quasi-steady state).

(iv) If q_P = 0.2 g product/g cells, P_0 = 0, determine the concentration of product in the vessel at t = 2 h.

(b) What is a photobioreactor? What are the culturing techniques in a photobioreactor?

8 + (1 + 3) = 12