MODELING AND SIMULATION IN BIOPROCESS
(BIOT 6131)

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.

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 of the following is not a cell growth model?
(a) Tessier model (b) Moser model
(c) Monod model (d) Michaelis Menten model.

(ii) Two compartment model is
(a) A type of structured model
(b) Where G component corresponds to cellular enzymes
(c) Overtly simplistic
(d) All the above.

(iii) What is the basic assumption in Briggs-Haldane model of enzyme substrate reaction?
(a) Rapid equilibrium
(b) Quasi steady state
(c) Substrate and inhibitor should be structurally similar
(d) None of the above.

(iv) In the accelerated phase, cell starts to
(a) increase and the division rate increases to reach a maximum
(b) decrease and the division rate increases to reach a maximum
(c) increase and the division rate decreases to reach a maximum
(d) increase and the division rate increases to reach a minimum.

(v) Monod model is
(a) a structured, segregated model
(b) an unstructured, segregated model
(c) a deterministic model
(d) an empirical model.

(vi) Penicillin is produced in _____ phase of growth.
(a) lag phase (b) log phase
(c) stationary phase (d) death phase

(vii) Which of the following statements applies to the bisection method used for finding roots of functions?
(a) Converges within a few iterations
(b) Guaranteed to work for all continuous functions
(c) Is faster than the Newton – Raphson method
(d) Requires that there be no error in determining the sign of the function.

(viii) Errors may occur in performing numerical computation on the computer due to
(a) rounding errors
(b) power fluctuation
(c) operator fatigue
(d) all of these.

(ix) The modified Euler's formula is the same as
(a) Runge-Kutta formula of the first order
(b) Runge-Kutta formula of the second order with b=1
(c) Runge-Kutta formula of the second order with b= ½
(d) none of the above.

(x) Which of the following is not an assumption for model for determination of concentration of oxygen in liquid phase for metabolic oxygen utilization?
(a) Rate of oxygen utilization= rate of oxygen transfer
(b) For sparingly soluble species the two equilibrated interfacial concentrations are related through linear relationship
(c) For sparingly soluble species the two equilibrated interfacial concentrations are related through non-linear relationship
(d) Oxygen transfer into cells from the bulk medium follows two film theory.

Group - B

2. (a) Differentiate between deterministic models and stochastic models.
[(CO1)(Differentiate/IOCQ)]
(b) Derive a mechanistic mathematical model of a process occurring in a living system.
[(CO2)(Derive/IOCQ)]
4 + 8 = 12

3. Develop a deterministic mathematical model for an enzyme-substrate reaction by using both the approaches. [(CO1)(Derive/IOCQ)]
(6 + 6) = 12

Group - C

4. A medium containing a vitamin is to be sterilized. Assume that the number of spores initially present is 10^5 spores/L. The values of the Arrhenius constant and E_{0d} for the spores are
E_{0d} = 65kCal/gmol
A = $10^{36}min^{-1}$.
For the inactivation of the vitamin, the values of E_{0d} and A are
E_{0d} = 10 kCal/gmol
A = 104 min^{-1}.

The initial concentration of the vitamin is 30 mg/L. Compare the amount of active vitamin in the sterilized medium for 10 L and 10,000 L fermenters when both are sterilized at 121˚C when we require in both cases that the probability of an unsuccessful fermentation be 0.001. Ignore the effects of the heat-up and cool-down periods. [(CO4)(Solve/HOCQ)]

12

5. (a) Create a model to determine sludge age in the activated sludge process. [(CO4)(Remember/LOCQ)]

   (b) What is BOD? [(CO4)(Remember/LOCQ)]

8 + 4 = 12

Group - D

6. (a) Derive a model equation to find out productivity in a Fed Batch system to overcome substrate inhibition.

   (b) What will be biomass balance equation and substrate balance equation for a fed batch system, where, both biomass and substrate will be expressed in terms of total mass (mg)? [(CO1)(Derive/IOCQ)]

6 + 6 = 12

7. In a fed batch culture operating with intermittent glucose addition values of the following parameters are obtained at time t=2 hrs, when the system is under quasi-steady state. V=1000 ml, F=200 ml/hr, So=100 g/L, μ_{max}= 0.3 hr^{-1}, Ks=0.1 g/L, Yx/s=0.5, Xo=30 gm. Find
   (i) initial volume of culture
   (ii) determine the concentration of growth limiting substrate in the vessel at quasi steady state
   (iii) determine the concentration of total amount of biomass in the vessel at t=2 hr
   (iv) if qp=0.2 g product/(hr. gm cells), Po=0, determine the concentration of production the vessel at t=2 hr. [(CO5) (Derive/IOCQ)]

12

Group - E

8. Solve the following equation by Newton–Raphson method.
   $X^3-5x+3=0$. [(CO6)(Solve/LOCQ)]

12

9. In a process of Lactic acid fermentation, the production of LA inhibits the microbial growth in non–competitive manner for which the following data is obtained. Find the kinetic constants of the microbial growth.

So=2000 mg		So=200 mg	
μ (hr^{-1})	I (mg)	μ (hr^{-1})	I (mg)
0.045	0	0.015	0
0.030	12	0.0098	12
0.019	17	0.0067	27

[(CO6)(Solve/HOCQ)]

12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	50	25

Course Outcome (CO):

After completing this course, students will be able to:
1. Understand the basic concepts of modeling and simulation
2. Differentiate between modeling and simulation
3. Classify mathematical models into deterministic and stochastic, structured and unstructured, segregated and non-segregated models
4. Derive mathematical models for various processes in the biological system
5. Apply different numerical techniques towards simulation of bioprocesses
6. Develop mathematical models for a given bioprocess

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