MODELLING AND SIMULATION IN BIOPROCESS
(BIOT 6131)

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

(iii) Michaelis-Menten is
(a) a deterministic model (b) a probabilistic model
(c) an empirical model (d) none of (a), (b) & (c).

(ii) Stationary phase is described as
(a) no further increase in the cell population after a maximum value
(b) deceleration of growth and division rate after the growth rate reaches a maximum
(c) acceleration of growth and division rate after the growth rate reaches a maximum
(d) deceleration of growth and division rate after the growth rate reaches a minimum.

(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 (a), (b) & (c).

(iv) Sterilization kinetics follows
(a) a deterministic model (b) a probabilistic model
(c) an empirical model (d) none of (a), (b) & (c).

(v) Leudeking-Piret model used for
(a) production kinetics (b) substrate utilization kinetics
(c) growth kinetics (d) none of (a), (b) & (c).

(vi) Wash out in steady state fermentation occurs when
(a) Dilution rate is less than specific growth rate
(b) Dilution rate is higher than specific growth rate
(c) Cell concentration reaches maximum
(d) Specific growth rate is maximum.

(vii) A completely mixed continuous stirred-tank reactor for the cultivation of cells is called?
(a) Turbidostat (b) Chemostat
(c) Haemostat (d) Thermostat.

(viii) Which of the following equation describes the relationship between μ and residual growth limiting substrate?
(a) Eyring equation (b) Van't Hoff equation
(c) Arrhenius equation (d) Monod equation.

(ix) If one starts with 10,000 (10^4) cells in a culture that has a generation time of 2 h, how many cells will be in the culture after 4 and 48 h?
(a) 4.0×10^4 cells, 1.7×10^{11} cells (b) 4.2×10^4 cells, 1.1×10^{11} cells
(c) 4.6×10^4 cells, 1.5×10^{11} cells (d) 4.8×10^4 cells, 1.3×10^{11} cells.

(x) What do you mean by "Quasi steady state"?
(a) Cell concentration remains virtually constant
(b) Cell concentration is virtually variable
(c) Total biomass remains constant with time
(d) Total biomass decreases with time.

Fill in the blanks with the correct word

(xi) Penicillin is produced in _____ phase of growth.

(xii) At steady state dilution rate is equal to _____.

(xiii) Simulation technology is used to describe the _____ of a model.

(xiv) The rate of mass accumulation in a chemostat under steady state condition is _____.

(xv) The equation f(x)=0 is given as $x^3 - x^2 + 4x - 4 = 0$. Considering the initial approximation at x=2 then the value of next approximation correct upto 2 decimal places (using Newton-Raphson method) is given as _____.

Group - B

2. (a) An autoclave malfunctions and the temperature reaches only 119.5℃ The sterilization time at the maximum temperature was 20min. The jar contains 10L of complex medium that has 10^5spores/L. At 121℃ k_d= $1min^{-1}$ and E_{0d}= 90Kcal/gmol. What is the probability that the medium is sterile? *[(CO2)(Apply/IOCQ)]*

(b) What type of mathematical model was used to solve the above problem *[(CO1)(Remember/LOCQ)]*

10 + 2 = 12

3. (a) What are the advantages of simulation technology? *[(CO1)(Remember/LOCQ)]*

(b) Differentiate between a stochastic model and a deterministic model. *[(CO1)(Differentiate/IOCQ)]*

(c) What are the factors that determine cell population kinetic modeling? *[(CO1)(Remember/LOCQ)]*

4 + 4 + 4 = 12

Group - C

4. A medium containing a vitamin is to be sterilized. Assume that the number of spores initially present is 10^5spores/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}=10kCal/gmol
A=10^4min^{-1}.
The initial concentration of the vitamin is 30mg/L. Compare the amount of active vitamin in the sterilized medium for 10L and 10,000L 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.

[(CO3)(Analyse/IOCQ)]

12

5. (a) Establish a model for determination of sludge age in activated sludge process.

[(CO3)(Derive/IOCQ)]

(b) What is BOD? *[(CO1)(Remember/LOCQ)]*

10 + 2 = 12

Group - D

6. (a) Two microorganisms are co-cultured in a bioreactor, where one carbon source is used by both microorganisms and other carbon source is used by only second microorganism.
   (i) Write the equations to express substrate degradation rate for the above case. Explain the significance of all the terms used in the modelled equations.
   (ii) What would be the specific growth rate of the first microorganism?

[(CO4)(apply/IOCQ)]

(b) Define in context to chemostat (i) flow recycle ratio (ii) cell recycle ratio.

[(CO3)(remember/LOCQ)]

(6 + 3) + 3 = 12

7. In a chemostat with recycle, the feed flow rate and the culture volumes are F= 100 mL/hr and V= 1000 ml, respectively. The system is operated under glucose limitation, and yield coefficient Yx/s is 0.5 gdw cells/ gm substrate. Glucose concentration in the feed is So=10 g glucose /L. The kinetic constant of the organisms are μ_m=0.2 hr^{-1}, Ks= 1 gm glucose /L. The value of C (the ratio of cell concentration in the recycle stream to the cell concentration in the reactor effluent) is 1.5. The recycle ratio α = 0.7. The system is at steady state.
   (i) Find the substrate concentration in the recycle stream (s).
   (ii) Find the specific growth rate (μ_{net})of the organism. *[(CO4)(Apply/HOCQ)]*

(6 + 6) = 12

Group - E

8. Ethanol formation from glucose is accomplished in a batch culture and the following data were obtained:

Time (hr)	Glucose g/L	Biomass (X, gm/L)
0	100	0.5
2	95	1.0
5	85	2.1
10	58	4.8
15	30	7.7
20	12	9.6
25	5	10.4

By fitting the biomass data in the logistic equation, determine the carrying capacity coefficient K, If $X\alpha$ =10.7 g/L. *[(CO6,CO5)(Compute/HOCQ)]*

12

9. Solve the following equation by Newton –Raphson Method.

$X^4 + x^3 + 3x = 7$

Assume $x_o = 1$ *[(CO6)(Solve/IOCQ)]*

12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	26	49	25

Course Outcome (CO):

After the completion of the 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 andunstructured, 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.*