Exam.Code:0912
Sub. Code: 7023

1079

B.E. (Biotechnology) Eighth Semester

BIO-804/814: Modeling and Simulation of Bio-Processes

Time allowed: 3 Hours Max. Marks: 50

NOTE: *Attempt five questions in all, including Question No. I which is compulsory and selecting two questions from each Section. State clearly your assumptions.*

x-x-x

1) Write briefly: *(1×10 = 10)*

a) Define useful measurable parameter is the respiratory quotient *(RQ)*?
b) What do you understand by data smoothing?
c) Define metabolic engineering.
d) What is the significance of metabolic Engineering?
e) What is product yield with respect to substrate?
f) Write down unsteady state mass balance for dynamic model of (CSTR)?
g) What do you understand by structured and un-structured models?
h) Write down characteristics of fed batch reactor.
i) Write down advantage and disadvantage of batch reactor.
j) A chemostat has a liquid volume of 4liters and is being fed at a rate of 8 liters per hour. Find dilution rate for this reactor.

SECTION-A

2. A) 1.5 kg salt is dissolve in water to make 100 liters. Pure water runs into a tank containing this solution at a rate of 5 l $min.^{-1}$; salt solution overflows at the same rate. The tank is well mixed. How much salt in the tank at the end of 15 min.? Assume the density of salt solution is constant and equal to that of water.

B) Assume that a reaction in the tank part (a) consume salt, at a rate given by the first order equation

$$r = k_1 C_A$$

Where k_1 is the first-order reaction constant and C_A is the concentration of salt in the tank. Derive an expression for C_A as a function of time. If $k_1 = 0.02$ $min.^{-1}$, how long does it take for the concentration of salt to fall to a value $\frac{1}{20}$ the initial level. *(4, 6)*

3. A) An electric heating-coil is immersed tank. Solvent at 15°C with heat capacity 2.1 kJ kg^{-1}°C is fed into the tank at of 15 kg h^{-1}. Heated solvent is discharged at the same flow rate. The tank is filled initially with 125 kg cold solvent at 10°C. The rate of heating by electric coil is 800 W. Calculate the time required for the temperature of solvent to reach 60°C.

B) The simple first order conversion of an enzyme A into product B may be complicated by the conversion B into new product C. This can be describing by the equation:

$$A \xrightarrow{K_1} B \xrightarrow{K_2} C$$

Each step of the reaction will have a unique rate constant K_1 for the conversion of an enzyme A into B and K_2 for the conversion of B to C. if the initial concentration of A at time A_0. Derive the concentration of A, B, and C in terms of time and rate constant. Also plot the concentration profile of reactant with time. *(5, 5)*

P.T.O.

4. A) Dean and Hinshelwood proposed two-compartment model shown bellow for a bacterial cell.

$$\frac{dX_1}{dt} = \alpha_1 X_2 \qquad \frac{dX_2}{dt} = \alpha_2 X_1$$

The rate of changes of component X_1 and X_2 follow the equations shown in the boxes above with α_1 and α_2 being kinetic constants. Solve this model of X_1 and X_2 with time t for the cases:

$$\alpha_1 = \alpha_2 \quad ; \quad \text{and} \quad \alpha_1 > \alpha_2$$

B) Using the following model equations predict the time. Clearly state all assumptions.

$$\frac{dx}{dt} = \mu x \ , \qquad \mu = \frac{\mu_{max} S}{K_s + S} \ , \qquad Y_{X/S} = \frac{\Delta X}{\Delta S}$$

C) After an 8 mg injection of dye, the readings of dye concentration in mg/L at two second intervals are shown in the table. Use Simpson's 3/8th rule to estimate the cardiac output.

t	0	2	4	6	8	10	12	14	16	18	20
Dye conc. (mg/L)	0	2.4	5.1	7.1	7.6	5.4	3.9	2.3	1.6	0.7	0

(3, 3, 4)

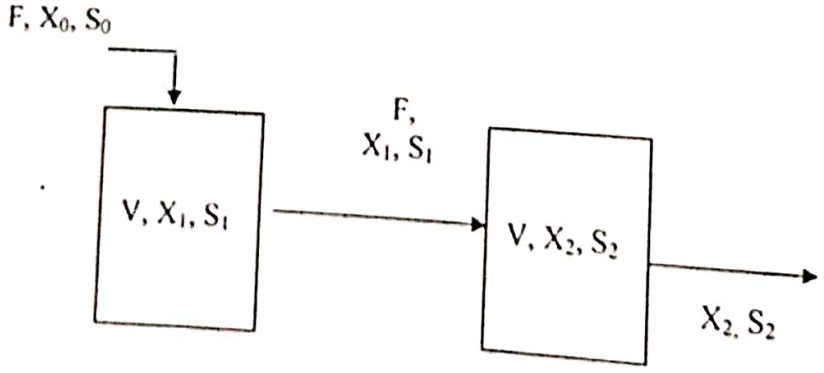
SECTION-B

5) Discuss the balance equations for each component as given two chemostat model (Fig.1) arranged in series. Consider an organism which follows the Monod equation where $\mu_m = 0.5 h^{-1}$ and $K_S = 2$ g/l

a) In continuous perfectly mixed vessel at steady state with no cell death if $S_0 = 50$ g/l and $Y_{X/S} = 1$(g cells/g substrate), what dilution rate D will give the maximum total rate of cell production?

b) For the same value of D using tanks of the same size, what is concentration of cell biomass and substrate concentration in first and second vessels?

(10)



6. A) A feed solution containing a enzyme A ($C_A = 1$ kmolm^{-3}) is fed to a CSTR or to a PFR at a volumetric flow rate of 0.001 m^3 s^{-1}, and converted to product P in the reactor. The first-order reaction rate constant is 0.02 s^{-1}. Determine the reactor volumes of the CSTR and PFR required to attain a fractional conversion of A, $X_A = 0.95$.

B) In fed-batch fermentor, substrate stream is added continuously to the reactor. Develop a suitable mathematical model with the following kinetics:

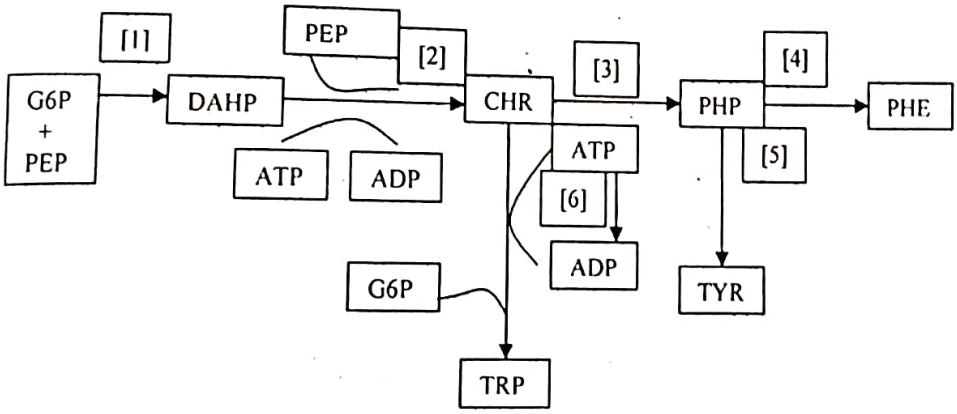
$$r_X = \mu X\,, \quad \mu = \frac{\mu_{max} S}{K_S + S}, \qquad r_S = -\frac{r_X}{Y}\,, \; D = \frac{F_0}{V}$$

Convert the model in the dimensionless using the following transformation:

$$V' = \frac{V}{V_0}, \quad X' = \frac{X}{YS_0}\,, \quad S' = \frac{S}{S_0}\,, \; F' = \frac{F_0}{V_o\mu}\,, \; K'_S = \frac{K_S}{S_0}\,, \; \mu' = \frac{\mu}{\mu_m}\,, \; F' = \frac{dV'}{dt'} \text{ and } t' = t\mu_m$$

(4, 6)

7. A) The metabolic pathway for aromatic amino acid synthesis is given bellow; identify the substrates, products, intermediates. Construct the stoichiometric model and develop the matrix form.



The simplified metabolic pathway for aromatic amino acid synthesis by *S.cerevisiae.*
The chemical species are G6P = glucose-6-phosphate, PEP = phosphenol pyruvate, DHAP= 3-deoxy-D-arabinoheptulosonate-7-phosphate, CHR = chroismatec, PHP = prephanate, PH E= phylalanin, TYR = tyrosin, TRP = tryptophan.

B) The *Zymomonas mobilis* used to convert glucose to ethanol in batch fermenter under anaerobic conditions. The yield of biomass from substrate is 0.06 g g^{-1}, specific rate of product formation is 3.4 h^{-1}, and maximum specific growth rate of *Zymomonas mobilis* is approximately 0.3 h^{-1}. 5 g bacteria are inoculated into 50 liters of medium containing 12 gL^{-1}. Determine the batch culture time required to

I. Produce 15 g biomass
II. Achieve 90% substrate conversion and
III. Produce 100 g ethanol.

(5, 5)

x-x-x