KUMARAGURU college of technology
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Register Number:……..…

MTECH DEGREE EXAMINATIONS: DEC 2022

(Regulation 2018)

First Semester

BIOTECHNOLOGY

P18BTI1202: Bioprocess Modelling and Simulation

COURSE OUTCOMES

CO1: Conceptualize mathematical and engineering concepts in bioprocess modeling and simulation

CO2: Identify and analyze mathematical model in biochemical engineering systems

CO3: Select the appropriate components of SuperPro Design software

CO4: Apply the concepts of MATLAB and SIMULINK in bioprocess systems.

CO5: Ability to solve and analyze data using MATLAB

CO6: Apply, design and interpret process flowsheeting using SuperPro Design software

Time: Three Hours **Maximum Marks: 100**

Answer all the Questions:-

PART A (10 x 1 = 10 Marks)

1. Can the nitrogen content of bacteria and fungi be compared based on their typical ranges? CO1 [K_3]

   Assertion (A): The nitrogen content of bacteria is slightly higher than that of fungi.

   Reason (R): The typical range of nitrogen content for bacteria is 11-14%, while that for fungi is 6.3-9.0%.

   a) Both A and R are true and R is the correct explanation of A
   b) A is false but R is true
   c) Both A and R are true but R is not a correct explanation of A
   d) Both are false

2. A continues reactor has a liquid volume of 2 liters and is being fed at a rate of 4 liters per hour. The dilution rate for this reactor would be CO1 [K_2]

   a) 2 liters
   b) 2 $hours^{-1}$
   c) 4 liters per hour
   d) 8 liter per hour

3. What happens during the lag phase? CO2 [K_2]

   a) Cells synthesis new proteins and membrane components
   b) Cells just growing
   c) Lag phase does not really grows
   d) Cells produce antibiotics to kill competing organism

4. Matching type item with multiple choice code CO2 [K_3]

List I (method)	List II (Process)
A. Fermentation	I. The raw material or compound that is consumed by microorganisms or cells in a bioprocess.
B. Bioreactor	II. The microorganisms or cells introduced into a bioprocess to initiate the reaction.
C. Inoculum	III. The process by which microorganisms or cells convert organic substrates into useful products.
D. Substrate	IV. A vessel or container in which biological reactions take place.

A	B	C	D
a)	I	II	III
b)	I	III	I
c)	II	I	IV
d)	III	IV	II

5. Which of the following would be best described as a secondary metabolite? CO3 [K_3]

1. Penicillin
2. Ethanol
3. Acetic Acid from oxidation of ethanol
4. Sugars

a) 1 only
b) 2 only
c) Both 3 and 4
d) Both 2 and 3

6. Which of the following is not true with regards to the Monod and the Michaelis Menten Model? CO3 [K_2]

a) The Monod model was derived from an analysis of the mechanism of microbial growth
b) The Michaelis Menten Model was derived from a curve fitting exercise
c) The Michaelis Menten model was derived from a analysis of the mechanism of microbial growth
d) The Monod model was derived from a curve fitting exercise

7. What is the most effective approach for maximizing biomass productivity of *Bacillus subtillus,* given its high biomass yields at low glucose concentrations and high dissolved oxygen concentrations? CO5 [K_3]

i. Batch fermenter with a high initial glucose concentration
ii. Continuous fermenter with a low initial glucose concentration

iii. Fed batch fermenter

iv. Increase the surface area of the reactor

a) ii, iii b) i, iv

c) iii d) iii, iv

8. Assertion (A): Increasing the agitation speed in a bioreactor can improve oxygen transfer rates. CO4 [K_3]

Reason (R): Agitation helps to break up oxygen bubbles and distribute them throughout the culture medium, leading to increased oxygen transfer rates

a) Both A and R are true and R is the correct explanation of A

b) A is false but R is true

c) Both A and R are true but R is not a correct explanation of A

d) Both are false

9. The degree of reduction for acetic acid is CO5 [K_2]

a) 9 b) 4

c) 6 d) 2

10. Arrange the tasks of modeling from the following set of data CO6 [K_2]

I. Analyse data and Evaluate results

II. Refine research question and develop hypotheses

III. Design experiment(s) to test hypotheses and collect data

IV. Refine model and hypotheses

a) I – II- III -IV b) III-IV-II-I

c) II –III- -I -IV d) IV-II-I-III

PART B (10 x 2 = 20 Marks)

11. Write the advantages of developing the mathematical models for specific process CO1 [K_2]

12. Summarize advantage and disadvantage of batch, continuous and fed batch operation CO1 [K_2]

13. Differentiate structured model and unstructured model with suitable examples CO2 [K_2]

14. Calculate the degree of reduction for methane and Lactic acid CO2 [K_2]

15. What do you mean by the system is in equilibrium CO3 [K_2]

16. Define copiotroph and oligotroph. CO3 [K_2]

17. Plot two Michaelis-Menton plot and mention the region for first order and zeroth order CO4 [K_2]

18. What do you mean by Techno-Economical Analysis (TEA)? CO6 [K_1]

19. What do you understand about the direct cost estimation used in TEA? CO6 [K_2]

20. A homogenization with a rated grind rate of 10,000 kg/hr cost $500,000 in 2010. What would a homogenization with a grind rate of 15,000 kg/hr cost in 2023? Use a power law coefficient of 0.6 for sizing. By assuming 1Rs in 2010 = 1.25 Rs at 2023. CO5 [K_2]

PART C (10 x 5 = 50 Marks)

21. What are the different mathematical models used in biological systems, and how do they compare to one another? CO1 [K_2]

22. What is the general procedure for developing mathematical models of biological systems? CO2 [K_2]

23. Describe the mathematical relationship between cell formation and substrate consumption batch fermentation? CO2 [K_2]

24. What is the accuracy of two steam-sterilizable dissolved oxygen probes, as determined by measuring the oxygen level in a gas-sparged solution known to have a dissolved oxygen tension of 50% air saturation, and analyzing the resulting data? CO1 [K4]

Probe	Measurement 1	Measurement 2	Measurement 3	Measurement 4	Measurement 5
1	47.5	48.5	47.8	47.3	48.0
2	45.2	46.1	45.5	45.7	46.0

(a) Calculate the sample mean, standard deviation, and standard error for each probe.

(b) Which probe exhibits the greater degree of measurement scatter? Explain your answer.

(c) Which probe is more accurate? Explain your answer.

25. Assume that experimental measurements for a certain organism have shown that cells can convert two-thirds (wt/wt) of the substrate carbon (alkane or glucose) to biomass. CO3 [K_4]

a. Calculate the stoichiometric coefficients for the following biological reactions:

Hexadecane:

$C_{16}H_{34} + a\ O_2 + b\ NH_3 \rightarrow aA\ c(C_{4.4}H_{7.3}N_{0.86}O_{1.2}) + d\ H_2O + e\ CO_2$

Glucose:

$C_6H_{12}O_6 + a\ O_2 + b\ NH_3 \rightarrow aA\ c(C_{4.4}H_{7.3}N_{0.86}O_{1.2}) + d\ H_2O + e\ CO_2$

b. Calculate the yield coefficients $Y_{X/S}$ (g dw cell/g substrate), $Y_{X/O2}$ (g dw cell/g O_2) for both reactions. Comment on the differences.

26. Explain how the different parameters involved in the Monod growth kinetics are determined? CO3 [K_3]

27. Elucidate the Pros and Cons ASPEN Plus in comparison with SuperPro Designer Software CO3 [K_2]

28. An enzyme-linked immunosorbent assay (ELISA) is a widely used biochemical assay that is commonly used for measuring the concentration of various analytes in biological samples to determine the accuracy of the ELISA, a dilution series is performed across a range of virus concentrations, and absorbance measurements are obtained using a spectrophotometer. The results are shown in the table below: CO4 [K_4]

Virus concentration (ng/ml)	Absorbance
6	2.88
3	2.52
1.5	2.22
0.75	2.07
0.38	1.65
0.28	1.35

Develop the linear relationship between virus concentration and absorbance

29. List out the factors affecting the cost of manufacturing for a bioproduct CO5 [K_2]

30. Emphasis the steps involved in performing a Techno-economic analysis. CO6 [K_2]

Answer any TWO Questions

PART D (2 x 10 = 20 Marks)

31. Growth and nutrient uptake in batch cultures of the freshwater diatom, *Cyclotella meneghiniana,* are studied under silicate-limiting conditions. Unbuffered freshwater medium containing 25 µM silicate is inoculated with cells. Samples are taken over a period of 4 days for measurement of cell and silicate concentrations. The results are as follows. CO1 [K_4]

Time (days)	Cell concentration (cells/L) (x10^6)	Siliacate concentration (µM)
0	4.43	8
0.5	5.42	7.92
1	5.98	7.72
1.5	6.97	7.02
2	7.62	6.34

2.5	8.12	5.43
3	9.52	4.87
4	10.44	3.12

(a) Does this culture exhibit exponential growth?

(b) What is the value of μmax?

(c) Is there a lag phase?

(d) What is the observed biomass yield from substrate?

(e) Is the observed biomass yield from substrate constant during the culture?

32. A brewery company produces a liquid that contains 10% ethanol and 90% water. The company pumps this liquid at a rate of 50,000 kg/h to a distillation column. The column produces a distillate of 45% ethanol and 55% water from the top of the column at a rate of one-tenth that of the feed. What is the composition of the waste 'bottoms' from the still, and what is the rate of alcohol loss in the bottoms? CO2 [K_4]

33. A startup company is proposing to produce ethanol from bagasse, a by-product of sugarcane. The feedstock consists of 34% cellulose, 27.2 % hemicellulose, 20.31% lignin, and 13.43% ash. The company claims to have developed a new process that can produce 532 L ethanol/dry metric ton of feedstock. As a bioprocess engineer, the feasibility of the estimates provided by the company will be scrutinized. CO6 [K_4]

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