FOURTH SEMESTER BTECH DEGREE EXAMINATION 2015
(SCHEME: 2013)
13.404 COMPUTER PROGRAMMING IN C++ (B)
MODEL QUESTION PAPER
Time: 3 hours Maximum marks: 100

PART-A

Answer all questions. Each question carries 2 marks

1. What are the advantages of object oriented programming?

2. What is dynamic memory allocation*?*

3. Write a function using reference variables as arguments to swap the values of a pair of integers.

4. Explain the array of structure.

5. Distinguish between implicit and explicit type conversion.

6. Illustrate infix to post fix conversion with an example.

7. Describe the importance of destructors.

8. What is function overloading?

9. Distinguish between class and object.

10. What is a constructor?

PART-B

Answer one full question from each module. Each question carries 20 marks.

MODULE - I

11. a) What are the arithmetic operators in C++. Give its operational hierarchy and write a program to show that the operators given inside set of parenthesis will not follow the hierarchy concept with operators given outside. (10)

b) Write a C++ program to solve a quadratic equation taking into account of all possible cases. (10)
12. Write a C++ program to perform addition and multiplication of two matrices of compatible size. (20)

MODULE - II
13. Write a C++ function to add two matrices of size 'n' Using this function write a program to find A+B+C, where A,B,C are arrays of the size 'n'. Use dynamic memory allocation.

(20)

14. Create a **Student** structure with data members **roll_no, name** and **total marks**. Write a main function to create an array of 10 Students and read and display the student details. (20)

MODULE - III

15. Write a C++ program to create an employee database using inheritance. (20)

16. Define a class Complex Number having data members real part and imaginary part. Define member functions to
a. Add two complex numbers.

b. Multiply two complex numbers. (20)

MODULE - IV

17. Write a C++ program to implement the insertion and deletion operations of a linked list. (20)

18. Write a C++ program to implement
a. Quick sort

b. Insertion sort. (20)

FOURTH SEMESTER BTECH DEGREE EXAMINATION 2015
(SCHEME: 2013)

INDUSTRIAL BIOPROCESS TECHNOLOGY -

MODEL QUESTOIN PAPER

PART A

Each question carries two marks.

1. Differentiate primary and secondary metabolites.
2. What are auxotrophic mutants.
3. Explain briefly on immobilized enzymes.
4. What is replacement culture?
5. Explain about UASB.
6. Give the flow chart for production of lysine.
7. Differentiate biofertilizer from biopesticide.
8. What is scaling up of a fermentation process?
9. Briefly explain the role of microbes in oil leaching,
10. Explain about one biopreservative.

PART B .

answer one question from each module. Each question carries 20 marks.

Module 1

11. a. Explain the history of fermentation industry.

    b. Explain the component parts of a fermentation process.

12. Explain the isolation, preservation and strain improvement of industrially useful microorganism.

Module 2

13 Explain the various downstream processes associated with fermentation industry.

14 Explain the aerobic and anaerobic methods of effluent treatment.

Module 3

15 Describe the production of penicillin with various problems associated.

16 Explain the production of vitamins with the use of various microorganisms

Module 4

17. Explain the production of various recombinant proteins

18. Describe the production of various beverages.

FOURTH SEMESTER BTECH DEGREE EXAMINATION 2015
(SCHEME: 2013)

INDUSTRIAL BIOPROCESS TECHNOLOGY -   MODEL QUESTOIN PAPER

PART A Each question carries two marks.

1. What is biotransformation?
2. What are the uses of morphologically favourable strains in fermentation industry?
3. Explain about precursors in fermentation media.
4. Explain a batch fermentation process,
5. How is two phase aqueous extraction used in fermentation insustry?
6. Give the flow diagram for purification of lactic acid.
7. How is cocoa fermented.?
8. Explain about Devine and Collego.
9. Comment on the various byproducts of fermentation industry,
10. Explain about the inoculation from a laboratory fermenter to a production fermentor.

PART B .

Answer one question from each module. Each question carries 20 marks.

Module 1

11. Explain about the various sterilization methods of a fermentor and its accessories.

12. Explain about the various media requirements for industrial fermentations.

Module 2.

13 Explain on the immobilized biocatalysts, their advantages and applications.

14. Explain about the various bioreactors for plant and animal cell cultures.

Module 3

15. Explain the production of acetic acid with the various constraints associated with production.

16. Explain the production of alcohol from various raw materials.

Module 4

17. Explain the production of Industrial enzyme.

18. Explain the production of fermented foods.

FOURTH SEMESTER BTECH DEGREE EXAMINATION 2015

(SCHEME: 2013)

13.402 CHEMICAL AND BIOCHEMICAL REACTION ENGINEERING (B)

Time:3Hours   **Max. Marks: 100**

PART - A

Answer all questions. Each question carries 2 marks.

1.   Given the reaction $2NO_2 + 1/2\ O_2 \longrightarrow N_2O_5$, what is the relation between the rates of formation and disappearance of the reaction components?
2.   What is the significance of activation energy?
3.   Analyse the performance of SCSR and CSTR based on handling of catalyst decay and ease of sampling and analysis?
4.   What is the concept of ideality in a PFR?
5.   What are the moments of RTD?
6.   What is meant by stability of a bioreactor?
7.   What is meant by optimum recycle ratio?
8.   What are structured kinetic models?.
9.   What is an adiabatic operating line?
10.   What is the importance of stimulus response studies in reactor analysis?

PART - B

Answer any one question from each module. Each full question carries 20 marks.

Module I

11.   The reaction between A and B giving C and D as the products was studied in a batch reactor. The concentration-time data obtained are as follows.
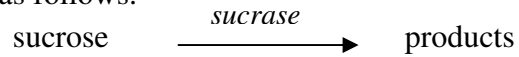   Time(min)   :0   50   100   150   200   250   300
      C_A(mol/dm^3)x10^3 :50   38   30.6   25.6   22.2   19.5   17.4
      Obtain the reaction rate constant and the order of the reaction using differential method of analysis if the concentration of A and B were 0.5 mol/dm^3 initially.

Or

12. The following data are obtained for the decomposition of azo isoprene at 270^0C. Treat the decomposition reaction as A→ B + C for calculation purpose and find the order of reaction and the value of the rate constant.

Time(s)	:0	180	360	540	720	1020
Pressure(mm Hg)	:35.15	46.3	53.9	58.85	62.2	65.2

Module II

13. a) Derive the performance equation of an ideal PFR and apply the same to a first order variable density system. (12)
    b) Which of the following arrangements give more conversion for a second order reaction?
    i) CSTR followed by a PFR
    ii) PFR followed by a CSTR (8)

OR

14. Under appropriate conditions A decomposes as follows:

$$ A \xrightarrow{k_1=0.1/min} R \xrightarrow{k_2=0.1/min} S $$

R is to be produced from 1000 litre/h of feed in which C_{A0} = 1 mol/l, $C_{R0}=C_{S0}=0$. What size of MFR will maximise the concentration of R and what is $C_{R,max}$ in the effluent stream from this reactor? Derive all the equations required.

Module III

15. Derive the dispersed plug flow model for non ideal reactors and extend the same for large extents of dispersion as well as for small extents of dispersion.

Or

16. Calculate the mean residence time and variance of the reactor characterised by the following data obtained from a pulse input at 320 K.
    a)Construct the C(t) and E(t) curves as a function of time.
    b) Determine the fraction of material leaving the reactor that has spent between 3 and 6 min in the reactor

t (min)	:0	1	2	3	4	5	6	7	8	9	10
	12	14									
C(g/m^3)	:0	1	5	8	10	8	6	4	3	2.2	1.5
	0.6	0									

Module IV

17. At the room temperature sucrose is hydrolysed by the catalytic action of the enzyme sucrase as follows.

$$\text{sucrose} \xrightarrow{\quad sucrase \quad} \text{products}$$

Starting with a sucrose concentration $C_{A0} = 1$ millimol/litre and an enzymatic concentration $C_{E0} = 0.01$ millimol/litre, the following kinetic data are obtained in a batch reactor . C_A values are in millimol/litre. Obtain the rate equation and the M-M parameters.

$C_{A,}$	0.8	0.6	0.5	0.3	0.2	0.1	0.0	0.0	0.01	0.00	0.002
r	4	8	3	8	7	6	9	4	8	6	5
t, hour	1	2	3	4	5	6	7	8	9	10	11

Or

18. Write notes on
    a) Air lift loop reactor
    b) Bubble column reactors
    c) Photo bioreactor
    d) Trickle bed bioreactors

FOURTH SEMESTER BTECH DEGREE EXAMINATION 2015

Biotechnology and Biochemical Engineering

(2013 Scheme)

Model Question Paper

13.406 **BIOPROCESS ENGINEERING** (B)

Time : 3 Hours   Max. Marks : 100

Missing data, if any, may be assumed suitably.

Part – A

Answer all Questions. Each carries 2 marks.

1. Sketch the flow sheet for recombinant protein production from bacteria, highlighting the upstream, fermentation and downstream stages.
2. Distinguish between growth and production media, with examples.
3. Define Del factor for sterilization. An unsterile bath initially contains 10^{10} viable cells. Find the Del factor for sterilization, if a contamination risk of 1 in 1000 is considered acceptable.
4. Discuss the chemical method for $K_L a$ estimation. Mention its limitations.
5. Explain passive immobilization. Mention any two of its applications in the bioprocess industry.
6. Describe "scale- up window".
7. Explain ANNs and their application in bioprocess control.
8. What is bioprocess simulation? What are its practical benefits?
9. What is metabolic flux analysis?
10. Explain the operation of a perfusion bioreactor for animal cell culture.

(10 x 2 = 20 marks)

Part – B

Answer any one full question from each module.

MODULE- I

11. **a)** Determine the amount of $(NH_4)_2SO_4$ to be supplied in a fermentation medium where the final cell concentration is 30 g/l in a 10^3 l culture volume. Assume that the cells are 12 % nitrogen by weight and $(NH_4)_2SO_4$ is the only nitrogen source. **(5 marks)**

b) Derive an expression for the efficiency of fibrous filter for sterilizing air. Calculate the filter depth for 90 % efficiency of removal of spores from air when the filter constant is 0.42 cm^{-1}. **(5 marks)**

c) The time – temperature profile during heating a medium for thermal sterilization is shown in the table below. Calculate the Del factor for heating using the graphical integration method:

Time (min)	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Temperature (^{0}C)	100	103.4	106.7	109.5	111.6	113.8	116.4	118.7	121.0

(10 marks)

12. **a)** Production of recombinant protein by a genetically engineered strain of *E.coli* is proportional to cell growth. Ammonia is used as the nitrogen source for aerobic breakdown of glucose. The recombinant protein has an overall formula of $CH_{1.55}O_{0.31}N_{0.25}$. The yield of biomass from glucose is measured at 0.48 g/g; the yield of recombinant protein from glucose is about 20 % that for cells. Calculate the amount of ammonia required and the oxygen demand.
(7 marks)

b) An autoclave malfunctions, and the temperature reaches only 119.5^0 C. The sterilization time at the maximum temperature was 20 min. The jar contains 10 litres of complex medium that has 10^5 spores/l. At 121^0C, the thermal death constant is 1.0 min^{-1} and the activation energy is 90 kcal/g mol. What is the probability that the medium was sterile? **(5 marks)**

c) Medium at a flow rate of 2 m^3/h is to be sterilized by heat exchange with steam in a continuous sterilizer. The liquid contains bacterial spores at a concentration of 10^{12} m^{-3}; the activation energy and the Arrhenius constant for thermal destruction of these contaminants are 283 kJ/g mol and 10^{39} h^{-1} respectively. A contamination risk of one organism surviving every 60 days' operation is considered acceptable. The sterilizer pipe has an inner diameter of 0.1 m; the length of the holding section is 24 m. The density of the medium is 1000 kg/m^3 and the viscosity is 3.6 kg/m. h. Calculate the sterilizing temperature, assuming a Damkohler number of 42. **(8 marks)**

MODULE- II

13. **a)** A genetically engineered strain of yeast is cultured in   a bioreactor at 30^0 C for production of   heterologous protein. The oxygen   requirement is 80 mmol/l.h; the critical oxygen concentration is 0.004 mM. The solubility of oxygen in the fermentation broth is estimated to be 10 % lower than in water, due to solute effects.

   a) What is the minimum mass transfer coefficient necessary to sustain this culture if the reactor is sparged with air at approximately 1 atm pressure?

   b) What is the mass transfer coefficient required, if pure oxygen is used instead of air?

   (6 marks)

b) The air supply to a fermenter was turned off for a short period of time and then restarted. Oxygen solubility has been determined as 7.3 ppm, under current operating conditions. Estimate the OUR and $K_L a$ in this system, from the tabulated measurements of dissolved oxygen (DO), given below:

	Air off						Air on											
Time (min)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
DO (ppm)	3.3	2.4	1.3	0.3	0.1	0.0	0.0	0.3	1.0	1.6	2.0	2.4	2.7	2.9	3.0	3.1	3.2	3.2

(8 marks)

c) A stirred tank reactor is to be scaled down from 10 m^3 to 0.1 m^3 . The dimensions of the large tank are: $D_t = 2$ m ; $D_i = 0.5$ m ; N = 100 rpm.

a) Determine the dimensions of the small tank , by using dimensional similarity.

b) What would be the required rotational speed of the impeller in the small tank if the following criteria were used?

   1) Constant tip speed
   2) Constant impeller Re number

(6 marks)

14. **a)** In cultivation of baker's yeast in a stirred and aerated tank, lethal agents are added to the fermentation medium to kill the organisms immediately. Increase in DO concentration upon addition of lethal agents is followed with the aid of a DO analyzer and a recorder. Using the following data, determine the oxygen transfer coefficient for the reactor. Saturation DO concentration is 9 mg/l.

Time (min)	1	2	2.5	3	4	5
DO (mg/l)	1	3	4	5	6.5	7.2

(6 marks)

b) A 200-1itre stirred fermenter contains a batch culture of *Bacillus subtilis* bacteria at 28^0C. Air at 20^0 C is pumped into the vessel at a rate of 1 vvm; (vvm stands for volume of gas per volume of liquid per minute). The average pressure in the fermenter is 1 atm. The volumetric flow rate of off-gas from the fermenter is measured as 189 1 min^{-1}. The exit gas stream is analysed for oxygen and is found to contain 20.1% 0_2. The dissolved-oxygen concentration in the broth is measured using an oxygen electrode as 52% air saturation. The solubility of oxygen in the fermentation broth at 28^0 C and 1 atm air pressure is 7.8 x 10^{-3} kg m^{-3}.

(a) Calculate the oxygen transfer rate.
(b) Determine the value of $k_L a$ for the system.

(**8 marks**)

c) After a batch fermentation, the system is dismantled and approximately 75 % of the cell mass is suspended in the liquid phase (2 1), while 25 % is

attached to the reactor walls and internals in a thick film of approximately 0.3 cm thickness. 50 % of the target product (intracellular) is associated with each cell fraction. The productivity of this reactor is 2 g product/l at the 2 l scale. What would be the productivity at 20,000 l scale if both the reactors had a height to diameter ratio of 2 to 1? **(6 marks)**

MODULE- III

15. **a)** Explain the common methods for foam sensing and control in an industrial fermenter. **(6 marks)**

    b) Discuss the role of filters and estimators in measurement analysis in bioprocess context. **(6 marks)**

    c) What is bioprocess modeling? Describe any one suitable fermentation model, highlighting its structure and the pertinent assumptions implicit in its development. **(8 marks)**

16. Briefly describe the following:
    a) Programmed batch bioreaction
    b) Direct regulatory control
    c) Flow cytometry
    d) Sequential injection chromatography
    e) Data smoothing and interpolation methods

    (5 x 4 = 20 marks)

MODULE- IV

17. **a)** Gel immobilized cells of *Papaver somniferum* can make codeine from codeinone. The rate of codeinone uptake is first order, with a rate constant of 3.3×10^{-8} l/g cells dry weight –s. The diffusivity of codeinone in the gel is 0.2×10^{-9} m^2/s. For a gel particle of 4 mm diameter with a 25 % volume loading of cells (95 % water), what will be the effectiveness factor? **(6 marks)**

    b) Assume that all plasmid containing cells have eight plasmids; that an antibiotic is present in the medium, and the plasmid- containing cells are totally

resistant; and that a newly born, plasmid- free cell has sufficient enzyme to protect a cell and its progeny for three generations. Estimate the fraction of plasmid containing cells in the population in a batch reactor starting with only plasmid containing cells after five generations. **(6 marks)**

c) Compare the following immobilization methods used for animal cells in terms of their relative advantages and disadvantages: microcarrier (surface) culture, porous beads, encapsulation, gel entrapment. **(8 marks)**

18. **a)** The detoxification of a slightly hydrophobic compound in a patient's blood is performed using a hollow fiber bioartificial liver, which functions as an extracorporeal assist device. Draw a diagram and describe the potential mass transfer limitations on the rate of detoxification by intracellular enzymes.

(8 marks)

b) Calculate the probability of forming a plasmid – free cell due to random segregation for a cell with 50 plasmid monomer equivalents, given the following information:

(i) 40 % of the total plasmid DNA is in dimmers and 16 % in tetramers.

(ii) The distribution of copy numbers per cell is as follows, assuming monomers only:

No. of plasmids	< 3	4 – 8	9- 13	14 – 18	19- 23	24 – 28	29 – 33	34- 38	>39
%	0	4	10	25	25	20	12	4	0

(8 marks)

c) Describe the process for formation of hybridomas. **(4 marks)**

FOURTH SEMESTER BTECH DEGREE EXAMINATION 2015

Biotechnology and Biochemical Engineering

(2013 Scheme)

Model Question Paper

13.406 **BIOPROCESS ENGINEERING** (B)

Time : 3 Hours   Max. Marks : 100

Missing data, if any, may be assumed suitably.

Part – A

Answer all Questions. Each carries 2 marks.

1. Explain the rationale for bio-organic reaction medium engineering.
2. Describe the Richard's rapid method for design of sterilization cycles.
3. What is Nutrient Quality Criterion? Discuss its relevance in determining the thermal regime for sterilization processes.
4. Explain the oxygen balance method for K_La estimation.
5. Explain cell immobilization by ion- exchange gelation process.
6. What is momentum factor? Explain its utility as a scale up criterion for bioprocess systems.
7. Explain bioprocess model validation using MATLAB.
8. Compare open and closed loop control of bioprocesses.
9. Discuss the kinetics of monoclonal antibody production by hybridoma cells.
10. How do mutations in a host cell contribute to genetic instability in a recombinant cell culture?

                                                                      (10 x 2 = 20 marks)

Part – B
Answer any one full question from each module.

MODULE- I

11. **a)** A continuous sterilizer with a steam injector and a flash cooler will be employed to sterilize medium continuously with the flow rate of 2 m^3/hr. The time for heating and cooling is negligible with this type of sterilizer. The typical bacterial count of the medium is about 5×10^{12} m^{-3}, which needs to be reduced to such an extent that only one organism can survive during two months of continuous operation. The heat-resistant bacterial spores in

the medium can be characterized by an Arrhenius coefficient (k_{d0}) of 5.7×10^{39} hr^{-1} and an activation energy (E_d) of 2.834×10^5 kJ/kmol. The sterilizer will be constructed with the pipe with an inner diameter of 0.102 m. Steam at 600 kPa (gage pressure) is available to bring the sterilizer to an operating temperature of 125°C. The physical properties of this medium at 125°C are c = 4.187 kJ/kg K, ρ = 1000 kg/m^3, and μ = 4 kg/m hr.

  c) What length should the pipe be in the sterilizer if you assume ideal plug flow?
  d) What length should the pipe be in the sterilizer if the effect of axial dispersion is considered?

(12 marks) b)
An 1 litre fermentor initially contains 10^4 spores at 20^0C. Assuming a holding temperature of 120^0C, calculate the time required to achieve a probability of contamination of 0.001. Neglect the heating and cooling periods. What would be the probability of contamination for 100 litres of broth, at the same holding temperature? The activation energy and Arrhenius constant for thermal deactivation of spores are 283 kJ/mol and $10^{36.2}$ s^{-1} respectively.

(8 marks)

12. **a)** A filter bed of glass fibers (D_c = 15 μm, the bed depth B =10 cm, and packing density α = 0.03) is being used to sterilize air (20°C, 1 atm) with an undisturbed upstream velocity, v_0, of 10 cm/s. The air stream contains 5,000 bacteria per cubic meter (d_p = 1 μm and ρ_p = 1 g/cm^3).

  c)   Estimate the single fiber collection efficiency by inertial impaction, by interception, and by diffusion.
  d)   Estimate the collection efficiency (η) of the filter bed.

(12 marks) b)
The specific death constants of heating and cooling for sterilization of a medium at 121^0C are 0.1 min^{-1} and 0.2 min^{-1} respectively. The initial batch contains 6 x 10^{15} organisms at 30^0C. The heating, holding and cooling times are 20 min, 30 min and 30 min respectively. The decimal reduction time during holding is 2 min. Find the

sterilization effect. **(8 marks)**

MODULE- II

13. a) A gas component A in air is absorbed into water at 1 atm and 20 ^{0}C. The Henry's law constant H_m of A for this system is 1.67×10^3 Pa.m^3 kmol^{-1}. The liquid film mass-transfer coefficient k_L and gas-film coefficient k_G are 2.50×10^{-6} m.s^{-1} and 3.00×10^{-3} m.s^{-1}, respectively.

(i)   Determine the overall coefficient of gas–liquid mass transfer K_L (m s^{-1}).

(ii)   When the bulk concentrations of A in the gas phase and liquid phase are 1.013×10^4 Pa and 2.00 kmol.m^{-3}, respectively, calculate the molar flux of A. **(6 marks)**

b) To measure $k_L a$, a fermenter was filled with 10 litres of 0.5 M sodium sulfite solution containing 0.003 M Cu^{++} ion and the air sparger was turned on. After exactly 10 minutes, the air flow was stopped and a 10 ml sample was taken and titrated. The concentration of the sodium sulfite in the sample was found to be 0.21 mol/l. The experiment was carried out at 25^{0}C and 1 atm. Calculate the oxygen uptake and $k_L a$. **(6 marks)**

c) *Serratia marcescens* bacteria are used for production of threonine. The maximum specific oxygen uptake rate of *S. marcescens* in batch culture is 5 mmol O_2 g^{-1} h^{-1}. The bacteria are grown in a stirred fermenter to a cell density of 40 g l^{-1}; $k_L a$ under these circumstances is 0.15 s^{-1}. At the fermenter operating temperature and pressure, the solubility of oxygen in the culture liquid is 8×10^{-3} kg m^{-3}. Is the rate of cell metabolism limited by mass-transfer, or dependent solely on metabolic kinetics? **(8 marks)**

14. **a)** A strain of *Azotobacter vinelandii* is cultured in a 15 m^3 stirred fermenter for alginate production. Under current operating conditions $k_L a$ is 0.17 s^{-1}. Oxygen solubility in the broth is approximately 8×10^{-3} kg m^{-3}.

(a) The specific rate of oxygen uptake is 12.5 mmol g^{-1} $h^{-1.}$ What is the maximum possible cell concentration?

(b) The bacteria suffer growth inhibition after copper sulphate is accidently added to the fermentation broth. This causes a reduction in oxygen uptake rate to 3 mmol g^{-1} h^{-1}. What maximum cell concentration can now be supported by the fermenter?

(8 marks)

b) Consider the scale up of a fermentation from a 10 l to 10,000 l vessel. The small fermenter has a height to diameter ratio of 3. The impeller diameter is 30 % of the tank diameter. Agitator speed is 500 rpm and three Rushton impellers are used. Determine the dimensions of the large fermenter and agitator speed for:
   a) Constant P/V
   b) Constant impeller tip speed
   c) Constant Reynolds number
   Assume geometric similarity. **(12 marks)**

MODULE – III

15. **a)** Elaborate on the applications of digital computers in fermentation technology. Also mention the salient features of various software systems used for bioprocess modelling and simulation. **(10 marks)**

b) Describe any two novel analytical techniques employed for the determination of dissolved oxygen levels in fermentation broths. Compare the methods in terms of their merits and limitations. **(10 marks)**

16. **a)** Discuss the benefits of ANNs in bioprocess control. Highlight the features of knowledge based expert systems, with the aid of a suitable example/case study from the bioprocess context. **(10 marks)**
    b) Explain the theoretical principles and operation of any two flow based micro-analytical techniques applied to bioprocess monitoring. Also indicate their specific applications. **(10 marks)**

MODULE – IV

17. **a)** Explain metabolic control theory and flux analysis. Discuss their relevance in pathway engineering, with a suitable example. **(8 marks)**

b) Estimate the number of generations of growth needed for genetically modified microorganisms from 1 mL culture to a 33,000L production-scale fermenter. Assume that the inoculum size in each stage of the scale-up is 5 percent except the first inoculation step. **(4 marks)**

c) The uptake of the auxin, Indole acetic acid,by suspension cultures of parthenocisus sp. is nearly zero order at 1 nmol/mg dry cell weight –min. The diffusivity of IAA in water is 5 x 10^{-6} cm^2 /s. Beads of calcium alginate are most conveniently made as spheres with a 4 mm diameter. Assume the beads are made 25 % by volume of plant cells. Assume the plant cells are 90 % water and that the diffusivity of IAA in the gel is the same as in water. If the external concentration is maintained at 2 μmol, will IAA penetrate to the centre of the bead? **(8 marks)**

18. **a)** Hybridoma cells immobilized on surfaces of sephadex beads are used in a packed column for the production of monoclonal antibodies. Hybridoma concentration is approximately 5 g/l in the bed. The flow rate of the synthetic medium and glucose concentration are 2 l/h and 40 g/l respectively. The rate constant for monoclonal antibody production is 1 g biomass/litre for 24 hours. Assume that there are no diffusion limitations and glucose is the rate limiting nutrient. Determine the volume and the height of the packed bed for 95 % glucose conversion. Bed diameter is 0.2 m. Neglect the growth of hybridomas and assume first order kinetics. **(10 marks)**

b) Derive equations to describe the dynamics of a plasmid containing population when the plasmid – free host is auxotrophic for a metabolite, M which is made and released from a plasmid- containing cell into the medium in a chemostat. **(10 marks)**