CHARLES DARWIN UNIVERSITY

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 1, 2017

FINAL EXAMINATION	**DURATION**
ENG446 – Bioprocess Engineering	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

Please ensure that your name and student number are clearly indicated on your Answer Sheet and at the top of this examination paper.

1.1 The examination has 2 sections

Section A: Short Answer Questions.
Total No of Marks for this section: 20
This section should be answered in the Answer Booklet provided.
ANSWER ALL 4 QUESTIONS.
Each Question carries 5 marks. Suggested Time allocation for Section A: 40 mins

Section B: Problems
Total No of Marks for this section: 80
This section should be answered in the Answer Booklet provided.
ANSWER ALL 4 QUESTIONS.
Each Question carries 20 marks. Marks for each sub-question are indicated.
Suggested Time allocation for Section B: 140 mins

1.2 Read ALL questions carefully

EXAM CONDITIONS

<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.

This is a RESTRICTED OPEN BOOK examination

Any non-programmable calculator is permitted

Three A4 sheets of handwritten or typed double-sided notes permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
No additional printed material is permitted	1 x 20 Page Book

Section A
Short Answer Questions
Total No of Marks for this section: 20

This section should be answered in the Answer Booklet provided.
ANSWER ALL 4 QUESTIONS.

Each Question Carries 5 marks. Suggested Time allocation for Section A: 40 mins

---

Question 1

Explain what is meant by washout in a chemostat.

(Marks: 5)

Question 2

Give reasons why fermenter performance can change with scale.

(Marks: 5)

Question 3

What is sterility assurance level and how is it used to determine holding time?

(Marks: 5)

Question 4

Briefly explain with the aid of a sketch, the concept of the breakthrough curve and how it is used to design a packed adsorption column.

(Marks: 5)

Section B
Problems
Total No of Marks for this section: 80

This section should be answered in the Answer Booklet provided.
ANSWER ALL 4 QUESTIONS.

Each Question carries 20 marks. Marks for each sub-question are indicated.
Suggested Time allocation for Section B: 140 mins

Question 5

A pilot scale stirred tank aerobic fermenter has a tank diameter of 0.6 m and is fitted with flat-blade turbine impellers with a diameter of 0.24 m. The pilot scale fermenter operated at an impeller rotational speed of 1.5 s^{-1} and volumetric air flowrate of 0.5 m^3 min^{-1}. A geometrically similar production scale fermenter is to be constructed. The diameter of this fermenter will be 2m and the impeller diameter will be 0.8m. It is decided that k_La will be used as the scale-up criterion. The superficial gas velocity will be the same for both the fermenters.

For the turbine impellers, the following correlation is applicable:

$$k_La = c\ v_s^m (N^3 D^2)^n$$

where c is a constant, v_s is the superficial gas velocity, N is the impeller rotational speed, D is the tank diameter and $m = n = 2/3$.
The power input (P) to the impeller is given by the following equation which is applicable for turbulent flow.

$$P = N_p \rho N_i^3 D_i^5$$

where $N_p$is the power number, ρ is the density, $N_i$is the impeller rotational speed and D_i is the impeller diameter.

(a) Determine the impeller rotational speed and the air flow rate for the production scale reactor.
(Marks: 15)

(b) Determine the ratio of power input required for the production scale stirrer to the power input required for the pilot scale stirrer assuming turbulent flow.
(Marks: 5)

Question 6

Consider two microbial species which are competing for the same growth limiting substrate.

(a) Derive the conditions under which these two species can theoretically coexist.

(Marks: 15)

(b) Briefly explain why in practice, this is not usually possible to achieve. Under what practical conditions might the organisms co-exist?

(Marks: 5)

Question 7

An organism is grown in a chemostat under steady state conditions with flow rate of the inlet stream set at 600 l hr^{-1}. The substrate concentration in the inlet stream is 90 g l^{-1}. The maximum specific growth rate is 0.65 hr^{-1}, biomass yield is 0.65 and K_s = 5 g l^{-1}. The feed is sterile. The chemostat can be operated with and without external recycle.

(a) The chemostat is operated without recycle. Determine the wetted volume of the chemostat and the cell concentration in the outlet stream if the outlet substrate concentration is 4 g l^{-1}.

(Marks: 10)

(b) Determine the substrate concentration in the fermenter if the chemostat is operated with external recycle with a recycle ratio of 0.4 and cell concentration factor of 2. The wetted volume is the same as in (a).

(Marks: 10)

Question 8

A polysaccharide product has to be separated from a clarified fermentation broth using ultrafiltration. The product has a gelation concentration of 25 g/l. The fluid flows through open membrane tubes of diameter 2.4 cm and length 2 m at a velocity of 0.34 m/s. The fluid density is 1020 kg/m^3. The filter is operated under gel polarization conditions and the product concentration entering the filter is 12 g/l. The filtrate contains 0.5 g/l of the product.

(a) Calculate the filtration flux.

(Marks: 15)

(b) Calculate the rejection coefficient of the membrane.

(Marks: 5)

Additional Data

$$Sh = M\ Re^{\alpha} Sc^{\beta} \left(\frac{d_h}{L}\right)^{w}$$

where Sh, Re and $Sc$are the Sherwood, Reynolds and Schmidt number respectively, d_h is hydraulic diameter of the flow channel and L is the length of the flow channel. The values of M,α, β and w are given in the table below:

Flow Conditions	$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$	$\boldsymbol{w}$	$\boldsymbol{M}$
Laminar	0.43	0.33	0.33	1.86
Turbulent	0.89	0.3	0	0.023