# UNIVERSITY COLLEGE LONDON

University of London

## EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

*B.Eng.* *B.Sc.* *Coll Dip* *M.Eng.*

**Biochemical Eng E141: Biochemical Reactor Engineering**

COURSE CODE : **BENGE141**

UNIT VALUE : **0.50**

DATE : **13-MAY-04**

TIME : **10.00**

TIME ALLOWED : **3 Hours**




**TURN OVER**

*Answer **FOUR QUESTIONS.*** **Only the first four answers given will be marked.**
*ALL questions carry a total of **25 MARKS** each, distributed as shown* [ ]

**1.**

a) In the scale-up of a fermentation process there are four 'rules of thumb' that are commonly used by industry. Describe each of these briefly and explain the common feature of all the methods. [5]

b) You are involved in the scale-up of a fermentation using a filamentous fungus from 100 L (total volume) to 15 $m^3$ (total volume) based a constant power/unit volume ratio. Both vessels have an aspect ratio of 3:1 and are equipped with 3 Rushton turbines (Power number/turbine = 5). The tank to impeller diameter ratio is 3: 1 for both vessels. The density of the broth is 1050 kg $m^{-3}$ and the viscosity is 0.035 Pa s.

i) Calculate the agitation operation conditions for the 15 $m^3$ vessel based on $P_{ug}/V = 2.0$ kW $m^{-3}$. Clearly state any assumptions made. [10]

ii) Comment on the effect of scale-up on cell damage given that cell breakage occurs at a tip speed of greater than 3.5 m $s^{-1}$. [4]

iii) Discuss briefly what effect may scale-up have on the dissolved oxygen profile within the 15 $m^3$ vessel. [6]

**2.**

a) Briefly describe what information is required for the design of a batch sterilisation process. [4]

b) Calculate the holding time for a pilot-scale batch sterilisation given the following information. [10]

- the probability of a contamination is 1 in 1000
- the initial spore concentration is $2 \times 10^7$ spores $mL^{-1}$
- sterilisation below 100°C is negligible
- heating from 100°C to 121°C is at 2.5°C $min^{-1}$
- cooling from 121°C to 100°C is at 5°C $min^{-1}$
- the death rate constant k at 121°C is 2.54 $min^{-1}$
- the Del factor for 121°C is 12.55
- broth volume is 700 L

c) Explain briefly how you would overcome the problems caused if the medium contained i) rapeseed oil and ii) amino acids. [4]

**CONTINUED**

d) The production scale process for the fermentation described in part (b) operates by using a continuous steriliser. Steam is available at 130°C and the medium needs to be produced at a rate of 5 $m^3$ per hour. Given that the death rate constant at 130°C is 17.524 $min^{-1}$, the diameter of the holding pipe is 40 mm and the acceptable risk of contamination is 1 organism surviving 60 days of operation, calculate for the system on the basis of 1 hour:

i) the total Del factor
ii) the holding pipe resistance time
iii) the length of the holding pipe [7]

Clearly state all your assumptions.

**3.**

a) Define the terms mixing time ($t_m$), circulation time ($t_c$) and turnover time ($t_t$) and outline experimental approaches to their determination in a stirred-tank fermenter. [10]

b) Describe how the liquid phase mixing time will vary depending on the design, operation and size of the vessel. [7]

c) In large scale fermenters poor mixing leads to the creation of a heterogeneous environment. Using specific examples explain how poor mixing might lead to decreases in the productivity of a microbial fermentation process. [8]

**4.**

a) In a batch fermentation process explain why the average chemical composition of cultured *E. coli* cells will vary as a function of time and medium composition. [5]

b) You are investigating the pilot scale production of *E. coli* ($CH_{1.79}O_{0.5}N_{0.2}$, ash content 7.1% w/w) in a 2 $m^3$, working volume, fermenter. The batch fermentation process is aerobic using glucose as a carbon and energy source and ammonium hydroxide as a simple source of nitrogen. Previous trials have shown the yield of biomass on oxygen to be 1.53 g ($O_2$) g (dry cell weight)$^{-1}$. If your target biomass concentration is 16.5 g (dry cell weight) $L^{-1}$ calculate the minimum quantity of glucose required. Clearly state any assumptions made. [20]

**PLEASE TURN OVER**

5.

a) You have been charged with the design of a 15 $m^3$ stirred tank fermenter to be used for the production of an intracellular enzyme synthesised in *E. coli*. Clearly stating and justifying any assumptions made calculate:

- the dimensions of the tank
- the number, design and location of your chosen impellers
- the unaerated and aerated liquid heights
- the number and diameter of any baffles fitted to the tank. [14]

b) Pilot scale fermentations have shown that the *E. coli* broth typically attains a viscosity of 0.015 Ns $m^{-2}$ and a density of 1005 kg $m^{-3}$. If the maximum impeller speed to be used in the 15 $m^3$ tank designed in Part (a) is 200 rpm calculate the unaerated and aerated power requirements clearly stating any assumptions made. Specify also the power rating of the motor to be fitted to the fermenter. [11]

6.

a) Describe the key features of temperature sensors and pH sensors. [15]

b) List the potential problems in developing biosensors for fermentation processes. [5]

c) Describe how temperature sensors are utilised in the temperature control system of a fermenter. [5]

**PLEASE TURN OVER**

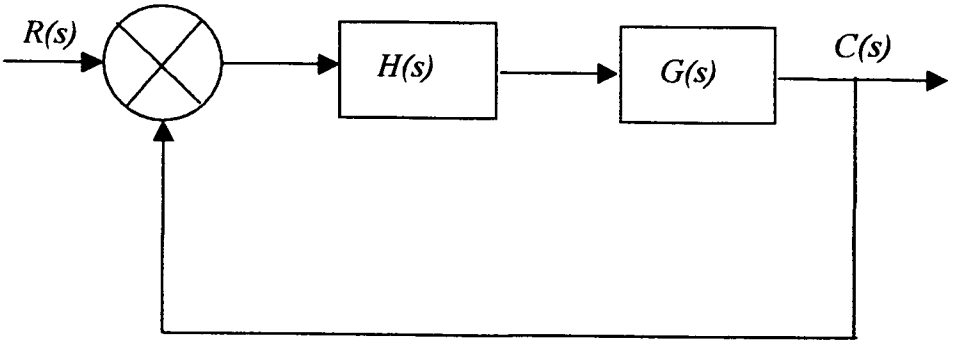
7.

a) Briefly explain the terms proportional (P) control, integral (I) control and proportional and integral (PI) control. [5]

b) The block diagram of a temperature control system of a fermenter is shown in the following figure, where G (s) is the transfer function of the fermenter and $G(s) = \frac{s}{(s+4)(s+5)}$, H (s) is the transfer function of the controller, R (s) is the set point of the temperature at 37°C and C (s) is the response of the temperature in the fermenter. Derive the transfer functions of the closed system Gc (s) when –

i) H (s) is a P controller
ii) H (s) is a PI controller [10]

c) Derive the transient response of the temperature when a P controller, $k_p$=12, is implemented. [10]




**Closed System**

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