UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. *M.Eng.*

Fluid Flow and Mixing in Bioprocesses

COURSE CODE	:	**BENG1003**
UNIT VALUE	:	**0.50**
DATE	:	**03-MAY-06**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

TURN OVER

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

You may assume the following throughout the paper unless stated otherwise:

- *density of water = 1000 kg* m^{-3}
- *viscosity of water = 1 x* 10^{-3} *Pa s*
- *gravitational acceleration = 9.81 m* s^{-2}

1.

a) The rheology of a mycelial *Penicillium* broth is examined at the end of a fermentation cycle using an impeller viscometer and described as pseudoplastic.

i) Describe this rheological behaviour and give a possible explanation for why it occurs. [7]

ii) Explain why it is important to understand the rheology of fermentation broths. [4]

iii) Viscosity measurements using impeller viscometers must be carried out under laminar flow conditions. Describe a possible limitation when interpreting results of this experiment. What impact will replacing a turbine impeller with a helical ribbon impeller have on experimental results. [4]
For turbine impellers laminar flow corresponds to $Re_i < 10$
For helical-ribbon impellers laminar flow corresponds to $Re_i < 100$

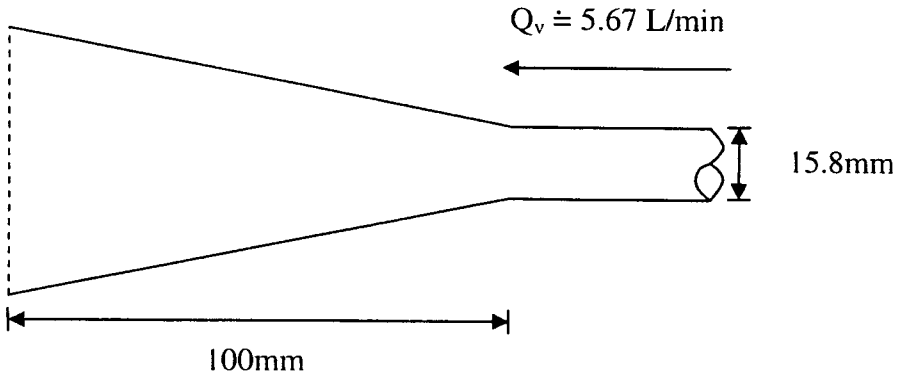
b) Explain, with the aid of examples, why dimensionless groups are useful when analysing biochemical engineering design problems. [8]

c) Indicate possible limitations with using dimensionless groups. [2]

PLEASE TURN OVER

2.

You are responsible for designing the pipework associated with cleaning a 100L fermenter. A spray head needs to be positioned inside the fermenter to spray cleaning solution onto the fermenter walls and impeller shaft after each cycle. The cleaning solution enters the spray head through a pipe with an inside diameter of 15.8 mm. The solution leaves in 24 streams, each with diameter 1.05 mm. The volumetric flowrate through the pipe is 5.67 L/min.



a) You initially consider placing the spray head horizontally at the side of the fermenter. Estimate the minimum gauge pressure needed at the inlet of the spray head. State any assumptions. [18]

b) You also consider placing the spray head vertically at the top of the fermenter. What impact will this have on the minimum gauge pressure needed at the inlet of the spray head? Which orientation would you recommend and why? [7]

CONTINUED

3.

a) Give examples of different components of a pipework system that contribute to the resistance to flow and, hence, cause frictional head losses. [3]

b) Consider fluid flowing in a pipe, diameter d and length L, at constant velocity, u. Using a force balance on a cylindrical fluid element in a section of the pipe, show that the head loss due to friction in the pipe, ΔH_f, can be expressed in terms of velocity heads as:

$$\Delta H_f = f\, 4\frac{L}{d}\frac{u^2}{2g}$$

where $f = \dfrac{\tau_w}{\frac{1}{2}\rho u^2}$

and τ_w is the pipe wall shear stress, ρ the fluid density and u the fluid velocity. [10]

c) Water flows at a rate of 0.057 $m^3\ s^{-1}$ in an old, rusty 0.152 m pipe that has a relative roughness (e/d) of 0.01. It is proposed that by inserting a smooth plastic liner with an inside diameter of 0.127m into the old pipe, the pressure drop per unit length can be reduced. Is it true that the lined pipe can carry the required 0.057 $m^3\ s^{-1}$ at a lower pressure drop than in the old pipe? Support your answer with appropriate calculations. [12]

A Moody chart is provided.

PLEASE TURN OVER

4.

a) Given the following data determine the particle size of the packing material contained within the column that is being described here. (You can assume that the fluid being pumped through the system is water.)

$\Delta P = 4$ *bar*
$Q = 50$ *L/h*
Column length = *15 cm*
Column diameter = *10 cm* [10]

b) If you increased the size of the particles by 20% and the column length by 5cm, what would the new pressure drop be? [5]

c) Why does the column diameter affect the flow behaviour of a packed bed? Sketch out the relationship between the critical velocity and column diameter as part of your answer. [10]

5.

a) In aerobic fermentations air is sparged continuously into the base of the fermenter. Why is this necessary? [3]

b) How do impellers in a fermenter influence oxygen transfer? [4]

c) What effect does aeration have on the power input and why? [8]

d) Consider a fermenter with a single impeller on a shaft. Explain, with the aid of sketches, the flow patterns achieved with different types of impellers in the fermenter. On each sketch, shade the regions where you expect the size of the air bubbles to be the smallest. [10]

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CHART FOR Q3

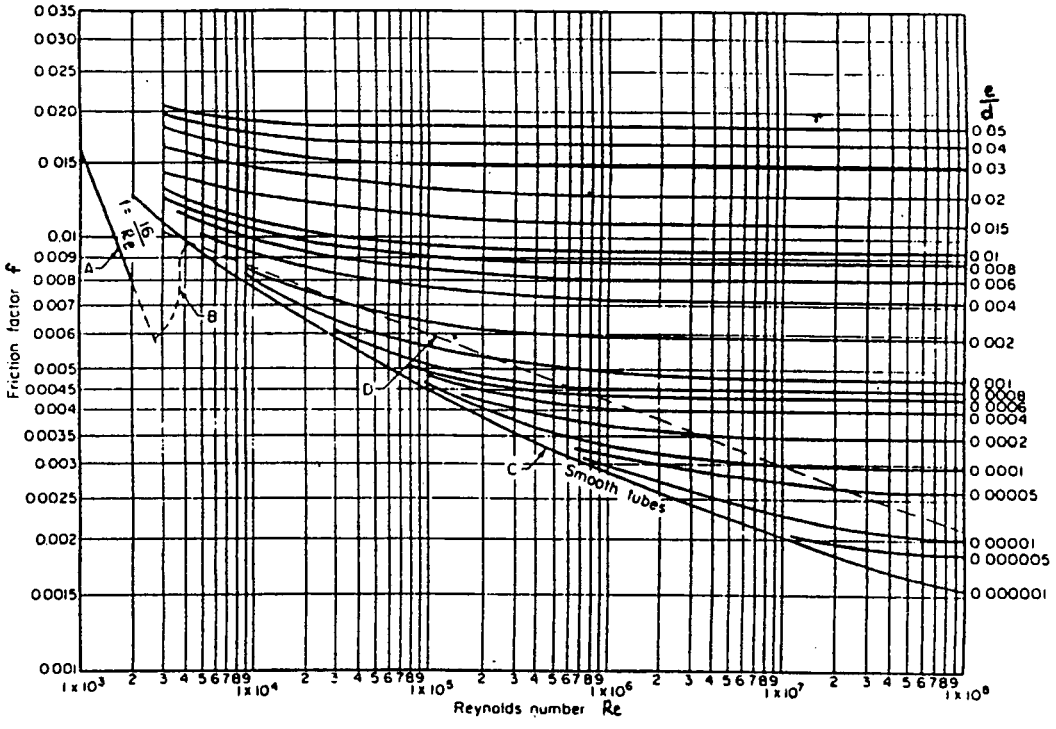

Figure 1. Moody chart

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