UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

B.Eng. *M.Eng.*

Biochemical Eng E102: Introduction to Biotransport Processes

COURSE CODE	:	**BENGE102**
UNIT VALUE	:	**0.50**
DATE	:	**30-APR-02**
TIME	:	**10.00**
TIME ALLOWED	:	**3 hours**

02-C0095-3-60

TURN OVER

UNIVERSITY OF LONDON

Biochemical Engineering

E102

Introduction to Biotransport Processes

ANSWER ***FIVE QUESTIONS***
Examination time: 3 hours
Additional information provided: *Graph paper*

1. As a new biochemical engineer in your first job you are asked to help a chartered engineer with the design of new biotransformation reactor. The bioreactor is a fully baffled mechanically agitated cylindrical tank with a dished bottom. It is equipped with an impeller having a diameter of 0.1m. The fluid in bioreactor has a density of 1200 kgm^{-3} and a viscosity of $2.5x10^{-3}$ Pa s. The impeller is a six bladed Rushton turbine rotating at 10.36 revolutions per second. You are asked to specify the power of the motor required for this job. To help you with this task you are given the following information, which was obtained for a geometrically identical system before you joined the company. [12]

P_o	4.0	3.9	6	6	6
Re	10^2	10^3	10^4	10^5	10^6

In the above table P_o refers to the impeller power number and Re is the impeller power number. Use this information to plot the powercurve for the impeller. (Graph paper supplied).

Assume a motor efficiency of 75%.

Identify the flow regime in the bioreactor. [3]
Briefly explain what experiments you would carry out to obtain the above data. [5]

TURN OVER

2. Biochemical engineers use drag coefficient-Reynolds number charts to obtain design information for operations such as sedimentation, filtration and centrifugation.

Explain what is meant by the terms "form drag", "skin friction" and "settling velocity"? [3]

The data below gives the relationship between the particle Reynolds number (Re_p) and drag coefficient, C_D for spherical particles

Re_p	0.1	1.0	10	100	1000	10000
C_D	238	27	4	1	0.5	0.4

Plot the C_D-Re_p chart using the above data and use it to identify the different flow regimes. [7]

Calculate the terminal velocity of a spherical particle, 0.5mm diameter, settling in a liquid having a density and viscosity of 1000 kgm^{-3} and 0.1 Nsm^{-2}. The density of the solid is 4.3×10^3 kgm^{-3}. Assume that the drag coefficient on the particle is given by the Stoke's equation. [7]

Verify your answer.
(Graph paper supplied.) [3]

3. For laminar steady flow of a Newtonian liquid in a pipe the velocity distribution as a function of radial position, r, from the centre of the pipe is given by:

$$u = \frac{1}{\mu}\left(\frac{\Delta P}{\Delta L}\right)\left(\frac{D^2}{16} - \frac{r^2}{4}\right)$$

where D is the diameter of the pipe, L is the length of the pipe, ΔP is the pressure drop across ΔL and μ is the viscosity of the liquid.

Briefly describe how you would derive the above equation. [7]
Sketch the shape of the velocity profile predicted by the above equation. [3]
What is the effect of the entrance region of the pipe on the velocity profile? [2]
What is the expression for the shear rate at the wall? [2]
What is the expression for the shear stress at the wall? [2]
At what Reynolds number does the flow change from laminar to turbulent? [2]
Sketch the velocity profile for steady laminar flow of a non-Newtonian shear thinning liquid in the pipe. [2]

TURN OVER

4. The contents of a bioreactor is to be pumped to an elevated tank through a pipe with an inside diameter of 0.05m and 100m long. The tank is located at a point 15m above the outlet of the pump. It is required to maintain a mass flow rate of 1.26 kgs^{-1}. The density and viscosity of the contents of the bioreactor are 800 kgm^{-3} and $3.6x10^{-3}$ Nsm^{-2}.

Calculate the average velocity in the pipe. [2]
Calculate the Reynolds number for flow and comment on your answer. [3]
Assuming a friction coefficient of 0.008 calculate the frictional pressure drop for flow through the pipe. [7]
Calculate the total head at the pump outlet. [3]
Calculate the power of the pump assuming an efficiency of 80%. [5]

5. Using Buckingham Π theorem show that the pressure drop, ΔP, for flow through a smooth, horizontal pipe may be expressed by the following relationship:

$$\frac{\Delta P}{\rho u^2} = fn(\mathrm{Re}, \frac{l}{d})$$

where r is the density of the liquid, Re is the Reynolds number, d is the pipe diameter and l is the pipe length, u is the average velocity through the pipe. [20]

6. A fermentation broth is pumped through a pipe of diameter 25mm. Its flow rate is monitored by measuring the pressure drop through an orifice plate with an orifice diameter of 15mm by means of a mercury-water manometer. A difference in levels of 340mm is recorded on the manometer. Calculate the volumetric flow rate in the pipe. Assume the density of the mercury is $13.6x10^3$ kgm^{-3} and the discharge coefficient of the orifice is 0.62. [15]

What would be the effect of using a venturi meter instead of the orifice meter? [5]

7. Air is contained in a vessel with a volume of $5m^3$ at 37°C and a pressure of 10^5 Pa. Assuming air is an ideal gas and contains N_2 and O_2 with molecular fractions 0.8% and 0.2% respectively calculate:

Partial pressure of O_2 [2]
Molar concentration of N_2 and O_2 [4]
Molar concentration of the mixture [2]
Mass concentration of each component [4]
Mass concentration of N_2 [2]
Total mass of gas in the vessel [2]
Average molecular weight of the mixture [4]

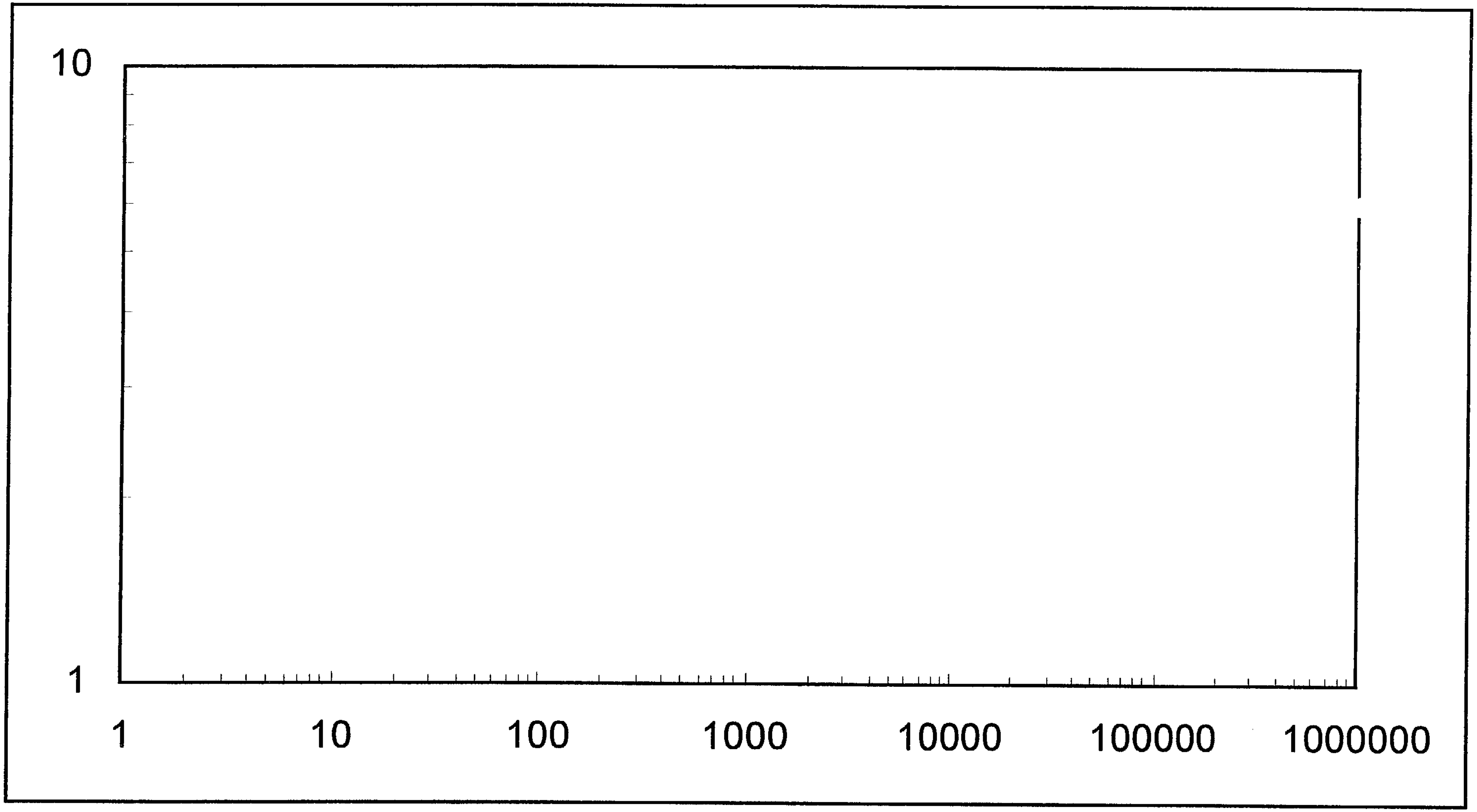
Assume the gas constant, R= 8.314 J/mole K

TURN OVER

8. In a simple tubular heat exchanger cooling water flowing at 0.4 kgs^{-1} enters at 8°C and leaves at 30°C. A hot process liquid flows co-currently at 1.1 kgs^{-1} entering at 60°C. Calculate the overall heat transfer coefficient assuming that the effective surface area is 1.0m^2 and that the specific heats of water and the process liquid are 4200 and 1500 J/kg °C respectively. [15]

Explain what would happen if the flow of the process liquid was reversed? Which is the more efficient method of operation? [5]

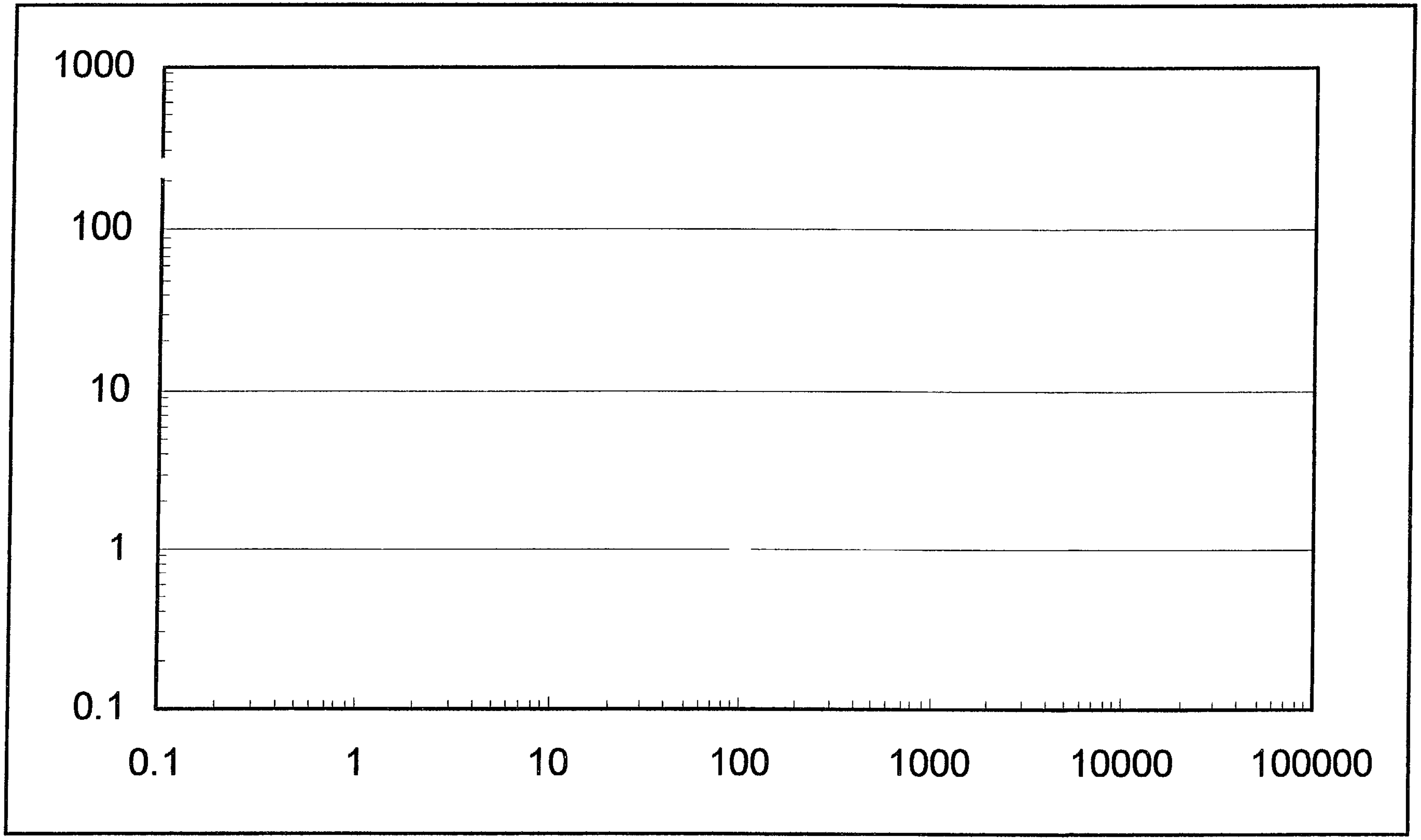
END OF PAPER



Graph paper for question 1

02-C0095a-3-60

TURN OVER



Graph for question 2

END OF PAPER