UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

B.Eng. *M.Eng.* *M.Sc.*

Chemical Eng E802: Transport Processes I

COURSE CODE	:	**CENGE802**
UNIT VALUE	:	**0.50**
DATE	:	**22-MAY-02**
TIME	:	**10.00**
TIME ALLOWED	:	**3 hours**

02-C0177-3-60

*Answer **FIVE** questions only.*
Each question carries a total of 20 marks distributed as shown [].

Graph paper available.

$g = 9.81$ m s^{-1}, $R = 8.314$ kJ kg^{-1} K^{-1}, 1 bar = 10^5 Pa..

1. Why is dimensional analysis used in engineering systems? [3]

The pressure drop per unit length, ΔP_l, for the flow of blood through a horizontal small-diameter tube is a function of the volume flow rate, Q, the tube diameter, D and the blood viscosity, μ. For a series of tests in which D = 2 mm and μ = 0.004 Pa s, the following data were obtained, where the pressure drop listed was measured over 300 mm length.

Q (m^3/s)	Pressure drop (Pa)
3.6×10^{-6}	1.1×10^{4}
4.9×10^{-6}	1.5×10^{4}
6.3×10^{-6}	1.9×10^{4}
7.9×10^{-6}	2.4×10^{4}
9.8×10^{-6}	3.0×10^{4}

Find the dimensionless groups relevant to the problem. [7]

Make use of the data given in the above table to determine a general relationship between ΔP_l, and Q (one that is valid for other values of D and μ). [10]

2. What is a system and what is a control volume? What are their differences? [5]

A tank initially contains 1000 kg brine which has 10% salt by mass. An inlet stream of pure water flows into the tank at a rate of 20 kg min^{-1}. The mixture in the tank is kept uniform by stirring. Brine is removed from the tank via an outlet pipe at a rate of 10 kg min^{-1}.

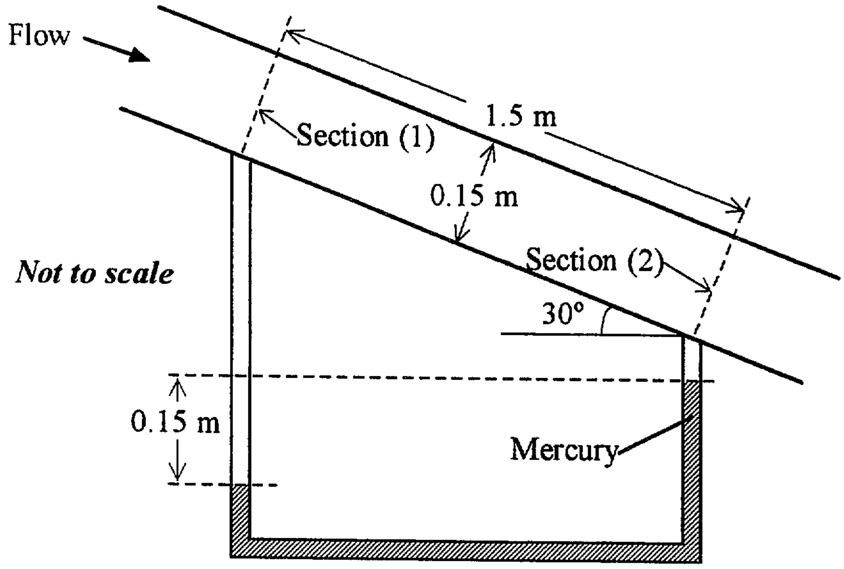
(i) What is the amount of brine in the tank at any time t ? [5]

(ii) How much time would have elapsed when the amount of salt in the tank is 50 kg ? [10]

TURN OVER

3. What are the three physical laws used in the conservation equations? What property is conserved in each one of them? [3]

Water flows steadily down an inclined pipe, with internal diameter 0.15 m, as indicated in the figure below.



Determine the following:

(i) the difference in pressure between sections (1) and (2), $(P_1 - P_2)$; [5]

(ii) the mechanical energy losses between sections (1) and (2); [7]

(iii) the net axial force exerted by the pipe wall on the flowing water between sections (1) and (2). [5]

Data: density of mercury = 13550 kg / m^3; density of water $= 1000 \text{ kg / m}^3$

4. Discuss briefly **TWO** of the following

(i) How is flowrate measured with a venturi and an orifice meter? What are the advantages and disadvantages of these two meters? [10]

(ii) What is the mechanism of momentum transfer? How is viscosity affected by temperature in gases and liquids? [10]

(iii) Colburn *j*-factors for heat and mass transfer [10]

5. A large reaction vessel in which acid is mixed at 190 °C has a wall thickness 12 mm and is coated on the inside with glass, 3 mm thick, in order to prevent corrosion. The outside of the vessel wall is coated with a layer of insulation 10 mm thick and the outer surface of this insulation is at 45 °C.

(i) What is the rate of heat loss per square metre of vessel surface? [5]

(ii) Calculate the temperatures at the glass/steel and steel/insulation interfaces. [6]

(iii) If the heat losses are to be reduced to 10% of current losses, by how much must the thickness of the insulation be increased? [5]

State carefully any assumptions that you use. [4]

Data: thermal conductivities ($\text{W m}^{-1} \text{K}^{-1}$): glass 0.92; steel 35; insulation 0.08.

TURN OVER

6. Discuss *briefly* the differences between laminar and turbulent flow in pipes. [7]

It is proposed to install a 25 mm internal diameter pipeline, essentially smooth, straight and level, to take a sample of a liquid from a larger pipeline to laboratories 200 m away. The pressure in the larger pipeline is 6 bar and it is required that the pressure be 2 bar at the outlet of the small, sample pipeline. Given that $c_f = 16/Re$ for $Re < 2000$ and that $c_f = 0.079Re^{-0.25}$ for $Re > 5000$, estimate the mass flowrate through the proposed pipeline. [10]

State carefully any assumptions that you use. [3]

Data: liquid properties: density = 1800 kg m^{-3} and viscosity = 0.72 mPa s.

7. Mass transfer data to and from small spheres in a liquid may be correlated by:

$$k_L = \frac{2D_{AB}}{d} + 0.31\left(\frac{\mu_L}{\rho_L D_{AB}}\right)^{-2/3}\left(\frac{\Delta\rho\mu_L g}{\rho_L^2}\right)^{1/3}$$

where k_L is the liquid film coefficient, D_{AB} is the diffusivity of solute A in solvent B, d is the sphere diameter, μ_L is the liquid viscosity, ρ_L is the liquid density, and $\Delta\rho$ is the difference in density between the sphere and the liquid, and is always positive. All are in SI units.

Oxygen is sparged into liquid in a vessel at 1.5 bar pressure and 40 °C forming bubbles of 300 μm average diameter. The concentration of oxygen in the bulk of the liquid may be taken as zero and the resistance to mass transfer across the gas-liquid interface assumed negligible. Calculate the molar flux of oxygen from the bubbles to the liquid. [10]

If 5 litre s^{-1} of oxygen is sparged into the vessel and the average retention time of the bubbles is 20 s what is the rate of mass transfer to the liquid. [7]

State carefully any assumptions that you have made. [3]

Data: water: $\rho = 994$ kg m^{-3}; $\mu = 6.95\times10^{-4}$ Pa s;
oxygen: solubility in water = 2.26×10^{-4} kmol O_2 m^{-3} bar^{-1}; and diffusivity in water = 3.25×10^{-9} m^2 s^{-1}.

END OF PAPER