UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. *M.Eng.*

Chemical Eng E866: Introduction to Chemical Engineering

COURSE CODE	:	**CENGE866**
UNIT VALUE	:	**0.50**
DATE	:	**16-MAY-05**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

05-C0191-3-80

TURN OVER

Answer FOUR questions. All questions carry a total of 25 marks each, distributed as shown [ ]. Show all workings and state all assumptions.

All pressures are absolute unless otherwise stated.
R = 8.314 J/mol K.1 atm = 760 mm Hg. 1 bar = 100 kPa.

1.

The reaction between ethylene and hydrogen bromide to form ethyl bromide is carried out in a continuous reactor. The product stream is analysed and found to contain 51.7 mole% C_2H_5Br and 17.3 mole% HBr. The feed to the reactor contains only ethylene and hydrogen bromide. Calculate the fractional conversion of the limiting reactant and the percentage by which the other reactant is in excess. If the molar flow rate of the feed stream is 165 mol s^{-1}, what is the extent of the reaction?

[25]

2.

Propylene is hydrogenated in a batch reactor:

$$C_3H_6\ (g) + H_2\ (g) \rightarrow C_3H_8\ (g)$$

Equimolar amounts of propylene and hydrogen are fed into the reactor at 25 ˚C and a total absolute pressure of 32.0 atm. Some time later the temperature is 235 ˚C.

(a) If the reaction goes to completion at 235 ˚C, what would be the final pressure?

[10]

(b) If the final pressure is 35.1 atm and the temperature 235 ˚C, what percentage of the propylene fed has reacted?

[15]

You may assume ideal gas behaviour for this problem.

3.

Liquid water is fed to a boiler at 24 ˚C and 10 bar and is converted at constant pressure to saturated steam. Use steam tables to calculate $\Delta\hat{H}$ (kJ kg^{-1}) for this process and then calculate the heat input required to produce 15,000 $m^3\ h^{-1}$ of steam at the exiting conditions. Assume that the kinetic energy of the entering liquid is negligible and that the steam is discharged through a 15-cm ID pipe.

[25]

PLEASE TURN OVER

4.

Butane and pentane are to be separated by continuous distillation in a fractionation column operating in conjunction with a total condenser and a partial reboiler. The feed to the column is 70 mol% butane as saturated vapour with a flowrate of 100 kmol h^{-1}. The required products are the distillate with 95 mol% butane and a bottoms product with 5 mol% butane.

(a) Sketch and label a simple flow diagram to show the arrangement of the column, condenser and reboiler and the approximate location of the feed. [5]

(b) Calculate the flowrates (kmol h^{-1}) of the product streams. [5]

(c) Assuming constant molar overflow and with the aid of the diagram supplied (Figure 1), which must be attached inside your answer book, use a graphical method to estimate the minimum reflux ratio for the separation and the number of equilibrium stages required inside the column if the reflux ratio used is 2.0 times the minimum. [15]

5.

(i) Consider a 1.8 m-high and 1.2 m-wide double-pane glass window consisting of two 4 mm thick layers of glass ($k_g = 0.78$ W m^{-1} °C^{-1}) separated by a 10 mm wide stagnant air space ($k_a = 0.026$ W m^{-1} °C^{-1}). Use the thermal resistance network to determine the overall heat transfer coefficient, thus determine the steady rate of heat transfer through the double-pane window for a day during which the room is maintained at 20°C while the temperature outside is –5°C.
Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be $h_1 = 10$ W m^{-2} °C^{-1} and $h_2 = 40$ W m^{-2} °C^{-1}. [12]

(ii) Explain the following aspects of a centrifugal pump:

(a) Describe in your own words what is the phenomenon of cavitation and how it affects the pump performance. [3]

(b) Describe what is meant by the term "net positive suction head" (NPSH), explaining the difference between $NPSH_A$ and $NPSH_R$. [3]

(c) Consider the following system, in which a centrifugal pump is employed to pump the fluid contained in the tank represented: [7]

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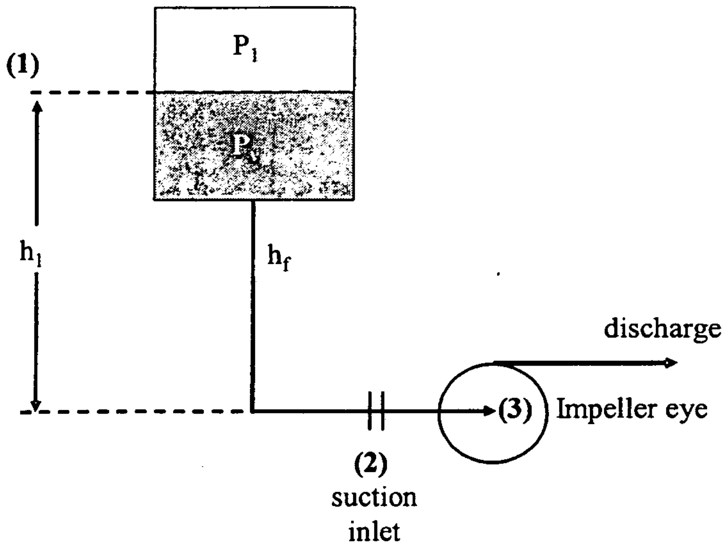

P_l is the pressure acting on the surface of the liquid inside the tank; h_l is the height of the liquid surface above the pump centre-line at the suction inlet; h_f is the total friction loss in the piping system. Write a mechanical energy balance between (1) and (2) for a unit mass (consider the liquid velocity on the surface of the tank u_l to be negligible compared to the velocity at the pump inlet u_2) and use it to obtain the expression for the NPSH available if the vapour pressure of the liquid contained in the reservoir is P_v.

Using the mechanical energy balance write the expression for the total head at the suction inlet and therefore the condition for which cavitation becomes probable, if the pressure drop at the suction inlet (3) is given as:

$$\Delta P = \phi \frac{u_3^2}{2g}$$

where ϕ is a pressure drop coefficient characteristic of pump geometry and u_3 is the fluid velocity at the impeller eye.

6.

(a) What determines the temperature and pressure ranges that typical reactors operate at? Give approximate ranges. [4]

(b) Give an example of a batch reactor made of wood. [2]

(c) Present three ways of temperature control in a batch reactor. [4]

(d) What are the advantages and disadvantages of fluidised bed reactors? [5]

(e) A well-mixed continuous stirred tank reactor of volume V is supplied with a reactant A of concentration C_{IN} in a solution with a volumetric flowrate of Q. Derive an expression for the conversion X, assuming the reaction to be second order in A with a rate coefficient of k. [10]

END OF PAPER

CANDIDATE NO. ______________ SEAT NO. ______________

Figure 1: Butane/Pentane Equilibrium curve