NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF APPLIED CHEMISTRY
END OF SEMESTER EXAMINATIONS – DECEMBER 2001
CHEMICAL ENGINEERING PLANT DESIGN – SCH 4108
TIME – (3) THREE HOURS

INSTRUCTIONS TO CANDIDATES

1. All questions carry equal marks.
2. Answer any ***FOUR*** questions.
3. Show all your working steps clearly in any calculation.
4. Start the answer for each question on a fresh page.

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1. (a) What are the basic components of a Chemical Manufacturing Process. (7 marks)

   (b) One of the stages in the solution of a design problem is the determination of the degrees of freedom.

   (i) What are degrees of freedom. (2 marks)

   (ii) Explain the meaning of each of the following scenarios in relation to process optimization:

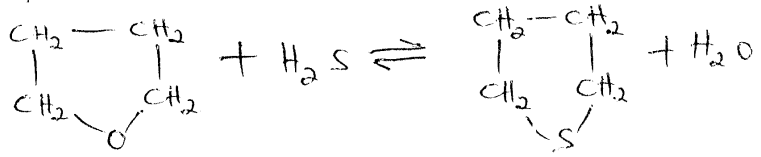
   Degrees of freedom (fd) = 0 (2 marks)

   Degrees of freedom (fd) > 0 (2 marks)

   Degrees of freedom (fd) < 0 (2 marks)

   (c) One of the factors that affect the optimum operation of a distillation unit is the reflux ratio. Explain how the reflux ratio affects the total annual costs of running a distillation unit. (10 marks)

2. A Chemical Engineering Consultant for a large refinery complex has been asked to investigate the feasibility of manufacturing 1.44×10^{-2} kgs^{-1} of thiophane, an odorant made from a combination of tetrahydrofuran (THF) and hydrogen sulphide. The essential reaction is given as follows:



The process consists of essentially the following steps:

(i) THF is vaporized and mixed with H_2S to one mole of THF and reacted over an alumina catalyst.

(ii) Reactor vapours are cooled to 300K and phase separated.

(iii) The noncondensable gases are removed and burned in a fume furnace while the crude thiophane is caustic washed.

(iv) The caustic treated thiophane is then batch distilled in a packed tower and sent to storage before eventual shipment.

(v) The recoverable THF from the caustic column is fed back to the reactor from a waste separator.

(vi) The aqueous bottoms stream is stored for further processing in the plant.

(a) Analyse this process and summarise it with a flowsheet. (12 marks)

(b) If the conversion in the reactor is 80% and 90% of the thiophane which is fed into the phase separation stage is collected after the final separation unit, Calculate:

(i) The amount of thiophane which is fed into the phase separation unit in kgs^{-1}. (2 marks)

(ii) The feed rate of tetrahydrofuran (THF) and H_2S in kgs^{-1} (8 marks)

(iii) Calculate the annual production rate of thiophane if the plant availability is 85%. (3 marks)

NOTE: Assume the whole process is continuous in solving all the problems.

3. (a) What do you understand by the following terms:

(i) Economic Optimum Production Rate. (2 marks)

(ii) Breakeven Production Rate. (2 marks)

(iii) By means of a sketch diagram explain the relationship between Cost of Production and the Rate of Production per day. (On your graph show; Fixed Costs, Total Production Costs, Total Income, Loss and Profit Regions). (6 marks)

(b) A plant produces steel at the rate of P tones per day. The variable costs per tonne of steel have been found to be $\$47.73 + 0.1P^{1.2}$. The total daily fixed charges are \$1750.00 and all other expenses are constant at \$7325.00 per day. If the selling price per tonne of steel is \$173 00. Determine:

(i) The profit per tonne of steel at a production schedule giving the minimum cost per tonne. (4 marks)

(ii) From (i) above calculate the total daily profit at the production schedule in (i). (2 marks)

(iii) The daily profit at a production schedule giving the maximum daily profit. (5 marks)

(iii) Show that the breakeven production rate is 88 tonnes/day. (4 marks)

4. (a) Describe how the optimization of a single variable problem can be solved:

(i) Analytically
(ii) Graphically

Use the equation:

$G = 2x + \frac{8}{x} + 1$ to illustrate your procedure.

where G = Total cost of installing pipe lagging.

x = thickness of pipe. (13 marks)

(b) What factors are considered for the allocation of fluids in heat exchangers to either the shell side or the tube side. (12 marks)

5. The purchased equipment cost for a plant which produces pentaerythritol (solid-fuel processing plant) is $3000 000 (three million). The plant is to be an addition to an existing formaldehyde plant. The major part of the building cost will be for indoor construction, and the contractor's fee will be 7% of the direct plant cost. All other costs are close to the average values found for typical chemical plants.

On the basis of the information given in Table 1 on page 4, Calculate:

(a) The total direct plant cost (physical plant cost). (8 marks)

(b) The fixed capital investment. (8 marks)

(c) The total capital investment. (4 marks)

(d) Describe in brief what you understand by the following terms:

(i) Predesign cost estimates. (3 marks)
(ii) Contingency allowance. (2 marks)

ITEM	PROCESS TYPE		
	FLUIDS	FLUIDS-SOLIDS	SOLIDS
f_1 Equipment erection	0.4	0.45	0.50
f_2 Piping	0.7	0.45	0.20
f_3 Instrumentation	0.20	0.15	0.10
f_4 Electrical	0.10	0.10	0.10
f_5 Building process	0.15	0.10	0.05
*f_6 Utilities	0.50	0.45	0.25
*f_7 Storages	0.15	0.20	0.25
*f_8 Site Development	0.05	0.05	0.05
*f_9 Ancillary Building	0.15	0.2	0.30
f_{10} Design and Engineering	0.30	0.25	0.20
f_{11} Contractor's Fee	0.05	0.05	0.05
f_{12} Contingency	0.10	0.10	0.10

*Omitted for minor extensions or additions to existing site.

Working capital is 15% of the fixed capital investment.

6. The purchased cost of a tubular heat exchanger, carbon steel shell, stainless steel tubes, heat transfer area 500m^2, was \$150 000 (one hundrec and fifty thousand) in 1986. Estimate the purchased cost of a similar heat exchanger of heat transfer area 300m^2 in 1990, using the information given below,
Marshall and Swift Equipment Cost Index (all industry):

For 1986 – 798
For 1990 – 904

Equipment vs. capacity exponent is 0.44 (Cost Capacity Factor) (8 marks)

(b) Sketch a typical cash flow diagram for a typical industrial operation. Briefly explain the characteristic regions involved. (10 marks)

(c) It is desired to have \$90000 available 12 years from now. If \$50000 is available for investment at the present time, what discrete annual rate of compound interest on the investment would be necessary to give the desired amount. (7 marks)

END OF QUESTION PAPER!!!