UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

M.Sc.

M6: Advanced Process Engineering

COURSE CODE	:	**CENG00M6**
DATE	:	**07-MAY-02**
TIME	:	**14.30**
TIME ALLOWED	:	**3 hours**

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UNIVERSITY OF LONDON

Chemical Engineering

M6

*Answer **Question 1** and **THREE** other questions from the rest of the paper.*
Each question carries a total of 25 marks, distributed as shown [ ].

1. a) Describe the Simulated Annealing optimisation procedure through the use of an algorithm. Identify the aspects of this procedure which require tailoring for specific optimisation problems. Describe how simulated annealing can be applied to distillation sequence synthesis in terms of the above aspects. [10]

b) A plug flow reactor can be modelled by a series of continuously stirred tank reactors (CSTR). The design of a plug flow reactor can be achieved by identifying the number and the size of the CSTR units. Draw a superstructure graph which would form the basis for a MINLP synthesis problem to find the optimum process for the production of component C given a feed stream containing A and B and an equilibrium reaction, A+B $\Leftrightarrow$ C. It may be assumed that A is the most volatile component, C the least and that only one sharp distillation unit is needed for product purification. Also, assume a maximum of 2 CSTR units. State all further assumptions made in generating the superstructure. How many binary variables are required to represent this superstructure? [13]

c) Describe the main advantage and the main disadvantage of the P-Graph approach. [2]

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2. a) Solve the following constrained optimisation problem analytically:

Min $f(x) = 2x_1^2 - 2x_1x_2 + 2x_2^2 - 6x_1 + 6$

Subject to
$h(x) = x_1 + x_2 - 2 = 0$

If the constraint above were an inequality constraint would the solution you found still be a solution? Explain your reasoning. [12]

b) Explain how the Sequential Quadratic Programming method is based on a quadratic approximation to the Lagrangian. [4]

c) Why is the BFGS update the most commonly used of the Quasi Newton updates for optimisation? [4]

d) What are the main causes of failure of the SQP algorithm and how would you proceed if the algorithm did fail? [5]

3. a) State the basic steps in any gradient based algorithm for unconstrained optimisation. [5]

b) Show that one step of the Newton algorithm without line search from the initial point $x = [0\ 0]^T$ gives the solution to the problem and explain why this is so.

Min $f(x) = (x_1 - 8)^2 + (x_2 - 5)^2 + 16$ [10]

c) What is meant by the trust region line search method? [4]

d) Why do discontinuities in models cause problems for gradient based algorithms? What would you do to assist the method in finding a solution? [6]

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4. a) Formulate the following logical implication by a mixed integer linear set of constraints by using 0-1 variables:

$$If \ \sum_i A_i X_i \le B \ \ then \ \sum_j C_j Z_j \le D$$

where X and Z are continuous variables; and A_i, C_j, B and D are given parameters. [12]

b) Consider a company which examines P candidate products for manufacturing over the next T years. Each product p is characterised by a given annual demand, D_{pt}, and expected profit, M_p, if product p is selected.

Assume that each product will be manufactured over the T-year period if it is selected. It is also given that the company is constrained by an annual maximum capacity, C, for the total manufacturing and distribution of the selected products. The objective is to choose the appropriate products so as to maximise the total profit of the company. Formulate the above zero-one integer programming problem.

How can the selection of a maximum of N $(N \le P)$ be forced in the above model? [13]

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5. a) A blending company can purchase up to five ingredients: *A, B, C, D* and *E*. Formulate the following cases as mixed integer linear programming constraints:

i) Select at least three ingredients.
ii) If ingredient *E* is selected then *A* or *B* should be chosen.
iii) If ingredients *A* and *B* are both selected, then ingredient *D* should be selected.
iv) If only *B* or *C* is chosen, then ingredient *A* should not be selected. [10]

b) A company considers placing *M* fire stations studying *K* alternative locations to serve a production plant of *N* units. Each processing unit *i* can be reached (served) by a potential fire station at location *k* within T_{ik} minutes. All response times (T_{ik}) are known parameters.

The objective is to select the best *M* locations to place plant fire stations in order to minimise the maximum response from any selected location to the processing units to be served. Assume that each processing unit should be allocated to exactly one fire station. Formulate the above problem as a mixed integer linear programming model. [15]

END OF PAPER