COMPUTER SCIENCE TRIPOS Part II (General)
DIPLOMA IN COMPUTER SCIENCE

Thursday 2 June 1994 1.30 to 4.30

Paper 13 (Paper 4 of Diploma in Computer Science)

Answer **five** *questions.*
Submit the answers in five **separate** *bundles each with its own cover sheet.*
Write on **one** *side of the paper only.*

1 Digital Electronics and Computer Design

Write about 300 words about the purpose of and prospects for asynchronous logic systems. [15 marks]

Distinguish speed-independent and self-timed circuits from conventional asynchronous circuits. [5 marks]

2 Computer Structures

Write short notes explaining the following:

(*a*) hard-wired control of a CPU [6 marks]

(*b*) asynchronous operation of a bus [7 marks]

(*c*) delayed branching in a pipelined RISC processor [7 marks]

3 Digital Communication I

Define the term *flow control*. [5 marks]

How does it differ from *congestion control*? [3 marks]

What is meant by the terms *entry level*, *hop by hop* and *end to end* flow control? When is each appropriate? [8 marks]

Sketch the design of a simple flow control protocol. [4 marks]

4 Graphics

Discuss transformations applied to 3D wireframe objects. [12 marks]

Discuss the use of homogeneous coordinate representations

(*a*) for presenting concepts [4 marks]

(*b*) within programs [4 marks]

5 Programming in C

Write a program in C which can solve cryptarithmetic puzzles in the format of the sum of two words. For example, given the input

```
 SEND
+MORE
-----
MONEY
```

the program would output

```
 9567
+1085
-----
10652
```

N.B. Each letter represents a different digit. [20 marks]

6 Programming Language Compilation

Discuss two possible strategies that you might use to translate the abstract syntax tree corresponding to an integer expression composed of simple variables, integer constants and the usual integer operators $+$, $-$, $*$ and / into reasonable quality code for a machine with eight general-purpose registers.

You should pay particular attention to how you would control the allocation of registers and anonymous store locations, and you should outline what optimisations are convenient to perform. [20 marks]

7 Artificial Intelligence II

Explain how genetic algorithms differ from conventional mathematical methods for optimisation. [10 marks]

What are the advantages and disadvantages of genetic algorithms? [10 marks]

8 Databases

Describe how a data model is represented in a *relational database*, and explain how one might specify a *relational database schema*. [5 marks]

What is meant by a *referential integrity constraint* in a relational database? [3 marks]

Each year the number of tourists coming to Cambridge increases by 10%. Most of the pressure falls on a limited number of identified sites in the city centre. The Tourist Board has restricted the size of any group visiting such a site to 20, and requires a group of ten people or more to get a permit in advance. Most bookings are made either by tour operators or directly by independent guides: the Tourist Board will arrange guides for groups if asked to do so.

A database is being installed to coordinate bookings and to provide information about the opening times of sites. Each site has separate opening times for summer and winter (owing to college autonomy, changes of season differ from site to site). Permits are issued to start on the hour or on the half-hour: they are valid either for 1 hour or for 2 hours, the duration being fixed for each site. The final permits of each day are timed to expire at the site's closing time. Each site has a fixed capacity, and no booking can be accepted that would cause it to be exceeded. The charge for a permit depends only on the site and the season. (Occasionally sites are closed for several hours during the normal opening period, for example when recording is taking place in King's College Chapel. The protocol is to inform the Tourist Board at least 6 months in advance.)

The Tourist Board issues permits to visit an identified site at a given time on a given day, specifying the booking agent and the number in the group. Bookings can be made up to 6 months beforehand. Permits are issued to registered tour operators and guides on account, but in all other cases payment must be made in advance. The data held for registered guides includes not only account details but also their working hours and charges.

Design a schema for the relational database that is to record this information for the Tourist Board. You may find it helpful to use domain types `DATE`, `TIME` and `MONEY` in addition to standard programming language datatypes. You do not need to specify the transactions that maintain the database, but you should state clearly any assumptions that influence the schema design. [12 marks]

9 Specification and Verification of Hardware

Discuss the problems of providing tractable models of transistors suitable for hardware verification by formal proof. Compare and contrast at least two different models. Illustrate your discussion with concrete examples of transistor circuits.

[20 marks]

10 Complexity

For each of the following statements state whether the claim made is true, false or if more information is needed before a judgement can be made. Give one-sentence justifications of your assertions.

(a) Sorting a list of numbers into ascending order is an NP problem.

(b) Sorting a collection of programs into order so that the ones that finish quickly come before those that run for a long time is an NP-complete problem.

(c) To be NP-complete is to be as difficult as any solvable problem can be.

(d) Any NP problem can be solved (on an ordinary computer) in polynomial space and exponential time.

(e) The problem of determining whether a k-clique is present in a graph is known to be NP-complete. Therefore for large graphs and large values of k it will always be impossible (in practice) to find such a clique even if it is known that one exists.

(f) For the purposes of complexity theory each of the cost functions $n \log n$, $n^{1.573}$ and $n!$ counts as polynomial growth.

[20 marks]

11 Computation Theory

Explain *Turing's Thesis*. [5 marks]

(a) What is meant by saying that a Turing machine has *searching* states? Show that any Turing machine computation can be effected by a machine with searching states, equivalent in the sense that the head movements are identical and the same symbols are written to the tape. [5 marks]

(b) Show that, subject to suitable encoding, any computation can be carried out by a Turing machine having only two states. [10 marks]

12 Professional Practice and Ethics

Discuss the relations among the following concepts:

(a) secrecy

(b) confidentiality

(c) anonymity

(d) control of personal information

(e) privacy

[20 marks]