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

Wednesday 1 June 1994 1.30 to 4.30

Paper 12 (Paper 3 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

A sequential machine with two input wires and a single output has a behaviour
specified in the following transition table:

		Next state					Output			
Initial state	Input	00	01	10	11	Input	00	01	10	11
a		c	b	a	a		0	0	0	1
b		d	b	b	e		0	1	1	1
c		e	d	e	a		0	0	0	1
d		b	d	b	a		0	1	1	1
e		a	d	c	c		0	0	0	1

Demonstrate that this behaviour could be exhibited by a machine with fewer states.
[12 marks]

Draw the state diagram for the reduced machine.   [8 marks]

2 Computer Structures

What are the parameters which characterise the operation of a cache?   [8 marks]

Describe three methods of mapping memory blocks to cache blocks.   [7 marks]

Would the cache be a help or a hindrance if the CPU were used to handle
continuously changing data such as video?   [5 marks]

3 Digital Communication I

Define the term *circuit* as used in "circuit switching".   [4 marks]

Sketch the design of the in-band switching function of a circuit switch which switches 4×2 Mbps trunks each supporting 32×64 Kbps channels.   [8 marks]

Describe how you would augment this design to allow the set up and clearing of connections. You should invent your own simple protocol for this purpose.
                                                                [8 marks]

4 Graphics

Discuss sampling artifacts and their effect on image quality on a raster display.
                                                               [10 marks]

What can be done to reduce or eliminate them?   [10 marks]

5 Programming in C

Write a program in C which, given two integer inputs J and K, will output the combinations of J things partitioned into K groups. For example, if $J = 5$ and $K = 3$, the output would be:

```
(5,0,0)
(4,1,0)
(3,2,0)
(3,1,1)
(2,2,1)
```

                                                               [20 marks]

6 Programming Language Compilation

Suggest how you would represent Lambda-expressions in a form suitable for a simple Lambda-evaluator in which the environment is represented as a linked list of name–value pairs. [5 marks]

Outline the design of the evaluator, paying particular attention to the treatment of bound variables, abstractions and applications. [5 marks]

Augment your evaluator to cope with sufficient expression operators, including a built-in version of the Y operator so that when the evaluator is given the abstract syntax tree for

```
Y (λf.λn. n=0 -> 1, n*f(n-1)) 5
```

it will yield 120. [10 marks]

7 Artificial Intelligence I

Compare and contrast *heuristic search* and *exhaustive search*. [6 marks]

Which compromises are accepted by the heuristic approach? [8 marks]

Illustrate your answer with examples of heuristics. [6 marks]

8 Databases

What are the primitives in terms of which a network data model is presented?
[4 marks]

Explain how such a data model is specified in the CODASYL Schema Data Definition Language. [6 marks]

How does an application programmer in COBOL gain access to a CODASYL database? [3 marks]

Describe the COBOL programmer's model of the database, illustrating your answer with suitable data manipulation commands. [7 marks]

[TURN OVER

9   Specification and Verification of Hardware

Briefly discuss each of the following topics:

(a) the representation of schematic diagrams in predicate calculus   [5 marks]

(b) the use of primitive recursion in hardware specification   [5 marks]

(c) modelling combinational and sequential circuits   [5 marks]

(d) temporal abstraction   [5 marks]

10   Complexity

What is a Hamiltonian Circuit?   What is the Boolean Satisfiability Problem "3-SAT"?   [5 marks]

In 50 to 100 words each, sketch

(a) how an efficient solution to 3-SAT would allow you to construct an efficient solution to the Hamiltonian Circuit problem   [6 marks]

(b) how an efficient solution to the Hamiltonian Circuit problem would allow you to solve 3-SAT   [6 marks]

(c) what is meant by "efficient" in this context   [3 marks]

You are not expected to include technical details of any constructions you need in deriving one algorithm from another: a clear statement of what can be done will suffice.

11 Computation Theory

The Halting Problem for register machines is unsolvable. State, without proof, a precise form of this result. [3 marks]

Let the computation by program p on data d be represented by the natural number k that codes the pair (p, d). By considering the set $H(k)$ of the HALTing computations represented by codes $k' \leqslant k$, show that there is an increasing total function $h(k)$ which *grows too fast* to be computable. [6 marks]

Given $h : \mathbb{N} \to \mathbb{N}$ with the above property

$$\text{let} \;\; f(k) \;\; = \;\; h(k) + k$$
$$\text{and} \;\; g(x) \;\; = \;\; \sup\{k : f(k) \leqslant x\}.$$

Then $f : \mathbb{N} \to \mathbb{N}$ is strictly increasing, and $g : \mathbb{N} \to \mathbb{N}$ satisfies

$$g(f(k)) \;\; = \;\; k, \quad g(x) < k \quad \text{for all } x < f(k).$$

Show that g *grows too slowly* to be computable in the following sense...
given $G : \mathbb{N} \to \mathbb{N}$ such that

(a) $\{G(n) : n \in \mathbb{N}\}$ is unbounded

(b) $G(n) \leqslant g(n)$ for all $n \in \mathbb{N}$

then $G(n)$ is *not* computable. [11 marks]

12 Software Engineering

Discuss the reasons why substantial software systems often take longer to implement than planned and do not perform as well as expected. [10 marks]

If you were in charge of a large team implementing such a system, how would you ensure that the product was both reliable and finished on time? [10 marks]