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

Tuesday 1 June 1993 1.30 to 4.30

Paper 11 (Paper 2 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 Distributed Systems

A distributed software system follows the client-server model. The microkernel on which it is based supports multi-threaded processes. A remote procedure call (RPC) package is used for client-server interactions. The RPC system runs above an unreliable, datagram-based communications service.

(*a*) Explain how timers may be used in the RPC protocol to achieve client-server synchronisation. [10 marks]

(*b*) Discuss how the RPC system may support the location of remote procedures. [7 marks]

(*c*) Discuss the requirements on the RPC system that follow from the use of multi-threaded processes. [3 marks]

2 Common Lisp

You are asked by your manager to write a Lisp macro, `itercall`. Evaluating `(itercall` F E`)` evaluates E, which is expected to yield a non-negative integer n. It then executes the function calls `(`F `1)`, ..., `(`F n`)` in succession, and returns `nil`.

(a) Your first version of the macro expands to a loop, which uses the symbol `i` as an index variable and the symbol `n` to store the initial value of E. Present the code for this version. [5 marks]

(b) Your manager complains that the function

```
(defun test1 (i) (itercall (lambda (x) (print (cons x i))) 10))
```

does not work as expected. Explain the problem and suggest how to fix it by modifying the macro. [4 marks]

(c) Your manager requests a final modification: `(itercall` F E`)` should generate straight-line code instead of a loop provided E is an integer constant less than twenty. Present the code for this version. Will it run faster than the previous versions? [11 marks]

Note: `(integerp` x`)` tests whether x is an integer. Each time `(gensym)` is called, it returns a new symbol not previously used in the Lisp system.

3 Software Engineering

Give a brief description of the main constructs used in a VDM specification. [7 marks]

Discuss to what extent the notation used in VDM is significantly different from that used in a conventional programming language. [6 marks]

Use VDM to specify a function that will find the difference between the largest and the smallest values held in an integer array. [7 marks]

4 Prolog

The following Prolog clauses define the procedure named `reverse`. The goal `reverse(X,Y)` succeeds for the list `X`, instantiating `Y` to the reverse of the list `X`. For example, evaluating the goal `reverse([a,b,c],Q)` instantiates `Q` to `[c,b,a]`.

```
reverse(X,Y) :- rev(X,[],Y).

rev([],L,L).
rev([H|T],R,Y) :- rev(T,[H|R],Y).
```

Explain how this procedure works, using a small example. [10 marks]

What is the outcome of the goal `reverse(L,[a,b,c])`? Explain your answer carefully. [10 marks]

5 Programming Language Compilation

Give a brief description of the main features of Lex and Yacc. [5+5 marks]

Illustrate their use by outlining how you would construct a parser for expressions composed of identifiers, integers, function calls and the operators `*`, `/`, `+` and `-`. [10 marks]

6 UNIX Case Study

Show how race conditions can arise:

(a) among processes over access to shared data [4 marks]

(b) between processes and interrupt-driven routines [4 marks]

Discuss why the UNIX kernel cannot be run on a shared-memory multiprocessor. [7 marks]

Outline how the UNIX kernel could be modified to run on a shared-memory multiprocessor. [3 marks]

Describe briefly an alternative approach. [2 marks]

7 Operating System Functions

In relation to virtual memory, describe the terms *segment*, *page* and *translation lookaside buffer* (TLB). [6 marks]

The operating system for a microprocessor supports a virtual memory model which implements both segmentation and paging. The only hardware assistance for the virtual memory system in the microprocessor is an on-chip TLB.

Outline the data structures held by the operating system. [5 marks]

Describe the actions of the operating system in response to an address exception due to not matching the address issued by the processor in the TLB. [5 marks]

How can the operating system use access permissions to aid its page replacement policy? [4 marks]

8 Data Structures and Algorithms

Describe

(a) how to determine whether or not a point is inside a simple plane closed polygon, paying proper attention to awkward cases [6 marks]

(b) how, with luck, to exclude large numbers of points from the convex hull of a set of points in the plane, with due consideration of what can go wrong [7 marks]

(c) how to compute economically the convex hull of the points that are left after the measures you have described in (b) above [7 marks]

9 Graphics II

When scan-converting items for display, a Z-buffer is sometimes used to avoid some sorting. Outline its operation and limitations. [12 marks]

The use of an A-buffer will improve matters. Explain why. [8 marks]

10 Numerical Analysis I

What is meant by the term *loss of significance*? What is the essential difference between the terms *condition* and *stability* in numerical analysis? Define the term *machine epsilon* and explain why it is an important parameter. [6 marks]

Use the recurrence formula

$$\cos[(k+1)\theta] = 2\cos\theta\cos[k\theta] - \cos[(k-1)\theta]$$

with starting values $\cos 0 = 1$, $\cos\theta = \frac{1}{\sqrt{2}} + \varepsilon$ to evaluate $\cos 2\theta$ and show that loss of significance occurs. [4 marks]

Evaluate $\cos 3\theta$ and $\cos 4\theta$, ignoring terms $O(\varepsilon^3)$. On this evidence, comment on the stability of the formula. [8 marks]

Is the computed value of $\cos 2\theta$ acceptable? Explain your answer. [2 marks]

11 Discrete Mathematics

Let A be a non-empty set, and $\prec$ be a relation on A. What is meant by saying that $(A, \prec)$ is a partially ordered set? [3 marks]

What additional conditions must be satisfied if $(A, \prec)$ is to form:

(a) a totally ordered set [1 mark]

(b) a well-ordered set [2 marks]

(c) a complete partially ordered set? [3 marks]

Suppose now that A is a non-empty set, R a relation on A, and $B \subseteq A$ a non-empty subset. Write $R_B = R \cap (B \times B)$ for the relation induced on B by R. Show that if $(A, \prec)$ is a partially ordered set, so also is $(B, \prec_B)$. [1 mark]

On the set $\mathbb{Z} = \{0, \pm 1, \pm 2, \ldots\}$ of integers define the following relations:

(i) $\leqslant = S^*$, the reflexive transitive closure of $S = \{(n, n+1) : n \in \mathbb{Z}\}$

(ii) $d = \{(m, n) : \exists\, q \in \mathbb{Z}$ such that $mq = n\}$

For each of the set $\mathbb{Z}$ and its subsets $\mathbb{N} = \{0, 1, 2, 3, \ldots\}$, $\mathbb{N}^+ = \{1, 2, 3, \ldots\}$ say whether the relations $\leqslant$ and d induce a partial ordering. Identify instances in which any of the cases (a)–(c) arises, giving your reasons briefly. [10 marks]

12 Proving Programs Correct

Explain in detail the method of verification conditions for establishing the truth of partial correctness specifications. [10 marks]

Outline a proof that the method is correct. [10 marks]