

COMPUTER SCIENCE TRIPOS Part II (General)

DIPLOMA IN COMPUTER SCIENCE

Wednesday 5 June 1996 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 Processor Architecture

What is a *branch delay slot* and why does it arise? [7 marks]

How can branch delays be avoided? [7 marks]

If a processor exhibited one branch delay slot how would you reorder (and possibly modify) the instructions in the following loop to gain a performance advantage?

```

loop
    ldr r2,r3,#4    % r2=load(r3), r3=r3+4
    add r4,r4,r2    % r4=r4+r2
    add r1,r1,#1    % r1=r1+1
    cmp r1,#10     % compare r1 with constant 10
    bne loop       % branch if not equal to loop

```

[6 marks]

2 Computer Architecture

Write short notes on *each* of the following parameters of cache design:

(a) size [4 marks]

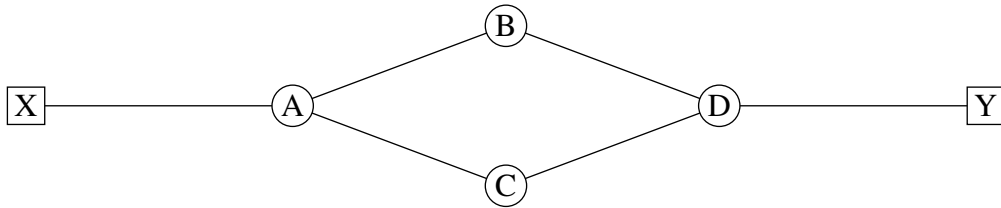
(b) mapping function [4 marks]

(c) replacement algorithm [4 marks]

(d) write policy [4 marks]

(e) block size [4 marks]

3 Digital Communication I



Hosts X and Y are communicating through the data network provided by the switches A, B, C and D and the links interconnecting them as shown above. Initially all packets are travelling through switches A, C and D.

- (a) A packet is corrupted on the link between C and D. Describe the events that take place to recover from the error when
- (i) an end to end flow and error control protocol is in operation [5 marks]
 - (ii) flow and error control are performed on a hop by hop basis [5 marks]
- (b) Switch C fails. Describe the events that follow to recover when
- (i) the network is a datagram network [5 marks]
 - (ii) the network is connection oriented [5 marks]

4 Graphics

Consider the control of detail in a curve represented as a sequence of straight line segments.

Describe Douglas and Peucker's algorithm for removing superfluous points. [10 marks]

Describe how Overhauser interpolation can be used to introduce additional points. [10 marks]

5 Business Studies

In a project plan what is meant by a *critical path*, and why is the concept useful?
[5 marks]

A certain software project has two phases. Each phase has three tasks (analysis, coding and testing) which must be performed sequentially. Analysis for phase 2 cannot be started until analysis for phase 1 is complete. The effort in person-weeks, as estimated by the programmers, in each task is given in the table below.

Task	Phase 1	Phase 2
Analysis	4	8
Coding	4	4
Testing	4	8

Two staff are assigned to the project. Tasks may be performed by either member of staff. Analysis and coding tasks can have only one person usefully working at a time whereas, for testing, the time to completion is inversely proportional to the effort expended.

Draw PERT and GANTT charts for the project, and indicate the critical path.
[5 marks]

Staff are each paid £24,000 per annum. The company allows for overheads of 100% of salary. Equipment worth £50,000 will be needed, depreciated over 5 years. Payment is proposed as 25% on start, 25% on delivery of the first phase, and 50% on completion. Draw up a rough budget and cash flow for the project. How much working capital (excluding equipment purchase, but including depreciation) is required?
[5 marks]

What price and delivery would you quote for this project? Explain the additional factors you have considered in formulating your quotation.
[5 marks]

6 Programming in C and C++

For *five* of the following C or C++ features write a very short fragment of code (perhaps 2 or 3 lines will suffice in most cases) that illustrates the syntax involved. In each case explain very briefly what your example achieves.

- (a) preprocessor macros and conditional compilation
- (b) casts that convert from one pointer type to another
- (c) C and C++ style comments
- (d) the declaration of a simple C++ class
- (e) overloading the operator '+'
- (f) the C `setjmp` function
- (g) the `switch` statement, including a `default` label

[4 marks each]

7 Compiler Construction

Outline the key features of the design of the part of a compiler that will translate the abstract syntax tree representation of a program into a stack-based intermediate code. Concentrate on those features used in the translation of the following fragment:

```

...
LET i = k
LET j = k
WHILE (i>0) AND (j<100) DO { i := i-1; j := j+2 }
...

```

In particular, concentrate on the mechanism you would choose to deal with

- (a) the scopes of identifiers [6 marks]
- (b) the compilation of boolean expressions involving the operators NOT, AND and OR [6 marks]
- (c) the translation of the WHILE command [4 marks]
- (d) the translation of the two assignments [4 marks]

8 Prolog for Artificial Intelligence

An *ordered integer binary search tree* (or OIBS tree) is either empty or a tuple (T, N, U) , where T and U are also OIBS trees and N is an integer. Every node in T has a value less than N , which in turn is less than the value of every node in U .

- (a) Give two Prolog terms which are suitable for representing an empty OIBS tree and a node in the OIBS tree respectively. [2 marks]
- (b) Define a Prolog procedure `insert(Item, T, NT)`, where `Item` is an integer being inserted into OIBS tree `T`, producing an OIBS tree `NT`. If `Item` is already present in `T`, then `NT` equals `T`. [9 marks]
- (c) Define a Prolog procedure `lookup(Item, T)`, where `Item` is to be looked for in OIBS tree `T`. A `lookup` goal will succeed if `Item` is found, or fail otherwise. [9 marks]

9 Databases

Describe the essentials of the ODMG-93 standard for Object Database Management. [7 marks]

To what extent do these proposals conform to the ANSI/SPARC architecture for database management? [3 marks]

Describe how binary relationships can be modelled directly within the ODMG-93 standard. [4 marks]

In what way is it possible to create a representation for n -ary relationships that is similar to that of the relational model? [2 marks]

Explain how these alternative approaches allow a navigational style of data manipulation as well as supporting an extension of SQL. [4 marks]

10 Designing Interactive Applications

Some of today's photocopiers are connected by networks to repair centres so that technicians can monitor their performance and detect problems without visiting customer premises. Although this offers cost savings, it can have a negative impact on customer relations. Suggest an explanation for this, drawing on your knowledge of the service technician's job. [5 marks]

You have been asked to design a modification to a networked photocopier, to enable users to send messages to the repair centre when they encounter problems. Again drawing on your understanding of the nature of photocopier repair work, produce a rough design for the message-system user interface. Include a one-sentence problem statement, a mental-model description and an outline of the design of the user interface itself. [15 marks]

11 Introduction to Functional Programming

Describe how recursive definitions are modelled in the λ -calculus using Y . [6 marks]

Consider the following attempt to define Y in ML:

```
val Y = fn f => (fn x => f (x x)) (fn x => f (x x))
```

Explain why this doesn't work. [6 marks]

Give a satisfactory definition of Y in ML and illustrate its use by defining the factorial function. [4 + 4 marks]

12 Computer Vision

Discuss the problem of face recognition and face detection based on wavelet encodings of facial structure and facial features. How can one distinguish between those facial undulations that are generic (universal, or normally present in all faces), and those which are particular to a given face and which therefore distinguish it from others? How can statistical decision theory formalize these two pattern recognition problems – face detection and face recognition? What are the main advantages and disadvantages of using wavelets for the encoding of faces? [20 marks]

13 Complexity Theory

- (a) Show that the problem 3-SAT is at least as hard to solve as n-SAT. [5 marks]
- (b) Show that the task of finding a minimum cost closed circuit in a weighted directed graph (a Travelling Salesman Problem of the minimization variety) is at least as hard as the Hamiltonian Circuit Problem. [5 marks]
- (c) Show that the class NP-complete is contained in the class P-space. [5 marks]
- (d) Show that the class P-space is contained in the class EXP-time. [5 marks]

In each case ensure that your answer makes it clear what the problems and classes involved are. Standard results do not need to be proved provided they are clearly stated.

14 Numerical Analysis II

In Peano's theorem, if a quadrature rule integrates polynomials of degree N exactly over an interval $[a, b]$, then the error in integrating $f \in C^{N+1}[a, b]$ is conventionally expressed as

$$E(f) = \int_a^b f^{(N+1)}(t)K(t) dt$$

where

$$K(t) = \frac{1}{N!} E_x[(x-t)_+^N].$$

Explain the notation $(x-t)_+^N$ and E_x . [3 marks]

It follows directly from Taylor's theorem that

$$E(f) = \frac{1}{N!} E_x \left\{ \int_a^x f^{(N+1)}(t)(x-t)^N dt \right\}.$$

Explain clearly, in simple stages, how to complete the proof of Peano's theorem. [8 marks]

For the mid-point rule, what is N ? [1 mark]

If $K(t)$ does not change sign in $[a, b]$ then

$$E(f) = \frac{f^{(N+1)}(\xi)}{(N+1)!} E(x^{N+1})$$

for some $\xi \in (a, b)$. Use this result to simplify

$$E(f) = \int_{-1}^1 f(x) dx - 2f(0) \quad [8 \text{ marks}]$$