THE UNIVERSITY OF WESTERN AUSTRALIA

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

SECOND SEMESTER EXAMINATIONS **NOVEMBER 1997**

PROGRAMMING LANGUAGES AND SOFTWARE DESIGN 210 **623.210**

Time allowed: 3 Hours
Reading time: 10 minutes

This paper contains
Section A
Section B
7 pages

Instructions

Answer as many questions as you can in the time allowed. There are 96 marks on this paper. A reasonable target is 85 marks.

Write answers to Section A on the question paper and hand it in with your answers to Section B.

Name	
Student Number	

Section A

Short Answer Questions Total 46 marks

Write your answers on this sheet in the space provided.
*The answers to each part in **Section A** should require no more than two concise sentences. In some cases, a single word or expression will suffice.*
If you need more space or wish to change your answer, use your answer book. Make sure to number the question clearly in your answer book.

Marks

Program efficiency

1 $\sqrt{n}$ is $O(n^2)$. True or False? 1

2 What is meant by the statement "f is $\Theta(g)$"? 2

3 Arrange the following functions of n in the order in which they grow as n approaches infinity (slowest growing function first): 3

n^2 1.0005^n n^{1000} $\sqrt{(n^3)}$ $\log_2 n$

4 What is meant by the statement: "This algorithm runs in O(1) time". 2

5 Other than time, name a factor which sometimes needs to be considered in determining the complexity of an algorithm. 1

6 Give an example of an algorithm in which this factor might be important. 1

Programming strategy

7 If you working on a large software project, would you insist that code was written in ANSI standard C? Give two reasons for your answer. 2

8 If I was constructing a software model for a class of **`vehicle`**s, what files would I create? Provide a one line description of the contents of each file. 3

9 Why do I ensure that the details of the attributes of a software class are hidden in the implementation file so that users of the class cannot access them? (At least two reasons – one sentence each.) 2

10 In defining function `f`, the following comment has been added to the specification. 2

```
double f( int n );
/* Pre-cond: n >= 0 */
```

What should be added to the implementation of this function?

Searching

All the questions in this subsection are related: read all the questions before answering any of them.

11 I need to search a large ($>10^6$) collection of items. Arrange the following searching algorithms in order of their expected running time – slowest first. If you would expect two algorithms to take about the same time, then group them together. Consider the actual searching time only – assume that any necessary data structures have been built already. 3

(a) Linear search
(b) Hash table lookup
(c) Red-Black tree search
(d) Binary search

12 List two of the problems encountered in obtaining good performance with hash table lookup schemes? 2

13 What are the best and worst time complexities found with hash table lookup schemes? 2

14 What time complexity can I always obtain as long as I have a rule for ordering items in my collections? 1

15 What is the time complex to ***add*** an item to (a) a collection set up for binary searching and (b) a red-black tree? 2

16 What are the best and worst time complexities for searching a binary tree? 2

17 Under what conditions would you obtain these best and worst times? (One sentence each – a simple diagram or two might help!) 2

18 When would I need to use a complex tree-balancing algorithm, such as the one to build a red-black tree? 2

Sorting

All the questions in this subsection are related: read all the questions before answering any of them.

19 I need to sort a large ($>10^6$) collection of items. Arrange the following sorting algorithms in order of their expected running time – slowest first. If you would expect two algorithms to take about the same time, then group them together. Assume that you have so much memory on your computer that memory will not be a factor. 3

(a) Quick sort
(b) Insertion sort
(c) Radix sort
(d) Heap sort

20 When would you use insertion or bubble sort effectively? Explain your answer. 2

21 I can obtain better performance from another algorithm. What is it? 1

22 Give two restrictions on the use of this algorithm. 2

Graphs

23 Why is it necessary to be able to distinguish between problems which map to the travelling salesman's problem and the minimum spanning tree problem? 2

24 What data structure would you use to determine whether adding an edge to a graph causes a cycle? Write one sentence describing how this structure is used. 2

25 What is the time complexity of the cycle determining operation? 1

Hard problems

26 Give the time complexity of a typical intractible algorithm 1

27 Can I solve such a problem for (a) small n? (b) large n? In each case, add to your yes or no answer a phrase describing the quality of the best answer that you can obtain with a practical computer. 3

Verifying functions

28 Why is the concept of equivalence classes useful in verifying functions? 2

Section B

QUESTION B1 15 marks

You are developing a private network for your company which has a very large number of outlets all over the country for its mechanically produced, sterile (untouched by human hands!) hamburgers. Each outlet must be connected to the network so that management can arrange to ship all the packaging (the most significant component of your company's output) to the outlets just as it is needed. This network is to be just like the Internet, with nets of multiple redundant links connecting all the outlets. Nodes will be placed in strategic locations. From each node it is possible to have multiple links to other nodes. Network nodes receive large numbers of messages (not all relevant to the company's operations – see below) and are responsible for forwarding them to their correct destination. Links use a variety of technologies – copper wire, optical fibre and satellite. (The chairman of the board hasn't really understood the Internet yet, so there is a very low bandwidth link between his secretary's desk and his: his secretary copies the messages onto pieces of paper and carries them into his office.) All of these links have different bandwidths and thus different costs associated with sending a message over them. In cases of extreme packaging shortage, outlets have to communicate directly with each other to arrange emergency supplies.

As part of the network design process, you have to determine:

(a) The most efficient routing for messages from any outlet to any other. Which algorithm would you use for this? What is its complexity?

(b) The most efficient route for a broadcast message (which emanates from the chairman's office) to reach all nodes. Which algorithm would you use for this? What is its complexity?

(c) The chairman hasn't heard of Internet television yet, so insists on visiting each outlet once a year to encourage the workers. He's getting rather frail now, so that it's important that the most efficient way for him to do this is found. For some reason, this pure public relations exercise has landed on your desk too – perhaps because you have the only up-to-date database containing all the outlet locations. You are required to plan his route. Which algorithm would you use for this? How long would it take you to compute the chairman's route?

(d) You once accidentally showed a few of your colleagues how the network was could run all the chat programs – because it was using standard Internet protocols. Within two days, the prototype network became clogged with messages that seemed to contain little more than "Hi" followed by a name and questions about the weather at other outlets around the country. When the chairman heard about this, he thought it was magnificent that all his employees were talking to each other and refused your request to junk all chat packets from the network. You were forced to add a filter which tagged all chat packets as "non-urgent" and packaging supply and other messages which were actually relevant to the company's operations with 57 other levels of urgency. Which

algorithm should you use at each network node to ensure that messages relating to the company's operations take precedence over the weather? If there are, on average, **n** messages waiting for forwarding at each node at any one time and it takes approximately **c** microseconds to allocate space for a new message, compare its urgency level with another and decide to swap their positions. Approximately how long will it take to receive each message at a node?

QUESTION B2 10 marks

Your P9 computer is able to analyse one million chess moves per second. A genetic engineer has succeeded in combining some of Kasparov's DNA with some recovered from Einstein's fingerprints in a cloned monkey which can now - with absolute reliability - think 10 moves ahead. Assume there are, on average, about 20 possible moves at each position. Assume also that you are able to purchase and connect together, without loss of efficiency, as many of your P9's as you need. You have 100 seconds for each move. How many P9's will you need in order to at least draw with this monkey?

QUESTION B3 25 marks

Design a software module for supporting operations on a class of graphs. This class must provide all the methods necessary to calculate a minimum spanning tree (MST). (Provision of methods to support other common graph algorithms will attract a small bonus - a maximum of 5 marks which will be used to compensate for other flaws in your answer and increasing your chance of obtaining the maximum 25 marks for this question.)

Rules:

i) Graphs consist of a set of nodes and edges.
ii) Initially a graph will be constructed with no nodes and no edges.
iii) Nodes and edges are to be added separately.
iv) The number of nodes and edges in the graph at any one time needs to be available.

(a) Provide a complete formal software definition for the graph class. This should be in the form of a program module that would be accepted by an ANSI C compiler. (Minor syntactic errors will be ignored.)

(b) Suggest a set of data structures which could be used effectively internally in the graph structure to handle the nodes, edges and any other information needed by the class to support operations on it. Obviously, the structures you mention should be sufficient to implement the minimum spanning tree algorithm.

(c) Describe how the cycle determining step of the MST algorithm will work. You may do this by

i) simply describing the algorithm step by step in natural language (with appropriate references to the actual data structures to be used) or
ii) providing suitable annotated actual code (The comments should be sufficiently detailed to enable the algorithm to be understood.) or
iii) any combination of (i) and (ii).

It is strongly suggested that appropriate diagrams to show the working of the algorithm should be used to augment your description.