Computer Science Department

Dummy Cover Sheet

B.A./B.Eng. B.Sc. B.Sc (Econ)

B400 Introductory Programming 1996-97 and resit 1995-96

2 hours 30 minutes

*Part A of this paper is **compulsory**. You should attempt **all of question 1** in part A and any **THREE** questions from part B. All questions carry equal credit.*

*The use of electronic calculators is **not** permitted.*

Part A

Compulsory question

Question 1

(a) Explain what is meant by the terms (i) CPU, (ii) main memory, (iii) cache memory, (iv) disc memory or store. Draw a diagram illustrating how these components are connected in an idealised, stored program computer. Include in your diagram any other components that you think are usually present and explain their function.

[9 marks]

(b) Explain why there are three kinds of memory in the idealised stored program computer in (a) above and discuss whether, in practice these are sufficient.

[7 marks]

(c) Explain why digital, stored program computers are frequently used nowadays to solve problems in science or engineering and what it means "to program" such a machine, describing the kind of program that you would write to solve such a problem and how it is converted into a form that enables the machine to carry out the desired calculation.

[9 marks]

[TURN OVER]

Part B *Attempt THREE questions from this section.*
When writing code, remember to include comments and note that more importance will be attached to the approach adopted than to detailed correctness of the syntax.

Question 2

(a) Describe how a DO-loop may be used to carry out repetitive calculations, explaining (i) how to initialise the required variables, (ii) how the DO-loop is entered, (iii) how execution is controlled whilst the loop is repeatedly evaluated, and (iv) how it may be left.

[9 marks]

(b) Explain how DO-loops may be nested and write a program fragment that can be used to generate the multiplication tables up to an integer value N not greater than 20, commencing with the 1 times table, and arrange for the output to be printed as a square with the results aligned in rows and columns.

[7 marks]

(c) In fairyland, multiplication of two integers, I and J, has been redefined always to lie in the range [1,9] the result I#J (where # is the fairyland multiplication operator) being obtained by: (i) obtaining the value of the usual product, (ii) adding its decimal digits, and (iii) if the result of step (ii) lies in the range [1,9] it is used, otherwise, step (ii) is repeated.

Thus, for example, in fairyland, 5#5 = 7 and 8#6 = 3. Amend your code in (b) above to produce a similar multiplication table in fairyland.

[9 marks]

[CONTINUED]

Question 3

A particular medical imaging system produces tomographic images of the human head in which the density of organic material in a 25x25x25 cm^3 volume is recorded with a spatial resolution of 2.5x2.5x2.5 mm^3. These images are to be manipulated on a 32-bit digital computer equipped with 16 Mbytes of RAM and a large 4Gbyte disc.

(a) Show how you would set up appropriate three-dimensional array variables D and I in the Fortran language respectively to: (i) store the raw image data D as real numbers, (ii) store I as integer *intensity* values, and (iii) write a program fragment to convert the raw data (i) into the integer form (ii) with values lying in the range 0-255, explaining any precautions you would take in order to ensure that your program runs efficiently. Comment on what performance change you would expect to see if at most only 3 Mbytes of RAM were available for storing the data arrays.

[8 marks]

(b) It is desired also to store the integer intensity values at *half* the spatial resolution of the original image by averaging the values of I over groups of *eight* neighbouring positions in the image array. Write a program fragment to perform this averaging and create a reduced resolution image to be stored as contiguous values in an array IR.

[7 marks]

(c) Explain what is meant by a FORMAT statement in FORTRAN 77 and describe how it may be used to control the output of numerical data. If the first and second dimensions of the arrays defined in (a) above represent the horizontal, x and y spatial axes, and the third represents the vertical axis, z, show how you would output the reduced resolution intensity values, IR, as a series of consecutive horizontal slices taken at progressively increasing values of z, each beginning a new page with the positive x axis horizontal to the right and the positive y axis vertically upwards, as is conventional.

[10 marks]

[TURN OVER]

Question 4

(a) Describe what is meant by a function subprogram and explain how it differs from (i) a generic function, (ii) a statement function, and (iiii) a subroutine.

[8 marks]

(b) Write a function subprogram to be called DOTP to calculate the inner (dot) product of two one-dimensional arrays A and B each containing N elements, defined mathematically by:

$$c = \sum_{i=1}^{N} a_i b_i = a_1 b_1 + a_2 b_2 + a_3 b_3 + \ldots + a_N b_N$$

and show how it would be used in a main program in which it was desired to set the variable C equal to the value of the inner product of two one-dimensional arrays X and Y.

[7 marks]

(c) (i) A module is also required to calculate the outer product of A and B, defined mathematically as the two-dimensional array C whose elements $c_{ij} = a_i b_j$. Write a suitable subprogram that would implement this module and write a fragment of the main program showing how it would be used.

(ii) A matrix is a two-dimensional array with particular mathematical properties. One property is that the product P of two matrices R and S, is defined mathematically as the matrix whose elements are given by:

$$p_{ij} = \sum_{k=1}^{M} r_{ik} s_{kj}$$

where R is an L x M matrix possessing L rows and M columns and S is an M x N matrix with M rows and N columns. Use what you have done in (b) and (c) (i) above to construct a module (a function subprogram or subroutine as appropriate) that may be used to calculate the product P.

[10 marks]

[CONTINUED]

Question 5

(a) Describe how a one-dimensional integer array N may be used as a pointer to the elements of a second one-dimensional array A. Illustrate how this works if the array N has the values defined by the statements:

```
PARAMETER (ND = 5)
DATA (N(I),  I=1,ND) /2, 5, 3, 4, 1/
```

and show what code you would use to exchange the pointers to two elements of A.

[7 marks]

(b) Write a program fragment to exchange successive pointers to two elements of the array A if the value of the first array element is smaller than the value of the second. Use this program fragment to develop the code required to sort N by a bubble-sort method so that it points to elements of A in *descending* order. Discuss the advantages and disadvantages of using a pointer array N in this way.

[9 marks]

(c) After N has been sorted so that it points to the ND elements of A in descending order, an additional, new element is added after the last, smallest element of A. Show how you would modify the bubble sort code developed in part (b) above, to read in the new value of A to four significant figures, and to adjust N so that it points to all the elements of A now defined, once again in descending order. Comment on the efficiency of your modified code in comparison to completely resorting the pointers to all the elements of the new array A by the method developed in (b) above.

[9 marks]

[TURN OVER]

Question 6

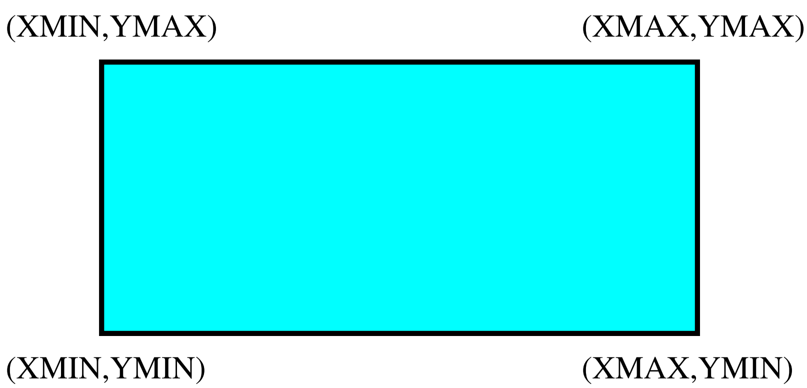
(a) Describe what is meant by the terms (i) logical variable, (ii) logical expression, (iii) logical operators, and (iv) relational operators in a Fortran program and explain how they may be used to control the execution of a program.

[7 marks]

(b) Explain how the block IF structure works, how block IF structures may be nested and how the block IF structure may be extended by use of the ELSE IF construct. Take care to include in you explanation a description of how control is transferred. Illustrate your answer by writing a program fragment to determine whether three integers, I, J and K are all even, all odd or mixed and to set the values of three logical variables EVEN, ODD and MIXED accordingly.

[9 marks]

(c) Write a program fragment to test whether a point (X,Y) in two-dimensions is inside or outside the rectangular window defined by its vertices (XMIN,YMIN), (XMIN,YMAX), (XMAX,YMIN), and (XMAX,YMAX) as sketched below.



You may assume XMIN < XMAX, and YMIN <YMAX. Describe how you would modify your code so as to test whether two points (X1,Y1) and (X2,Y2) were: (i) both inside the rectangular window, (ii) both outside, or (iii) one inside and one outside, and to print out corresponding messages.

[9 marks]

[End of paper]