King's College London

UNIVERSITY OF LONDON

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the Authority of the Academic Board.

M.Sci. EXAMINATION

CP/4731 C and C++ programming for physicists

SUMMER 1999

Time allowed: **THREE HOURS**

Candidates must answer any THREE questions. No credit will be given for attempting a further question.

The approximate mark for each part of a question is indicated in square brackets.

Good answers to questions will include plans and explanations in addition to sections of C or C++ code.

TURN OVER WHEN INSTRUCTED

Answer THREE questions

1) Write a short function in C, called `Ei(x)`, with a single positive argument x, which returns the value of the exponential integral to 5 significant figures. Use the series:

$$\mathrm{Ei}(x) = g + \ln x + \frac{x}{1.1!} + \frac{x^2}{2.2!} + \frac{x^3}{3.3!} + \cdots$$

for $x < |\ln e|$, and the asymptotic expression:

$$\mathrm{Ei}(x) = \frac{e^x}{x}\left(1 + \frac{1!}{x} + \frac{2!}{x^2} + \frac{3!}{x^3} + \cdots\right)$$

for $x > |\ln e|$, where e is the smallest number such that $(1+e)$ is perceived by the computer to be different to 1. It is sufficient to terminate the series once the latest term is smaller than the required precision.

The value of Euler's number g is 0.5772156649.

[20 marks]

2) In an experiment, three readings of a physical quantity y (call them y_1, y_2 and y_3) were taken for each value of x. The results are stored in a file called `data.d` in the form of an integer, N, which is the number of values of x_i, then N lines each of which contains four floating point numbers: x_i, $y_1(x_i)$, $y_2(x_i)$, $y_3(x_i)$.

Write a program in C which reads the data from the file, allocates just enough space for the x_i and the mean value of $y(x_i)$ for each value of x_i. Use the formulae, given below, to calculate the straight line which best fits the data and print out the formula of the line: $y = mx + c$.

$$m = \frac{S_{xy} - S_x S_y}{\Delta}, \quad c = \frac{S_{xx} S_y - S_x S_{xy}}{\Delta}, \quad \text{where}$$

$$S_x = \frac{1}{N}\sum_{n=1}^{N} x_i\ , \quad S_{xx} = \frac{1}{N}\sum_{n=1}^{N} x_i^2\ , \quad S_{xy} = \frac{1}{N}\sum_{n=1}^{N} x_i y_i\ , \quad S_y = \frac{1}{N}\sum_{n=1}^{N} y_i\ ,$$

$$\Delta = S_{xx} - (S_x)^2$$

[20 marks]

[SEE NEXT PAGE]

3) Explain the differences between pointers (in C or C++) and references (in C++).

[2 marks]

Show how the elements of one- and two-dimensional arrays can be manipulated by means of pointers, or, interchangeably, by using the index (or indices).

[8 marks]

Write a short function in C or C++ which, given two 3×3 float arrays representing matrices as arguments, calculates their matrix product.

[10 marks]

4) Design a hierarchy of classes of shapes in C++:
`Point` contains just the position (x, y) of a point in 2-D.
`Shape2d` contains one point and a virtual function which calculates the area of the shape.
`Square` contains a point (its centre) and the length of its side, and the area function.
`Circle` contains a point (its centre) and its radius, and the area function.
Each class should contain the constructors and functions which would allow it to be used to manipulate these shapes.

[20 marks]

5) Explain what is meant by overloading in C++.

[2 marks]

Write a class of one-dimensional float arrays, such that the [] brackets are overloaded to check the bounds of the array every time an element of an array of that class is used. The space for the array should be allocated dynamically. Show how it would be used.

[18 marks]

[FINAL PAGE]