2006 SCHOLARSHIP EXAMINATION

WRITTEN SECTION

DEPARTMENT	Computer Science
COURSE TITLE	7th Form Scholarship
TIME ALLOWED	Two hours
NUMBER OF QUESTIONS IN PAPER	Eleven
NUMBER OF QUESTIONS TO BE ANSWERED	Eleven
VALUE OF EACH QUESTION	The value of each question is indicated.
GENERAL INSTRUCTIONS	Candidates are to answer ALL questions in the answer booklet provided.
SPECIAL INSTRUCTIONS	None
CALCULATORS PERMITTED	Yes

Section A: Computing Concepts

1. Convert the eight bit binary number 01010101 to:

    (a)   Octal (base 8)

    (b)   Hexadecimal (base 16)

    (c)   Decimal (base 10)

    (5 marks)

2. In the following loop the variable X is of a floating point type (real):

    Do
       X = X – X*0.1
    Until X = 0

    Note that = could be == in some languages. What is wrong with controlling a loop in this way?

    (5 marks)

3. When we write down numbers, we express negative numbers by placing a "-" (minus sign) at the beginning. Similarly in binary, we could start by letting the leftmost bit in an integer be the "sign bit". If the left-most bit is a zero, the integer is positive, if it is a one, it is negative. To make it easy to design computers which do integer arithmetic, we would like for our integers to obey the following rules:

    1. Zero is positive and -0 = 0

    2. The leftmost bit should tell us the sign of the integer.

    3. The negative of a negative integer is the original integer. That is -(-7) = 7.

    4. x - y should give the same result as x + -y. That is, 12 - 5 should give us the same result as 12 + -5.

    5. We should not have to treat negative and positive numbers in different ways when we do addition and subtraction with them.

    A simple and elegant way to represent integers which obeys these rules is called "two's complement". The two's complement of an integer is found by changing all bits from 1 to 0 and 0 to 1 resp. (this is called the one's complement), then adding 1 to the result. The 8-bit integer representing 25 (decimal) is 00011001. The two's complement of 25 is 1110 0111.

    ```
    0001 1001
    1110 0110 - the one's complement, change 1's to 0's and 0's to 1's
         +1
    ---------
    1110 0111 - the two's complement
    ```

    By working through an example using decimal 25 show that property three -(-25) = 25 holds for two's complement numbers.

    (5 marks)

4. A typical PC today contains only one processor, but can run multiple programs at once, such as a word processor alongside an audio playback program. How can this be true? The very latest PCs have multiple "cores". What does this mean and how does this alter the execution of multiple programs?

    (10 marks)

5. If you're using Microsoft Windows or a version of Linux and have a connection to the Internet, one of the useful programs you can use is called **traceroute** and it shows the path your packets of data are taking to a given Internet destination. If you had typed say:

    traceroute www.cs.waikato.ac.nz

    you would be told that the packets don't simply go from your machine to this site. What other possible things could be in the way?

    (5 marks)

6. What are the factors that determine the running time (how long it takes to complete) of a computer algorithm?

    (5 marks)

Section B: Programming

Note: In answering questions 7 – 10 you should notice that the question wording fails to explain what your program fragment should do in some situations. Where this is the case you should describe the problem, choose and implement a solution. Marks will be awarded for this analysis.

7. Assuming access to code that would tell you if a given number was prime or not, for example a Boolean function `isPrime(X)` such that:

$$isPrime(5) = true \text{ and } isPrime(6) = false$$

The mathematician Goldbach conjectured that "every even number larger than two can be written as the sum of two prime numbers". For example, $4 = 2 + 2$, $8 = 3 + 5$, $10 = 3 + 7$, $100 = 89 + 11$. Write a code fragment to demonstrate that this is true for even numbers from 2 to 100.

(10 marks)

8. Write a program fragment to determine if any of the characters in an array of characters are particular punctuation symbols, eg. it could detect one of "; :", or one of ", ! %".

(10 marks)

9. An array holds the distances of various towns to a given town. If we had to write a program fragment to determine the closest town or if there are two towns that are exactly the same distance away from the given town, which of these two problems would be easier and why?

(10 marks)

10. Consider the following expression ((a+b) * ((c + d) – e)). Expressions like these can be very complicated and when we come to analyse them we often want to know simply whether or not the parentheses are "balanced" i.e. for every left parenthesis "(" there exists a closing right parenthesis ")". If we ignore the actual expressions then in our example the pattern is (( ) (( ))) – so four left and four right = balanced. If the pattern was contained in an array P, eg P = [(,(,), (, (,),),)] write a code fragment that determines if P is balanced.

(10 marks)

Section C: Problem Solving

11. Consider the program fragment below which takes as input an Array A[1 .. n] of numbers (where n is always known in advance):

```
(1)        for i = 1 to n – 1 do begin
(2)           small = i
(3)           for j = i + 1 to n do
(4)              if A[j] < A[small] then small = j
(5)           temp = A[small]
(6)           A[small] = A[i]
(7)           A[i] = temp
(8)        end
```

(a) Show how the array A = [4, 6, 3] is processed by the program fragment (here n = 3).

(10 marks)

(b) If you had to name this program fragment what would you call it?

(5 marks)

(c) What is the purpose of the lines (5)-(7)?

(5 marks)

(d) If the array A was very large (n = 1,000,000), which line or lines would occupy most of the processing time?

(5 marks)