Birkbeck

(University of London)

BSc/FD EXAMINATION

Department of Computer Science and Information Systems

Introduction to Computer Systems (BUCI008H4)

CREDIT VALUE: 15 credits

Summer 2017 Examination

SUMMARY ANSWERS

Date of examination: Wednesday 31 May 2017
Duration of paper: 2.30pm - 4.30pm

There are **ten** questions in this paper.

Answer all **ten** questions.

Each question carries **10** marks in total.

Calculators and other electronic devices are not permitted.

The examination is closed book.

No supplementary material is provided.

This paper is not prior disclosed.

1. (a) Add the decimal integers 15 and 27. Show your working. (**2** marks)

Answer: 42. One mark for the answer and 1 mark for the working.

(b) Subtract the binary number 101 from the binary number 11001. Show your working.

Answer: 10100. One mark for the answer and 1 mark for the working.

(**2** marks)

(c) Write out the binary representation of the number $2^6 + 2^4$. Justify your answer.

(**2** marks)

Answer: 1010000. The binary number contains 1 in the 5th place from the right, 1 in the 7th place from the right and 0 elsewhere. One mark for the answer and one mark for the explanation.

(d) Explain the way in which the binary representation of a number specifies that number as a sum of powers of 2. (**4** marks)

Answer: a binary digit 1 in the ith place from the right corresponds to 2^{i-1}. *A digit 0 in the ith place from the right indicates that there is no corresponding power of two. The number is equal to the sum of the powers of two associated with each binary digit 1. Two marks for an example without a more general explanation.*

2. (a) Which of the following are examples of Boolean statements and which are not examples of Boolean statements.

i) $(3 + 7) * 2$

ii) $(3 + 7) == 2$

iii) $C = 4$

iv) $6 < 10$

(**4** marks)

Answer: No, Yes, No, Yes. One mark deducted for each error. Two marks if each Yes is included but each No is omitted.

(b) Write out the truth table for the Boolean operation $A\ OR\ B$. The truth values can be indicated by T, F or by 0, 1. (**4** marks)

A	B	$A\ OR\ B$
0	0	0
1	0	1
0	1	1
1	1	1

Answer: One mark for each correct row.

(c) Let x, y be two integers. Write out a Boolean expression that is true if x is strictly less than y or strictly greater than $y + 5$ and that is false otherwise. (**2** marks)

Answer: $x < y\ OR\ x > y + 5$. *One mark if the Boolean expression is placed inside an if statement.*

3. The Brookshear floating point representation for a binary fraction x consists of eight bits, labeled s, e_1, e_2, e_3, m_1, m_2, m_3, m_4 from left to right. If x is zero, then all eight bits are zero. If x is strictly negative, then the sign bit s is 1. If x is strictly positive, then the bit s is zero. Next, suppose x is not zero. To obtain the remaining seven bits, x is written in the form

$$\pm 2^r * 0.t$$

where r is an integer and t is a bit string such that the leftmost bit of t is 1. The bits e_1, e_2, e_3 together comprise the three bit excess notation for r and the bits m_1, m_2, m_3, m_4 of the mantissa are the leftmost four bits of t.

(a) Obtain the Brookshear floating point representation for the decimal fraction $3+(1/4)$. Show clearly the values of the sign bit s, the decimal integer exponent r and the bit string t. (**6** marks)

Answer: 01101101. Three marks for the correct answer. One mark each for the correct identification of $s = 0$*,* $r = 2$ *and* $t = 1101$.

(b) What feature of floating point representation allows the representation of very large numbers and of very small numbers near to 0? (**4** marks)

Answer: the feature is the exponent r. The value of 2^r *increases rapidly as r increases and* 2^{-r} *rapidly approaches 0 as r increases. Two marks for large numbers and two marks for small numbers. Two marks only for naming the exponent without providing further information.*

4. (a) Explain the terms track and sector as applied to a hard drive (magnetic disk). Why do the tracks have a particular shape? (**6** marks)

Answer: a magnetic disk stores data in tracks which form concentric circles on the disk. Once the read-write head has moved to the correct track it can read or write to the track without making any further movement. Each track is divided into sectors. Each sector stores part of the data in the track. Two marks for each item.

(b) A hard drive has a capacity of 4 Terabytes. The data rate for reading from the hard drive is 100 Megabytes per second. How many seconds will it take to read the entire disk? Justify your answer. (**4** marks)

Answer: 40000 seconds. Two marks for the correct answer and two marks for the justification.

5. (a) Give an example of a non-empty two dimensional array of integers. (**2** marks)

Answer: Any reasonable example accepted.

(b) Explain how it is possible to store a two dimensional array in a memory consisting of a one dimensional list of cells. (**2** marks)

Answer: the rows are placed side by side in memory. Any reasonable answer accepted.

(c) Write a pseudocode algorithm to add the numbers in a one dimensional array of integers and print the result. The name of the array is A, the array contains n elements, array indexing begins with 0 and the array is non-empty ($n > 0$). (**6** marks)

Answer:

$i = 0$

$sum = 0$

while ($i < Length(A)$)

   $sum = sum + A[i]$

   $i = i + 1$

endWhile

$print(sum)$

Any reasonable answer accepted, including answers given in the form of a function.

6. The table included below in this question describes instructions of length 16 bits, made by concatenating an op-code and an operand. The first four bits record the op-code. The remaining 12 bits record the operand. Four bits are required to specify a register R and eight bits are required to specify a memory location XY. Each register holds eight bits and each memory location holds eight bits.

   Each 16 bit instruction is coded by four hexadecimal digits. For example, the four hexadecimal digits $37A9$ specify an instruction with op-code 3, in which the 7 refers to register 7 and $A9$ refers to the memory cell $A9$. The registers are numbered in hexadecimal from 0 to F.

   All memory addresses in this question are given in hexadecimal notation.

Op code	Operand	Description
1	RXY	Load register R with the bit pattern in memory cell XY.
2	RXY	Load register R with the bit pattern XY.
3	RXY	Store the bit pattern in register R at memory cell XY.
4	$0RS$	Move the bit pattern in register R to register S.
5	RST	Add (two's complement) the bit patterns in registers R and S. Put the result in register T.
6	RST	Add (floating point) the bit patterns in registers R and S. Put the result in register T.
7	RST	Or the bit patterns in registers S and T. Put the result in register R.
8	RST	And the bit patterns in registers S and T. Put the result in register R.
9	RST	Exclusive Or the bit patterns in registers S and T. Put the result in register R.
A	$R0X$	Rotate the bit pattern in register R one bit to the right X times.
B	RXY	Jump to the instruction in memory cell XY if the bit pattern in register R is equal to the bit pattern in register 0.
C	000	Halt.

(a) Explain in detail the action of the instruction with op-code 8. Include an example in your answer. (**4** marks)

Answer: The ith entry of the register R is obtained by applying the Boolean operation AND to the ith entries of registers S and T. Two marks for the explanation and two marks for an example.

(b) Write a program to load the contents of memory cell 91 into a register, set the right-most four bits equal to zero and then store the resulting bit string in memory cell 92.

(**6** marks)

Answer:
1191
22F0
8312
3392
Any reasonable answer accepted. Two marks deducted for each error.

7. (a) Define the term algorithm. Why is algorithm an important concept in computer science? (**4** marks)

Answer: An algorithm is an ordered set of unambiguous executable steps that defines a terminating process. Each task that a computer performs requires an algorithm. Two marks for the definition. Two marks for the importance of algorithms. Any reasonable answers accepted.

(b) Explain why there is no algorithm for printing out all the integers less than or equal to 5. (**2** marks)

There are infinitely many integers less than or equal to 5. Any candidate algorithm must terminate and so will only be able to print out a finite number of integers.

(c) Describe a method for implementing a loop in a program. In addition to the description, write out a small amount of pseudocode as an example. (**4** marks)

Answer: a while loop contains a Boolean expression and a block of code. The expression is evaluated. If the value is true then the code is executed and the expression evaluated again. If the value is false then the statement immediately following the while loop is executed. The block of code in the while loop is executed repeatedly until the evaluation of the Boolean expression yields false. Two marks. Any reasonable example accepted for two marks.

8. (a) A list of numbers is to be stored either in an array or in a linked list. Describe one advantage of using a linked list. Describe one disadvantage of using a linked list.

(**2** marks)

Answer: it is easy to add items to a linked list by manipulating pointers. A disadvantage of a linked list, compared to an array, is that it takes longer to access items in the list. One mark each. Any reasonable answer accepted.

(b) Describe the way in which the head pointer and the null pointer are used in a linked list. (**4** marks)

Answer: the head pointer points to the first item in a linked list. The null pointer is used to mark the last element in the list. Two marks each.

(c) Consider the following section of memory.

10	11	12	13	14	15	16	17	18	19
H	12	A	16	C	0	B	14	D	0

The numbers 10 to 19 are addresses. The boxes are individual cells in the memory. The section of memory contains a linked list. Each element in the list consists of data and a pointer, stored in adjacent memory cells. For example, the element $(A, 16)$ consists of data A and the pointer 16. The data A are stored in cell 12 and the pointer is stored in cell 13. The items A, B, C, D are data, H is the head of the list and the null pointer is 0. The linked list with head H contains the data items A, B, C. Describe the actions on pointers required to replace the item B in the list with the item D. Draw a diagram to show the updated section of memory. (**4** marks)

Answer: the value of the pointer in cell 13 is changed from 16 to 18 in order to point to D, and so include D in the list. The value of the pointer in cell 19 is changed from 0 to 14 in order to include C in the new list.

10	11	12	13	14	15	16	17	18	19
H	*12*	*A*	*18*	*C*	*0*	*B*	*14*	*D*	*14*

Two marks for the description in words and two marks for the diagram.

9. (a) Explain why a sequential file is appropriate for storing music (audio) or video. (**2** marks)

Answer: in music or video the data in a file are required in sequential order, and this order is the same as the order in which the data are stored.

(b) Describe the structure of an index file. (**4** marks)

Answer: an index file consists of records. Each record holds some data and a unique key by which the record can be identified. In addition to the records the file contains an index. The index contains a list of the keys of the records in the file. Each key is paired with the address in memory where the corresponding record is to be found.

(c) An indexed file contains at most 2^6 records. The indexed file is stored in a memory with 2^{14} cells. What is the maximum size of the index in bits? Justify your answer. (**4** marks)

Answer: $20 \times 2^6 = 1280$ *bits. Each entry in the index requires 6+14 bits and there are* 2^6 *entries. Two marks for the answer and two marks for the justification.*

10. Consider the following pseudocode for a function gcd. The arguments m, n are strictly positive integers such that $m \geq n$. The function gcd returns the greatest common divisor of m and n.

function $gcd(m, n)$
  while $(m \neq n)$
    $r = m - n$
    $m = maximum(n, r)$
    $n = minimum(n, r)$
  endWhile
  return m
endFunction

(a) What happens if gcd is called with $m > 0$ and $n = 0$? Revise the pseudocode for gcd to produce a new function $gcd1$ that returns the greatest common divisor of m and n if $m \geq n > 0$ and returns m if $m > n = 0$. (**4** marks)

Answer: if $m > 0$ *and* $n = 0$*, then the while loop never terminates.*

function $gcd1(m, n)$


```
    if(n == 0)
        return m
    endIf
    while (m ≠ n)
        r = m − n
        m = maximum(n, r)
        n = minimum(n, r)
    endWhile
    return m
endFunction
```

Two marks for stating that the while loop does not terminate and two marks for the code.

(b) The pseudocode for gcd fails if $m < n$. Revise the pseudocode for gcd to produce a new function $gcd2$ that takes strictly positive integers m, n as arguments and returns the greatest common divisor of m and n without making the assumption that $m < n$ or that $n < m$. In other words $gcd2(m, n)$ and $gcd2(n, m)$ both return the correct greatest common divisor of m and n. (**6** marks)

Answer:

```
function gcd2(m, n)
    if(n > m)
        r = m
        m = n
        n = r
    endIf
    while (m ≠ n)
        r = m − n
        m = maximum(n, r)
        n = minimum(n, r)
    endWhile
    return m
endFunction
```

Any reasonable answer accepted. Two marks deducted for each error.

