Birkbeck

(University of London)

BSc/FD EXAMINATION

Department of Computer Science and Information Systems

Introduction to Computer Systems (BUCI008H4)

CREDIT VALUE: 15 credits

Summer 2019

Date of examination: Tuesday 11th June 2019
Duration of paper: 13.30–15.30

SUMMARY ANSWERS

There are **ten** questions in this paper.
Answer all **ten** questions.
Each question carries **ten** 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) Multiply the decimal number 13 by the decimal number 17. (**2** marks)

Answer: 221. Two marks.

(b) Convert the decimal numbers 13 and 17 to the corresponding binary numbers. (**2** marks)

Answer: 1101, 10001. One mark each.

(c) Add the two binary numbers obtained in part (b) of this question. Show any carries. (**2** marks)

Answer: 11110. There is a carry from the rightmost column to the next column. One mark for the correct addition, one mark for the carry.

(d) Convert the decimal numbers 13 and 4 to the corresponding hexadecimal numbers. (**2** marks)

D and 4. One mark each.

(e) Add the two hexadecimal numbers obtained in part (d) of this question. (**2** marks)

11. Two marks.

2. (a) Let e be an integer in the range -4 to 3. The three bit excess notation for e is given by the standard binary representation for $e + 4$. Write out a table showing the three bit excess notation for integers in the range -4 to 3. (**2** marks)

Answer:

3	*111*
2	*110*
1	*101*
0	*100*
-1	*011*
-2	*010*
-3	*001*
-4	*000*

1/4 mark for each correct row.

(b) Let e be an integer in the range -4 to 3. The three bit two's complement notation for e is given by the rightmost three bits of the standard binary representation of $e + 8$. Write out a table showing the three bit two's complement notation for integers in the range -4 to 3. (**2** marks)

Answer:

3	*011*
2	*010*
1	*001*
0	*000*
-1	*111*
-2	*110*
-3	*101*
-4	*100*

1/4 mark for each correct row.

(c) Let $E(e)$ be the three bit excess notation for an integer e in the range -4 to 3. Similarly, let $TC(e)$ be the two's complement notation for e. Show that the bit string given by the rightmost three bits of $E(2)+E(-1)$ is *not* equal to $E(2-1)$. Next, show that the bit string given by the rightmost three bits of $TC(2)+TC(-1)$ is equal to $TC(2-1)$.

(**6** marks)

Answer: E(2)=110, E(-1) = 011, E(2)+E(-1) = 1001. The rightmost three bits are 001 which is not equal to E(1) (three marks). TC(2) = 010, TC(-1) = 111, TC(2)+TC(-1) = 1001. The rightmost three bits are 001 which is equal to TC(1) (three marks).

3. In this question the Boolean variable A has the value True (or 1) and the Boolean variable B has the value False (or 0). The value of the Boolean variable C is unknown.

(a) Write out the truth table for the Boolean operator OR. (**4** marks)

Answer:

C	*D*	*C OR D*
0	*0*	*0*
0	*1*	*1*
1	*0*	*1*
1	*1*	*1*

One mark for each correct row.

(b) Show how the truth table in part (a) of this question can be used to obtain the value of the Boolean expression A OR B. (**2** marks)

Answer: Check the row of the truth table for which A has the value True and B has the value False. The value in the third column (True) is the value of A OR B (two marks)

(c) Evaluate the following expressions.

i) $(A \text{ AND NOT}(B)) \text{ OR } C$

ii) $A \text{ AND } (2 == 1)$

iii) $7 + 8 == 15$

iv) $3 < 0$

(**4** marks)

Answer: True, False, True, False.

4. 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, $0.t$ is a binary number and the leftmost bit of the bit string 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 floating point representation for the decimal fraction -5/2. Show your working. In particular, show clearly the value of the integer r and the way in which this value is obtained. (**6** marks)

Answer: 11101010 (three marks). r=2 (one mark). Origin of r (one mark). One mark for additional plausible working. Three marks for the correct answer with no working.

(b) Obtain the decimal representation for the number with the floating point representation 01111111. In particular, show clearly the value of the integer r and the way in which this value is obtained. (**4** marks)

Answer: 7+(1/2) (two marks). r=3 (one mark). Origin of r (one mark). Two marks for the correct answer with no working.

5. 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 S and T. Put the result in register R.
6	RST	Add (floating point) the bit patterns in registers S and T. Put the result in register R.
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: place the address XY in the program counter if the bit pattern in register R is equal to the bit pattern in register 0.
C	000	Halt.

(a) State the op-code for the instruction 1192. Which register or registers are used when this instruction is carried out? (**2** marks)

Answer: the op-code is 1 (one mark). The register 1 is used (one mark).

Question 5 continues on the next page.

(b) **This is part (b) of question 5.** The following three instructions are performed.

1192
2280
8312

In what way does the final bit string in register 3 depend on the initial bit string in the memory location 92? (**4** marks)

Answer: if the left most bit of the bit string in memory location 92 is 1 then the content of register 3 is 80 = 10000000, otherwise the content of register 3 is 00 = 00000000 (four marks).

(c) Assume that register 0 contains 00, memory cell 20 contains C0 and memory cell 21 contains 00. Append a fourth instruction to the three instructions in part (b) of this question to ensure that the machine halts if the final bit string in register 3 is 00. (**4** marks)

Answer: B320 (four marks).

6. (a) Define the term *pointer*. (**2** marks)

Answer: a pointer is a storage area containing an address at which a piece of information is stored (two marks).

(b) Explain how the head pointer and the nil pointer are used in the formation of a linked list. (**4** marks)

Answer: the head pointer contains the address of the first element on the list (two marks). The nil pointer marks the last item on the list (two marks).

(c) The top row of the following table shows 10 memory locations and three data items A, B and C. The second row of the table contains the addresses of the corresponding memory locations in the top row.

			A		C			B	
31	32	33	34	35	36	37	38	39	40

Copy the table into your script. Include in your copy of the table pointers in order to create a linked list in which the data items A, B, C occur in alphabetical order. The head of the linked list points to memory location 31. In your copy, the memory location immediately following a given data item should contain a pointer to the next item on the list, except for the last data item. (**4** marks)

Answer:

34			*A*	*39*	*C*	*nil*		*B*	*36*
31	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*

One mark for each correct pointer, making total of four marks.

7. (a) Describe the way in which the data on a magnetic disk are arranged in tracks and sectors. Why do the tracks have their particular shape? (**4** marks)

Answer: the data on a disk are arranged in concentric circular tracks (one mark). Each track is divided into sectors (one mark). The track is circular because if the disk rotates with the read write head held stationary, then that part of the disc moving under the read write head forms circle. The data in a given track can be read without moving the read write head (two marks).

(b) Define the terms *seek time*, *latency* and *access time*, as applied to a magnetic disk. (**3** marks)

Answer: the seek time is the time for the read write head to move to the correct track (one mark). The latency is the time taken for the required data item to pass under the read write head once the head has reached the correct track (one mark). The access time is the sum of the seek time and the latency (one mark).

(c) A magnetic disk has an access time of 12 milliseconds, i.e. 12/1000 seconds. The rate at which data can be read from the disk is 125 Megabytes a second. Find the size in Megabytes of a file for which the time to read the file is the same as the access time. (**3** marks)

Answer: 3/2 MB (two marks). One mark for the working.

8. The following pseudo-code defines a function f which has as arguments two arrays A and B which have the same length. The entries in the array A are numbers. Each entry of B is either the number 0 or the number 1. Array indexing begins with 0.

function $f(A, B)$

  $sum0 = 0$

  $sum1 = 0$

  $i = 0$

  while $i < length(A)$

    if $B[i] == 0$

      $sum0 = sum0 + A[i]$

    else

      $sum1 = sum1 + A[i]$

    endIf

    $i = i + 1$

  endWhile

  return $sum1 - sum0$

endFunction

(a) What is returned by the function f if it is called with A equal to $[2, 4, -3]$ and B equal to $[1, 0, 1]$ (**2** marks)

Answer: -5 (two marks).

(b) Describe the way in which the return value of f is calculated in the general case, i.e. A and B satisfy the requirements given before the pseudo-code for f but no further information about A and B is available, except that the length of A is at least 1.

(**4** marks)

Answer: sum0 is the sum of the values A[i] such that B[i] is zero. Similarly, sum1 is the sum of the values A[i] such that B[i] is one. The value returned by f is the difference, sum1-sum0 (four marks).

(c) Suppose that the function f is called with arguments $A1$ and $B1$ such that $A1$ and $B1$ are arrays of the same length, $A1$ contains numbers and each entry of $B1$ is either the number -1 or the number 1. How is the return value of f calculated? Assume that the length of $A1$ is at least 1. (**4** marks)

Answer: The numbers in A1 are added together and the resulting total is returned (four marks).

9. The following code defines a function $pTriangle$.

```
function pTriangle(n)
  i = 1
  while i <= n
    print(" * ")
    i = i + 1
  endWhile
  print(newline)
  if n > 1
    pTriangle(n − 1)
  endIf
endFunction
```

The function $pTriangle$ prints a triangle of asterisks. For example, the function call $pTriangle(3)$ yields

```
* * *
**
*
```

(a) What feature of the code for $pTriangle$ ensures that $pTriangle$ is recursive? (**2** marks)

Answer: the function call pTriangle(n-1) occurs within the code for pTriangle(n) (two marks).

(b) What feature of the code for $pTriangle$ ensures that $pTriangle$ eventually halts? (**2** marks)

Answer: The function call pTriangle(n-1) has a smaller argument than the original function call pTriangle(n). The sequence of function calls stops when the argument n is less than or equal to 1 (two marks).

(c) Write pseudo-code for a function $pRow$ that takes an integer n as an argument and prints out a row of n asterisks followed by a newline. It can be assumed that $n \geq 1$. (**2** marks)

Answer:

function $pRow(n)$
  $i = 1$
  while $i \leq n$
    print("")*
    $i = i + 1$
  endWhile
  print(newline)
endFunction

Two marks. One mark deducted for each major error.

(d) Write pseudo-code for a new function pT which is obtained by revising the pseudo-code for $pTriangle$. As part of the revision, the while loop in $pTriangle$ is replaced by a function call to $pRow$. The printout from pT should be identical to the printout from $pTriangle$. (**4** marks)

Answer:

function $pT(n)$
  pRow(n)
  if $n > 1$
    $pT(n - 1)$
  endIf
endFunction

Four marks. One mark deducted for each major error.

10. (a) Define the following terms in the context of the tables of data in a relational database.

i) row (or tuple)
ii) attribute
iii) primary key
iv) foreign key

(**4** marks)

Answer: i) a single data item in a table; ii) a column in a table containing part of the data for each row; iii) a single attribute that uniquely defines a row; iv) an attribute in a table that uniquely identifies a row in a second table. One mark each, making four marks.

(b) What is meant by the lossless decomposition of a table? (**2** marks)

Answer: in a lossless decomposition a given table is divided into two or more tables, such that the given table can be recovered exactly from the tables produced by the division (two marks).

(c) The table A is decomposed into the tables B and C, as shown below. Explain in detail why this decomposition is not lossless. (**4** marks)

Table A:

name	department	tel. no.
Jones	Sales	555-2222
Smith	Sales	555-3333
Baker	Personnel	555-4444

Table B:

name	department
Jones	Sales
Smith	Sales
Baker	Personnel

Table C:

department	tel. no.
Sales	555-2222
Sales	555-3333
Personnel	555-4444

Answer: it is not possible to obtain the individual telephone numbers of Jones and Smith from tables B and C (four marks).