Birkbeck

(University of London)

BSc/FD EXAMINATION

Department of Computer Science and Information Systems

Introduction to Computer Systems (BUCI008H4)

CREDIT VALUE: 15 credits

Summer 2018

SUMMARY ANSWERS

Date of examination: Friday 1st June 2018
Duration of paper: 14.30 – 16.30

There are **nine** questions in this paper.
Answer all **nine** 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 binary numbers 1001 and 11001. Show the carries, if any. (**2** marks)

Answer: 100010. One mark for the correct answer. One mark for showing the carry.

(b) Subtract the binary number 1011 from the binary number 11101. Show the borrowed digits, if any. (**2** marks)

Answer: 10010. One mark for the correct answer. One mark for showing the borrow.

(c) Multiply the binary numbers 101 and 1101. Show your working. (**4** marks)

Answer: 1000001. Two marks for the correct answer. Two marks for the working.

(d) Multiply the decimal numbers 101 and 1101. Show your working. (**2** marks)

Answer: 111201. Two marks.

2. (a) Obtain the four bit two's complement representations for the decimal integers 4 and 6. (**2** marks)

Answer: 0100 and 0110. One mark each.

(b) Obtain the four bit two's complement representation for the decimal integer -6 from the two's complement representation for 6. Explain your answer. (**4** marks)

Answer: 1010. Two marks for the correct answer and two marks for the explanation.

(c) Give a general method for obtaining the two's complement notation for an integer $-m$ from the two's complement notation for m. (**4** marks)

Answer: if $m = 0$, then m and $-m$ have the same two's complement representation. If $m \neq 0$, then write the bit string for the two's complement representation of m in the form $s||1||t$, such that t is a string of zeros. The twos complement representation for $-m$ is complement$(s)||1||t$. Alternatively, add 1 to the complement of the two's complement representation of m. Four marks.

3. (a) Evaluate the following Boolean expressions for $A = True$ and $B = False$.

   i) $A\ OR\ B$

   ii) $A\ AND\ (6 > 3)$

   iii) $B\ OR\ (4 == 5)$

   iv) $NOT(A\ OR\ B)$

(**4** marks)

Answer: True, True, False, False. One mark for each correct answer.

(b) Write out the truth table for the Boolean operator $==$, i.e. the truth table for $C\ ==\ D$, where C and D are Boolean variables. (**4** marks)

Answer:

C	*D*	*C = = D*
0	*0*	*1*
1	*0*	*0*
0	*1*	*0*
1	*1*	*1*

Four marks. One mark for each correct row.

(c) Two Boolean expressions are observed to have the same truth table. What is the consequence of this observation for calculations involving the two expressions. (**2** marks)

Answer: In any calculation one of the expressions can be replaced by the other, with no change in the results of the calculation. Two marks.

4. (a) 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.

Obtain the Brookshear representation for the binary fraction $-5/4$. Show clearly the values of the sign bit s, the decimal integer exponent r and the bit string t. (**6** marks)

Answer: s = 1, r = 1, t = 1010. The representation is 11011010. Three marks for the correct representation, one mark each for s, r, t.

(b) Find the values of r and t for the largest positive number that has an exact Brookshear representation. (**4** marks)

Answer: r = 3, t = 1111. Two marks each.

5. (a) A computer consists of a CPU connected to a memory. Describe the three parts of the machine cycle. (**3** marks)

Answer: the three parts of the machine cycle are fetch an instruction from memory, decode the instruction and then carry out the instruction. One mark for each part.

(b) Describe the three types of register in the CPU and state how they are used in the machine cycle. (**6** marks)

Answer: the three types of register are the programme counter, the instruction register and the general purpose registers. The programme counter holds the address of the next instruction in memory, the instruction register holds the current instruction and the general purpose registers are used for carrying out the instruction. Six marks. One mark for each type of register and one mark for each description of how they are used.

(c) What is meant by the von Neumann bottleneck? (**1** mark)

Answer: the bus connecting the CPU to the memory is overloaded, because it has to transfer instructions as well as data to the CPU. One mark.

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 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 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) State the opcode for the instruction 9321. Which register or registers are used when this instruction is carried out? (**2** marks)

Answer: The opcode is 9. 1/2 marks. The registers are 3, 2 *and* 1. *3/2 marks.*

(b) Let s be a bit pattern with 8 bits. Let t be the bit pattern 11111111. The Exclusive Or of the bit patterns s and t produces the bit pattern obtained by reversing the bits in s. Write instructions to reverse the bits in the bit pattern stored in register 1 and put the resulting bit pattern in register 3. (**2** marks)

Answer:
22FF
9321
One mark for each instruction. One mark deducted for each error.

(c) Write instructions to load the contents of the memory cell 91 into a register, reverse the bits in the register and store the resulting bit pattern in memory cell 92. (**6** marks)

Answer: 1191, 22FF, 9321, 3392. Two marks for 1191, two marks for 3392, one mark for 22FF, one mark for 9321. Any reasonable version accepted.

7. (a) Give an example of a 4×4 array with distinct integer values. (**2** marks)

Answer: any reasonable answer accepted.

(b) The i, jth value of an array A is $A[i, j]$. The indices i, j begin with $i = 0$, $j = 0$. Identify the value $A[1, 2]$, given that A is the array in part (a) of this question. Explain how the notation $A[1, 2]$ specifies a value in the array A. (**4** marks)

Answer: Two marks for the value A[1, 2] and two marks for the explanation. The first index refers to a row, the second index refers to a column. The row and column intersect at a unique value of A.

(c) Consider the following pseudo code

$x = 100$
$row = 3$
$v = 100$
$i = 0$
while $i < 4$
  if $A[row, i] == 100$
    $print(100)$
  endIf
  $i = i + 1$
endWhile

What is printed? Justify your answer. (**4** marks)

Answer: 100 is printed for each entry of the fourth row of A equal to 100. Each printed value is on a new line. Two marks. The values in the fourth row of A are checked one by one in the while loop. The if statement is used to decide whether to print 100. Two marks.

8. (a) State one advantage of using pseudo code. (**2** marks)

Answer: Pseudo code is used to sketch out algorithms without being distracted by the details of a particular programming language. Two marks.

(b) Consider the following function

function $temp(c)$
  $f = (9/5) * c + 32$
  return f

endFunction

Identify the name of the function, the parameter of the function and the body of the function. (**4** marks)

Answer: The name is temp, the parameter is c and the body of the function consists of the two statements after the header. One mark for temp, one mark for c and one mark each for the two statements, giving a total of four marks.

(c) Use the function in part (b) of this question to make a function call with a parameter value of 5. Assign the return value to a variable ft. What is the return value? (**4** marks)

Answer: ft = temp(5). Two marks. The return value is 41. Two marks

9. In the following code for the function $binarySearch$, L is a non-empty ordered list. The function $binarySearch$ returns $True$ if a is an element of L otherwise it returns $False$. List indexing begins with the index 0. The element of L with index 0 is written as $L[0]$.

```
function binarySearch(L, a)
  i1 = 0
  i2 = length(L) − 1
  while i2 > i1 + 1
    j = largest integer ≤ (i1 + i2)/2
    if L[j] == a
      return True
    endIf
    if a < L[j]
      i2 = j
    else
      i1 = j
    endIf
  endWhile
  return (a == L[i1] or a == L[i2])
endFunction
```

(a) Suppose that the length of L is 6. Find the value of j in the first iteration of the while loop. Justify your answer. (**2** marks)

Answer: j = largest integer $\leq$ (0+5)/2 = 2. One mark for the correct value and one mark for the justification.

(b) What happens if binarySearch is called with L equal to the empty list? Justify your answer. (**4** marks)

Answer: The code in the while loop is not executed. Two marks. There is an array bounds error when an attempt is made to execute the statement a = = L[i1]. Two marks.

(c) Suppose that $L = [a, b, c, d, e, f]$ and that the function call $binarySearch(L, b)$ is made. List the elements of L that are used to evaluate the expression $L[j] == b$ in each execution of the while loop. Justify your answer. (**4** marks)

Answer: in the first iteration j = 2 and c is used. The new values of i1 and i2 are i1 = 0 and i2 = 2. The value of j in the second iteration is j = 1 and b is used. The iterations stop because the element b is found. Two marks for c, b and two marks for the justification.

