SOLUTIONS AND MARKING SCHEME

Queen Mary University of London

Student Number :	....
First Name :	....
Last Name :	....
Calculator Model Name :	....

Midterm 2019–2020 Wednesday 6th November 2019, 11.00

ECS404U Computer Systems and Networks **Duration:** $1\frac{1}{2}$ **hours**

YOU ARE NOT PERMITTED TO READ THE CONTENTS OF THIS QUESTION PAPER UNTIL INSTRUCTED TO DO SO BY AN INVIGILATOR.

Instructions:
This paper contains FOUR questions. **Answer ALL questions**.

Calculators are permitted in this examination. Please state on your answer book the name and type of machine used.

COMPLETE ALL ROUGH WORKINGS IN THE ANSWER BOOK AND CROSS THROUGH ANY WORK WHICH IS NOT TO BE ASSESSED.

IMPORTANT NOTE:
THE *ACADEMIC REGULATIONS* STATE THAT POSSESSION OF UNAUTHORISED MATERIAL AT ANY TIME WHEN A STUDENT IS UNDER EXAMINATION CONDITIONS IS AN ASSESSMENT OFFENCE AND CAN LEAD TO EXPULSION FROM QMUL.

PLEASE CHECK NOW TO ENSURE YOU DO NOT HAVE ANY NOTES, MOBILE PHONES OR UNATHORISED ELECTRONIC DEVICES ON YOUR PERSON. IF YOU HAVE ANY THEN PLEASE RAISE YOUR HAND AND GIVE THEM TO AN INVIGILATOR IMMEDIATELY. PLEASE BE AWARE THAT IF YOU ARE FOUND TO HAVE HIDDEN UNAUTHORISED MATERIAL ELSEWHERE, INCLUDING TOILETS AND CLOAKROOMS IT WILL BE TREATED AS BEING FOUND IN YOUR POSSESSION. UNAUTHORISED MATERIAL FOUND ON YOUR MOBILE PHONE OR OTHER ELECTRONIC DEVICE WILL BE CONSIDERED THE SAME AS BEING IN POSSESSION OF PAPER NOTES. MOBILE PHONES CAUSING A DISRUPTION IS ALSO AN ASSESSMENT OFFENCE.

EXAM PAPERS MUST NOT BE REMOVED FROM THE EXAM ROOM.

ALL MOBILE PHONES MUST BE SWITCHED OFF AND STORED IN YOUR BAGS.
Write your answers on the question paper.
If the box for a solution is too small, use the blank page opposite.
Basic calculators are allowed, but not ones that do binary conversion.

Examiners:
Dr A Khouzani and Prof E Robinson

1. This question is about Computer Architecture

   (a) (5 points) Give two reasons why a mobile phone should be regarded as a computer. The first should be *functional* and the second in terms of its constructional architecture.

   (5 marks — basic)

   Solution: A standard bookwork question.

   i. The point of this part is to make sure students understand the concept of a functional definition. It should be clear that mobile phones do the same kinds of things computers like laptops do, and examples should be given: Both phones and computers like laptops can do similar things. These include browsing the internet, displaying videos, and even making calls over digital networks, eg by Skype or WhatsApp.

   ii. The internal architecture of a mobile phone is similar to that of a laptop. Both have cpu's, short-term memory in the form of RAM and long-term memory in the form of straight flash memory or a solid-state disk built on flash memory. They are connected together by a motherboard. Both have various peripherals for IO, though the typical peripherals for a phone differ from those for a laptop.

   Marking scheme: (i) 2 marks total: 1 for being clear that they understand the concept of functionality and one for a credible answer.
   (ii) 3 marks total: 2 marks for a clear answer with reasonable detail, and 1 for giving suitable examples of components.

   (b) (5 marks) Define the concept of **latency**. Use it to explain why computers with solid state disks are more responsive than those with traditional hard disks. (5 marks — medium)

   Solution: Latency is the time between a request and the (start of) its fulfilment.
   Conventional hard disks have moving mechanical parts, and these take time to get into the correct position to read or write data (typical of the order of 0.01 seconds). This means it can take a long time to read pieces of data from a disk if they are in different locations. By contrast, solid state disks have no mechanical parts, and so their latency is micro-seconds, and independent of file location. This means that solid state disks have a much lower average latency for a read request, and so computers that have them are more responsive.

   Marking scheme: 2 marks for the definition, 1 if unclear or contains errors.
   3 marks for explanation, 2 if minor errors or somewhat unclear, 1 if major errors or very unclear.

   (c) (7 marks) i. What is the function of a *capacitor* as an electrical component of a circuit?

   ii. What are the electrical components used to construct DRAM? (Give an indication of how they are used).

   iii. What are the electrical components of SRAM?

   iv. Why do you think it is relatively easy to include SRAM on the chip that holds a cpu and not DRAM? Justify your answer.

   (7 marks — advanced)

   Solution:

i. A capacitor stores charge.

ii. DRAM uses capacitors and transistors. Each cell uses a single capacitor to store charge encoding a single bit (positive for 1 and negative for 0, for instance), while the transistor acts as a switch controlling access, cutting the capacitor off and holding charge there, or opening it up and allowing the charge to be read or changed.

iii. SRAM just uses transistors, but both nmos and pmos. These are used to construct two interacting inverters which forms the storage for a single bit, and also as switches to control access to the cell.

iv. The basic reason is because the different components being used place different requirements on the way the chip is formed. A cpu just uses transistors, but DRAM also requires a layer of capacitors. Combining both of these with top-level performance is difficult.

Marking scheme:

i. 1 mark

ii. 2 marks: 1 for getting components right and 1 for indication of use

iii. 2 marks: 1 for getting components right and 1 for indication of use

iv. 2 marks: 1 for getting that adding capacitors to a cpu is not easy, and 1 for anything else reasonable said.

(d) (8 marks) Figure 1 depicts a logic circuit.

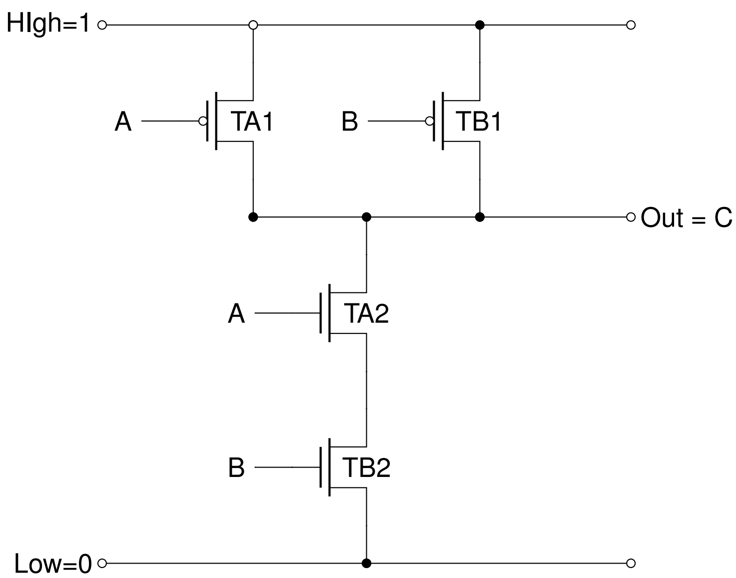

Figure 1: A logic circuit

i. Complete the following table to show whether the circuits across TA1 and TA2 are open or closed for different potentials at A:

A	TA1	TA2
1	open	closed
0	closed	open

Solution: 2 marks: 1 only if systematically wrong (ie reversed).

ii. Complete the following table to give the output at C for the following inputs at A and B:

A	B	C
1	1	0
1	0	1
0	1	1
0	0	1

Solution: 2 marks: deduct 1 for each error.

iii. Explain your answer for the case when A=1 and B=0.

Solution: In this case transistors TA2 and TB1 are closed, while TA1 and TB2 are open. This means there is a an open circuit from Low to C, but a closed circuit from High to C through TB1. The output at C is therefore 1.

Marking scheme: 2 marks: 1 for getting right idea, 1 for clear explanation.

iv. Which of the following connectives does the gate compute. Explain your answer:

A	B	A and B	A or B	A implies B	A nand B	A nor B	A xor B
T	T	T	T	T	F	F	F
T	F	F	T	F	T	F	T
F	T	F	T	T	T	F	T
F	F	F	F	T	T	F	F

Solution: A nand B since using the standard correspondence T=1, F=0, the truth table for nand corresponds to the output table for the gate.

Marking scheme: 2 marks: 1 for getting right answer, 1 for providing some explanation.

(8 marks — basic)

2. This question is about forms of digital representation.

   (a) (8 marks) This part is about the binary representation of (unsigned) numbers, and addition and multiplication in binary.

      i. The following bit sequences represent unsigned integers in binary form. Translate them to standard decimal explaining your reasoning:
         - `0101 1001`
         - `0010 1101`

      ii. Using the standard *binary long addition* algorithm, compute the *sum* of `0101 1001` and `0010 1101` as unsigned binary integers. Your answer should also be an unsigned binary integer.

      iii. Using the standard *binary long multiplication* algorithm, compute the *product* of `0101 1001` and `0010 1101` as unsigned binary integers. Your answer should also be an unsigned binary integer.

(8 marks — basic)

Solution:

i.
- $\texttt{0101 1001}_2 = 64 + 16 + 8 + 1 = 89_{10}$
- $\texttt{0010 1101}_2 = 32 + 8 + 4 + 1 = 45_{10}$

ii.

01011001	
00101101	+
10000110	ans
1111 1	carries

iii.

01011001	
00101101	$*$
01011001	
0101100100	
01011001000	
0101100100000	+
0111110100101	ans
1110111	carries

Marking scheme:

i. 3 marks: 2 if minor errors: 1 if major issues: 0 if nothing of value

ii. 2 marks: 1 if algorithm clear but errors

iii. 3 marks: 2 if minor errors: 1 if major issues: 0 if nothing of value

   (b) (5 marks) This part is about binary representation of signed integers.

      i. Compute the 8-bit 2's complement representations of
         - -43
         - 11

      ii. Add these together using unsigned long addition.

      iii. Explain what number is represented by the result.

(5 marks — basic)

Solution:

i. In n-bit two's complement the leading bit represents -2^{n-1}, so in 8-bit two's complement it represents -128. The remaining bits represent positive powers of 2 as in ordinary unsigned notation. So to represent -43 we will have a leading 1 representing -128, and the remaining bits have to represent $128 - 43 = 85$. Now $85 = 64 + 16 + 4 + 1$ so 85 unsigned is `101 0101` (using 7 bits) and -43 is that with a leading 1: `1101 0101`. Positive numbers are represented as unsigned (with a leading 0). So 11 is `0000 1011`.

ii.

`11010101`	
`00001011`	$+$
`11100000`	ans
`11111`	carries

iii. `1110 0000` represents $-128 + 64 + 32 = -128 + 96 = -32$. This is $-43 + 11$.

Marking scheme:

i. 2 marks: 1 if issues, 0 if nothing of value

ii. 1 mark, all or nothing

iii. 2 marks, 1 for correct result, and 1 for explanation.

(c) (5 marks) This part is about the representation of floating point numbers.

32-bit IEEE floating point uses the first bit as the sign of the number, and then the next 8 bits contains the exponent. This is in the form of *exponent* $+$ *bias*, where in this case *bias* $= 127$. The final 23 bits contain the binary digits of the significand, stripped of the leading one. Given the 32-bits representing a floating point number:

$$10101001\ 11010101\ 11101010\ 11000011$$

Write down:

- the sign bit, and indicate whether the number is positive or negative
- the eight bits that represent the exponent in the IEEE representation, and give the exponent
- the 23 bits that represent the significand.

(5 marks — medium)

Solution:

- the sign bit: is 1 so the number is negative.
- the eight bits that represent the exponent are: `0101001 1`. These represent $64 + 16 + 2 + 1 = 83$. The exponent is then $83 -$ bias $= 83 - 127 = -44$.
- the significand (mantissa) is $1010101\ 11101010\ 11000011$

Marking scheme: One mark each for: sign, positive, exponent bits, exponent, significand.

(d) (7 marks) This part of the question is about text representation.

i. The unicode code point for the character 'a' is U+0061, and the bit pattern that represents 'a' in UTF-8 is `0110 0001`. Explain the link between the code point and the bit pattern.

ii. The unicode code point for the character 'ê' is U+00EA, while the bit pattern that represents 'ê' in UTF-8 is `1100 0011 1010 1010`. Explain why UTF-8 uses a different number of bits to represent 'a' and 'ê', and why the bit pattern for 'ê' has a more complex relationship to the code point than is the case for 'a'.

(7 marks — advanced)

Solution:

i. 'a' is an ASCII character (codepoints 0 to 127) and its UTF-8 representation is simply the last eight bits of the codepoint (the codepoint is in hex, so the last eight bits are `0110 0001`.

ii. 'ê' is not an ASCII character (codepoint is greater than 127) and UTF-8 uses more than eight bits to represent it (unicode has a great deal more than the 256 characters that can be represented in eight bits). The code point is `1110 1010` and this is incorporated into the UTF-8 representation, but not in a simple fashion. The complexity is due to the need to be able to tell reliably where UTF-8 characters begin and end.

Marking scheme:

i. 3 marks total. 1 for getting that the codepoint is given in hex and the other for the derivation of the bit pattern .

ii. 4 marks total, 1 for recognising the importance of ASCII, one for impact of number of characters in unicode, one for recognising ê is not ASCII while 'a' is, one for some explanation about link between codepoint and bit pattern.

End of questions