UNIVERSITY OF LONDON

GOLDSMITHS COLLEGE

Department of Computing

B. Sc. Examination 2016

IS51009C
Fundamentals of Computer Science

Duration: 3 hours

Date and time:

This paper is in two parts: part A and part B. You should answer ALL questions from part A and THREE questions from part B. Part A carries 40 marks, and each question from part B carries 20 marks. The marks for each part of a question are indicated at the end of the part in [.] *brackets.*

There are 100 marks available on this paper.

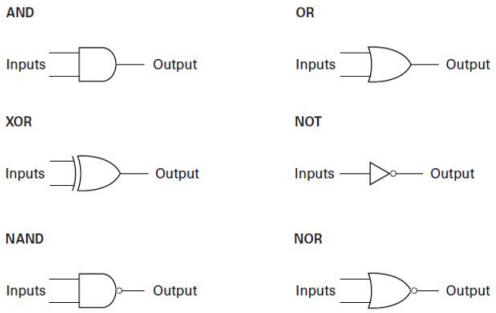
THIS PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM

Part A

Answer all questions. There is only one correct answer for each question.

Question 1

This figure should remind you of the descriptive shapes of the four basic logic gates along with the NAND and NOR gates.



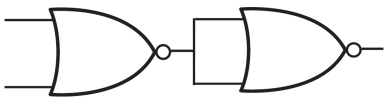
(a) When does an AND gate with two inputs output 1? [4]

i. When both inputs are 1
ii. When both inputs are 0
iii. When the inputs are different
iv. Never

(b) When does a XOR gate with two inputs output 1? [4]

i. When both inputs are 1
ii. When both inputs are 0
iii. When the inputs are different
iv. Never

(c) Which of the following logic gates does the following circuit consisting of NOR gates behave like? [4]



i. a NAND gate
ii. a AND gate
iii. a XOR gate
iv. an OR gate

(d) In which type of network topology is the collision detection protocol used? [4]

i. STAR topology networks
ii. BUS topology networks
iii. Both STAR and BUS
iv. None of the above

(e) Which of the following is **not** a category of machine language instructions [4]

i. Data Transfer
ii. Arithmetic/Logic
iii. Reduced Instruction Set Computing (RISC)
iv. Control

(f) Assume we have a logic gate with N inputs. How many rows would the truth table for the particular logic gate have? [4]

i. 2^{N-1}
ii. 2^{N+1}
iii. 2^{N}
iv. N^2

(g) Assume that odd parity is used when transmitting bit patterns, and you have received the pattern 01001. Which is the safest conclusion you can reach? [4]

i. No errors have occurred
ii. One error has occurred
iii. An odd number of errors has occurred
iv. None of the above

(h) What does real-time processing stand for? [4]

i. Performing one task per second
ii. Performing a task in accordance with deadlines in the real-world
iii. Performing a task with updates every millisecond
iv. None of the above

(i) Consider the problem of searching for a particular entry in a large but sorted database. Which algorithm would be preferable? [4]

i. Sequential Search
ii. Binary Search
iii. Both the above would be equally preferable

(j) What is the relationship between problems that belong in the polynomial complexity class (P) and problems that belong in the non-deterministic polynomial complexity class (NP)? [4]

i. P = NP

ii. P $\neq$ NP

iii. We don't know (P=?NP), but suspect P $\neq$ NP

iv. None of the above

Part B

Question 2 Operating Systems and Compression

(a) Which part of the operating system deals with file, memory as well as process management? [3]

(b) Mention (i) one advantage, and (ii) one disadvantage of Random Access Memory (RAM) against mass storage. [3]

(c) Assume that the main memory (RAM) of your computer only has 2 GB free, and you are trying to load an application that requires 3 GB of RAM. How would an operating system compensate for that, and which problems may arise? Explain your answer. [3]

(d) Given the following contents of a text file, answer the questions below.

AAE EEE XAX EEE AAE

i. Briefly describe (in a sentence or two) how you would encode the file above by using (1) run-length encoding and (2) dictionary-based encoding. [3]

ii. Given that the text above contains the following symbols with the specific frequency of appearance shown below, draw the corresponding Huffman tree. Note that space (symbolized as ' ') is also a character. What is the encoding for letter `'E'`? Does this agree with what you expected and why? [4]

Symbol	frequency of appearance
' '	4
'A'	5
'E'	8
'X'	2

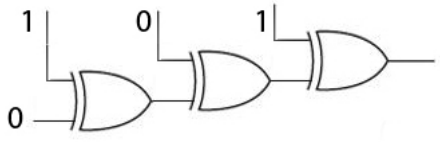
iii. You are asked to develop a set of error-correcting codes in order to transmit the message above. You therefore need to come up with 6-bit binary codes for each of the four symbols `'A','E','X'` and ' ' that appear in the text above. Try to design the code so that each codes have a hamming distance of three to each other. What is the maximum number of errors that can be corrected via this code? Explain your answer. [4]

Question 3 Data Storage

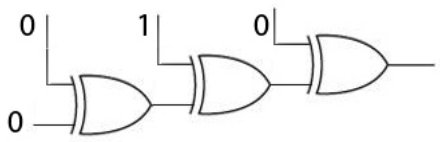
(a) Write down the truth table for (i) the NOR gate, and (ii) the NAND gate [4]

(b) Given the circuit in the figures below, answer the following questions.

i. What is the output of the circuit in case the input is: [2]

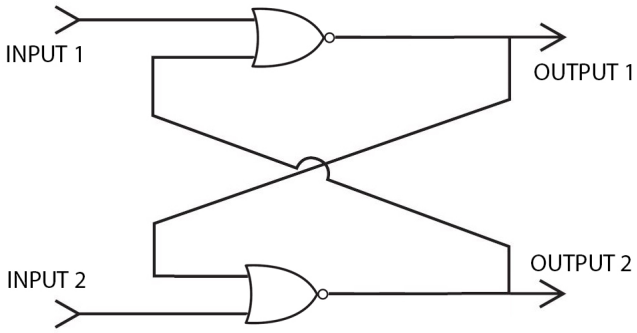


ii. What is the output of the circuit in case the input is: [2]



iii. How does the input relate to the circuit's output? [3]

(c) You are given the following circuit, consisting of two NOR gates. Assume that initially, both inputs are set to zero.



i. Assume that while both inputs are initially set to 0, input 1 changes to 1. What is the output of the circuit? Draw the circuit with the appropriate inputs in your answer sheet and explain your answer. [2]

ii. Now assume that input 1 changes back to 0, with input 2 remaining zero. What is the output of the circuit? Draw the circuit with the appropriate inputs in your answer sheet and explain your answer. [2]

iii. Is this circuit a flip-flop? Explain your answer. [2]

iv. Assume that we were to connect another identical circuit right next to the one above, with output 1 of the first circuit linked to input 1 of the second, and output 2 of the first circuit linked to input 2 of the second. What would change with respect to the original circuit regarding the outputs? Explain your answer. [3]

Question 4 Algorithms & Theory of Computation

(a) Which algorithm would be considered the most efficient given the categories below? [3]

i. $\Theta(n^n)$

ii. $\Theta(n^{10})$

iii. $\Theta(n)$

iv. $\Theta(logn)$

(b) The binary search algorithm finds the position of an element in a sorted array, for example a specific name in an alphabetically sorted list of names. It does so by repeatedly dividing the list in two at each step, and only looking at one of the resulting partitions. How many steps would you expect binary search to take when searching through a sorted list of n names and why? [3]

(c) What does it mean for an algorithm to belong to the complexity class $\Theta(f(n))$? [3]

(d) Consider a game where the aim is to guess a password consisting of 6 characters for a specific user account on a particular website. You are given no further information, so your only choice is guessing and then entering your guess on the website. If you enter the correct password, access is granted, else you are met with a failure message. You can try entering a password as many times as you want.

i. Would you say that this problem belongs in the P (polynomial) class of problems? Explain your answer. [2]

ii. Would you say that this problem belongs in the NP (non-determinstic polynomial) class of problems? Explain your answer. [2]

(e) Briefly describe (i) a Turing Machine, and (ii) how a Turing Machine works. [4]

(f) What is the halting problem? In which class of problems does it belong? Explain your answer. [3]

Question 5 Data Manipulation

(a) Briefly describe the role of (i) the program counter and (ii) the instruction register within the architecture of a central processing unit. [3]

(b) Given the binary pattern 0110, apply the machine language instructions (i) right shift, and (ii) left shift, clearly showing the result after applying each of the operations. Which common mathematical operation does (i) and which mathematical operation does (ii) perform on the binary pattern? Do you think that this approach might lead to any issues with accuracy? Give an example to justify your answer and explain. [3]

(c) You are given the decimal numbers `-1` and `2`.

i. Convert the values above to binary using two's complement with `4`-bits. [2]

ii. Perform the addition in two's complement and show (i) the result in binary, and (ii) the result in decimal. What do you observe with respect to the correctness of the result? [2]

(d) You are given the following table that describes a machine language:

Opcode	Operand	Description
1	RXY	LOAD the register R with the bit pattern found in the memory cell whose address is XY. Example: 14A3 would cause the contents of the memory cell located at address A3 to be placed in register 4.
2	RXY	LOAD the register R with the bit pattern XY. Example: 20A3 would cause the value A3 to be placed in register 0.
3	RXY	STORE the bit pattern found in register R in the memory cell whose address is XY. Example: 35B1 would cause the contents of register 5 to be placed in the memory cell whose address is B1.
4	0RS	MOVE the bit pattern found in register R to register S. Example: 40A4 would cause the contents of register A to be copied into register 4.
5	RST	ADD the bit patterns in registers S and T as though they were twos complement representations and leave the result in register R. Example: 5726 would cause the binary values in registers 2 and 6 to be added and the sum placed in register 7.
7	RST	OR the bit patterns in registers S and T and place result in register R. Example: 7CB4 would cause the result of ORing the contents of registers B and 4 to be placed in register C.
8	RST	AND the bit patterns in register S and T and place result in register R. Example: 8045 would cause the result of ANDing the contents of registers 4 and 5 to be placed in register 0.
C	000	HALT execution. Example: C000 would cause program execution to stop

(i) Using the machine language described above, write a machine language program that subtracts 1 (in two's complement) from the value stored at memory address A0. You can use any registers you feel necessary in your program. [5]

(ii) You are given the following program in the machine language described above: [5]

210F
12A0
8212
32A0
C000

Explain what running this program does (try to explain what the entire program does rather than what each instruction does individually).