



## Examination Paper

Examination Session:

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Exam Code:

COMP1071-WE01

**Title: Computer Systems**

Release Date/Time	13/05/2022 09:30
Latest Submission Date/Time	14/05/2022 09:30
Format of Exam	Online open book exam
Duration:	2 hours
Word/Page Limit:	None
Additional Material provided:	None
Expected form of Submission	A SINGLE PDF file submitted to Gradescope
Submission method	Gradescope

**Instructions to Candidates:** Answer ALL questions.

**Section A Machine Architecture and Digital Electronics**  
**(Dr Ioannis Ivrissimtzis & Dr Eleni Akrida)**

**Question 1**

(a) Consider the following Boolean expression

$$F = \bar{A} \cdot B \cdot C + \bar{B} \cdot \bar{C} + A \cdot C \cdot \bar{D}.$$

- i. Show by Boolean Algebra manipulation that  $F$  can be represented by the following Product of Sums (PoS) form:

$$F = (A + B + \bar{C}) \cdot (\bar{B} + C) \cdot (\bar{A} + \bar{C} + \bar{D})$$

**[4 Marks]**

- ii. Consider a 2-level logic implementation of  $F$  using OR gates followed by an AND gate (and any NOT gates required, since only unnegated input variables are available). Assume that the gates have finite propagation delay. Describe in detail what happens at the output  $F$  when the inputs  $(A, B, C, D)$  change from  $(1, 1, 0, 1)$  to  $(1, 1, 1, 1)$ .

**[3 Marks]**

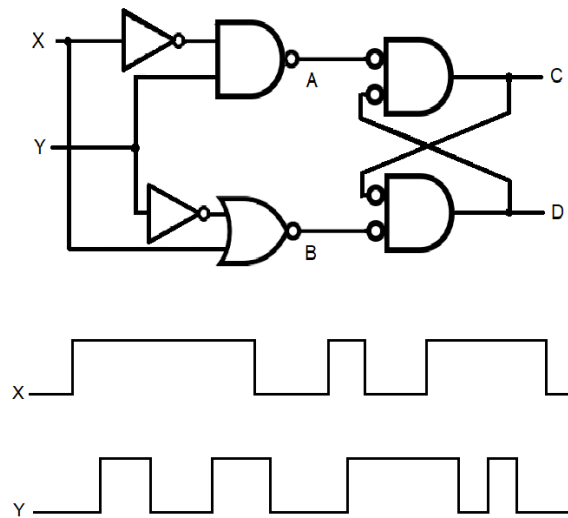
- iii. Using a Karnaugh map or otherwise, determine the other single input variable change that will give rise to a behaviour of the output similar to that observed in part (a ii). Explain your working.

**[2 Marks]**

- iv. Using a Karnaugh map or otherwise, determine a modified PoS expression for  $F$  that will eliminate the behaviour of the output observed in parts (a ii) and (a iii). Explain your working.

**[2 Marks]**

- (b) The timing diagrams for signals  $X$  and  $Y$  shown below are applied to the circuit below. Draw the timing diagrams for the signals  $A$ ,  $B$ ,  $C$ , given the initial value of  $C = 0$  and the initial value of  $D = 1$ . Assume virtually no delay from the time that the input to a gate changes to the time the output of that gate responds to the change.

**[6 Marks]**

- (c) Assume that  $a, b$  are stored in registers  $\$t0$  and  $\$t1$ , respectively. Translate the following high-level programming language statement into MIPS assembly code.

$$a = 2a + b - 1;$$

**[3 Marks]**

- (d) Write the MIPS assembly instructions corresponding to the following binary machine language instructions, and briefly explain the effect of each instruction. Show how you arrived at your answers.

i. 001000 01000 01000 0000000000000001

**[3 Marks]**

ii. 100011 11100 01000 0000000000000100

**[3 Marks]**

The binary op-codes of the `addi` and `lw` instructions are 001000 and 100011, respectively. The register numbers of  $\$t0$  and  $\$gp$  are 8 and 28, in decimal, respectively.

- (e) Consider the following MIPS assembly language snippet.

```

.....
                li    $t0, 5
                li    $s0, 0
loop:           add    $s0, $s0, $t0
                addi   $t0, $t0, -1
                bne    $t0, $0, loop
.....

```

**continued**

- i. Translate into MIPS machine language the bne instruction in the last line of the snippet. Write your answer in hexadecimal. Show how you arrived at your answer.

The binary op-code of the bne instruction is 000101. The register numbers of \$t0 and \$0 are 8 and 0, in decimal, respectively.

**[6 Marks]**

- ii. What number will be stored in register \$s0 after the snippet has been executed? Briefly explain your answer.

**[2 Marks]**

## Section B Operating Systems (Dr Barnaby Martin)

### Question 2

(a) Suppose that a set of processes A to E arrive at the ready queue at different times where the first time is 0.

- i. Suppose the following Gantt chart shows the execution of First Come First Served (FCFS). What can you say about the arrival times of the processes A to E?

B	B	B	B	B	E	E	C	C	C	C	C	C	C	A	D	D	D	D	D
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

**[2 Marks]**

Suppose now the table below shows the actual arrival and burst times together with priority (smaller numbers indicate higher priority).

Process	Priority	Arrival Time	Burst Time
A	5	6	1
B	4	0	5
C	2	3	7
D	1	8	5
E	3	2	2

Draw a Gantt chart showing the execution of the processes for each of the following CPU scheduling algorithms.

- ii. Shortest Job First (SJF). **[2 Marks]**

- iii. Round Robin (RR) with priority and a time slice of 2 units. **[4 Marks]**

(b) For each of the scheduling algorithms in part (a) give the average waiting time. **[6 Marks]**

(c) Consider a disk with 250 cylinders (from 0 to 249). Suppose the head is on cylinder 110 and is tracking backwards. It then receives requests for I/O to blocks in cylinders

98, 10, 197, 5, 65, 61, 100, 171, 173, 84

Calculate the seek time for each of the following disk scheduling algorithms.

- i. First Come First Served (FCFS)

**continued**

ii. Shortest Seek Time First (SSTF)

iii. Scan (SCAN)

iv. Look (LOOK)

**[8 Marks]**

(d) Consider the page reference string which is  $\_, \_, \_, \_, 4, 2, \_, 1, 1$  in which  $\_$  represents an unknown page number. Suppose its realisation under a First In First Out (FIFO) algorithm gives the following frame allocation where we assume there are three frames and the frames are initially empty.

5	5	5	1	1	1	1	1	1	1
	4	4	4	4	4	3	3	3	3
		2	2	2	2	2	2	4	4

i. Give the page reference string.

**[1 Mark]**

ii. How many page faults did FIFO produce?

**[2 Marks]**

Find the total number of page faults for each of the page replacement algorithms listed below that would occur with a three frame reference memory allocation assuming that the frames are initially empty. Show your working.

iii. Least Recently Used (LRU)

**[4 Marks]**

iv. Optimal (OPT) using numeric minimum for ties

**[4 Marks]**

**Section C Databases**  
**(Dr Robert Lieck)**

**Question 3**

- (a) This part of the question is about the Relational Data Model. Consider the following relation:

ComposerID	Surname	FirstInitials	YearOfBirth	YearOfDeath	Epoch	Country
C01	Byrd	W	1543	1623	Renaissance	England
C02	Bach	JS	1685	1750	Baroque	Germany
C03	Berlioz	LH	1803	1869	Romantic	France

What is the cardinality of this relation and what is the degree of this relation? What is the domain of FirstInitials? **[3 Marks]**

- (b) For the following scenario, draw the Entity-Relationship (ER) diagram using the UML notation, clearly showing the entities, their named relationships and the constraints of these relationships. In your diagram, resolve the many-to-many relationships.

A song is composed by exactly one artist. An artist may compose one or more songs, but they do not need to compose any songs at all. Artists may play on one or more recordings, but they do not need to play on any recording at all. At least one artists plays on any recording. Each recording is the recording of exactly one song. Songs may be recorded one or more times, but some are not recorded at all.

**[10 Marks]**

- (c) Consider the relation “CarLicence”, which has the following relation schema:

**CarLicence** (car\_ID, owner\_ID, licence\_expiry\_Date, owner\_Name, owner\_Address, car\_Year, car\_Brand, brand\_Country)

where the attributes of the primary key are underlined, according to standard notation.

- i. Normalize the relation to the 2nd normal form (2NF) and specify which are the primary keys and the foreign keys. **[4 Marks]**

**continued**

- ii. Normalize the relation to the 3rd normal form (3NF) and specify which are the primary keys and the foreign keys. **[4 Marks]**

(d) Consider the following relation schemas of the relations “Staff” and “Branch”:

**Staff** (StaffID, Name, Salary, Age, BranchID)

**Branch** (BranchID, City)

Write an SQL statement for each of the following queries:

- i. List the name and salary of all staff older than 30 working in a branch in Durham. **[3 Marks]**
- ii. List the ID of each branch together with the number of staff with a salary greater than 1000 working in that branch. **[4 Marks]**
- iii. For every branch, list the ID and number of staff with a salary less than the average salary of all staff. Order the results (in increasing order) according to the BranchID. **[5 Marks]**