Durham University

Examination Paper

Examination Session:	Year:	Exam Code:
May/June	2024	COMP1071-WE01

Title: Computer Systems

Time Allowed:	2 hours	
Additional Material provided:	None	
Materials Permitted:	None	
Calculators Permitted:	Yes	Models Permitted: Casio fx-83GT range and Casio fx-85GT range
Visiting Students may use dictionaries:	Yes	

Instructions to Candidates:	Answer ALL questions. Students must use the Computer Science answer booklet.

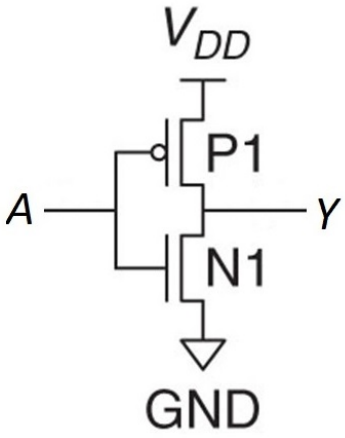
Section A Digital Electronics and Machine Architecture (Dr Farshad Arvin & Dr Ioannis Ivrissimtzis)

Question 1

(a) Briefly explain the concept of a functionally complete set. **[1 Mark]**

(b) Complete the truth table for the given circuit.

A	P1	N1	Y
0			
1			



[3 Marks]

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(c) Consider the following Boolean representation

$$Y = \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + \bar{A}BC + ABC$$

i. Complete the following Karnaugh map for the Boolean representation in Q1(c) with minimum number of circles.

A \ BC	00	01	11	10
0				
1				

[2 Marks]

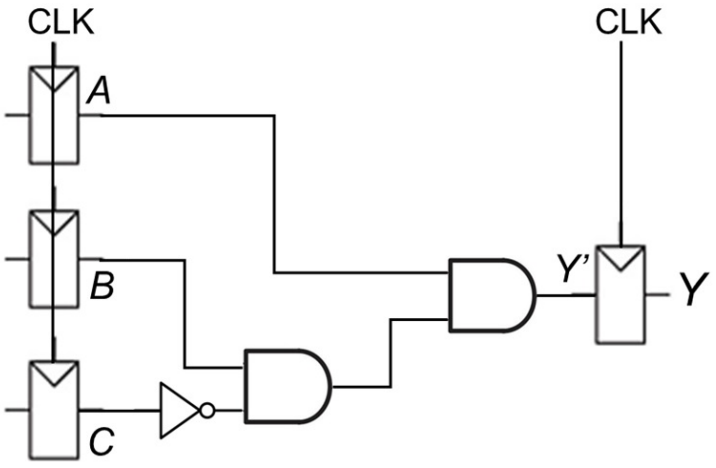
ii. Write the simplified Boolean representation.

[2 Marks]

iii. Draw the logic gate implementation based on the simplified Boolean representation, in part Q1(c)ii. **[3 Marks]**

iv. Show on the Karnaugh map if there is a static hazard in the circuit. Briefly describe how can we remove a static hazard using the Karnaugh map. **[2 Marks]**

(d) Consider the following circuit,



The propagation and contamination delays of each logic gate are $t_{pd} = 1$ ns and $t_{cd} = 0.4$ ns, and the clock-to-Q propagation and contamination delays of the flip-flops are $t_{pcq} = 4$ ns and $t_{ccq} = 0.6$ ns. The setup and hold times of each flip flop are $t_{setup} = 3$ ns and $t_{hold} = 1.5$ ns.

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i. What is the maximum clock frequency that you could safely set for this circuit? **[2 Marks]**

ii. Show that there is a hold time violation in the circuit. **[2 Marks]**

(e) Briefly describe what each of the following MIPS instructions does, and classify it as an R-type, I-type or J-type instruction:

i. addi $t0, $t0, 1 **[2 Marks]**

ii. j exit **[2 Marks]**

(f) Translate the following instruction into MIPS machine language:

addi $s0, $t0, 1

Write your answer in hexadecimal. Show how you arrived at your answer.

The binary op-code of the addi instruction is 001000. The decimal register numbers of $s0 and $t0 are 16 and 8, respectively. **[5 Marks]**

(g) Briefly describe ports in Arduino. For Port D, briefly describe each of the following I/O registers: **DDRD**, **PIND**, and **PORTD**. **[4 Marks]**

(h) Give a brief description of how the following AVR assembly snippet works:

```
LDI   R20, 100
loop:
  SUBI   R20, 1
  BRNE   loop
```

In your description you should mention registers R20 and status register, and the instructions LDI, SUBI and BRNE. **[4 Marks]**

End of Section A **continued**

Section B Databases
(Dr Robert Lieck)

Question 2

(a) This part of the question is about the Relational Data Model. You are managing a database for a library and need to store information about 10,000 books. For each book, you need to store: title, author, publication date, number of pages, and publisher. You also assign a unique ID to each book. What is the cardinality and the degree of the resulting relation? What is the domain for the number of pages (constrain the domain as much as reasonably possible)? **[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, indicate many-to-many relationships with a dashed line and resolve them.

> A book is published by exactly one publisher, but publishers may have published one or more books. A book is written by one or more authors and authors may have written any number of books (or no books at all). An author may be employed by exactly one publisher or no publisher at all and publishers may employ multiple authors or no authors at all.

[10 Marks]

(c) Consider the relation "BookPurchase", which has the following relation schema:

> **BookPurchase** (<u>bookID</u>, <u>buyerID</u>, purchaseDate, bookTitle, bookPublisher, buyerName, publisherAddress)

where the attributes of the primary key are underlined.

i. Specify all functional dependencies that you can infer from the attributes' names (include potential transitive dependencies but omit any additional dependencies that could be inferred using Armstrong's axioms). **[4 Marks]**

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ii. Normalise the relation to the 2nd normal form (2NF) and specify which are the primary keys (underline) and the foreign keys (mark with an asterisk *). **[2 Marks]**

iii. Normalise the relation to the 3rd normal form (3NF) and specify which are the primary keys (underline) and the foreign keys (mark with an asterisk *). **[2 Marks]**

(d) Consider the following relations "Book" and "Author" with schemata:

Book (bookID, authorID, title, pages, publicationYear)
Author (authorID, name, dateOfBirth)

Write a single SQL statement for each of the following queries (use JOIN clauses if you need to combine tables):

i. List the title and author for all books published after 1990. **[3 Marks]**

ii. Get the total number of books written by the author named 'Shakespeare' and their average number of pages. (You can assume there is only one author with name 'Shakespeare'.) **[4 Marks]**

iii. List authors alphabetically and for each author, list the number of books they have written with a number of pages above the average of all books. **[5 Marks]**

End of Section B **continued**

Section C Operating Systems (Dr Anish Jindal)

Question 3

(a) Consider that the following processes are being scheduled using a preemptive, round-robin scheduling algorithm.

Process	Arrival time	Burst time	Priority
P_1	0	20	50
P_2	25	25	30
P_3	30	25	30
P_4	60	15	35
P_5	100	10	5
P_6	105	10	15

Each process is assigned a numerical priority (a higher number indicating a higher priority). In addition to the processes listed above, the system also has an idle task (which consumes no CPU resources and is identified as P_{idle}). This task has priority 0 and is scheduled whenever the system has no other available processes to run. If a process is preempted by a higher-priority process, the preempted process is placed at the end of the queue. Considering the time quantum of 10 units:

i. Draw a Gantt chart showing the execution order of the processes. **[3 Marks]**

ii. What is the average waiting and turnaround time for the processes? **[2 Marks]**

iii. What is the CPU utilisation rate? **[1 Mark]**

(b) i. What are various process states in an operating system? **[5 Marks]**

ii. Using Amdahl's Law, what would be the speedup gain for an application that has 80 percent parallel component with four processing cores? **[2 Marks]**

(c) What is the purpose of demand paging in memory management? Provide at least one advantage and one disadvantage of using demand paging. **[4 Marks]**

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(d) Consider the following page-reference string:

$$0, 1, 2, 3, 4, 1, 4, 3, 2, 1, 0$$

Indicate the number of page faults for the following page replacement algorithms assuming demand paging with three initially empty frames. Show your working.

i. First In First Out (FIFO) **[2 Marks]**

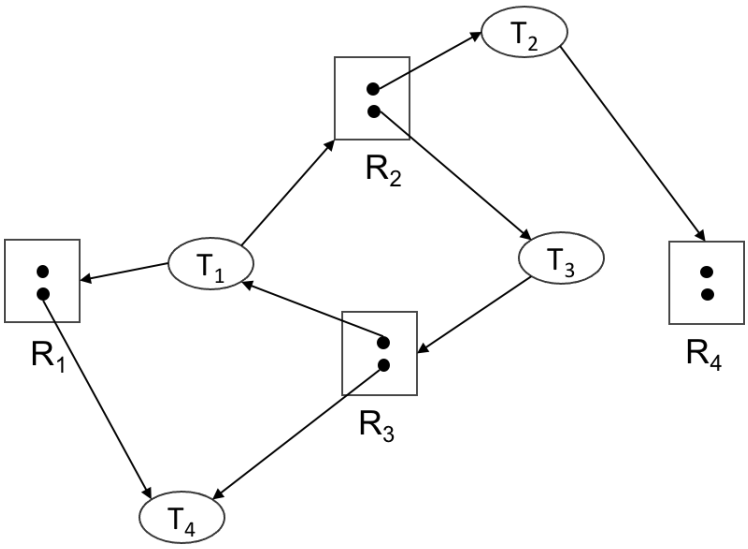
ii. Least Recently Used (LRU) **[2 Marks]**

iii. Optimal (OPT) **[2 Marks]**

(e) This part of the question relates to the deadlock in an operating system.

i. What are the necessary conditions for a deadlock to occur in the system? Briefly discuss each of them individually. **[4 Marks]**

ii. From the resource allocation graph shown in the following figure, comment and justify on whether the deadlock can occur or not.



[2 Marks]

(f) Consider a disk with 200 cylinders (from 0 to 199). The head is initially at cylinder number 53 moving towards larger cylinder numbers on its servicing pass. Consider a disk queue with requests for I/O to blocks on cylinders:

$$98, 183, 41, 122, 14, 124, 65, 67$$

What is the total head movement (in number of cylinders) while servicing these requests for the following disk scheduling algorithms?

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i. SCAN **[2 Marks]**

ii. LOOK **[2 Marks]**

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