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

Question 1

(a) Somebody claims that the unsimplified "product of sums" form of the Boolean function F, given in the following truth table, is

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

$$(A+\overline{B}+C+D)\cdot(A+\overline{B}+C+\overline{D})\cdot(\overline{A}+B+C+\overline{D})\cdot$$

$$(\overline{A}+B+\overline{C}+D)\cdot(\overline{A}+B+\overline{C}+\overline{D})\cdot(\overline{A}+\overline{B}+C+\overline{D}).$$

Input A	Input B	Input C	Input D	Output F(A,B,C,D)
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	1	0	0	1
0	0	1	1	0
0	1	0	1	1
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	1	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

How would you prove that the Boolean expression they have come up with is not correct for F, and that the correct formula in PoS form is the following, instead?

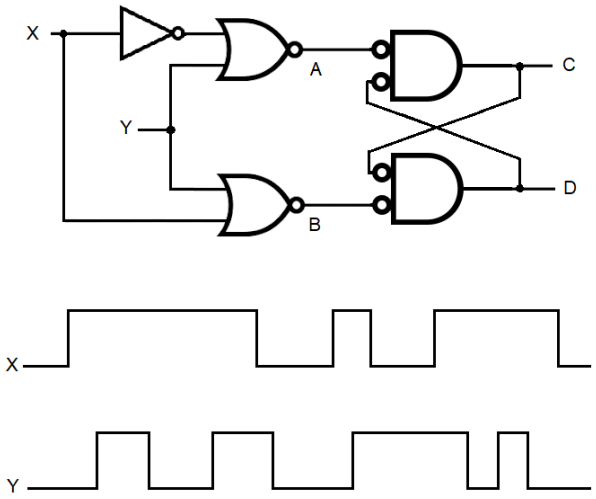
$$F = (A+B+\overline{C}+\overline{D})\cdot(A+\overline{B}+\overline{C}+D)\cdot(A+\overline{B}+\overline{C}+\overline{D})\cdot$$

$$(\overline{A}+B+C+D)\cdot(\overline{A}+\overline{B}+C+D)\cdot(\overline{A}+\overline{B}+\overline{C}+D)\cdot(\overline{A}+\overline{B}+\overline{C}+\overline{D})$$

[3 Marks]

continued

(b) The timing waveforms (diagrams of signal values over time) for signals X and Y shown below are applied to the circuit below. Draw the timing waveforms for the signals A, B, C, given the initial value of $C = 1$ and the initial value of $D = 0$. 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.



[7 Marks]

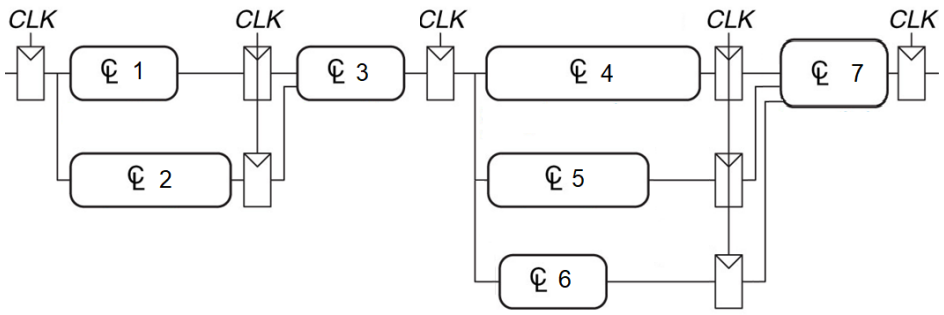
(c) Calculate the maximum clock frequency that you could set for the circuit shown below, showing all your working. The propagation delays of the seven blocks of combinational logic, and the delays of any other components in the circuit are as follows:

Registers: $t_{ccq} = 45ps$, $t_{pcq} = 60ps$, $t_{setup} = 40ps$, $t_{hold} = 30ps$;

CL1: $t_{pd1} = 2.1ns$; CL2: $t_{pd2} = 3ns$; CL3: $t_{pd3} = 2.5ns$;

CL4: $t_{pd4} = 3.9ns$; CL5: $t_{pd5} = 3.2ns$; CL6: $t_{pd6} = 2.7ns$;

CL7: $t_{pd7} = 3.5ns$.



[7 Marks]

continued

(d) Assume that a, b, c, x are stored in registers \$s1-\$s4. Translate the following high-level programming language statement into MIPS assembly code.

$$a = a + b + c - x;$$

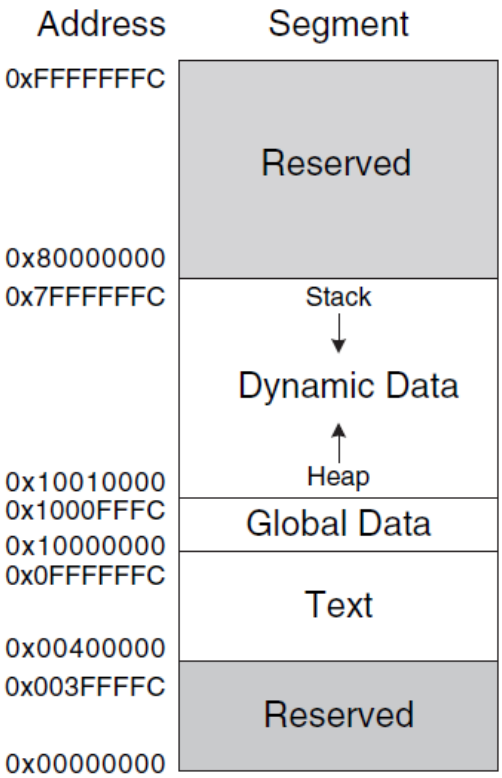
[4 Marks]

(e) Translate into MIPS machine language the instruction

```
add    $t0, $t1, $0
```

The 6-bit function code for the add instruction is 100000. The register numbers of \$t0, \$t1 and \$0 are 8, 9, and 0, respectively. Write your answer in hexadecimal. Show how you arrived at your answer. **[5 Marks]**

(f) The figure below shows the segmentation of the MIPS memory map.



Briefly discuss the considerations that led to the following characteristics.

i. The whole memory is 4GB, the highest word address being 0xFFFFFFFC. **[2 Marks]**

ii. The highest address in the Text segment is 0x0FFFFFFC. **[3 Marks]**

iii. The size of the Global Data segment is restricted to 64KB, consisting of the addresses between 0x10000000 and 0x1000FFFC. **[3 Marks]**

End of Section A **continued**

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? **[2 Marks]**

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

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	0	4
B	1	9	3
C	2	8	2
D	4	6	6
E	3	3	5

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 100 and is tracking backwards. It then receives requests for I/O to blocks in cylinders

$$28, 63, 143, 0, 57, 133, 13, 177, 65, 68$$

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

i. First Come First Served (FCFS)

ii. Shortest Seek Time First (SSTF)

continued

iii. Cyclic Scan (C-SCAN)

iv. Cyclic Look (C-LOOK) **[8 Marks]**

(d) Consider the page reference string which is $\_, \_, \_, \_, 4, \_, \_, \_, \_, \_, \_, 1$ 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.

1	4	2	0	4	1	4	3	5	1	2	1
1	1	1	0	0	0	0	3	3	3	2	2
	4	4	4	4	1	1	1	5	5	5	5
		2	2	2	2	4	4	4	1	1	1

i. Give the page reference string. **[1 Marks]**

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. Assume that the frames are initially empty. Show your working.

iii. Least Recently Used (LRU) **[4 Marks]**

iv. Optimal (OPT) using LRU for ties **[4 Marks]**

End of Section B **continued**

Section C Databases
(Dr Konrad Dabrowski)

Question 3

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

> Every house is designed by one architect. An architect can design one or more houses or no houses at all. Every client buys one house and a house can be bought by one client or no clients at all. Building a house can require the work of one or more specialists, or no specialist at all. A specialist can work on one or more houses or no houses at all.

[10 Marks]

(b) Consider the relation "Student_Module", which has the following relation schema:

> **Student_Mark** (student_ID, module_code, student_name, module_mark, college_name, college_address)

In the schema of this relation the attributes of the primary key are underlined, according to the 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]**

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

(c) Based on the following relation schemas of the relations "Booking" and "Customer", write an SQL statement for each of the given queries:

> **Booking** (BookingID, BookingLocationID, Price, CustomerNo, Year)
>
> **Customer** (CustomerNo, Age, CustomerName, Email, City, Address, PostCode, SignupYear)

continued

i. List the name and age of all customers living in Durham who have had a booking after the year 2017. **[3 Marks]**

ii. List the name of each customer together with the number of bookings they have had with a price greater than 200. **[4 Marks]**

iii. For every booking location, list the number of bookings with a price less than the average price of all bookings. Order your results (in increasing order) according to the booking location ID. **[5 Marks]**

(d) Consider the relations **RailwayStation** (Station_ID, City, NumberOfPlatforms) and **Airport** (Airport_ID, City, NumberOfRunways, FlightsPerDay). Provide Relational Algebra expressions for the following:

i. List all cities where there is both a railway station and an airport. **[1 Marks]**

ii. List all cities where there is either a railway station or an airport (or both). **[1 Marks]**

iii. List all cities where there is a railway station but not an airport. **[1 Marks]**

END OF PAPER