NATIONAL UNIVERSITY OF SINGAPORE
FACULTY OF ENGINEERING

EXAMINATION FOR

(Semester II: 2021/2022)

(LumiNUS E-Exam)

EE5903 – REAL TIME SYSTEMS

April / May 2022 - Time Allowed: **2** Hours

INSTRUCTIONS TO CANDIDATES:

1. This examination paper contains **FIVE** (5) questions and comprises **FIVE** (5) pages.
2. Answer **Question 1** (compulsory) in Section A and any **THREE** (3) of the remaining **FOUR** (4) questions in Section B. Question 1 in Section A carries 20 Marks and each question in Section B carries 10 Marks.
3. This is a CLOSED BOOK exam.
4. Provide your answers in the same order as they appear. **If you interleave your answers, your responses will not be marked.**
5. Programmable calculators are not allowed.
6. You are allowed to bring and use only ONE (1) A4 handwritten guide sheet containing the required contents on both sides.
7. **Recall the instructions sent to you earlier on this E-exam.**
8. **DO NOT forget to merge your signed declaration on the first page as instructed.**

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<u>SECTION A</u>: The question in this section is <u>compulsory</u>.

Q.1 Answer all questions. Each question carries 2 marks. Give **one or two line answers** for questions that require comments.

(i) Consider a task set comprising three tasks with zero phasing. The execution times and the periods of the tasks T1, T2, and T3 are (5,20), (20,100), and (30,250) respectively. Decide on the length of the major cycle to be used in an embedded controller.

(ii) For a task set given by the tuples defined as (index, arrival time, execution time) for a set of four tasks are (1,0,7), (2,2,4), (3,4,1), and (4,5,4), determine the complete scheduling sequence to be used using a Shortest Remaining Time First (SRTF) strategy.

(iii) In the Q.1 (ii), identify two tasks that have minimum waiting times and determine their waiting times.

(iv) Consider a system of 3 components with a parallel hardware configuration. If the reliability of each component is 0.8, what is the overall reliability of this parallel computing system? If the same reliability needs to be achieved with a serial system using the same components as above, what is the minimum number of devices needed in your serial configuration?

(v) Five independent tasks with identical priority arrive at a scheduler at times 0, 1, 3, 5, and 7 respectively, with each task demanding 3 seconds of processing time. Compute and tabulate the response times of the individual tasks, waiting delays encountered by the tasks, and average waiting time of this task set.

(vi) Verify using Liu and Layland criteria if the task set given by (20,100), (30,150), and (90,200) is schedulable or not.

(vii) Suppose a thread is running in a critical section of code, i.e., it has acquired all the locks through proper arbitration. Can it get context switched? Why or why not? Will your answer remain the same for threads run by the kernel?

(viii) What are the three main parameters that a deadlock avoidance algorithm is required to keep track? Which category does Banker's algorithm falls in (avoidance or prevention) and why?

Q.1 continued on Page 3

(ix) Consider a critical section accessing problem by two processes P0 and P1. The solution used by P0 is as follows. P1 is symmetric. Shared variable: flag[i] : Boolean, initially set to FALSE. What is the major problem with this solution, if any?

```
while (TRUE) {
  flag[0] = TRUE; /* declare entry first */
  while (flag[1]);
  CS();
  flag[0] = FALSE;
  Non_CS();
}
```

(x) EDF strategy is known to produce a sub-optimal solution on a multiprocessor system even when the task ready times are equal. The main problem is due to ________________________; and _________________________ is an immediate solution used commonly to avert the problem.

(2 x 10 = 20 Marks)

<u>SECTION B</u>: Answer ANY (ONLY) THREE (3) questions in this section.

Q.2. This question has three parts. Answer all the parts.

(i) Consider a pre-emptible task set given in the following table. The priorities are assigned to the task such that lower the number higher is its priority. If two tasks with identical priority are ready to run at the same time, then decide using First-Come-First-Serve (FCFS) scheme. Do the following. (a) Determine a schedule and compute the average waiting time of the tasks. (b) If execution times of the tasks 1 and 3 are now 7, compare the average waiting times of the two schedules and what is your inference?

Table 1: Task Characteristics for Q.2

Task indices	Priority	Execution Time	Arrival Time
1	1	4	0
2	2	3	0
3	1	7	6
4	3	4	11
5	2	2	12

(8 Marks)

Q.2 continued on Page 4

(ii) For a ________________ scheduler in an embedded system handling periodic tasks, the major cycle of a set of tasks S = {T_i, i = 1, 2, …, N} with their respective periods {p_1, p_2,…, p_N} is given by _________________regardless of the individual task phases.

(2 Marks)

Q.3 This question has three parts. Answer both the parts.

(i) Show that for **a set of periodic harmonic tasks**, the total CPU utilization is less than or equal to one. Clearly present your argument.

(3 Marks)

(ii) For the task set given below, show that there is no feasible schedule using RMA and DMA strategies. T1 = (e1=5, p1=10, d1=22); T2 = (e2=12, p2=60, d2=15); T3 = (e3=20, p3=100, d3=25).

(5 Marks)

(iii) Based on your observation in Q.3 (ii) above, if you are allowed to fine-tune either the period or the deadline of task T3, what will be your choice of the parameter? What is the value you will assign to that parameter to construct a feasible DMA schedule, assuming you wish to follow the same priority order as your original DMA schedule? Justify your choice.

(2 Marks)

Q.4 Apply Banker's algorithm to the snapshot given in the table below. Assume that there are 5 processes and 4 resource types A, B, C, and D. The maximum number of resource instances are 3, 17, 16, and 12, respectively. Compute the need matrix and verify if the entire system is in a safe state.

Table 2: Resource allocation and availability data for Q.4

	Allocation				Maximum				Available			
	A	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
P0	0	1	1	0	0	2	1	0	1	5	2	0
P1	1	2	3	1	1	6	5	2				
P2	1	3	6	5	2	3	6	6				
P3	0	6	3	2	0	6	5	2				
P4	0	0	1	4	0	6	5	6				

(10 Marks)

Q.5 This question has three parts. Answer all of them.

(i) On a supersonic engine, a control system (CS) has five synchronous CPUs that analyze all other sub-systems and compare the results among each other. To propel the engine at t=1, four out of five CPUs must agree on the system parameters. If all agree, the propulsion is enabled. If one CPU fails and four agree, the fifth CPU is ignored and the propulsion is triggered. If two CPUs fail to agree, the propulsion is cancelled. The reliability of the entire control system (CS) is maintained at 0.995. What is the probability of successful propulsion? Assume an exponential reliability model for the control system.

(5 Marks)

(ii) In the above capsule mentioned in Q.5 (i), there are two additional CPUs that are identical in a parallel configuration where the second unit is in standby and will be activated only upon failure of the primary unit. The switching to the backup unit is considered certain. The failure rate for each CPU is 0.002 failures/hour. What is the reliability for 200 hours?

(2 Marks)

(iii) Compute the failure rate of a CPU in the system using the following probability distribution function $f(t) = 0.2e^{-0.2.t}$, $t \geq 0$.

(3 Marks)

END OF PAPER