# National Exams May 2016

# 04-Soft-A4 Real-time Systems

# 3 hours

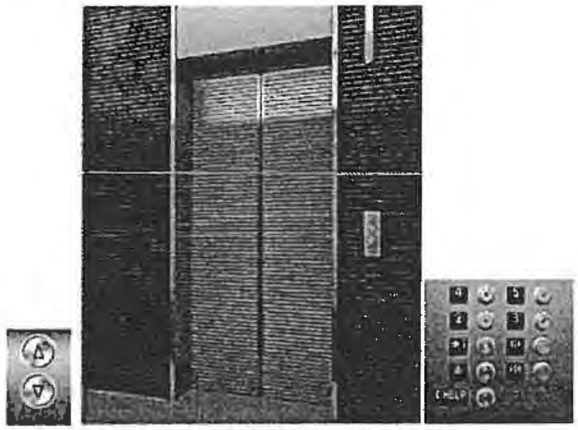
## Note

- If doubt exists as to the interpretation of any question, the candidate is urged to submit with the detailed answer paper, a clear statement of any assumptions made.
- Candidates may use one of two calculators, the Casio or Sharp approved models. This is a Closed Book exam.
- Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
- All questions are of equal value (20% each).

## Question 1 (20%)

Consider an elevator system in a 5 level office building in downtown Toronto as shown in the diagram below. Suppose that the elevator specs are as follows:

- 3 seconds to open the door,
- 5 seconds to close the door,
- 10 seconds to maintain the door open for letting traffic in/out,
- 20 seconds to travel from the first floor to the $5^{th}$ floor, and
- 7 seconds to travel one level.



**(1)** Draw a finite-state machine model representation of the elevator control system,

(2) What would be quickest time possible for a passenger to get out the elevator at $5^{th}$ floor from the time that the 'going-up' button is pressed at the first floor?

(3) What would be the longest time possible for a passenger to reach $5^{th}$ floor from the first floor?

(4) If the $3^{rd}$ floor has the highest priority for the elevator usage, repeat (3)

## Question 2 (20%)

Explain the following scheduling concepts:

1. Fixed Priority Preemptive Scheduling
2. Dynamic-Priority Preemptive Scheduling
3. Rate-Monotonic Scheduling
4. Deadline-Monotonic Scheduling
5. Earliest-Deadline-First Scheduling
6. Least Slack Scheduling

## Question 3 (20%)

1. What are the desired features of a RTOS (Real-Time Operating System)?
2. Why or why not the Microsoft Windows and Mac OS be used in real-time applications? and
3. Can you list four commercially available real-time operating systems for real-time applications?
4. Define Hard vs. Soft real-time systems
5. What are the fundamental differences between a real-time system and a non-real-time system?

## Question 4 (20%)

Suppose that you are in charge of designing a collision avoidance system for an automobile.

radar 


You are using a radar detector to measure the distance of the car in front of you, and a warning will be issued to you when your car is within 15 meters from the car ahead, so that you can stop your vehicle by applying the brakes manually. If you are within 10 meters to the car ahead, the collision avoidance system will deploy automatic break to stop your car.

Support that you are traveling at 50 km/h, the breaking distance is 6 meters, the safe distance between your car and the car ahead of you is 1 meter,

(1) Draw a complete state diagram of the operation of the collision avoidance system for a stationary object (parked car) and moving object (slower moving car)
(2) Analyse the real-time requirements of the sensor, decision-making unit, and the automatic breaking system;
(3) Derive a formula to link that the real-time requirements to the initial speed of the car and the breaking distance.

## Question 5 (20%)

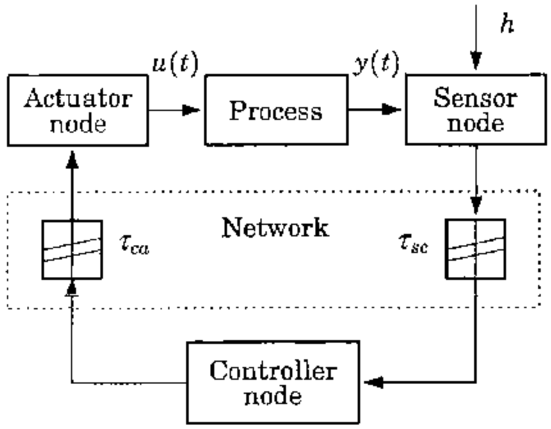
Four single-instance tasks are listed in Table below:

| Task | Arrival Time | Computational time (ms) | Absolute deadline (ms) |
|---|---|---|---|
| T1 | 0 | 4 | 15 |
| T2 | 0 | 3 | 12 |
| T3 | 2 | 5 | 9 |
| T4 | 5 | 2 | 8 |

(1) Schedule the tasks using First-Come-First-Serve (FCFS) scheduler, and draw a timing diagram to illustrate the scheme
(2) Analyze the result from Step (1). Does FCFS scheduler work in this case?
(3) Re-schedule these tasks using EDF algorithm to meet the real-time requirements. Illustrate this by a timing diagram.

## Question 6 (20%)

A real-time distributed control system is shown below, where the sensor, the controller, and the actuator reside on different nodes in a network. The network introduces a constant delay $\tau_{sc}$ between the sensor node and the controller node, and another constant delay $\tau_{ca}$ between the controller node and the actuator node. The open-loop process, itself, is an unstable system.




(1) Briefly describe a network protocol that fits the constant delay model.

(2) How would the network delay affect the performance of this closed-loop control system?

(3) Suppose that a controller has been designed for the process assuming zero network delay. The phase margin in the design was $\phi = 45°$ and the crossover frequency $\omega_c = 3.5$ rad/s. How large can the total network delay ($\tau_{sc} + \tau_{ca}$) be without causing the closed-loop control system becoming unstable?