

## National Exams

### Real-time Systems

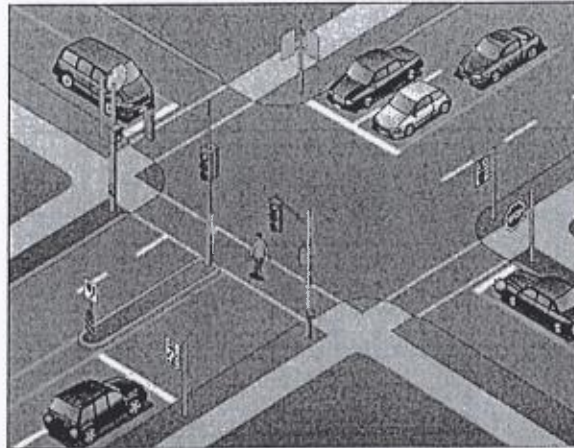
**3 hours**

#### **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 that a traffic intersection has red, yellow and green lights in two directions and stop signs in the other two (as shown). There are two pedestrian walk push buttons on two corners with four push button states.



(1) Draw a finite-state model representation of a traffic control model for this intersection.

(2) Assuming that it takes 20 sec for a pedestrian to walk across the road and 30 sec for vehicles to stop in time when the light changes, and when a car approaches a stop sign, the light will change in 60 sec for a duration of 30 sec, design an intersection traffic controller for the safety of pedestrians and passing vehicles by drawing state diagram and perform analysis on the real-time requirements of the control system.

**Question 2 (20%)**

Explain the following scheduling concepts:

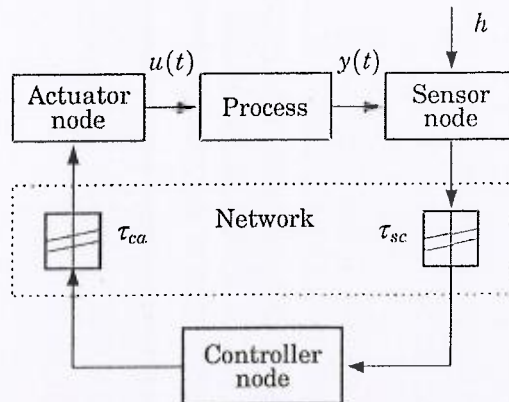
1. Fixed Priority Preemptive Scheduling
2. Dynamic-Priority Preemptive Scheduling
3. Rate-Monotonic Scheduling
4. Deadline-Monotonic Scheduling
5. Earliest-Deadline-First Scheduling
6. Least Slack Scheduling

**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 system

**Question 4 (20%)**

A distributed control system is shown in the figure 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.



- (1) Briefly describe a network protocol that fits the constant delay model.
- (2) How would excessive 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  $\phi = 45^\circ$  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?

**Question 5 (20%)**

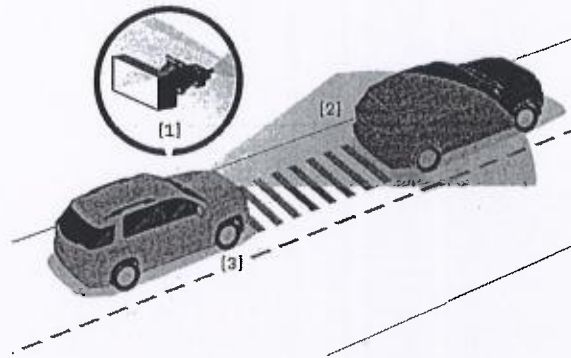
Four single-instance tasks are listed in Table below:

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%)

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



You are using radar [1] to measure the distance of the object [2] in front of your car, and a warning will be issued to you when your car is within 15 meters to the object in front of you, so that you can stop your vehicle [3] by applying the brakes manually. If you are within 10 meters to the object, the collision avoidance system will deploy automatic break to stop the car.

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

- (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 break;
- (3) Derive a formula to link that the real-time requirements to the initial speed of the car and the breaking distance.