AALTO UNIVERSITY

FIRST SEMESTER, 2020/2021

DISTRIBUTED INTELLIGENT AUTOMATION SYSTEMS

ELEC 8102

(Time Allowed: THREE hours)

NOTE: Fill your name and student ID on every page of this form.
You may attempt all questions.
Threshold to pass the course is 50% marks and more.
Put the answers in the same form, in the boxes below the questions, you
may use additional sheets if needed.

SURNAME:

FORENAME(S):

ID:

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MARKS:		
1	Out of 20	
2	Out of 10	
3	Out of 10	
4	Out of 05	
5	Out of 15	
6	Out of 10	
TOTAL: (Out of 70)		

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Question 1) State-based design of automation control logic.   20 marks (10/10)

Consider the finite-state machine in Figure 1. It is controlling the automatic elevator in a two-story building. State S1 is the initial state. The state machine operates with the following Boolean variables:
- Up, Dn – commands to move the lift up and down accordingly;
- Close, Open – commands to close and open doors of the cabin.
- Bt1, Bt2 – lift calling buttons at the floor 1 and 2 accordingly;
- CabBt1, CabBt2 – buttons in the cabin for selecting the desired destination floor;
- DoorsClosed – sensor signal indicating that the doors of the lift are closed
- AtFlr1, AtFlr2 – Sensor signals indicating that the lift cabin has reached the Floor 1, and Floor 2, respectively.
- RESTART – button at the central control room to handle faults.
- ALARM – sound and light warning at the central control room.

Let us assume that the cabin is fully automatic: it opens its doors once it arrives at the desired floor and closes the doors automatically after 60 seconds, so you don't need to implement the door control.

Complete the following two tasks a) and b).
 a) Add the following features to this state machine:
1. If the lift remains motionless on the first floor for more than 2 minutes, it should automatically return to the second floor.
2. If moving from a floor to floor takes more than 2 minutes, the ALARM should be raised. State machine should transition to the alarm state and the corresponding output variable should be set to TRUE.
3. Once ALARM is raised, the elevator should be stopped and not react to any further commands from buttons until the RESTART button is pressed and held for 5 seconds.
4. Once the lift exits the alarm state, it should continue moving to the same direction. The ALARM variable should be reset to FALSE.

You can modify the state machine directly on Figure 1 and explain in the box below.

For starting timer in a state, use the following notation:

➔T1.IN(10s) means: start timer T1 for 10 seconds when the state is entered.

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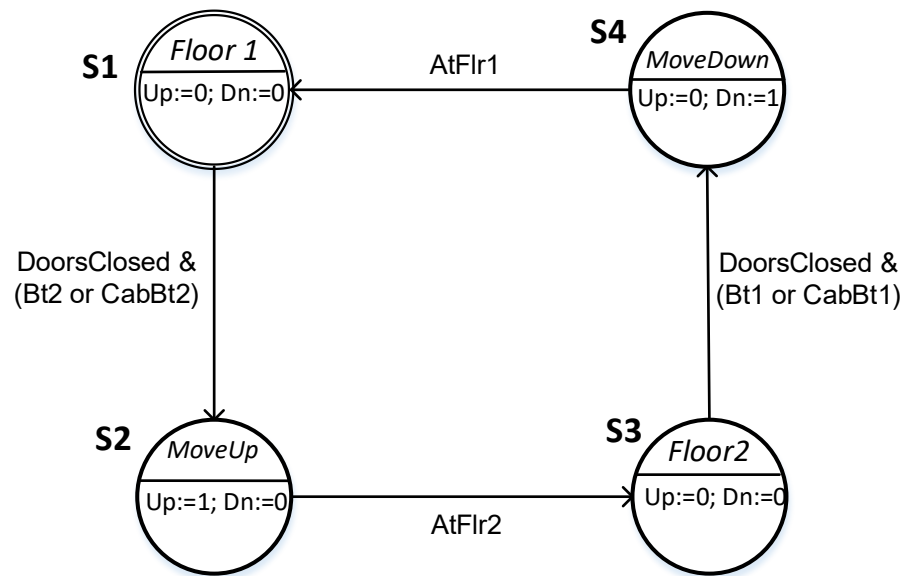**S1** Floor 1 / Up:=0; Dn:=0   AtFlr1   **S4** MoveDown / Up:=0; Dn:=1

DoorsClosed & (Bt2 or CabBt2)

DoorsClosed & (Bt1 or CabBt1)

S2 MoveUp / Up:=1; Dn:=0   AtFlr2   **S3** Floor2 / Up:=0; Dn:=0

Figure 1.

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b) Implement the modified state machine in Boolean logic and ladder diagrams.

First, present the Boolean equations implementing the state machine and after that the ladder diagram based on the Boolean equations.

<u>Notation and declarations:</u>

Timers are declared as follows

`T1: TON;`

T1.IN(10s) means start timer T1 preset to 10 seconds at the arrival to the state (rising edge).

For Boolean operations, please use the following notation:

A+B is A or B;

A B is A and B;

$\bar{A}$ is the negation of A.

Put the Boolean equations in this box. See the reminder below.

The state transition function is the logical sum of conditions on all incoming arcs to the state including the virtual loopback arc condition.

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Draw the ladder diagram in this box using the ladder guidelines. Extend the provided grid, if needed.

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Question 2 Happened before ordering of events and Lamport clocks   10 marks (2/2/3/3)

The strict partial order relation "happened before" (as defined in the lectures) is denoted by the arrow sign, e.g. $a \rightarrow b$. The word "strict" means that $a \rightarrow a$ is false for any event a

a) For n processes, define the conditions when with use of vector clocks the happened-before relation of two events can be determined and describe how it is done. Explain why.
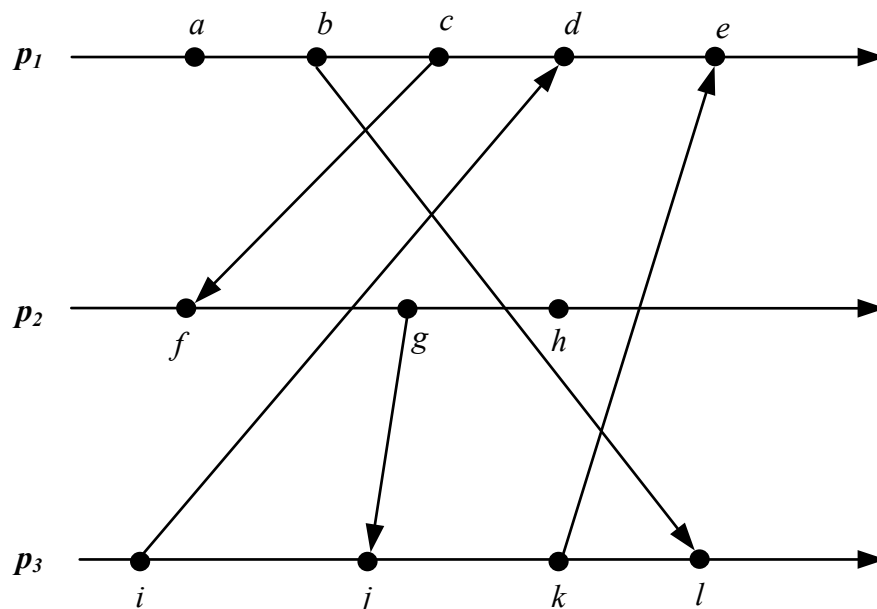

Figure 2.

b) Assign vector clocks to the events in the process diagram in Figure 2.

c) Find at least one event that has exactly 4 happened-before events.

d) List all events that happened-before event "e".

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Question 3: Clock synchronization.   **10 marks (3/4/3)**

a) A client attempts to synchronize with time server. It sends simultaneously 4 request messages and records the round-trip times and timestamps returned by the server in the table below.

	Round-trip (ms)	Time (hr:min:sec.msec)
1	33	12:09:10.665
2	28	12:09:10.667
3	30	12:09:10.666
4	31	12:09:10.663

Which of these times should it use to set its clock? To what time should it set it? Estimate the accuracy of the setting with respect to the server's clock. Provide the full calculation.

b) Client receives 3:31:46.0 (hr:min:sec.msec) from time server with round trip 18ms. It is known that the time between sending and receiving a message in the system concerned is at least 8 ms, estimate the accuracy.

c) If clocks C1...C4 are internally synchronized with bound D, does it mean that they are externally synchronized with bound D? Why?

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Question 4 and 5: Engineering with IEC 61499 Function Blocks

INFORMATION for Question 4 and 5

Consider a chemical tank plant as illustrated in Figure 3 below. The plant has the following sensors and actuators:

- MaxLevel, HighLevel, LowLevel, MinLevel, corresponding to four level sensors in descending order from the highest to the lowest level. Outputs high if they get submerged in the liquid, otherwise it outputs low.
- Three temperature sensors MaxTemp, MidTemp, and MinTemp in descending order from highest to lowest temperature level.
- A chemical gas sensor GasSensor (with binary outputs) outside of the tank. It outputs high if it detects the presence of the gas, otherwise it outputs low.
- One heater Heat (binary output).
- Two liquid inlets FastInlet and SlowInlet, and one outlet. The outlet is connected to the next processing station to supply liquid from this tank.
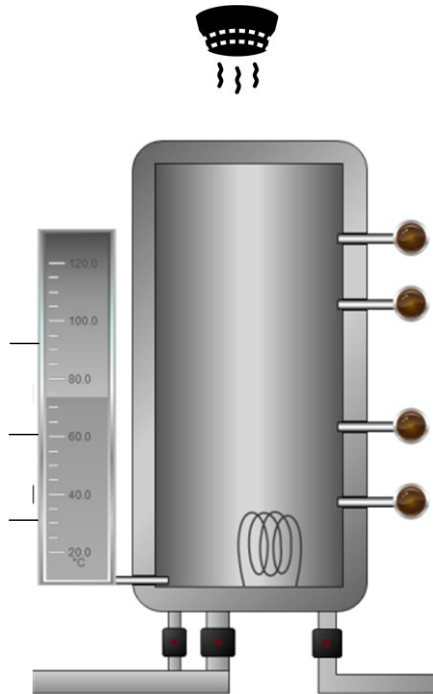

Figure 1. Illustration of the Plant.

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The production should satisfy the following requirements below:

1. The temperature of the liquid must be kept between MaxTemp and MidTemp level (it should alternate and reach those two levels).
2. The liquid in the tank should be transferred to the next processing station when the liquid's temperature is above MidTemp.

3. The liquid level should be maintained in between MaxLevel and MinLevel (it should alternate and reach those two levels).
4. When the liquid level is between HighLevel and LowLevel, the rate of change of liquid level (whether the level is increasing or decreasing) should be higher than when then the liquid is between MinLevel and LowLevel or between HighLevel and Max Level.
5. The liquid emits a dangerous gas which can be detected by the GasSensor. If the tank is somehow leaking such gas at any point in time, all liquid should be taken out from the tank and no more heating process should occur. Upon no detection of the gas by GasSensor, the plant should operate back normally.

Some important points that **must be taken into account**:
- Use the state-based approach.
- The initial condition: Some liquid is present in the tank. The liquid level is at the MinLevel and the temperature is below MinTemp.
- Some of the plant's physical characteristics:
    o There is heat dissipation that if the heater is off, the liquid's temperature will drop. The heater's heating capability is higher than the heat dissipation.
    o Heater, inlets, and outlet have mechanical components, such that these actuators must not be alternatingly turned on and off very quickly to avoid mechanical wear.
    o Note that, with regards to their flow rates, slow inlet < outlet < fast inlet. In other words, the flow rate of the FastInlet is higher than the SlowInlet. The flow rate of the Outlet is higher than the SlowInlet, but lower than the FastInlet. The sum of the flow rate of both FastInlet and SlowInlet is higher than the Outlet's flow rate.

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Question 4:   **5 marks**

Based on the specifications, **develop** a control application as a network of IEC 61499 basic function blocks with inputs and outputs based on the plant's specifications above.

- A template of the application composed of two controller function blocks is provided in Figure 4. The template is incomplete, so you need to **connect** the input and output interfaces of the function blocks to the plant connectors ("FROM THE PLANT" and "TO THE PLANT"). **SnsEvt** corresponds to the event coming from the plant, which is generated in association to any changes of the value of any sensors, while **ControlEvt** refers to the event going to the plant. **E_MERGE** refers to a function block that merges two events. **PLCInit** generates the event which triggers the initialization of the function blocks.

- Note that both controller function blocks may or may not have missing input or output interface(s). If you think there are missing interfaces, then insert such interfaces on the controller function blocks and also connect all interfaces to their respective plant connectors. You may put your modifications directly on the provided drawings, or you may draw the function blocks on the answer text box.
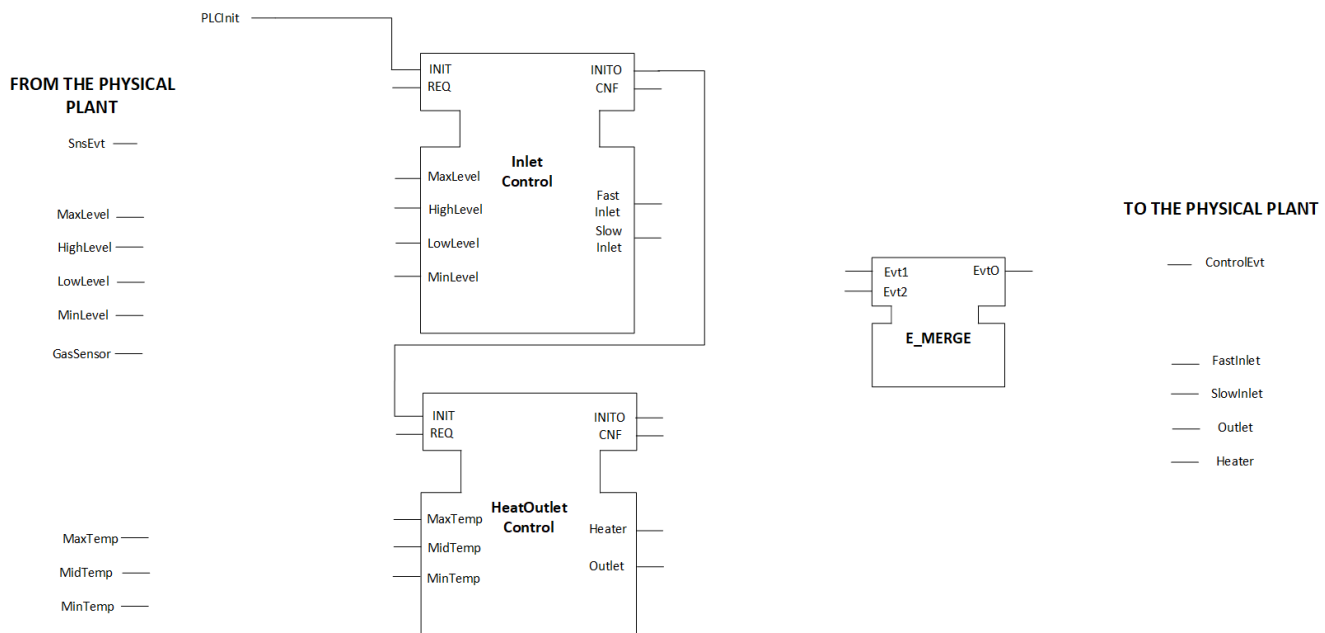
Figure 2. Controller Function Blocks.

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Question 5:   **15 marks**

Develop the **COMPLETE** Execution Control Chart / ECC of the controller IEC 61499 function blocks. Templates of the ECC of both controller function blocks are provided in Figures 5 and 6, along with several algorithms.

Note, that the templates are incomplete. They lack state transition conditions, names of the states and their algorithms, and the event output. Some state(s) may also be missing, so you may need to add those if you think this is the case. Then, explain and **describe** the states that you defined in the ECC!
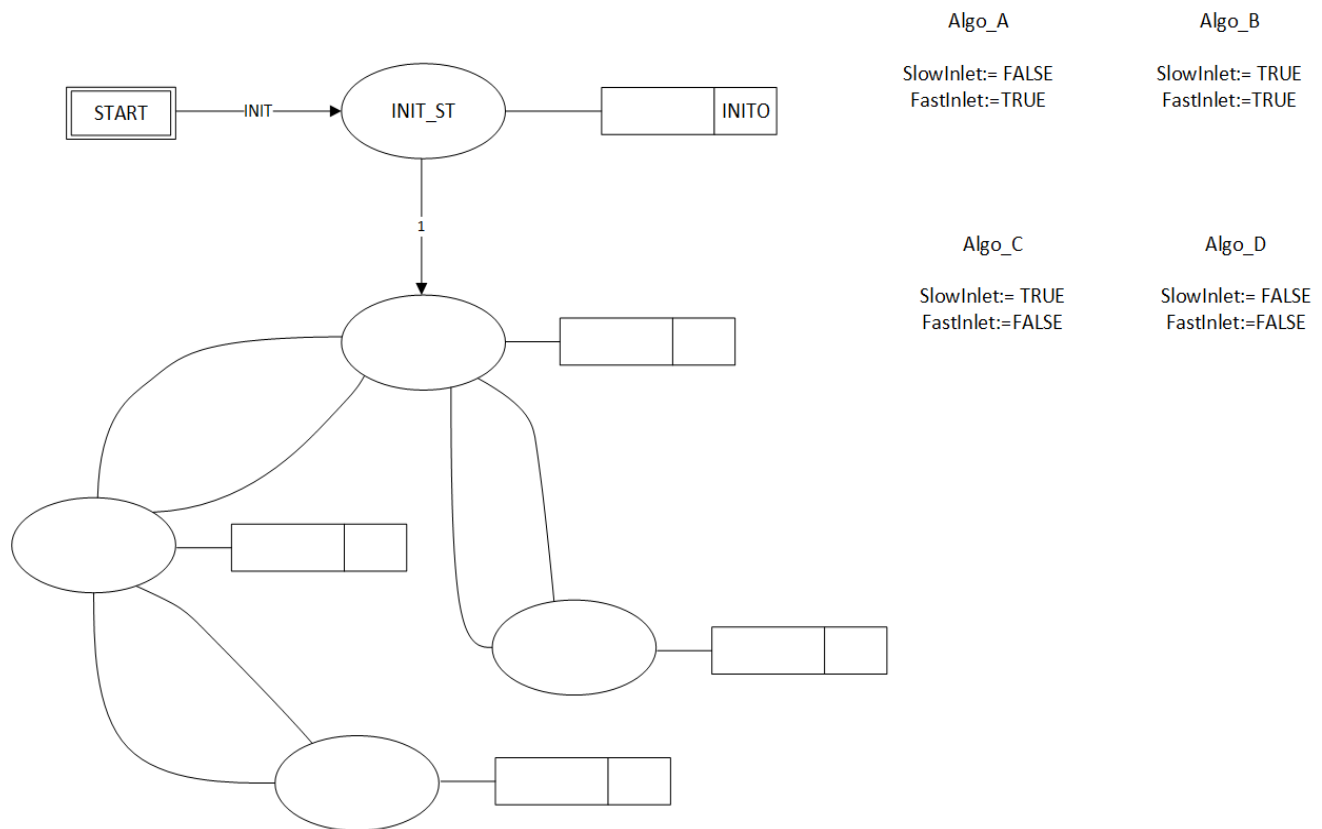

Figure 3. ECC of InletControl Function Block.
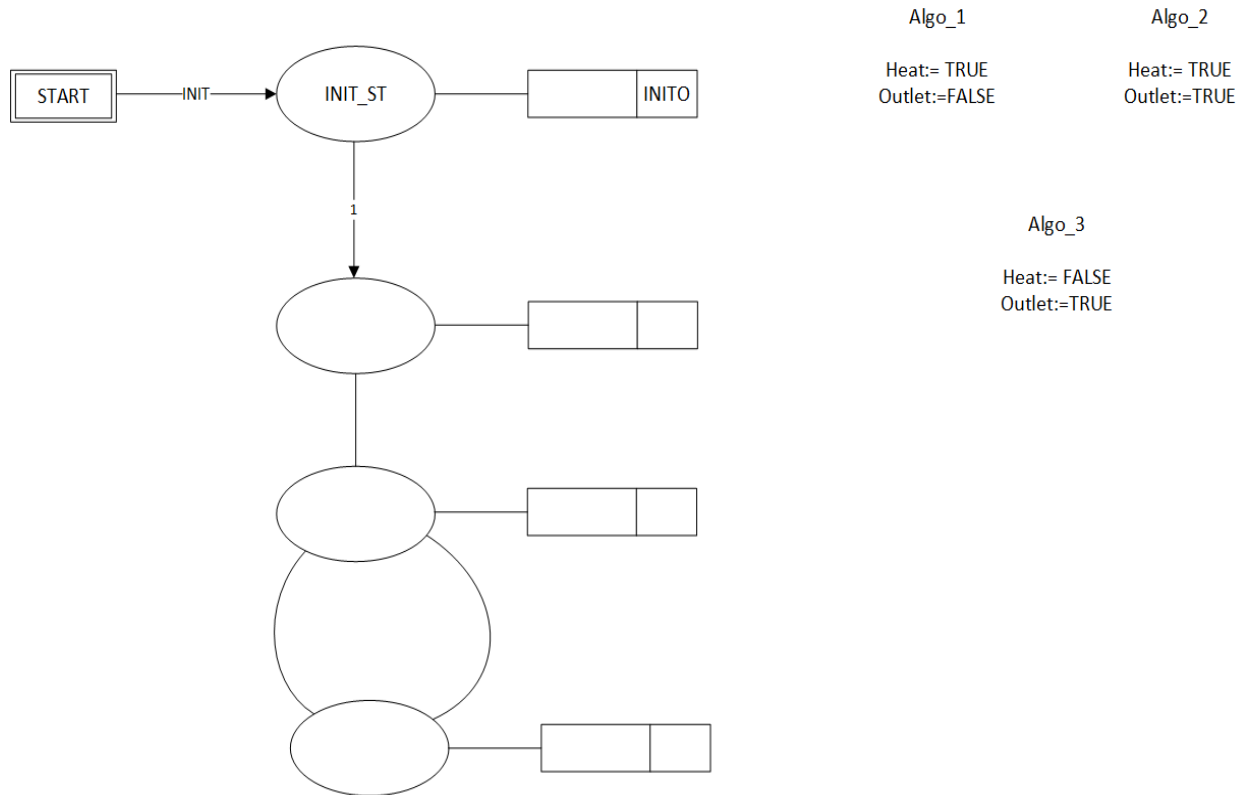
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Algo_1   Algo_2

Heat:= TRUE   Heat:= TRUE
Outlet:=FALSE   Outlet:=TRUE

Algo_3

Heat:= FALSE
Outlet:=TRUE

START —INIT→ INIT_ST — INITO

Figure 4. ECC of HeatOutletControl Function Block.

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Question 6 : Mutual exclusion.   **10 marks (5/5)**

The figure below presents a system of 3 processes, named Pn n={1..3}, using the multicast mutual exclusion algorithm to synchronise their access to the critical section (CS). It is assumed that the events when the processes needed to access the CS use Lamport clocks labeled for P1, P2, P3 as A, B, and C respectively.

a.   Complete the missing communications in the following graphical representation of the message flow. Label the arrows representing the communication with Lamport clock timestamps and process ID, using the following convention: <A,1> for P1, <B,2> for P2 and <C,3> for P3.
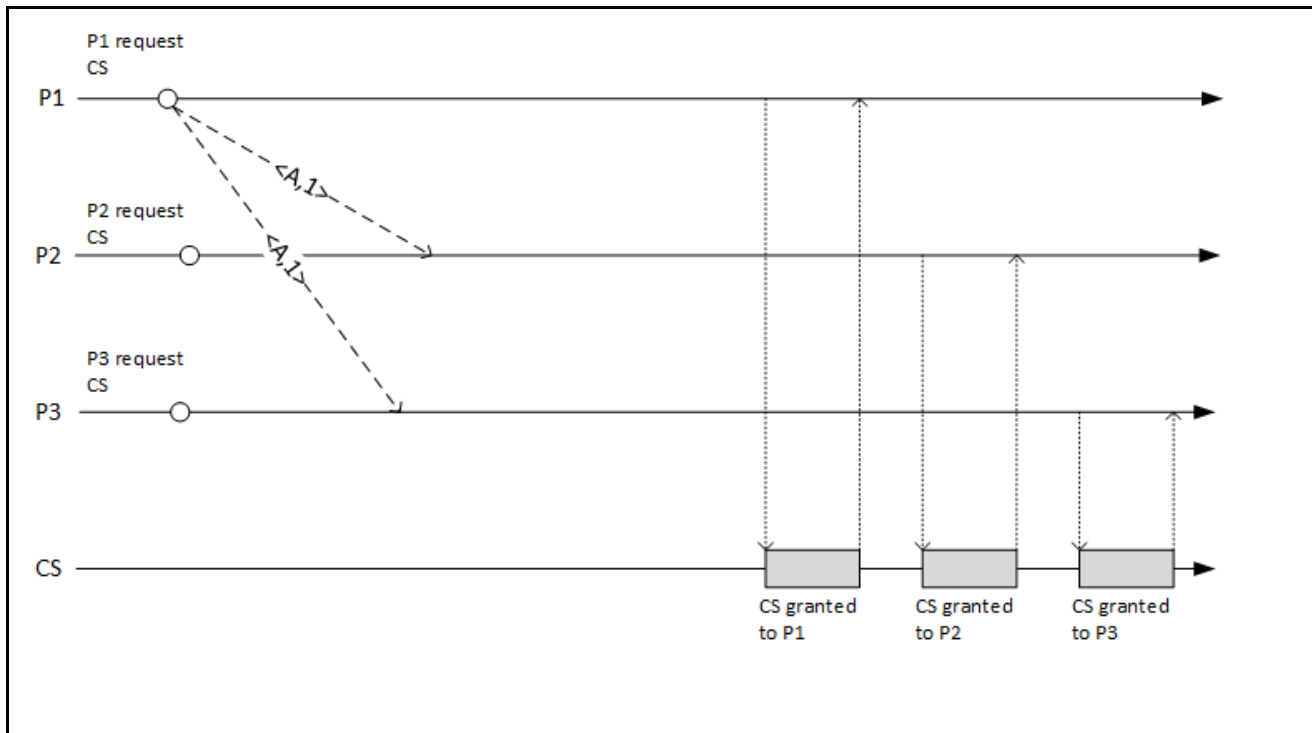
b) Assume that this system is being simulated in a computer, so all processes are executed by a single device in separate threads. Assign arbitrary values to the Lamport clock timestamps of the request messages A, B and C, so the CS access is granted in 3 different cases to P1, P2 or P3 respectively

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		Timestamp		
		A	B	C
CS granted to	P1			
	P2			
	P3			