Name: B.Anshuman

Roll No: 200259 (e.g. 170001) **Dept.**: EE (e.g. CSE)

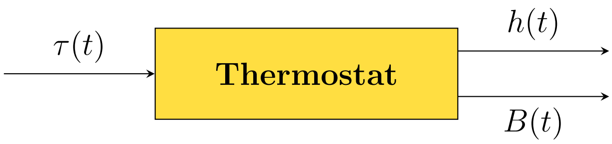
Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

Total: **40 marks**

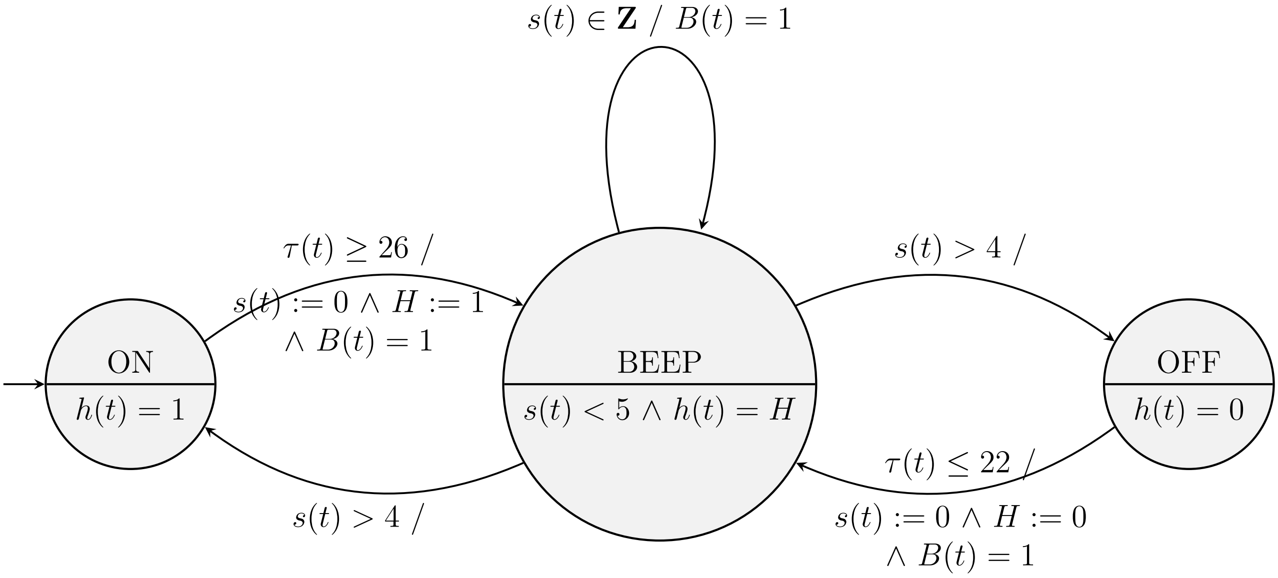
1. Write the answers **neatly** in the given boxes.
2. You may discuss the solutions with the other students, but you have to write them in your own words.

Problem 1. (10 points) Construct a timed automation model of a thermostat where the heater will be switched on when the room temperature is less than 22°C and switched off when the temperature is above 26°C. We also have the following additional requirement. Before switching on or off, it will generate a “beep” sound every second for 5 seconds as a warning. That means once the system senses that the temperature is less than 22°C, it will generate the warning first, and then the heater will be switched on. Similarly, a warning sound will be issued before switching off the heater after the temperature reaches 26°C.

The following block represents the thermostat in question.



This internally works as a state machine with:
Input: $\tau(t)$ (Temperature)
Output: $h(t)$ (Heater On pure signal), $B(t)$ (Beep pure signal)
Variables: $s(t) \in \mathbf{R}$ (Global Clock), $H \in \{0,1\}$ (Current state of Heater)



Note that $s(t)$ changes as $\dot{s}(t) = 1$ for this state machine. Also expression written in lower part of a mode is its invariant.

Name: B.Anshuman

Roll No: 200259 e.g. 170001

Dept.: EE e.g. CSE

Name: B.Anshuman

Roll No: 200259 (e.g. 170001)

Dept.: EE (e.g. CSE)

Name: B.Anshuman

Roll No: 200259 e.g. 170001 **Dept.**: EE e.g. CSE

Name: B.Anshuman

Roll No: 200259 e.g. 170001 **Dept.**: EE e.g. CSE

Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

Problem 2. (10 points) Consider the following protocol that ensures mutual exclusion among N processes using real-time clocks and a shared variable `lock`.

Initially `lock` is 0.

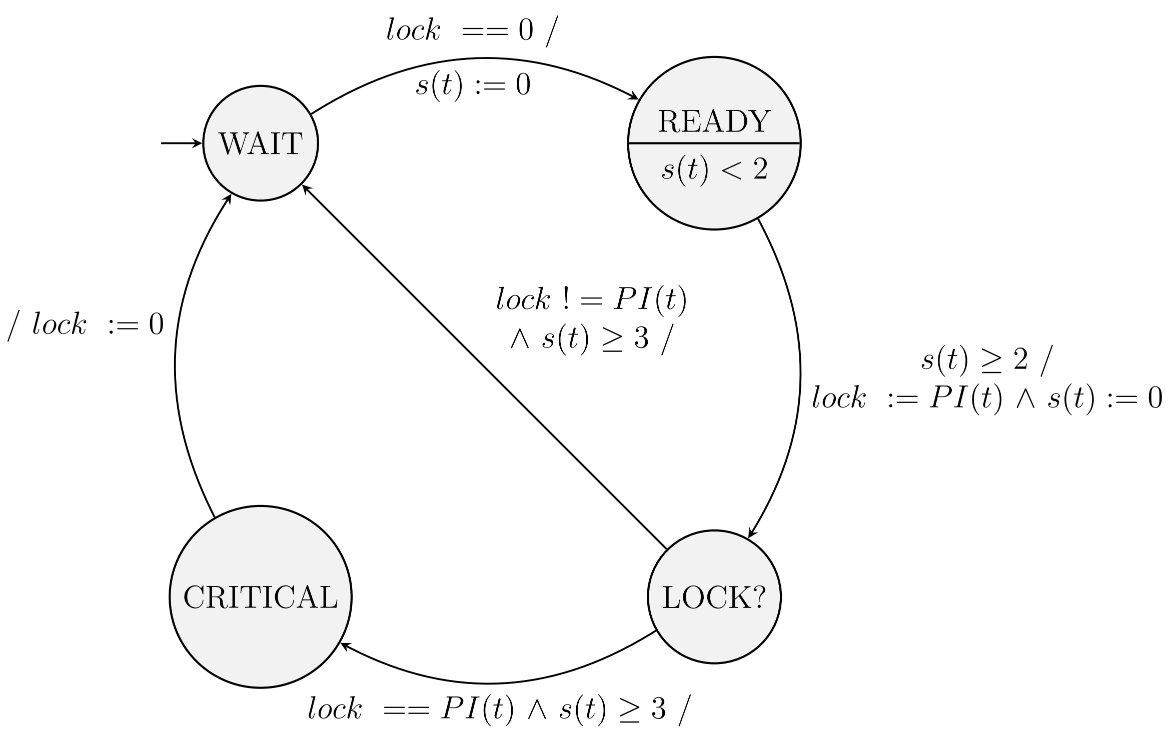
Every process follows the following process:

```
loop
   wait until lock = 0;
   wait for a delay <= 2;
   set lock to process id;
   wait for a delay >= 3;
   if lock = process id
    enter critical section;
   go back to the wait state
end
```

Draw a timed automaton to capture the behavior of a process that follows the protocol.

The following time automaton represents mutual exclusion among N processes.

Input: $PI(t)$ (Process ID)
Output: No apparent output, may happen from the hierarchical state **CRITICAL**.
Variables: $s(t) \in \mathbf{R}$ (Global Clock), $lock$ (shared variable)



Note that $s(t)$ changes as $\dot{s}(t) = 1$ for this state machine.

Name: B.Anshuman

Roll No: 200259 e.g. 170001 **Dept.**: EE e.g. CSE

Name: B.Anshuman

Roll No: 200259 (e.g. 170001) **Dept.**: EE (e.g. CSE)

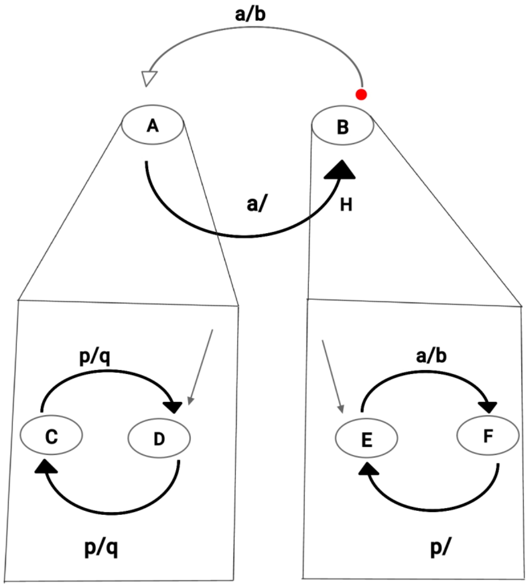
Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

Name: B.Anshuman

Roll No: 200259 (e.g. 170001) **Dept.**: EE (e.g. CSE)

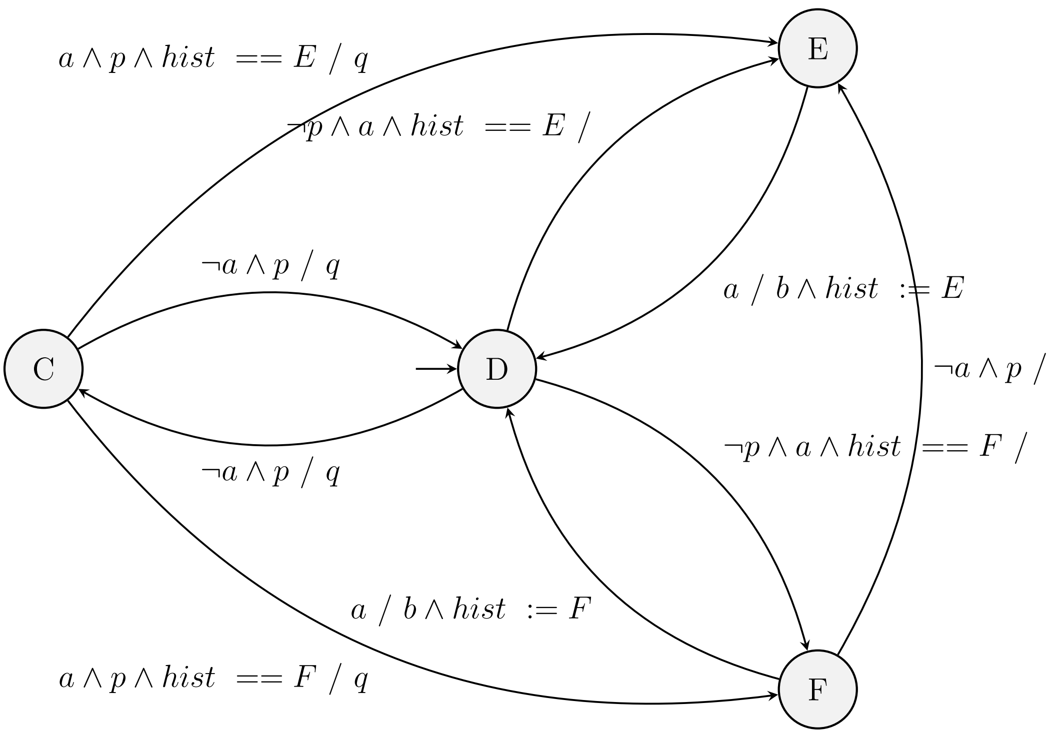
Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

Problem 3. (10 points) Construct an equivalent flat FSM giving the semantics of the hierarchy. Describe in words the input/output behavior of this machine.



The following extended state machine represents the above hierarchical representation.

Input: a (pure), p (pure)
Output: b (pure), q (pure)
Variables: $hist$ (stores history of B)



Name: B.Anshuman

Roll No: 200259 (e.g. 170001) **Dept.**: EE (e.g. CSE)

Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

We can expand the extended finite state machine to a vanilla finite state machine by considering nodes as (C, E); (C, F); (D, E); (D, F); (B, E); (B, F); instead of the above. The above and this would have no difference except that the extended finite state machine is more concise to represent without repetitions in transitions.

Name: B.Anshuman

Roll No: 200259
e.g. 170001

Dept.: EE
e.g. CSE

Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

Name: B.Anshuman

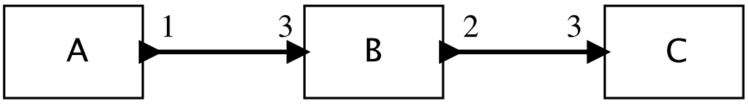
Roll No: 200259 (e.g. 170001) **Dept.**: EE (e.g. CSE)

Name: B.Anshuman

Roll No: 200259 (e.g. 170001) **Dept.**: EE (e.g. CSE)

Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

Problem 4. (10 points) Problem 8 in the Exercises of Chapter 6 in [LS15].



The numbers adjacent to the ports indicate the number of tokens produced or consumed by the actor when it fires. Answer the following questions about this model.

1. Let q_A , q_B , and q_C denote the number of firings of actors A , B , and C , respectively. Write down the balance equations and find the least positive integer solution.
2. Find a schedule for an unbounded execution that minimizes the buffer sizes on the two communication channels. What is the resulting size of the buffers?

1. Using the fact that each token gets stacked until consumed, and each block can consumes exactly the number of tokens shown at its input, generating exactly the number of tokens shown at its output, at one time.

$$\begin{aligned} q_A &= 3q_B \\ 2q_B &= 3q_C \end{aligned} \tag{1}$$

   $q_A = 9$, $q_B = 3$, $q_C = 2$ satisfies the above equations.

2. A schedule for an unbounded execution can be:

$$A, A, A, B, A, A, A, B, C, A, A, A, B, C, \cdots \tag{2}$$

   This minimizes the buffer sizes of the two communication channels to **3** (for A-B channel) and **4** (for B-C channel).

Name: B.Anshuman

Roll No: 200259 (e.g. 170001)

Dept.: EE (e.g. CSE)

Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 2
Deadline: September 2, 2022

Name: B.Anshuman

Roll No: 200259 e.g. 170001

Dept.: EE e.g. CSE

Name: B.Anshuman

Roll No: 200259 e.g. 170001 **Dept.**: EE e.g. CSE