Tutorial Session N°2: Semaphores

Objective: Understand and practice process synchronization using semaphores through exercises on task ordering, resource sharing, and classic concurrency problems.

Exercise 1

We consider the following three concurrent processes. The semaphore **mutex** is initialized to **1**, and the shared variable **x** is initialized to **3**.

Process P1	Process P2	Process P3
(a) P(Mutex);	(d) P(Mutex);	(g) P(Mutex);
(b) x := x + 1;	(e) x := x * 2;	(h) x := x - 4;
(c) V(Mutex);	(f) V(Mutex);	(i) V(Mutex);

1. Consider the following execution sequence: **a d b g c e f h i**. if this scenario is possible, what is the final value of x? justify your answer otherwise
2. Answer the same question for this execution sequence: **a d e b c f g h i**.
3. Determine all possible final values of **x** with respect to all possible execution sequences, and justify your answer.
4. Modify the above processes (using the semaphore mechanism) so that the final value of **x** is always guaranteed to be **3**.
5. If we use the TAS (Test And Set) instruction instead of the mutex to protect the shared variable x, list the problems that can occur?

Exercise 2

We consider a set of six sequential tasks **{A, B, C, D, E, F}**. Task **A** must precede tasks **B**, **C**, and **D**. Tasks **B** and **C** must precede task **E**. Tasks **D** and **E** must precede task **F**. Implement the synchronization of these tasks using semaphores, blocking and unblocking tasks while respecting the above execution order.

Exercise 3

Consider the parallel execution of the following two processes:

Process A:	Process B:

begin
repeat
T1;
until false;
end;
	begin
	repeat
	T2;
	until false;
	end;

1. Use one semaphore to synchronize the two processes so that the execution of task **T1** never occurs simultaneously with task **T2**.
2. Use two semaphores to synchronize the two processes so that the tasks always execute consecutively: **T1 T2 T1 T2 T1 T2 ...**
3. Use two semaphores to synchronize the two processes so that the tasks always execute in the following order: **T1 T2 T2 T1 T2 T2 T1 T2 T2 ...**

Exercise 4

Consider a barber shop with **N chairs** for waiting customers, and a **chair C** for the customer being served, and a **barber B**.

- ✓ If there are no customers, the barber **B** sleeps in chair **C**.
- ✓ When a customer arrives while the barber **B** is sleeping, the customer wakes him up, sits in **C**, and gets a haircut.
- ✓ If a customer arrives while the barber is busy: if one of the **N** chairs is free, the customer sits and waits; otherwise, the customer leaves.
- ✓ When the barber finishes a haircut and there are waiting customers, he serves the next customer.

The task is to synchronize the activities of the barber and his customers using semaphores. Detail the barber's and customers' operations and the role of each semaphore used.

Exercise 5

An ATM can be used by only one person at a time. When there are women and men waiting, a strict alternation must be ensured: after a woman uses the ATM, it must be a man's turn (if a man is waiting), otherwise women continue. The same applies for men. Initially, the turn is given to women.

Provide a synchronization scheme for the processes **WOMAN** and **MAN** using a semaphore mechanism.

Exercise 6

An Olympic swimming pool can receive swimmers from three synchronized swimming teams: **T1**, **T2**, and **T3**. To organize training sessions, the rule is: at any given time, the pool can accommodate any number of swimmers but from at most 2 teams. For example, swimmers from teams **T1** and **T3** can train simultaneously, but if a swimmer from team **T2** wants to enter, they must wait until all swimmers from one team have left the pool.

Propose a semaphore-based synchronization scheme for processes **T1**, **T2**, and **T3**, corresponding to swimmers from each team.

Exercise 7

A bridge can support a maximum load of **20 tons**. The bridge is crossed by **trucks weighing 20 tons** and **cars weighing 5 tons**. You are asked to manage access to the bridge so that:

- ✓ The maximum bridge load is respected.
- ✓ Priority is given to cars: when a car and a truck request access simultaneously, the car must be allowed first, provided the bridge's maximum capacity is not exceeded.

Propose a synchronization scheme for **truck** and **car** processes using semaphores.

Exercise 8

Cars coming from the north and the south must cross a bridge. On this bridge, only one lane of traffic can be used at a time, and only in one direction. Write an algorithm that allows cars to pass from north to south or from south to north by synchronizing them using semaphores at the bridge. There is no priority between cars coming from the north or the south; therefore, the solution must be fair (no starvation). Cars must cross the bridge in their order of arrival.

GOOD LUCK