Family Name_____ Name_____ Student ID_____

Ex 1: Consider the following algorithm:

```
Init:
        sn=0; last[]=[0]ⁿ; pending=∅; neighbors=%set of neighbors for the current process.

upon event xCast(m):
        sn=sn+1;
        for each pⱼ ∈ neighbors do
                send MSG (m, sn, myId) to pⱼ
        trigger XDeliver(m)

upon event rcv(m, snₘ, src, id):
        if src=id and src ∈ neighbors and snₘ > last[src]
                then trigger XDeliver(m)
                        last[src]=snₘ
                        for each pⱼ ∈ neighbors do
                                send MSG (m, snₘ, src, myId) to pⱼ
                else
                        pending = pending ∪ {<m, snₘ, src, id>}

when exists <m, snₘ, src> occurring at least f+1 times in pending and such that snₘ > last[src]:
        trigger XDeliver(m)
        last[src]=snₘ
        for each pⱼ ∈ neighbors do
                send MSG (m, snₘ, src, myId) to pⱼ
```
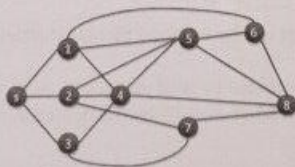
Consider the network depicted above

Let us assume that (i) each channel depicted in the figure is an authenticated perfect point-to-point link, (ii) up to f processes may by Byzantine in each neighborhood, (iii) s is the only process that can start an Xcast and (iv) each correct process executes the algorithm in Figure.

Discuss the truthfulness of the following sentences when f=1.

1. If a correct process p delivers a message m, them m has been previously broadcasted by a correct process s.
2. If a correct process s Xcast a message m, then m will be eventually delivered by every correct process.
3. Let us consider two messages m and m' broadcasted by the same source s. If a process p delivers m before than m', then m has been sent before than m' from q.

... must agree on a value that

Ex 2: Consider the partial execution depicted in the Figure
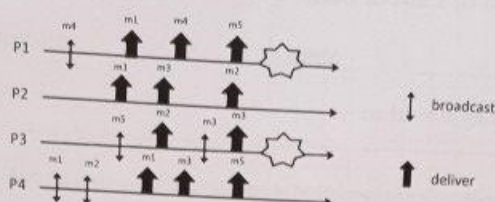
Answer to the following questions:

1. Complete the execution in order to have a run that: (i) satisfies Regular Reliable Broadcast specification and (ii) does not satisfy Uniform Reliable Broadcast specification and (iii) does not satisfy Total order Broadcast specifications.
2. Complete the execution in order to have a run that: (i) satisfies Uniform Reliable Broadcast specification and (ii) does not satisfy Total order Broadcast specifications.
3. Complete the execution in order to have a run that: (i) satisfies TO(UA, WNUTO) and (ii) satisfies FIFO order and (iii) does not satisfy causal order.

Ex 3: Consider the execution depicted in the following figure and answer the questions:
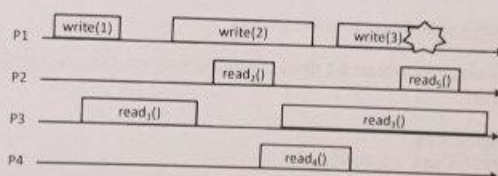
1. Define ALL the values that can be returned by read operations (Rx) assuming the run refers to a regular register.
2. Define ALL the values that can be returned by read operations (Rx) assuming the run refers to an atomic register.
3. Let us assume that values retuned by read operations are as follow: $read_1() \rightarrow 2$, $read_2() \rightarrow 1$, $read_3() \rightarrow 1$, $read_4() \rightarrow 2$, $read_5() \rightarrow 3$. Is the run depicted in the Figure linearizable?

Ex 4: Consider a distributed system constituted by n processes $\prod = \{p_1, p_2 \ldots p_n\}$ with unique identifiers that exchange messages through FIFO perfect point-to-point links and are structured through a line (i.e., each process p_i can exchange messages only with processes p_{i-1} and p_{i+1} when they exists). Processes may crash and each process is equipped with a perfect oracle (having the interface _new_right(p)_ and _new_left(p)_) reporting a new neighbor when the previous one is failing. Processes are also equipped with a leader election oracle.
Write the pseudo-code of an algorithm implementing a consensus primitive.