Calculi of Concurrency
Homework Problems 1

The **deadline** is May 12. Please deliver your **individual** solutions to Jan. To collect credits you have (1) to solve all exercises, (2) to attend the homework session on May 16, and to be ready to present your solutions at this session.

1. We investigated some concepts of process equivalence.
   - What are these concepts? Explain the intuition behind each of them.
   - Discuss how they relate to each other. Illustrate your discussion by examples of processes which are equivalent in some sense but not equivalent in the other.
   - Extend the comparison for the following trace equivalence relation. A *trace* (or an *experiment*) of a process is any sequence of observable actions that can be performed by this process. (So the possible internal reactions are ignored). P and Q are trace equivalent if they have the same set of traces.

2. Consider the processes defined as follows:

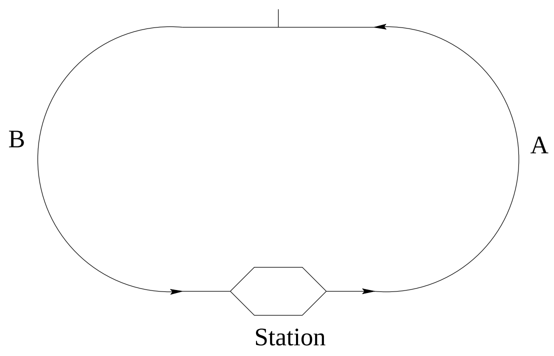
   $$S = p.S' \quad S' = v.S$$

   and

   $$D = p.S1 \quad S1 = p.S2 + v.D \quad S2 = v.S1$$

   Check whether D and $(S|S)$ are strongly bisimilar. Justify your answer.

3. A toy railway consists of:



- a loop of single track with one station with double track; the track outside station is divided into the segments A and B
- two trains.

The trains move collision-free in one direction and may be stopped at the station or at the segment connection. That is, there is at most one train in each segment and at most two trains at the station.

- Describe this system by a process definition, as simple as possible, with the only observable actions:
  `a` a train enters segment A
  `b` a train enters segment B
  `s` a train enters the station.
  Call this a specification.
- Design appropriate primitive processes describing the railway elements needed to achieve the requirements (e.g. semaphores) and combine them to process expressions describing the implementation of the system.
- Justify that the implementation is observationally equivalent to the specification and check this using CWB-NC.

4. (a) Describe in CCS/CWB the following processes which cyclically behave as follows:

   - B accepts a and sends $'b$ (call this *a to b transmission*)
   - P accepts either $a1$ or $a2$ and sends, respectively $'b1$ or $'b2$.
   - N is like P but nondeterministically decides at the beginning of each cycle which of the input messages can be received in this cycle.
   - R, can transmit concurrently $a1$ to $b1$ and $a2$ to $b2$.
   - S is a switch: it transmits $a1$ to $b1$ or $a2$ to $b2$, depending on its state; the state is selected by the control signals $c1$ and $c2$.

   (b) Let X, Y, Z be arbitrary processes, with names, respectively, ix, iy, iz (inputs) and co-names $'ox,' oy,' oz$ (outputs). Call the process $new\ c1, c2(\{c1/ox\}X|\{c1/iy, c2/oy\}Y|\{c2/iz\}Z)$ a *cross-link* from $'ox$ to iz with Y.

   Let $B1, ..., B4$ be four renamed instances of B. Each of them has thus an input ai and an output $'bi$. Use an instance of P to construct a cross-link from $'b1$ to $a3$ and from $'b2$ to $a4$. Describe this in CCS/CWB as a process $P4$. Thus, the observable actions of $P4$ are $a1$, $a2$, $'b3$ and $'b4$. Discuss informally how this process behaves, show and explain some traces of its simulation in CWB.

   (c) Repeat (b) above with N instead of P, giving $N4$. Explain the difference between $N4$ and $P4$. Are they observationally equivalent? Check this with CWB and explain the obtained result.