1. Consider the following program:

\[ x := \text{true} \quad || \quad y := \text{not } x \]

Assuming that the variables all start off with value \text{false}, and \text{||} allows arbitrary interleaving of the programs, draw the full transition system describing the program behaviour.

\textbf{Hint:} Use two program counters, one for the left program, one for the right. A state would thus be a quadruple \((pc_L, pc_R, x, y)\). The resulting transition system will have 16 states, of which only 5 are reachable.

2. The above program should satisfy the safety property

\textbf{Property 1: not (x and y)}

Give a trace showing that the program is not correct.

3. Describe the algorithm used by backward model-checking. In how many steps would a bug be found in the above system?

4. State the following property in terms of your program counter variables:

\textbf{Property 2: program terminated \implies x=y}

How many steps would be needed to verify it using backward model-checking?
5. Abstraction is applied to the above transition system by putting two states, \((pc_{1L}, pc_{1R}, x_1, y_1)\) and \((pc_{2L}, pc_{2R}, x_2, y_2)\), in the same equivalence class if the program counters are equal in the different states: \(pc_{1L}=pc_{2L}\) and \(pc_{1R}=pc_{2R}\), and the value of the expression \(x \leftrightarrow y\) is the same in the two states: \((x_1 \leftrightarrow y_1) = (x_2 \leftrightarrow y_2)\).

By drawing the reachable part of the resultant transition system or otherwise, construct a counter-example to property 2 in the abstracted system which is a false-negative.

[5 marks]