Exercise 1: 5 Points
Apply the CEGAR approach to the program below. Whenever you have to provide a sequence of statements you may return any sequence, but we encourage you to take the shortest sequence.
Document all intermediate steps.
Hint: If you choose the abstraction of traces wisely, then two iteration steps are sufficient.

```
x := 0;
while (x <= 100) {
y := true;
x := x + 1;
}
assert y == true;
```

Exercise 2: Abstraction of a Trace 2 Points
In the lecture we defined an abstraction $\pi^\#$ of a trace $\pi$, derived by replacing some of the statements $st$ with their abstract counterpart $\text{abstract}(st)$. The intuition is that sometimes a few statements in $\pi$ are sufficient to make it infeasible. A proof of infeasibility of $\pi^\#$ is then also a proof of infeasibility of $\pi$.

In this exercise, we consider a modified concept of abstraction: Instead of replacing assignments with their abstraction ($\text{havoc}$), we allow them to be deleted from the trace entirely.

Show that this is not a good notion of abstraction. In particular, give a trace $\pi$ and a corresponding abstraction $\pi^\#$, such that $\pi^\#$ is infeasible, but $\pi$ is feasible. Give a proof of infeasibility for $\pi^\#$, and an execution for $\pi$.

Exercise 3: Nondeterministic Finite Automata 2 Points
A nondeterministic finite automaton (NFA) is a tuple $\mathcal{A} = (Q, \Sigma, \Delta, Q_0, F)$ where $Q$ is
A finite set of states, $\Sigma$ is a finite alphabet, $\Delta \subseteq (Q \times \Sigma) \times Q$ is a transition relation, $Q_0 \subseteq Q$ is a set of initial states, and $F \subseteq Q$ is a set of final (or accepting) states.

A run for a finite word $w = a_1 \ldots a_n \in \Sigma^*$ in an NFA $A$ is a finite sequence of states $q_0q_1 \ldots q_n$ such that $q_0 \in Q_0$, and $(q_i, a_{i+1}, q_{i+1}) \in \Delta$ for all $i \in \{0, \ldots, n-1\}$. A run is accepting, if it ends in a final state $q \in F$.

A word $w \in \Sigma^*$ is accepted by an NFA $A$ if there exists an accepting run in $A$.

Let $\Sigma = \{a, b\}$. Consider the following NFA $A$ given by its graphical representation, where we mark initial states by ingoing edges, and final states by double circles.

For each of the following words, state whether they are accepted by the NFA $A$ or not. If a word is accepted by $A$, give an accepting run.

(a) $w_1 = aaab$

(b) $w_2 = ababa$

(c) $w_3 = abaabaa$

(d) $w_4 = abba$