0 Let $x$ be an integer state variable. Is the following specification implementable?

(a) $\lnot (x \geq 0 \land x' = 0)$

(b) $\lnot (x \geq 0 \lor x' = 0)$

1[9] Let $a$ and $b$ be integer variables. Express

\[
\begin{align*}
    a &:= a + b + 1. \\
    b &:= a - b - 1. \\
    a &:= a - b - 1
\end{align*}
\]

as simply as possible without using quantifiers, assignments, or dependent compositions.

2[9] Let $x$ be an integer variable, and let $t$ be the nonnegative extended real time variable. Here is a loop.

\[
R \iff x := x + 1. \quad R
\]

Suppose we charge time $2^{-x}$ for the recursive call, so that each iteration takes half as long as the one before. Prove that the execution time is $2^{-x}$. (If $x$ is initially 0, then the execution time is 1.)

3[18] Let $n$ be natural and let $s$ be a natural variable. Write a program for $s' = n^2$ without using multiplication or exponentiation. Use a for-loop with for-index $k$ and invariant $s = k^2$. Proof required.

end of test