Problem 1 (25 p)
Prove the following claim.
\[
\left( \begin{array}{c}
(w \leq y) \\
\land \\
(w \leq z) \\
\land \\
(x \leq y) \lor (x \leq z)
\end{array} \right) \implies (x + w \leq y + z)
\]

Problem 2 (20 p)
Consider the program $S$ below.
\[
\textbf{do } \ 0 < x \ \rightarrow \ x := x - 2 \ \textbf{od}
\]
Give $wp(S, R)$ for the following values of $R$.
- $R = \text{odd}(x)$.
- $x = -1$. 
• $x = -3$.

• $x = 0$.

• $x \geq 2$.

It is sufficient that you only give the definition of $wp(S, R)$. Do not explain how you found $wp(S, R)$. Do not prove that your solution is correct. Points will be deducted if you attempt that!!

**Problem 3 (25 p)**

Using the alternative command theorem, show that the following program is correct.

\[
\begin{align*}
\{ & (x = \max(x, y, z)) \lor (y = \max(x, y, z)) \} \\
\text{if } & (x \leq z) \land (y \leq z) \rightarrow w := z \\
& T \rightarrow w := x + y \\
\text{fi} \\
\{ & w \geq \max(x, y, z) \}
\end{align*}
\]

where $x$, $y$, and $z$ are natural numbers.

*Hint:* Formulate the two predicates $b = \max(a_1, a_2, a_3)$ and $b \geq \max(a_1, a_2, a_3)$.

**Problem 4 (30 p)**

Consider the following program:

\[
\begin{align*}
\{ & Q : (s = 1) \land (i = 0) \land (n > 0) \} \\
\text{inv } & P : ?? \\
\text{bound } & t : ?? \\
\text{do } & i < n \rightarrow s, i := s + 2i + 3, i + 1 \text{ od} \\
\{ & R : s = (n + 1)^2 \}
\end{align*}
\]

Define an invariant $P$ and a bound function. Show the correctness of the program through the iterative command theorem, using your definitions of $P$ and $t$.  

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