This is a 50-minute exam. While taking this exam, you may not consult any books, notes, or electronic devices.

1. Let $L$ be the language consisting of one 2-place predicate, $R$. Write an $L$-sentence $A$ with the following properties.

   (a) There exists at least one $L$-structure which satisfies $A$ and contains exactly 5 elements.

   (b) There is no $L$-structure which satisfies $A$ and contains less than 5 elements.

Which of the following sentences are logically valid?
In each case, use a structure or a tableau to justify your answer.

2. $(\forall x \exists y Rxy) \Rightarrow (\exists x \forall y Rxy)$.
3. $(\forall x (Hx \Rightarrow Mx)) \Leftrightarrow \neg \exists x (Hx \land \neg Mx)$.
4. $((P \Rightarrow Q) \Rightarrow P) \Rightarrow P$.
5. $((P \Rightarrow Q) \Rightarrow R) \Leftrightarrow (P \Rightarrow (Q \Rightarrow R))$.
6. $(\exists x (A \Rightarrow B)) \Leftrightarrow ((\forall x A) \Rightarrow B)$ where $x$ does not occur in $B$. 