Exercise 3.1. Transform the following concepts into negation normal form:

(a) \( \neg (A \land \forall r. B) \)
(b) \( \neg \forall r. \exists s. (\neg B \lor \exists r. A) \)
(c) \( \neg ((\neg A \land \exists r. \top) \lor \exists s. (A \lor \neg B)) \)

Exercise 3.2. Apply the tableau algorithm in order to check if the axiom \( A \sqsubseteq B \) is a logical consequence of the TBox \( \{ \neg C \sqsubseteq B, A \sqcap C \sqsubseteq \bot \} \).

Exercise 3.3. Apply the tableau algorithm in order to check satisfiability of the concept \( A \sqcap \forall r. B \) w.r.t. the TBox \( \{ A \sqsubseteq \exists r. A, B \sqsubseteq \exists r. \neg C, C \sqsubseteq \forall r. \forall r. B \} \).

Exercise 3.4. Markus wants to apply the tableau algorithm for checking the satisfiability of the concept \( B \sqcap \exists r. \neg A \) w.r.t. the TBox \( \{ A \sqsubseteq \exists r. \neg A \sqcap \exists r. B, \top \sqsubseteq 1 r \} \). He arrives at the situation depicted below and concludes that no further rules are applicable, since \( v_2 \) is blocked by \( v_1 \). What is Markus’ error? Continue the algorithm until its termination. (You don’t have to illustrate all intermediate steps, just provide the final state.)

\[
\begin{align*}
  v_0 & \quad \quad r^- \quad \quad L(v_0) = \{ B \sqcap \exists r. \neg A, B, \exists r. \neg A, C_T, \neg A, \leq 1 r \} \\
  v_1 & \quad \quad r^- \quad \quad L(v_1) = \{ A, C_T, \exists r. \neg A, \exists r. B, \leq 1 r \} \\
  v_2 & \quad \quad r^- \quad \quad L(v_2) = \{ A, C_T, \exists r. \neg A, \exists r. B, \leq 1 r \}.
\end{align*}
\]

Exercise 3.5. Extend the \( \leq 1 \) rule in a way that also qualified functionality axioms of the form \( \top \sqsubseteq 1 r. A \) can be treated correctly, where \( A \) is an atomic concept. Can you also treat arbitrary axioms of the form \( C \sqsubseteq 1 r. D \)?