**Exercise 1** [6 points] Consider the following UML Class Diagram.

![UML Class Diagram](image)

1. Formalize this diagram in DL-Lite\textsubscript{A,id}.
2. Which aspect(s) of this diagram cannot be captured in DL-Lite\textsubscript{A,id}? Provide a justification for your answer.

**Exercise 2** [6 points] Consider the following DL-Lite\textsubscript{A} ontology and queries.

TBox: \[ T = \{ A \sqsubseteq \exists R, \exists R^{-} \sqsubseteq B, R \sqsubseteq S, B \sqsubseteq \exists P, \text{funct}(R) \} \]

ABox: \[ A = \{ A(1) \} \]

Queries: \[ q_1(x) \leftarrow P(x, y), Q(x, y) \quad \text{and} \quad q_2(x) \leftarrow P(x, y), Q(x, y) \]

1. Draw the canonical model of \( \langle T, A \rangle \).
2. Compute the perfect rewriting of \( q_1 \) and of \( q_2 \) with respect to \( T \).
3. Compute the certain answers to \( q_1 \) and \( q_2 \) over \( \langle T, A \rangle \). Explain the difference in the answers.

**Exercise 3** [6 points] Consider the problem of answering unions of conjunctive queries in DL-Lite\textsubscript{A}.

1. What is the data complexity of this problem?
2. Suppose now that DL-Lite\textsubscript{A} is extended by allowing qualified existential restriction on the left-hand side of inclusion assertions, i.e., assertions of the form \( \exists P.A \sqsubseteq B \)

What is the data complexity of the considered problem in this case? Provide a justification for your answer.

**Exercise 4** [6 points] Consider the ALC family of expressive description logics.

1. Define the syntax and the semantics of the description logic ALCI.
2. Define the reasoning problems concept satisfiability and concept subsumption for a generic description logic \( L \).
3. Show that for ALC, concept satisfiability and concept subsumption can be mutually reduced to each other.
4. What is the complexity of concept satisfiability in ALC. Discuss briefly the sources of complexity.

**Exercise 5** [6 points] Check satisfiability of the following ALC-concept using Tableaux.

\[(A_1 \sqcap \exists P. (A_2 \sqcup A_3)) \sqcap \forall P. (\neg A_2)\]

**Exercise 6** [4 points] Bonus Question

Introduce two suitable bisimulation relations for ALC\textsubscript{F} and ALCI. Use these notions of bisimulation to prove that ALC\textsubscript{F} and ALCI have incomparable expressiveness.