Exercise 13.1  Consider the database $D$ consisting of the following tables (=relations).

<table>
<thead>
<tr>
<th>Person</th>
<th>Enrollment</th>
<th>Attendance</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>Name</td>
<td>PersonID</td>
<td>Since</td>
</tr>
<tr>
<td>1001</td>
<td>Ernie</td>
<td>1002</td>
<td>2017</td>
</tr>
<tr>
<td>1002</td>
<td>Bert</td>
<td>1003</td>
<td>2015</td>
</tr>
<tr>
<td>1003</td>
<td>Kermit</td>
<td>1004</td>
<td>2017</td>
</tr>
<tr>
<td>1004</td>
<td>Gonzo</td>
<td>1003</td>
<td></td>
</tr>
</tbody>
</table>

Describe the finite first-order interpretation $I_D$ that corresponds to $D$.

Reformulate each of the following SQL queries $Q$ into first-order queries $\phi_Q$. Which of the queries $\phi_Q$ are conjunctive queries? What are the answers to $Q$ on $D$ and what are the answers of $\phi_Q$ on $I_D$?

(a) SELECT * FROM Person

(b) SELECT Person.Name FROM Person, Attendance, Course
    WHERE Person.ID =Attendance.PersonID
    AND Course.ID = Attendance.CourseID
    AND Course.Title = ‘Description Logic’

(c) SELECT Person.Name FROM Person, Enrollment
    WHERE Person.ID = Enrollment.PersonID
    AND NOT EXISTS (SELECT * FROM Attendance
    WHERE Person.ID = Attendance.PersonID)

Exercise 13.2  Consider the $\mathcal{ALC}$ knowledge base $\mathcal{K} := (\mathcal{T}, \mathcal{A})$ with

\[
\mathcal{T} := \{ A \sqsubseteq B, B \sqsubseteq \exists r . A, C \equiv \neg D, \exists r . B \sqsubseteq \neg D, A \sqsubseteq \forall r . B, \forall r . A \sqsubseteq B \} \text{ and } \\
\mathcal{A} := \{(a,b): r, (b,c): r, (c,a): r, (b,b): r, (c,c): r, A : c\}.
\]

What are the certain answers to the following conjunctive queries on $(\mathcal{A}, \emptyset)$? What are the certain answers on $\mathcal{K}$?

(a) $r(x, y) \land B(y)$
Exercise 13.3 Consider a modified definition of data complexity for OMQA query entailment, where we do not require the ABox to be simple, i.e., we allow arbitrary ABoxes as input to the entailment problem. Can this affect the data complexity results?

Exercise 13.4 Can one use a reduction from non-$k$-colorability in graphs to show that the conjunctive query entailment problem in $\mathcal{ALC}$ is coNP-hard w.r.t. data complexity? What if $k$ is fixed?