1. Let $r$ be a binary relation from $A$ to $B$. An element $c$ of $C$, where $C$ is either $A$ or $B$, participates $n$ times in $r$ with respect to $C$ if $c$ appears as a $C$ component in $n$ and only $n$ of the ordered pairs in $r$.

(a) Give the minimum and the maximum number of times a person participates in the relation is taking: \{Person1, Person2, Person3\} → \{CS100, Math100, Chem100\} = \{(Person1, CS100), (Person1, Math100), (Person1, Chem100), (Person2, Chem100), (Person3, CS100), (Person3, Math100)\}.

(b) Suppose we wish to create a 4-ary relationship set among the object sets Student, Course, Semester, and Grade. Suppose further that we wish to constrain the relationship set so that there can be only one grade for a student in a particular course for a semester. Explain why it is not possible to express this constraint with participation constraints. Give the diagram for the 4-ary relationship set; include appropriate participation constraints and the co-occurrence constraint for the functional constraint.

2. Using the Ontology Editor, augment the OSM diagram given in Homework 1 so that it includes (1) a ternary relationship set for marriages that relates a husband, wife and marriage date (Husband and Wife are to be roles Person), and (2) parent-child relationship sets (Child, Mother, and Father should all be roles of Person, and the Mother and Father roles should be mutually exclusive).

3. Translate the OSM diagram in Figure 1 into a set of predicates and rules that characterize it as follows.

(a) Give the object-set predicates.

(b) Give the relationship-set predicates.

(c) Give the referential-integrity rules.

(d) Give the generalization/specialization rules.

(e) Give the participation-constraint rules.

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![Figure 1: OSM Model Instance (ABCDE).](image)
4. For the OSM model instance in Figure 1:

(a) Give a valid interpretation with at least one object in $B$ and one object in $E$. (Besides the one object in $B$ and the one object in $E$, your interpretation should have as few objects and relationships as possible.)

(b) Give an invalid interpretation with an object $x$ in both $C$ and $A$ and an object $y$ in $D$ which relates to $x$ in $A$. (Besides $x$ and $y$, your interpretation should have as few objects and relationships as possible.)

5. Consider the OSM model instance in Figure 2. Formally express the following constraints in predicate calculus. Also, state whether the OSM model instance already does or does not require that the constraint hold.

(a) Every Current Guest must have a reservation for the current Date. (Let the predicate $\text{Today}(x)$ be true if $x$ is the current date.)

(b) Different guests cannot have reservations for the same room on the same day.

Figure 2: OSM Model Instance (Bed and Breakfast).

6. Consider the OSM model instance in Figure 2.

Prove or Disprove: (Any proofs should be written formally in terms of predicate calculus by giving the statement to be proved in predicate calculus and then the proof as a derivation; any disproofs should be counterexamples written by giving the statement to be disproved in predicate calculus and a valid interpretation in which the statement does not hold.)

(a) Every Guest has a Guarantee Nr.

(b) Every Current Guest has a Guest Nr.

(c) Every Future Guest has a reservation for a Room on a date in the future. (Let the predicate $\text{FutureDate}(x)$ be true if $x$ is a date in the future.)

(d) If there is a reservation for Room 2 for today’s date, then a Current Guest holds that reservation. (Let the predicate $\text{Today}(x)$ be true if $x$ is the current date.)

(e) If a Future Guest has a reservation for a Room, then the Future Guest holds a Guarantee Nr.
7. Rewrite the OSM model instance in Figure 2 in description-logic notation as follows:

(a) Note that ternary relationship sets are not in description logics, so you must first introduce an object set to represent the reservation relationship set. Also, properly name (using reading direction arrows) the three new relationship sets and add appropriate participation constraints. Now, to show that you know what the description-logic predicates are, write down (only) the new ones introduced to fix the ternary relationship set (i.e., give the one-place predicate for the new reservation object set and the three two-place predicates for the three new relationship sets).

(b) To show that you know what the constraints are, find and write down all of them with the following exceptions: (1) among the fourteen participation constraints, there are only three variations (1, 0:*, and 1:*); just write any one example for 1 and 1:* and say why there is no constraint for 0:*, (2) write only one of the 14 referential integrity constraints, (3) in addition to the generalization/specialization constraints in the diagram, add an additional constraint saying that the union of Current Guest and Future Guest constitutes all the guests, and (4) if you can write constraint(s) for the co-occurrence constraint Room, Date -> Guest, I’ll be pleasantly surprised; if so, write it; if not say why the description-logic constraints given in class are insufficient for writing the constraint.

8. For the description logic formulation of the OSM model instance in Figure 1 given in class:

(a) Using Tableau Calculus, check the satisfiability of the OSM model instance in Figure 1. Give the model produced.

(b) Give an inconsistent Abox specification for the OSM model instance in Figure 1 and show using Tableau Calculus that it is inconsistent.

9. Use Tableau Calculus to do the following proofs.

(a) For the OSM model instance in Figure 4, prove: \( \text{ItalianProf}(x) \Rightarrow \text{LatinLover}(x) \).

(b) For the OSM model instance in Figure 2, prove that every Current Guest has a Guest Nr.

\[
\begin{align*}
\text{Lazy}(x) & \Rightarrow \neg \text{ItalianProf}(x) \\
\text{ItalianProf}(x) & \Rightarrow \neg \text{Lazy}(x) \\
\text{Mafioso}(x) & \Rightarrow \neg \text{ItalianProf}(x) \\
\text{ItalianProf}(x) & \Rightarrow \neg \text{Mafioso}(x)
\end{align*}
\]

Figure 3: OSM Model Instance (Italian).
10. For the OSM model instance in Figure 4, write Datalog rules for (a) \textit{Grandmother}(x, y), Person \( x \) is a grandmother of Person \( y \), and (b) \textit{Ancestor}(x, y), Person \( x \) is the ancestor of Person \( y \).

![Figure 4: OSM Model Instance (GenealogicalPerson).](image)

11. Using the Query facility (Tabs>Query>SPARQL) in the Ontology Workbench (given to you for Homework #1), write a SPARQL query to list names and birth dates of people born in November. Execute it against the RDF file your extraction ontology creates when applied to Page 551.

12. Create a query ontology that answers the following free-form queries applied to the information extracted from Page 551 by your extraction ontology.

(a) Birthdate of GARDNER BULLARD

(b) When did John Almon Bullard die?

You need not try to make your query ontology work generally for any reasonable query, just these two. I'd suggest making a case-insensitive dictionary with the names your system extracts from Page 551. Then, add just the keywords you need to make the queries work; it should be clear how to add more, or even how to obtain them semi-automatically from language resources like WordNet.