Answer Key for Exam I
Computer Programming 420
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1. True or False:

   (a) F All database management systems are relational.

   (b) F Every set is a bag.

   (c) F Relationships cannot have attributes in E/R diagrams.

   (d) T Relationships in E/R diagrams connect one or more entity sets.

   (e) T In ODL, every relationship must have an inverse.

   (f) T Every key is a superkey.

   (g) F Every superkey is a key.

   (h) F Attributes that are keys cannot appear in functional dependencies.

   (i) T If X is a key for the relation R, then there is functional dependency for R with $X \rightarrow$ all attributes.

   (j) T Every functional dependency is a multivalued dependency.

2. Answer in two sentences or less the following:

   (a) Why are there no "weak classes" in ODL (but there are weak entity sets in E/R diagrams)?

   `Because every object has an unique object id (OID), and so, has a key. Weak entity sets occur when a secondary entity set provides part of the key.`

   (b) What is an anomaly? Give an example.

   `An anomaly is a problem usually caused when too much information is crammed into one relation. For example, a redundacy anomaly can occur when information is stored in duplicate times in the table.`

3. Consider the relation $R(A, B, C, D, E)$ with the function dependencies:

$$A \rightarrow B, B \rightarrow C, C \rightarrow A, D \rightarrow E, \text{ and } E \rightarrow D$$

   (a) What are the keys of R?

   `The keys are:` AD, AE, BD, BE, CD, `and` CE.

   (b) How many superkeys are there of R? Justify your answer.

   `Recall that a superkey is key or a superset of a key. So, every superkey must consist of at least one of` $\{A, B, C\}$ `and` $\{D, E\}$ `(since every key has at least one element of each). This gives that the` number of superkeys is the number of ways to choose 1, 2, or 3 attributes from $\{A, B, C\}$ times the number of ways to choose 1 or 2 attributes from $\{D, E\}$, or:

$$\left(\binom{3}{1}+\binom{3}{2}+\binom{3}{3}\right)\cdot\left(\binom{2}{1}\binom{2}{2}\right) = (1+3+3)\cdot(1+2) = 21$$

Another way to do this question is to list out all possible superkeys and then count them:

For example, the superkeys of size 2 and 3 can be formed by:

$$\begin{aligned}
\text{the keys:}\quad & AD, AE, BD, BE, CD, CE\\
\text{adding A:}\quad & ABD, ABE, ACD, ACE\\
\text{adding B:}\quad & ABD, ABE, BCD, BCE\\
\text{adding C:}\quad & ACD, ACE, BCD, BCE\\
\text{adding D:}\quad & ADE, BDE, CDE\\
\text{adding E:}\quad & ADE, BDE, CDE
\end{aligned}$$

Removing the duplicates leaves:

$$\begin{gathered}
AD, AE, BD, BE, CD, CE\\
ABD, ABE, ACD, ACE\\
BCD, BCE\\
ADE, BDE, CDE
\end{gathered}$$

or 9 superkeys of size 2 and 6 superkeys of size 3.

To get the keys of size 4:

$$\begin{aligned}
\text{of size 3:}\quad & ABD, ABE, ACD, ACE, BCD, BCE, ADE, BDE, CDE\\
\text{adding A:}\quad & ABCD, ABCE, ABDE, ACDE\\
\text{adding B:}\quad & ABCD, ABCE, ABDE, BCDE\\
\text{adding C:}\quad & ABCD, ABCE, ACDE, BCDE\\
\text{adding D:}\quad & ABDE, ACDE, BCDE\\
\text{adding E:}\quad & ABDE, ACDE, BCDE
\end{aligned}$$

and remove duplicates to yield

$$\begin{gathered}
ABCD, ABCE, ABDE, ACDE\\
BCDE
\end{gathered}$$

and remove duplicates to yield 5 keys of size 4.

Since there's only one key with all 5 attributes, this gives $6 + 9 + 5 + 1 = 21$ possible superkeys.

4. Draw an E/R diagram for the following situations. Indicate any keys, weak entity sets, or subclasses.

   (a) Entity sets *Courses* and *Departments*. A course is given by a unique department, but its only attribute is its number. Different departments can offer courses with the same number. Each department has a unique name.

   (b) Entity sets *Computers*, *Laptops*, and *Owners*. A computer has a manufacturer, CPU speed, and a unique name. Laptops, have all the properties of computers, as well as their weight and battery life. Owners are identified by their names. Every computer has at most one owner, but owners can have several computers.

5. Give an ODL design for a database recording information about teams, players, and their fans, including:

   (a) For each team, its name, its players, its team captain (one its players), and the colors of its uniform.

   (b) For each player, his/her name.

   (c) For each fan, his/her name, favorite teams, favorite players, and favorite color.

6. For each of the following types of relationships, give an example and draws its E/R diagram:

   (a) one-one:

   (b) many-one:

   (c) many-many:

7. (a) Consider a relation $R(A, B)$ with two tuples: $R = \{(4, 1), (4, 2)\}$.

      i. Does $A \to B$ hold for this instance of R?
      Circle one: YES $\underline{\text{NO}}$

      ii. Does $A \twoheadrightarrow B$ hold for this instance of R?
      Circle one: $\underline{\text{YES}}$ NO

   (b) Now consider a relation $R(A, B, C)$ with two tuples: $R = \{(3, 2, 1), (4, 2, 6)\}$.

      i. Does $A \to B$ hold for this instance of R?
      Circle one: $\underline{\text{YES}}$ NO

      ii. Does $B \to C$ hold for this instance of R?
      Circle one: YES $\underline{\text{NO}}$

      iii. Does $A \twoheadrightarrow C$ hold for this instance of R?
      Circle one: YES $\underline{\text{NO}}$

8. Convert the following ODL description of a schema to a relational database schema. Remember that `Course` objects have an "object identity," and you may invent an attribute representing this OID, e.g. `CourseID`.

```
interface Course {
    attribute integer number;
    attribute string room;
    relationship Dept deptOf inverse Dept::coursesOf;
};

interface LabCourse : Course {
    attribute integer computerAlloc;
};

interface Dept (key name) {
    attribute string name;
    attribute string chair;
    relationship Set<Course> coursesOf
         inverse Dept::deptOf;
};
```

9. (a) Define Boyce-Codd Normal Form (BCNF):

   (b) Define Third Normal Form (3NF):

   (c) Define Fourth Normal Form (4NF):

   (d) Is every relation in Third Normal Form also in Boyce Codd Normal Form? If yes, explain why. If no, give an example that shows why this is not true.

   (e) Is every relation in Fourth Normal Form also in Boyce Codd Normal Form? If yes, explain why. If no, give an example that shows why this is not true.

10. Given the relation schema $R(A, B, C, D)$ with the functional dependencies

$$\begin{aligned} AB &\rightarrow C \\ BC &\rightarrow D \\ CD &\rightarrow A \\ AD &\rightarrow B \end{aligned}$$

(a) Indicate all the Boyce Codd Normal Form violations. Do not forget to consider dependencies that are not in the given set, but follow from them. However, it is not necessary to give violations that have more than one attribute on the right side.

(b) Decompose the relations, as necessary, into a collection of relations that are in Boyce Codd Normal Form.