Problem 1. (11 points) Design an E/R diagram for a database that records the information about movies, movie stars, and the fans of movie stars. The information includes:

1. For each movie, its title, its movie stars, its year of production, and its producer studio;
2. For each movie star, his/her name, and his/her gender;
3. For each fan, his/her name, his/her favorite movie star, and the other movie stars that he/she likes. (Notice that a person can have at most one “favorite” movie star, but can like multiple movie stars.)

Problem 2. (6 points) Consider the following relation called “Movies”:

<table>
<thead>
<tr>
<th>title</th>
<th>year</th>
<th>producerStudio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star Wars</td>
<td>1977</td>
<td>Fox</td>
</tr>
<tr>
<td>Mighty Ducks</td>
<td>1991</td>
<td>Disney</td>
</tr>
<tr>
<td>Wayne’s World</td>
<td>1992</td>
<td>Paramount</td>
</tr>
<tr>
<td>The Godfather</td>
<td>1972</td>
<td>Paramount</td>
</tr>
</tbody>
</table>

1) What is the schema of this relation? (2 points)
2) What are the attributes of this relation? (2 points)
3) How many tuples are there? (2 points)

Problem 3. (10 points) Consider a relation representing the satellites in the space. The attributes are the name of a satellite (assuming that no two satellites have the same name), the x-coordinate, the y-coordinate and the z-coordinate of a satellite, and a satellite’s velocities respectively in the x, y and z dimensions.

1) What functional dependencies (FD’s) do you expect to hold for this relation? (5 points)
2) What are the keys? (List all the keys.) (5 points)

Problem 4. (12 points) Consider a relation with schema R(A, B, C, D) and functional dependencies (FD’s) B→D, D→A and D→C.

1) List all the non-trivial FD’s that follow from the given FD’s. (But list only those with a single attribute on the right side.) (5 points)
2) List all the keys of R. (5 points)
3) List a superkey that is not a key. (2 points)
Problem 5. (10 points) Consider a relation with schema \( R(A, B, C, D, E, F) \) and functional dependencies (FD’s) \( AB \rightarrow C \), \( AB \rightarrow D \) and \( AB \rightarrow E \).

1) Indicate all the BCNF violations. (3 points)
2) Decompose the relation into a collection of relations that are in BCNF. (7 points)

Problem 6. (12 points) Suppose relations \( R(A, B, C) \) and \( S(C, D, E) \) are as shown below.

\[
\begin{array}{|c|c|c|}
\hline
A & B & C \\
\hline
5 & 12 & 1 \\
9 & 5 & 1 \\
7 & 80 & 2 \\
9 & 5 & 0 \\
\hline
\end{array}
\]

\[
\begin{array}{|c|c|c|}
\hline
C & D & E \\
\hline
2 & 12 & 5 \\
1 & 8 & 20 \\
0 & 0 & 5 \\
0 & 1 & 7 \\
\hline
\end{array}
\]

Give the results of the following relational algebra expressions. (Consider all the operations as set operations.)

1) \( \text{SELECT}_{B=5}(R) \); (2 points)
2) \( \text{PROJ}_{B,D}(R \Join_{R.A=S.E} S) \); (5 points)
3) \( \text{GAMMA}_{A,\text{AVG}(R)_B,\text{MAX}(E)_C,\text{COUNT}(D)}(R \ast S) \); (Note: GAMMA is the “grouping and aggregation” operator, and “\( \ast \)” is the “product” operator.) (5 points)

Problem 7. (25 points) Consider relations with the following schemas:

\[
\begin{align*}
\text{Movies} & (\text{title}, \text{year}, \text{producerStudio}) \\
\text{Moviestars} & (\text{name}, \text{movieIn}, \text{yearOfTheMovie})
\end{align*}
\]

Here “movieIn” means the movie that the movie start is in. The values with the attribute “movieIn” are the titles of the movies. Note that a movie star can be in multiple movies. Also note that we assume that there can be multiple movies with the same title; however, in the same year, no two movies can have the same title.

Now, give a SQL statement that finds:
1) All the studios that have produced movies whose titles begin with the five letters “Happy”; (5 points)
2) All the movie stars who have worked for the studio called “Paramount”. (5 points)
3) All the movie stars who have never worked for the studio “Paramount”. (5 points)
4) The titles of all movies made after the last movie that “Harrison Ford” played in. (5 points)
5) The names of those movie stars who have played in at least 3 movies. (5 points)

**Problem 8.** (6 points) The following algebraic laws hold for sets but not for bags. For each of the laws, give an example to show why it does NOT hold for bags.

1) \((R \cup S) \cap T = (R \cap T) \cup (S \cap T)\); (3 points)
2) \((R \cap S) - T = R \cap (S - T)\). (3 points)

**Problem 9.** (8 points) Convert the following E/R diagram, which is about soccer teams, to a relational database schema.

1) Using the object-oriented method. (4 points)
2) Using the straight-E/R method. (4 points)