Assignment 1: Relational Algebra (Spring 2019)

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Name: _____ Student ID: _____ Grade: _____

Question	1	2	3	4	5	6	7	8	9	10	Total
Score											

Notes

- **Print the assignment on A4 paper and answer the questions.**
- **Assignment due date: March 20, 2019.**

Questions

Consider the relational database concerning World War II capital ships. It involves the following relations.

- `Classes(class, type, country, numGuns, bore, displacement)`
- `Ships(name, class, launched)`
- `Battles(name, date)`
- `Outcomes(ship, battle, result)`

This database can be found at `https://dbis-uibk.github.io/relax/calc.htm` by loading the database named *"Database Systems The Complete Book – Exercise 2.4.3"*. We give in what follows a brief description of this database.

- Ships are built in "classes" from the same design, and the class is usually named for the first ship of that class. The relation `Classes` records the name of the class, the type (`'bb'` for battleship or `'bc'` for battlecruiser), the country that built the ship, the number of main guns, the bore (diameter of the gun barrel, in inches) of the main guns, and the displacement (weight, in tons).
- Relation `Ships` records the name of the ship, the name of its class, and the year in which the ship was launched.
- Relation `Battles` gives the name and date of battles involving these ships.
- Relation `Outcomes` gives the result (sunk, damaged, or ok) for each ship in each battle.

Write expressions of relational algebra to answer the following queries.

1. (3 points) Give the class names and countries of the classes that carried guns of at least 16-inch bore.
2. (3 points) Find the ships launched prior to 1921.
3. (3 points) Find the ships sunk in the battle of the Denmark Strait.

4. (3 points) The treaty of Washington in 1921 prohibited capital ships heavier than 35,000 tons. List the ships that violated the treaty of Washington.

5. (3 points) List all the capital ships mentioned in the database. (Note that there are some "dangling tuples" in this data, e.g., ships mentioned in `Outcomes` that are not mentioned in `Ships`.)

6. (5 points) List the name, displacement, and number of guns of the ships engaged in the battle of Guadalcanal.

7. (5 points) Find those ships that "lived to fight another day"; they were damaged in one battle, but later fought in another.

8. (5 points) Find those countries that had both battleships and battlecruisers. (3 points for one solution, and 5 points for two solutions)

9. (10 points) Find the classes that had only one ship as a member of that class. (3 points for one solution, 6 points for two solutions, and 10 points for three solutions and above)

10. (10 points) Find the oldest ship that survives (not sunk) the battles. (3 points for one solution, 6 points for two solutions, and 10 points for three solutions and above)

Answers

1. (3 points) Give the class names and countries of the classes that carried guns of at least 16-inch bore.

$$\Pi_{\texttt{class,country}}(\sigma_{\texttt{bore}\geq 16}(\texttt{Classes}))$$

2. (3 points) Find the ships launched prior to 1921.

$$\Pi_{\texttt{name}}(\sigma_{\texttt{launched}<1921}(\texttt{Ships}))$$

3. (3 points) Find the ships sunk in the battle of the Denmark Strait.

$$\Pi_{\texttt{ship}}(\sigma_{\texttt{battle}='\texttt{DenmarkStrait}'\wedge\texttt{result}='\texttt{sunk}'}(\texttt{Outcomes}))$$

4. (3 points) The treaty of Washington in 1921 prohibited capital ships heavier than 35,000 tons. List the ships that violated the treaty of Washington.

$$\Pi_{\texttt{name}}(\sigma_{\texttt{displacement}>35000}(\texttt{Classes} \bowtie \texttt{Ships}))$$

5. (3 points) List all the capital ships mentioned in the database. (Note that there are some "dangling tuples" in this data, e.g., ships mentioned in `Outcomes` that are not mentioned in `Ships`.)

$$\Pi_{\texttt{name}}(\sigma_{\texttt{type}='\texttt{bc}'}(\texttt{Classes} \bowtie \texttt{Ships}))$$

6. (5 points) List the name, displacement, and number of guns of the ships engaged in the battle of Guadalcanal.

$$\Pi_{\texttt{name,displacement,numGuns}}(\sigma_{\texttt{battle}='\texttt{Guadalcanal}'}(\texttt{Classes} \bowtie \texttt{Ships} \bowtie_{\texttt{name=ship}} \texttt{Outcomes}))$$

7. (5 points) Find those ships that "lived to fight another day"; they were damaged in one battle, but later fought in another.

$$\Pi_{\texttt{O1.ship}}((\rho_{\texttt{O1}}(\texttt{Outcomes}) \bowtie_{\texttt{O1.battle=B1.name}} \rho_{\texttt{B1}}(\texttt{Battles}))$$

$$\bowtie_{\texttt{O1.ship=O2.ship}\wedge\texttt{B1.date}<\texttt{B2.date}\wedge\texttt{O1.result}='\texttt{damaged}'} (\rho_{\texttt{O2}}(\texttt{Outcomes}) \bowtie_{\texttt{O2.battle=B2.name}} \rho_{\texttt{B2}}(\texttt{Battles})))$$

8. (5 points) Find those countries that had both battleships and battlecruisers. (3 points for one solution, and 5 points for two solutions)

   Solution 1:

$$\Pi_{\texttt{country}}(\sigma_{\texttt{type}='\texttt{bb}'}(\texttt{Classes})) \cap \Pi_{\texttt{country}}(\sigma_{\texttt{type}='\texttt{bc}'}(\texttt{Classes}))$$

   Solution 2:

$$\Pi_{\texttt{C1.country}}(\rho_{\texttt{C1}}(\texttt{Classes}) \bowtie_{\texttt{C1.country}=\texttt{C2.country}\wedge\texttt{C1.type}='\texttt{bb}'\wedge\texttt{C2.type}='\texttt{bc}'} \rho_{\texttt{C2}}(\texttt{Classes}))$$

9. (10 points) Find the classes that had only one ship as a member of that class. (3 points for one solution, 6 points for two solutions, and 10 points for three solutions and above)

   Solution 1 (Using group-by):

$$\Pi_{\texttt{class}}(\sigma_{\texttt{amt}=1}(\gamma_{\texttt{class;count(name)}\rightarrow\texttt{amt}}(\texttt{Ships})))$$

   Solution 2 (Using outer join):

$$\Pi_{\texttt{Ships1.class}}(\sigma_{\texttt{Ships2.name}=\texttt{null}}(\rho_{\texttt{Ships1}}(\texttt{Ships}) ⟕_{\texttt{Ships1.name}\neq\texttt{Ships2.name}\wedge\texttt{Ships1.class}=\texttt{Ships2.class}} \rho_{\texttt{Ships2}}(\texttt{Ships})))$$

   Solution 3 (Using inner join and exception):

$$\Pi_{\texttt{class}}(\texttt{Ships}) - \Pi_{\texttt{Ships1.class}}(\rho_{\texttt{Ships1}}(\texttt{Ships}) \bowtie_{\texttt{Ships1.name}\neq\texttt{Ships2.name}\wedge\texttt{Ships1.class}=\texttt{Ships2.class}} \rho_{\texttt{Ships2}}(\texttt{Ships}))$$

10. (10 points) Find the oldest ship that survives (not sunk) the battles. (3 points for one solution, 6 points for two solutions, and 10 points for three solutions and above)

    Solution 1 (Using outer join):

$$\texttt{Survived} = (\Pi_{\texttt{name}}(\texttt{Ships}) - \Pi_{\texttt{ship}}(\sigma_{\texttt{result}='\texttt{sunk}'}(\texttt{Outcomes}))) \bowtie \texttt{Ships}$$
$$\Pi_{\texttt{S1.name}}(\sigma_{\texttt{S2.name}=\texttt{null}}(\rho_{\texttt{S1}}(\texttt{Survived}) ⟕_{\texttt{S1.launched}>\texttt{S2.launched}} \rho_{\texttt{S2}}(\texttt{Survived})))$$

    Solution 2 (Using inner join and exception):

$$\texttt{Survived} = (\Pi_{\texttt{name}}(\texttt{Ships}) - \Pi_{\texttt{ship}}(\sigma_{\texttt{result}='\texttt{sunk}'}(\texttt{Outcomes}))) \bowtie \texttt{Ships}$$
$$\Pi_{\texttt{name}}(\texttt{Survived}) - \Pi_{\texttt{S1.name}}(\rho_{\texttt{S1}}(\texttt{Survived}) \bowtie_{\texttt{S1.launched}>\texttt{S2.launched}} \rho_{\texttt{S2}}(\texttt{Survived})))$$

    Solution 3 (Using aggregation):

$$\texttt{Survived} = (\Pi_{\texttt{name}}(\texttt{Ships}) - \Pi_{\texttt{ship}}(\sigma_{\texttt{result}='\texttt{sunk}'}(\texttt{Outcomes}))) \bowtie \texttt{Ships}$$
$$\Pi_{\texttt{name}}(\gamma_{\texttt{min(launched)}\rightarrow\texttt{earliest}}(\texttt{Survived}) \bowtie_{\texttt{earliest}=\texttt{launched}} \texttt{Ships})$$