CPS 216 Fall 2001
Homework #1
Due: Thursday, September 13

Please note: *Some problems, particularly those marked by "*" or "**," may require more than average thought. Start early, and don't hesitate to ask for help if you really get stuck. Under the Honor Code, however, you must acknowledge any help you received in completing this homework.*

Problem 1.

Consider a database containing information about World War II capital ships. It involves the following relations:

```
Class(class, type, country, numGuns, bore, displacement)
Ship(name, class, launched)
Battle(name, date)
Outcome(ship, battle, result)
```

Ships are built in "classes" from the same design. The relation `Class` records the name of the class, the type (`bb` for battleship and `bc` for battle cruiser), 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 `Ship` records the name of the ship, the name of its class, and the year in which the ship was launched. Relation `Battle` gives the name and date of battles involving these ships, and relation `Outcome` gives the result (`sunk`, `damaged`, or `ok`) for each ship in each battle. Write relational algebra expressions to answer the following queries.

(a) Give the class names and countries of the classes that carried guns of at least 16-inch bore.
(b) Find the ships sunk in the battle of the North Atlantic.
(c) The treaty of Washington in 1921 prohibited capital ships heavier than 35,000 tons. List the ships that violated the treaty of Washington.
(d) List the name, displacement, and number of guns for each ship engaged in the battle of Guadalcanal.
(e) Find those countries that had both battleships and battle cruisers.
(f) Find those ships that "lived to fight another day"; they were damaged in one battle, but later fought in another.
(g) * Find the classes that had exactly two ships as members of that class.
(h) * Find those ships that fought *only* in the battles that "California" fought in.
(i) ** Find those ships that fought in *every* battle that "California" fought in.

Problem 2.*

As discussed in class, the core operators in relational algebra are selection (σ_p), projection (π_L), cross product ($\times$), union ($\cup$), and difference ($-$).

(a) Show that the projection operator is necessary; that is, some queries that use the projection operator cannot be expressed using any combination of the other operators.
(b) Show that the selection operator is necessary; that is, some queries that use the selection operator cannot be expressed using any combination of the other operators.

Problem 3.

Consider a relation R (A, B, C, D) with FDs $AB \rightarrow C$, $C \rightarrow D$, and $D \rightarrow B$.

(a) Show that $\{A, B\}$ is a key of R (remember a key has to be minimal).
(b) What are the other keys of R? (Hint: A must be in every key of R; why?)
(c) $D \rightarrow B$ is a BNCF violation. Using this violation, we decompose R into R_1 (B, D) and R_2 (A, C, D). What are the keys of R_1?
(d) What are the FDs that hold in R_1? Do not list them all; instead, give a set of FDs from which all other FDs in R_1 follow. This set of FDs is called a "basis." When checking for BCNF violations, it suffices to check just the basis.
(e) Is R_1 in BCNF? Briefly explain why.
(f) What are the keys of R_2? (Hint: There is more than one.)
(g) What are the FDs that hold in R_2? Again, do not list them all; instead, give a basis.
(h) Is R_2 in BCNF? If yes, briefly explain why. Otherwise, decompose further until all decomposed relations are in BCNF, and then show your final results.

Problem 4.*

Using the chase procedure to prove or disprove the following claims. Recall that if a claim is true, the chase procedure gives a proof; otherwise, the chase procedure constructs a counterexample.

(a) In a relation R (A, B, C, D), if $A \twoheadrightarrow BC$, then $A \twoheadrightarrow B$.
(b) In a relation R (A, B, C, D), if $A \twoheadrightarrow B$ and $A \rightarrow C$, then $A \twoheadrightarrow D$.

Problem 5.

A store in Durham decides to go high-tech. Everyone knows that you are taking CPS 216, so you are asked to design a relational database for the store. After brainstorming with the store managers, you come up with the following specification:

- The store has multiple departments, identified by their names.
- Each department may have many employees but only one of them is the department manager.
- Employees are identified by their names. We also need to record their salaries. Each employee may work in only one department. Managers are employees as well, although each of them also gets to manage one department.
- The store sells various items identified by item IDs. Each item is carried by exactly one department, while each department may carry many items. For each item, we also need to keep a short description and its quantity in stock.
- The store deals with a number of suppliers identified by their names. We need to record their addresses. Each supplier supplies an item at a particular price. A supplier may supply any number of items, and the same items could be supplied by other suppliers (probably at different prices).
- The store receives orders identified by order IDs. Each order has a date, a shipping address, and may include different quantities of multiple items.

Show the final schema of your design. Indicate the keys of each relation. You can ignore attribute types, and you do not need to show any sample data.