You are given the following relational schema (keys are underlined):

\[
\text{BANK}(\text{Name}, \text{Address}) \\
\text{OWES}(\text{Debtor}, \text{Creditor}, \text{Amount})
\]

where \text{Debtor} and \text{Creditor} are bank names (they are foreign keys referencing \text{BANK}(\text{Name})). A bank can be a debtor and a creditor at the same time but not of the same bank. \text{Amount} has to be greater than zero and represents the debt of the \text{Debtor} to the \text{Creditor}.

**Problem 1 (40 pts)**

Write the following queries in relational algebra:

- **Query 1.1**: List all banks located in Buffalo that owe money to some bank located in Buffalo.

Write the following queries in SQL, possibly using views:

- **Query 1.2**: List all banks that do not owe anything to other banks.

- **Query 1.3**: For every bank \( B \), return its net debt defined as the difference between
  - the sum of all debts that \( B \) owes to other banks, and
  - the sum of all debts that other banks owe to \( B \).

  The net debt can be negative, positive, or zero.

**Solution.**

**Query 1.1:**

\[
\pi_{\text{Name}}(\sigma_{\text{Address}=\text{’Buffalo’}}(\text{BANK}(\text{Name}_1, \text{Address}_1)) \bowtie \text{OWES}(\text{Debtor}_1, \text{Creditor}_1, \text{Amount}_1) : \sigma_{\text{Creditor}_1=\text{’Buffalo’}}(\text{BANK}(\text{Name}_2, \text{Address}_2))).
\]

**Query 1.2:**

\[
\text{SELECT } b1.\text{Name} \text{ FROM BANK } b1 \\
\text{WHERE NOT EXISTS} \\
\quad (\text{SELECT } * \text{ FROM OWES} \\
\quad \text{WHERE OWES.}\text{Debtor}=b1.\text{Name})
\]

**Query 1.3:**

\[
\text{CREATE VIEW DEBT(}\text{Name}, \text{Amount}) \text{ AS} \\
(\text{SELECT } \text{Debtor}, \text{SUM(}\text{Amount}\text{)} \text{ FROM OWES} \\
\text{GROUP BY } \text{Debtor}) \\
\text{UNION} \\
(\text{SELECT } b1.\text{Name}, 0 \text{ FROM BANK } b1 \\
\text{WHERE NOT EXISTS} \\
\quad (\text{SELECT } * \text{ FROM OWES} \\
\quad \text{WHERE OWES.}\text{Debtor}=b1.\text{Name}));
\]
CREATE VIEW CREDIT(Name, Amount) AS
(SELECT Creditor, SUM(Amount) FROM OWES
 GROUP BY Creditor)
UNION
(SELECT b1.Name, 0 FROM BANK b1
 WHERE NOT EXISTS
 (SELECT * FROM OWES
  WHERE OWES.Creditor=b1.Name));

SELECT CREDIT.Name, DEBT.Amount-CREDIT.Amount
FROM CREDIT, DEBT
WHERE CREDIT.Name=DEBT.Name

Problem 2 (20 pts)

Consider the following queries:

Query 2.1: SELECT Address FROM BANK
           WHERE Name <> 'Citi'

Query 2.2: SELECT b1.Address FROM BANK b1
           WHERE NOT EXISTS
           (SELECT * FROM Bank b2
            WHERE b2.Name='Citi'
            AND b2.Address=b1.Address)

To do:

1. Explain what each query is doing.

2. Is there a database instance for which Query 2.1 and Query 2.2 return different results? Justify your answer.

Solution.

Query 2.1: Return the addresses of banks different than 'Citi'.
Query 2.2: Return the addresses of banks whose address is different from the address of 'Citi'.

For the following instance:

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citi</td>
<td>New York</td>
</tr>
<tr>
<td>HSBC</td>
<td>New York</td>
</tr>
</tbody>
</table>

Query 2.1 returns 'New York,' while Query 2.2 returns the empty set.