



# TASK 1

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Advanced Databases

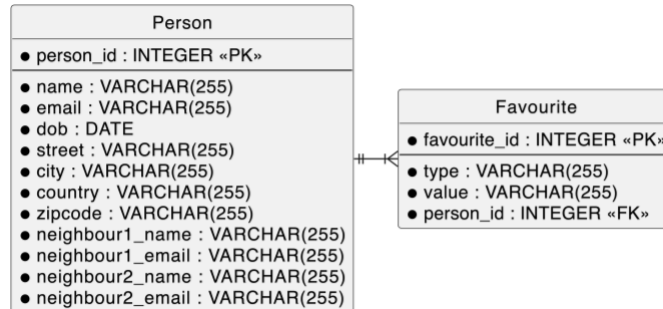
# TABLE OF CONTENTS

<i>First Normal Form (1NF)</i>	<b>1</b>
Person	<b>1</b>
Favourite	<b>1</b>
<i>Second Normal Form (2NF)</i>	<b>2</b>
Person	<b>2</b>
Address	<b>2</b>
NeighboursPair	<b>3</b>
<i>Third Normal Form (3NF)</i>	<b>3</b>
Person	<b>3</b>
PersonAddress	<b>4</b>
Address	<b>6</b>
NeighboursPair	<b>7</b>
Favourite	<b>8</b>
<i>Entity Relationship Diagram</i>	<b>9</b>
<i>SQL Queries</i>	<b>10</b>
Query 1: Display all persons' name and their ages in years	<b>10</b>
Query 2: Group Persons by their favourite drink and return average age of each group	<b>11</b>
Query 3: Display the average age of people who like Hiking	<b>11</b>
Query 4: Display the total number of people from each City and sort it in ascending order by total number of people	<b>12</b>
Query 5: Display name of person(s) whose neighbour is neighbour C	<b>13</b>
<i>Appendices</i>	<b>14</b>
A) Benchmark of Query 1	<b>14</b>
B) Benchmark of Query 2	<b>14</b>
C) Benchmark of Query 3	<b>14</b>
D) Benchmark of Query 4	<b>15</b>
E) Benchmark of Query 5	<b>15</b>

# FIRST NORMAL FORM (1NF)

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In the First Normal Form, each column should contain an atomic value, and each record should be unique. Additionally, each row should have a unique identifier (primary key).



## PERSON

The **Person** table is created with a primary key of `person_id`. This `person_id` is automatically incremented for each new entry, providing a unique identifier for each row.

## FAVOURITE

The **Favourite** table consists of the user's favourite information. This table is created with attributes of `favourite_id` as the primary key, `type` and `value`. The type is the type of the favourite, which in this case, is either drink, activity or book. The value is the value of this type, which is the `favourite_book`, `favourite_drink`, and `favourite_activity`.

There are many-to-one relationships with the Person table, meaning multiple favourites can belong to one person. This relationship is represented with `person_id` as a foreign key to the **Person** table in the diagram.

## Design Rationale

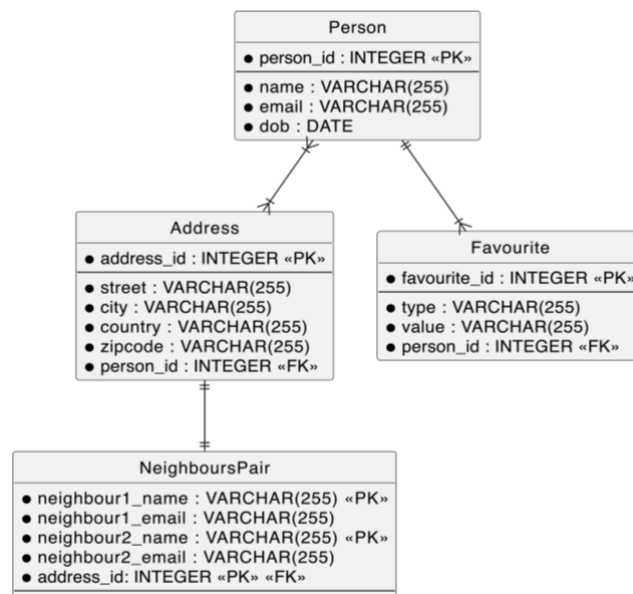
The Favourite attributes () could have been placed in a **Favourite** table with separate columns for each type of favourite that can be null. However, creating a **Favourite** table with `type` and `value` columns reduces the database design cost and enhances the scalability of the database design for the following reasons:

- This type-value structure unifies the data model. Therefore, the system can accommodate new types of favourites without altering the table schema, providing more dynamic expansion. For instance, adding a new favourite type called favourite destination only requires a new row in the table.
- This design simplifies queries to retrieve favourite information. Instead of querying multiple columns for different favourite types, the system can query a single table and filter by type.

If there is any additional information about the book, activity, or drink (such as the author of the book, or the drink's flavour), then the creation of separate tables for each type would be necessary. However, the current use case did not provide such information, making the type-value structure more suitable.

## SECOND NORMAL FORM (2NF)

In the Second Normal Form, all partial dependencies should be removed so that every non-key attribute should depend on the primary key. For this purpose, separate tables are created as *Person*, *Address*, , and *NeighboursPair*. *Favourite* Table from 1NF stayed as it is since it already satisfies 2NF.



### PERSON

The *Person* table only contains information about the person such as *name*, *email* and *dob*(date of birth) with a primary key of *person\_id*.

### ADDRESS

The address attributes (*street*, *city*, *country* and *zipcode*) were separated into a new table called *Address* with a primary key of *address\_id*.

The *Address* table has many-to-many relationships to the *Person* table with a foreign key of *person\_id*, meaning multiple addresses can belong to one person, and two different people can share the same address. Even though the use case did not include any example of two people sharing the same address, this design enhances the flexibility of the database.

## NEIGHBOURSPAIR

The *NeighboursPair* table contains the neighbour information for each address, including their names and emails as *neighbour1\_name*, *neighbour2\_name*, *neighbour1\_email*, and *neighbour2\_email*.

This table has a one-to-one relationship with the *Address* table, which means every address can exactly have one neighbour pair (two neighbours) associated with it. The relationship is indicated with *address\_id* as a primary key of the *NeighboursPair* table as well as a foreign key to the *Address* table.

## FAVOURITE

By fulfilling the 1NF, the *Favourite* table already satisfies the requirements of 2NF.

## THIRD NORMAL FORM (3NF)

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In the Third Normal Form, all the attributes must be functionally dependent on the primary key, and there should be no transitive dependency, which means non-key attributes should not be dependent on other non-key attributes. Therefore, the associated entities that have many-to-many relationships should be further normalised.

## PERSON

By fulfilling the 2NF, the *Person* table already satisfies the requirements of 3NF. Below is the SQL statement for creating the table:

```
CREATE TABLE
  IF NOT EXISTS Person (
    person_id INT AUTO_INCREMENT PRIMARY KEY,
    name VARCHAR(255) NOT NULL,
    email VARCHAR(255) NOT NULL,
    dob DATE NOT NULL
  );
```

The insertion of the data is achieved using Python. Below is the function that performs this operation:

```
def insert_person(row):
    cursor.execute("""
        INSERT INTO Person (name, email, dob)
        VALUES (%s, %s, %s)
    """, (row['Name'], row['Email'], row['DOB']))
    return cursor.lastrowid
```

The table contains 20 entries from the use case:

* person_id int	* name varchar(255)	* email varchar(255)	* dob date
1	Person 1	person1@email.com	1995-03-15
2	Person 2	person2@email.com	1993-06-22
3	Person 3	person3@email.com	1991-09-10
4	Person 4	person4@email.com	1998-12-05
5	Person 5	person5@email.com	1983-11-30
6	Person 6	person6@email.com	1989-07-18
7	Person 7	person7@email.com	1996-04-25
8	Person 8	person8@email.com	1990-01-09
9	Person 9	person9@email.com	1993-08-17
10	Person 10	person10@email.com	1997-10-22
11	Person 11	person11@email.com	1992-05-13
12	Person 12	person12@email.com	1986-02-27
13	Person 13	person13@email.com	1991-11-25
14	Person 14	person14@email.com	1987-02-01
15	Person 15	person15@email.com	1984-08-12
16	Person 16	person16@email.com	1990-03-09
17	Person 17	person17@email.com	1995-11-17
18	Person 18	person18@email.com	1994-06-20
19	Person 19	person19@email.com	1992-12-11
20	Person 20	person20@email.com	1988-09-25

## PERSONADDRESS

The *PersonAddress* serves as a pivotal junction table that resolves the many-to-many relationship by establishing a many-to-one relationship with the *Person* table and a many-to-one relationship with the *Address* table. This means that multiple entries in the *PersonAddress* table can reference the same person and multiple entries in the *PersonAddress* can reference the same address.

**Composite Primary Key:** The *PersonAddress* table uses a composite primary key, which is a combination of *person\_id* and *address\_id*. This composite key uniquely identifies each entry in the *PersonAddress* table, ensuring that each combination of person and address is unique. This design eliminates redundancy by preventing duplicate entries for the same person-address pair.

In this refined schema, each person can be associated with multiple addresses, and each address can be linked to multiple persons. This fulfils the requirements of 3NF, ensuring there are no transitive dependencies, thereby maintaining the data integrity and reduce data redundancy.

Below is the SQL statement for creating the table:

```
CREATE TABLE IF NOT EXISTS PersonAddress (  
    person_id INTEGER NOT NULL,  
    address_id INTEGER NOT NULL,  
    FOREIGN KEY (person_id) REFERENCES Person(person_id),  
    FOREIGN KEY (address_id) REFERENCES Address(address_id),  
    PRIMARY KEY (person_id, address_id)  
);
```

The insertion of the data is achieved using Python. Below is the function that performs this operation:

```
def insert_person_address(person_id, address_id):  
    cursor.execute("""  
        INSERT INTO PersonAddress (person_id, address_id)  
        VALUES (%s, %s)  
    """, (person_id, address_id))
```

The table contains 20 entries from the use case:

* person_id int	* address_id int
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20

## ADDRESS

Since the `PersonAddress` table is used to manage the many-to-many relationship between `Person` and `Address`, the foreign key `person_id` in the `Address` table is redundant and can be removed. This is because the `PersonAddress` table already captures the relationship between persons and addresses. Below is the SQL statement for creating the table:

```
CREATE TABLE
IF NOT EXISTS Address (
    address_id INT AUTO_INCREMENT PRIMARY KEY,
    street VARCHAR(255) NOT NULL,
    city VARCHAR(255) NOT NULL,
    country VARCHAR(255) NOT NULL,
    zipcode VARCHAR(20) NOT NULL
);
```

The insertion of the data is achieved using Python. Below is the function that performs this operation:

```
def insert_address(row):
    cursor.execute("""
        INSERT INTO Address (street, city, country, zipcode)
        VALUES (%s, %s, %s, %s)
    """, (row['Street'], row['City'], row['Country'], row['Zip Code']))
    return cursor.lastrowid
```

The table contains 20 entries from the use case:

* address_id int	* street varchar(255)	* city varchar(255)	* country varchar(255)	* zipcode varchar(20)
1	12 Maple St	London	England	E1 6AN
2	45 Oak Ave	Manchester	England	M1 2WD
3	89 Pine Rd	Birmingham	England	B1 1AB
4	23 Birch St	Edinburgh	Scotland	EH1 1YZ
5	67 Cedar Ln	Bristol	England	BS1 3XE
6	56 Elm St	Liverpool	England	L1 1AA
7	12 Maple St	Glasgow	Scotland	G1 2TF
8	89 Oak Dr	Leeds	England	LS1 3AB
9	123 Pine Rd	Newcastle	England	NE1 2AB
10	15 Elm St	Cardiff	Wales	CF10 3AF
11	78 Oak Ln	Sheffield	England	S1 4GT
12	56 Birch Rd	Nottingham	England	NG1 2PB
13	10 Holy St	Cardiff	Wales	CF10 2NF
14	34 Willow Rd	Edinburgh	Scotland	EH1 1AB
15	78 Cedar Ave	Cambridge	England	CB1 2SE
16	45 Maple Rd	Oxford	England	OX2 6TP
17	23 Birch Ave	Southampton	England	SO14 3HL
18	12 Elm Blvd	Leicester	England	LE1 3PL
19	56 Oak Rd	Norwich	England	NR1 4BE
20	89 Pine Ave	Cardiff	Wales	CF10 3BC



## NEIGHBOURSPAIR

By fulfilling the 2NF, the *NeighboursPair* table already satisfies the requirements of 3NF. Below is the SQL statement for creating the table:

```
CREATE TABLE
IF NOT EXISTS NeighboursPair (
    neighbour1_name VARCHAR(255) NOT NULL,
    neighbour1_email VARCHAR(255) NOT NULL,
    neighbour2_name VARCHAR(255) NOT NULL,
    neighbour2_email VARCHAR(255) NOT NULL,
    address_id INTEGER NOT NULL,
    FOREIGN KEY (address_id) REFERENCES Address (address_id),
    PRIMARY KEY (neighbour1_name, neighbour2_name, address_id)
);
```

The insertion of the data is achieved using Python. Below is the function that performs this operation:

```
def insert_neighbours_pair(row, address_id):
    cursor.execute("""
        INSERT INTO NeighboursPair (neighbour1_name, neighbour1_email, neighbour2_name, neighbour2_email,
        address_id)
        VALUES (%s, %s, %s, %s, %s)
        """, (row['Neighbour 1 Name'], row['Neighbour 1 Email'], row['Neighbour 2 Name'], row['Neighbour 2 Email'],
        address_id))
```

The table contains 20 entries from the use case:

* neighbour1_name varchar(255)	* neighbour1_email varchar(255)	* neighbour2_name varchar(255)	* neighbour2_email varchar(255)	* address_id int
Neighbour A	neighbourA@email.com	Neighbour B	neighbourB@email.com	1
Neighbour AA	neighbourAA@email.com	Neighbour AB	neighbourAB@email.com	14
Neighbour AC	neighbourAC@email.com	Neighbour AD	neighbourAD@email.com	15
Neighbour AE	neighbourAE@email.com	Neighbour AF	neighbourAF@email.com	16
Neighbour AG	neighbourAG@email.com	Neighbour AH	neighbourAH@email.com	17
Neighbour AI	neighbourAI@email.com	Neighbour AJ	neighbourAJ@email.com	18
Neighbour AK	neighbourAK@email.com	Neighbour AL	neighbourAL@email.com	19
Neighbour AM	neighbourAM@email.com	Neighbour AN	neighbourAN@email.com	20
Neighbour C	neighbourC@email.com	Neighbour D	neighbourD@email.com	2
Neighbour E	neighbourE@email.com	Neighbour F	neighbourF@email.com	3
Neighbour G	neighbourG@email.com	Neighbour H	neighbourH@email.com	4
Neighbour I	neighbourI@email.com	Neighbour J	neighbourJ@email.com	5
Neighbour K	neighbourK@email.com	Neighbour L	neighbourL@email.com	6
Neighbour M	neighbourM@email.com	Neighbour N	neighbourN@email.com	7
Neighbour O	neighbourO@email.com	Neighbour P	neighbourP@email.com	8
Neighbour Q	neighbourQ@email.com	Neighbour R	neighbourR@email.com	9
Neighbour S	neighbourS@email.com	Neighbour T	neighbourT@email.com	10
Neighbour U	neighbourU@email.com	Neighbour V	neighbourV@email.com	11
Neighbour W	neighbourW@email.com	Neighbour X	neighbourX@email.com	12
Neighbour Y	neighbourY@email.com	Neighbour Z	neighbourZ@email.com	13

## FAVOURITE

By fulfilling the 1NF and 2NF, the *Favourite* table already satisfies the requirements of 3NF. Below is the SQL statement for creating the table:

```
CREATE TABLE
IF NOT EXISTS Favourite (
    favourite_id INT AUTO_INCREMENT PRIMARY KEY,
    type VARCHAR(255) NOT NULL,
    value VARCHAR(255) NOT NULL,
    person_id INT,
    FOREIGN KEY (person_id) REFERENCES Person (person_id)
);
```

The insertion of the data is achieved using Python. Below is the function that performs this operation:

```
def insert_favourite(row, person_id):
    cursor.execute("""
        INSERT INTO Favourite (type, value, person_id)
        VALUES ('Book', %s, %s)
    """, (row['Favourite Book'], person_id))
    cursor.execute("""
        INSERT INTO Favourite (type, value, person_id)
        VALUES ('Drink', %s, %s)
    """, (row['Favourite Drink'], person_id))
    cursor.execute("""
        INSERT INTO Favourite (type, value, person_id)
        VALUES ('Activity', %s, %s)
    """, (row['Favourite Activity'], person_id))
```

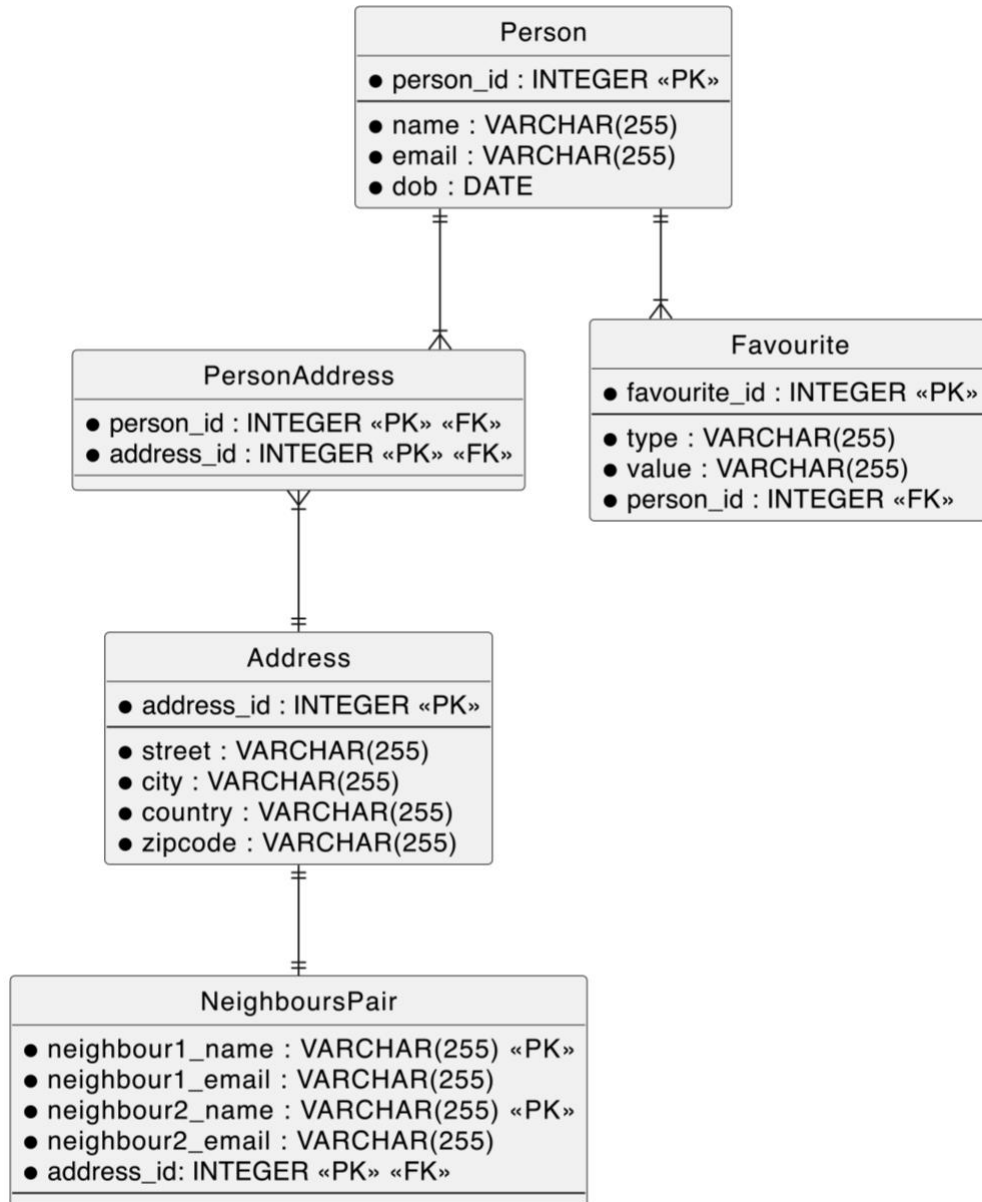
The table contains 60 entries from the use case. Below is an example of some records:

favourite_id int	type varchar(255)	value varchar(255)	person_id int
1	Book	A New Beginning	1
2	Drink	Lemonade	1
3	Activity	Outdoor Running	1
4	Book	The Road to Success	2
5	Drink	Coffee	2
6	Activity	Hiking	2
7	Book	Endless Possibilities	3
8	Drink	Smoothie	3
9	Activity	Swimming	3
10	Book	Journey of Life	4
11	Drink	Iced Tea	4
12	Activity	Travelling	4
13	Book	The Adventure Continues	5
14	Drink	Green Tea	5
15	Activity	Gardening	5
16	Book	Finding Inner Peace	6
17	Drink	Coconut Water	6
18	Activity	Reading	6
19	Book	Exploring New Horizons	7
20	Drink	Fruit Juice	7
21	Activity	Cycling	7

# ENTITY RELATIONSHIP DIAGRAM

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The Entity Relationship diagram is created using PlantUML as below:



An additional visibility modifier • to identify mandatory attributes that cannot be null.

# SQL QUERIES

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To make SQL queries more efficient, unique indexes are created:

```
CREATE UNIQUE INDEX person_id_index ON Person (person_id);
CREATE UNIQUE INDEX address_id_index ON Address (address_id);
CREATE UNIQUE INDEX favourite_id_index ON Favourite (favourite_id);
CREATE UNIQUE INDEX person_address_index ON PersonAddress (person_id, address_id);
CREATE UNIQUE INDEX neighbours_pair_index ON NeighboursPair (neighbour1_name, neighbour2_name, address_id);
```

## QUERY 1: DISPLAY ALL PERSONS' NAME AND THEIR AGES IN YEARS

```
SELECT name,
       TIMESTAMPDIFF(YEAR, dob, CURDATE()) AS age
FROM Person;
```

Q	name varchar(255)	age bigint
>	Person 1	29
>	Person 2	31
>	Person 3	33
>	Person 4	26
>	Person 5	41
>	Person 6	35
>	Person 7	28
>	Person 8	35
>	Person 9	31
>	Person 10	27
>	Person 11	32
>	Person 12	38
>	Person 13	33
>	Person 14	38
>	Person 15	40
>	Person 16	34
>	Person 17	29
>	Person 18	30
>	Person 19	32
>	Person 20	36

The benchmark of Query 1 before and after adding a unique index can be found in [Appendix A](#).

## QUERY 2: GROUP PERSONS BY THEIR FAVOURITE DRINK AND RETURN AVERAGE AGE OF EACH GROUP

```
SELECT f.value AS favourite_drink,  
       ROUND(AVG(TIMESTAMPDIFF(YEAR, p.dob, CURDATE())) , 2) AS average_age  
FROM Person p  
JOIN Favourite f ON p.person_id = f.person_id  
WHERE f.type = 'Drink'  
GROUP BY f.value;
```

favourite_drink varchar	average_age decimal
Lemonade	33.50
Coffee	31.00
Smoothie	33.00
Iced Tea	26.00
Green Tea	35.00
Coconut Water	32.50
Fruit Juice	31.00
Water	35.50
Hot Chocolate	31.00
Fruit Smoothie	27.00
Sparkling Water	32.00
Herbal Tea	35.50
Iced Coffee	40.00

The benchmark of Query 2 before and after adding a unique index can be found in [Appendix B](#).

## QUERY 3: DISPLAY THE AVERAGE AGE OF PEOPLE WHO LIKE HIKING

```
SELECT f.value as activity, ROUND(AVG(TIMESTAMPDIFF(YEAR, dob, CURDATE())) , 2) AS average_age  
FROM Person p  
JOIN Favourite f ON p.person_id = f.person_id  
WHERE f.type = 'Activity' AND f.value = 'Hiking';
```

Q	activity varchar	average_age decimal
>	Hiking	33.00

The benchmark of Query 3 before and after adding a unique index can be found in [Appendix C](#).

## QUERY 4: DISPLAY THE TOTAL NUMBER OF PEOPLE FROM EACH CITY AND SORT IT IN ASCENDING ORDER BY TOTAL NUMBER OF PEOPLE

```
SELECT a.city, COUNT(pa.person_id) AS total_number_of_people
FROM Address a
JOIN PersonAddress pa ON a.address_id = pa.address_id
GROUP BY a.city
ORDER BY total_number_of_people ASC;
```

city varchar	total_number_of_people bigint
Newcastle	1
Norwich	1
Leicester	1
Southampton	1
Oxford	1
Cambridge	1
Nottingham	1
Sheffield	1
London	1
Leeds	1
Glasgow	1
Liverpool	1
Bristol	1
Birmingham	1
Manchester	1
Edinburgh	2
Cardiff	3

The benchmark of Query 4 before and after adding a unique index can be found in [Appendix D](#).

## QUERY 5: DISPLAY NAME OF PERSON(S) WHOSE NEIGHBOUR IS NEIGHBOUR C

```
SELECT p.name AS person_name, np.neighbour1_name AS neighbour_name
FROM Person p
JOIN PersonAddress pa ON p.person_id = pa.person_id
JOIN NeighboursPair np ON pa.address_id = np.address_id
WHERE np.neighbour1_name = 'Neighbour C' OR np.neighbour2_name = 'Neighbour C';
```

person_name varchar	neighbour_name varchar
Person 2	Neighbour C

The benchmark of Query 5 before and after adding a unique index can be found in [Appendix E](#).

# APPENDICES

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## A) BENCHMARK OF QUERY 1

Display all persons' name and their ages in years

```
SELECT name,  
       TIMESTAMPDIFF(YEAR, dob, CURDATE()) AS age  
FROM Person; 2ms
```

Figure 1: The benchmark of Query 1 without indexing

```
SELECT name,  
       TIMESTAMPDIFF(YEAR, dob, CURDATE()) AS age  
FROM Person; 1ms
```

Figure 2: The benchmark of Query 1 after creating unique indexes

## B) BENCHMARK OF QUERY 2

Group Persons by their favourite drink and return average age of each group

```
SELECT f.value AS favourite_drink,  
       ROUND(AVG(TIMESTAMPDIFF(YEAR, p.dob, CURDATE()))), 2) AS average_age  
FROM Person p  
JOIN Favourite f ON p.person_id = f.person_id  
WHERE f.type = 'Drink'  
GROUP BY f.value; 2ms
```

Figure 3: The benchmark of Query 2 without indexing

```
SELECT f.value AS favourite_drink,  
       ROUND(AVG(TIMESTAMPDIFF(YEAR, p.dob, CURDATE()))), 2) AS average_age  
FROM Person p  
JOIN Favourite f ON p.person_id = f.person_id  
WHERE f.type = 'Drink'  
GROUP BY f.value; 1ms
```

Figure 4: The benchmark of Query 2 after creating unique indexes

## C) BENCHMARK OF QUERY 3

Display average age of people who likes Hiking

```
SELECT f.value as activity, ROUND(AVG(TIMESTAMPDIFF(YEAR, dob, CURDATE()))), 2) AS average_age  
FROM Person p  
JOIN Favourite f ON p.person_id = f.person_id  
WHERE f.type = 'Activity' AND f.value = 'Hiking'; 2ms
```

Figure 5: The benchmark of Query 3 without indexing



```
SELECT f.value as activity, ROUND(AVG(TIMESTAMPDIFF(YEAR, dob, CURDATE())), 2) AS average_age
FROM Person p
JOIN Favourite f ON p.person_id = f.person_id
WHERE f.type = 'Activity' AND f.value = 'Hiking'; 1ms
```

Figure 6: The benchmark of Query 3 after creating unique indexes

## D) BENCHMARK OF QUERY 4

Display the total number of people from each City and sort it in ascending order by total number of people

```
SELECT a.city, COUNT(pa.person_id) AS total_number_of_people
FROM Address a
JOIN PersonAddress pa ON a.address_id = pa.address_id
GROUP BY a.city
ORDER BY total_number_of_people ASC; 3ms
```

Figure 7: The benchmark of Query 4 without indexing

```
SELECT a.city, COUNT(pa.person_id) AS total_number_of_people
FROM Address a
JOIN PersonAddress pa ON a.address_id = pa.address_id
GROUP BY a.city
ORDER BY total_number_of_people ASC; 1ms
```

Figure 8: The benchmark of Query 4 after creating unique indexes

## E) BENCHMARK OF QUERY 5

Display name of person(s) whose neighbour is neighbour C

```
SELECT p.name AS person_name, np.neighbour1_name AS neighbour_name
FROM Person p
JOIN PersonAddress pa ON p.person_id = pa.person_id
JOIN NeighboursPair np ON pa.address_id = np.address_id
WHERE np.neighbour1_name = 'Neighbour C' OR np.neighbour2_name = 'Neighbour C'; 4ms
```

Figure 9: The benchmark of Query 5 without indexing

```
SELECT p.name AS person_name, np.neighbour1_name AS neighbour_name
FROM Person p
JOIN PersonAddress pa ON p.person_id = pa.person_id
JOIN NeighboursPair np ON pa.address_id = np.address_id
WHERE np.neighbour1_name = 'Neighbour C' OR np.neighbour2_name = 'Neighbour C'; 1ms
```

Figure 10: The benchmark of Query 5 after creating unique indexes