CS4.301 Data & Applications

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Relational Integrity Constraints

Constraints are **conditions** that must hold on **all** valid relation states.

There are three *main types* of (explicit schema-based) constraints that can be expressed in the relational model:

- **Key** constraints
- **Entity integrity** constraints
- **Referential integrity** constraints

Another schema-based constraint is the **domain** constraint

- Every value in a tuple must be from the *domain of its attribute* (or it could be **null**, if allowed for that attribute)

Candidate key & Super key difference

Super Key	Candidate Key
Super Key is an attribute (or set of attributes) that is used to uniquely identifies all attributes in a relation.	Candidate Key is a subset of a super key.
All super keys can't be candidate keys.	But all candidate keys are super keys.
Various super keys together makes the criteria to select the candidate keys.	Various candidate keys together makes the criteria to select the primary keys.
In a relation, number of super keys is more than number of candidate keys.	While in a relation, number of candidate keys are less than number of super keys.
Super key attributes can contain NULL values.	Candidate key attributes can also contain NULL values.

https://www.geeksforgeeks.org/difference-between-super-key-and-candidate-key/

Key Constraints (continued)

If a relation has several **candidate keys**, one is chosen arbitrarily to be the **primary key**.

- The primary key attributes are <u>underlined</u>.

Example: Consider the CAR relation schema:

- License_number & Engine_serial_number
- We chose Engine_serial_number as the primary key

The primary key value is used to *uniquely identify* each tuple in a relation

- Provides the tuple identity

Also used to *reference* the tuple from another tuple

- General rule: Choose as primary key the smallest of the candidate keys (in terms of size)
- Not always applicable – choice is sometimes subjective

Super & Primary key difference

S.NO	Super Key	Primary Key
1.	Super Key is an attribute (or set of attributes) that is used to uniquely identifies all attributes in a relation.	Primary Key is a minimal set of attribute (or set of attributes) that is used to uniquely identifies all attributes in a relation.
2.	All super keys can't be primary keys.	Primary key is a minimal super key.
3.	Various super keys together makes the criteria to select the candidate keys.	We can choose any of the minimal candidate key to be a primary key.
4.	In a relation, number of super keys are more than number of primary keys.	While in a relation, number of primary keys are less than number of super keys.
5.	Super key's attributes can contain NULL values.	Primary key's attributes cannot contain NULL values.

https://www.geeksforgeeks.org/difference-between-primary-key-and-super-key/

Relational Database Schema

Relational Database Schema:

A set S of relation schemas that belong to the same database.

S is the name of the whole **database schema**

S = {R1, R2, ..., Rn} and a set IC of integrity constraints.

R1, R2, …, Rn are the names of the individual **relation schemas** within the database S

Following slide shows a COMPANY database schema with 6 relation schemas

EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno

DEPARTMENT

Dname	<u>Dnumber</u>	Mgr_ssn	Mgr_start_date

DEPT_LOCATIONS

<u>Dnumber</u>	<u>Dlocation</u>

PROJECT

Pname	<u>Pnumber</u>	Plocation	Dnum

WORKS_ON

<u>Essn</u>	<u>Pno</u>	Hours

DEPENDENT

<u>Essn</u>	<u>Dependent_name</u>	Sex	Bdate	Relationship

Figure 5.5
Schema diagram for the COMPANY relational database schema.

Entity Integrity

Entity Integrity:

The *primary key attributes* PK of each relation schema R in S cannot have null values in any tuple of r(R).

This is because primary key values are used to *identify* the individual tuples.

t[PK] $\neq$ null for any tuple t in r(R)

If PK has several attributes, null is not allowed in any of these attributes

Note: Other attributes of R may be constrained to disallow null values, even though they are not members of the primary key.

Referential Integrity

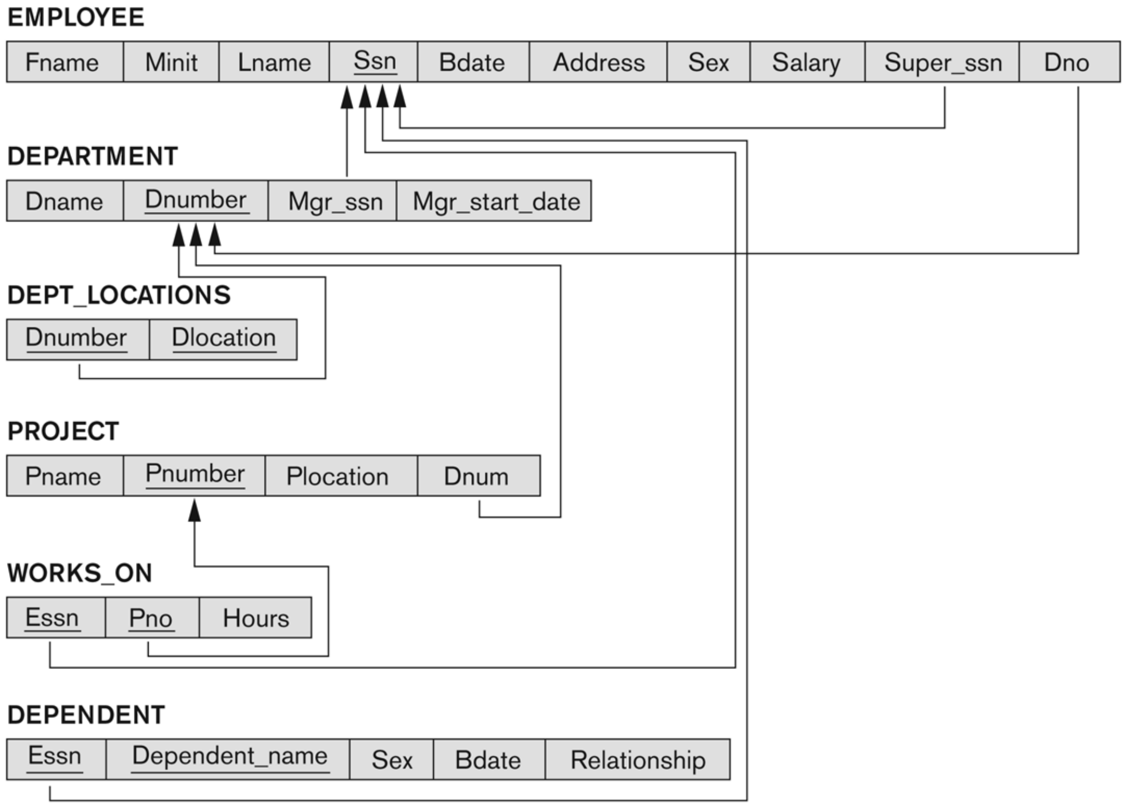
Tuples in the **referencing relation** R1 have attributes FK (called **foreign key** attributes) that reference the primary key attributes PK of the **referenced relation** R2.

A tuple t1 in R1 is said to **reference** a tuple t2 in R2 if t1[FK] = t2[PK].

A referential integrity constraint can be displayed in a relational database schema as a directed arc from R1.FK to R2.

Referential integrity constraints for Company

Figure 5.7
Referential integrity constraints displayed on the COMPANY relational database schema.



Update Operations on Relations

INSERT a tuple

DELETE a tuple

MODIFY a tuple

Integrity constraints should not be violated by the update operations

Several update operations may have to be grouped together

Updates may **propagate** to cause other updates automatically. This may be necessary to maintain integrity constraints

Possible violations for each operation

INSERT may violate any of the constraints:

- Domain constraint:
  - if one of the attribute values provided for the new tuple is not of the specified attribute domain
- Key constraint:
  - if the value of a key attribute in the new tuple already exists in another tuple in the relation
- Referential integrity:
  - if a foreign key value in the new tuple references a primary key value that does not exist in the referenced relation
- Entity integrity:
  - if the primary key value is null in the new tuple

Operation:
Insert <‘Cecilia’, ‘F’, ‘Kolonsky’, NULL, ‘1960-04-05’, ‘6357 Windy Lane, Katy, TX’, F, 28000, NULL, 4> into EMPLOYEE.
Result: This insertion violates the entity integrity constraint (NULL for the primary key Ssn), so it is rejected.

Operation:
Insert <‘Alicia’, ‘J’, ‘Zelaya’, ‘999887777’, ‘1960-04-05’, ‘6357 Windy Lane, Katy, TX’, F, 28000, ‘987654321’, 4> into EMPLOYEE.
Result: This insertion violates the key constraint because another tuple with the same Ssn value already exists in the EMPLOYEE relation, and so it is rejected.

Operation:
Insert <‘Cecilia’, ‘F’, ‘Kolonsky’, ‘677678989’, ‘1960-04-05’, ‘6357 Windswept, Katy, TX’, F, 28000, ‘987654321’, 7> into EMPLOYEE.
Result: This insertion violates the referential integrity constraint specified on Dno in EMPLOYEE because no corresponding referenced tuple exists in DEPARTMENT with Dnumber = 7.

What are the results?

Possible violations for each operation

DELETE may violate only referential integrity:

- If the primary key value of the tuple being deleted is referenced from other tuples in the database
  - Can be remedied by several actions: RESTRICT, CASCADE, SET NULL
    - RESTRICT option: reject the deletion
    - CASCADE option: propagate the new primary key value into the foreign keys of the referencing tuples
    - SET NULL option: set the foreign keys of the referencing tuples to NULL
- One of the above options must be specified during database design for each foreign key constraint

Operation:
Delete the WORKS_ON tuple with Essn = '999887777' and Pno = 10.
Result: This deletion is acceptable and deletes exactly one tuple.

Operation:
Delete the EMPLOYEE tuple with Ssn = '999887777'.
Result: This deletion is not acceptable, because there are tuples in WORKS_ON that refer to this tuple. Hence, if the tuple in EMPLOYEE is deleted, referential integrity violations will result.

Operation:
Delete the EMPLOYEE tuple with Ssn = '333445555'.
Result: This deletion will result in even worse referential integrity violations, because the tuple involved is referenced by tuples from the EMPLOYEE, DEPARTMENT, WORKS_ON, and DEPENDENT relations.

What are the results?

This lecture

Possible violations for each operation

UPDATE may violate domain constraint and NOT NULL constraint on an attribute being modified

Any of the other constraints may also be violated, depending on the attribute being updated:

- Updating the primary key (PK):
  - Similar to a DELETE followed by an INSERT
  - Need to specify similar options to DELETE
- Updating a foreign key (FK):
  - May violate referential integrity
- Updating an ordinary attribute (neither PK nor FK):
  - Can only violate domain constraints

Operation:
Update the salary of the EMPLOYEE tuple with Ssn = '999887777' to 28000.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 1.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 7.
Result: Unacceptable, because it violates referential integrity.

Operation:
Update the Ssn of the EMPLOYEE tuple with Ssn = '999887777' to '987654321'.
Result: Unacceptable, because it violates primary key constraint by repeating a value that already exists as a primary key in another tuple; it violates referential integrity constraints because there are other relations that refer to the existing value of Ssn.

Figure 5.7
Referential integrity constraints displayed on the COMPANY relational database schema.

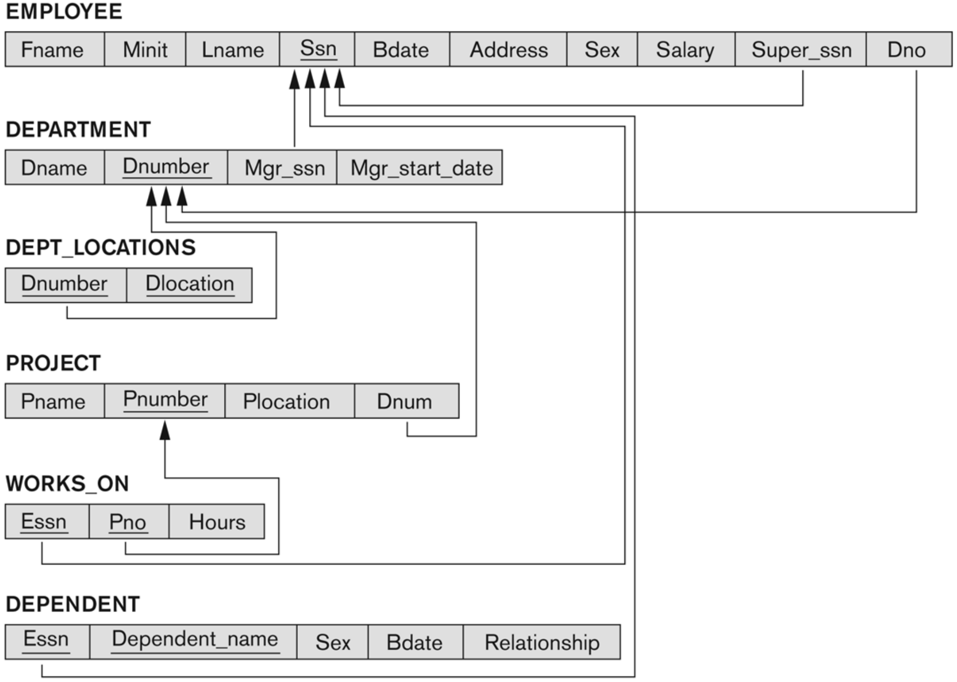


Figure 5.6
One possible database state for the COMPANY relational database schema.

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

Operation:
Update the salary of the EMPLOYEE tuple with Ssn = '999887777' to 28000.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 1.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 7.
Result: Unacceptable, because it violates referential integrity.

Operation:
Update the Ssn of the EMPLOYEE tuple with Ssn = '999887777' to '987654321'.
Result: Unacceptable, because it violates primary key constraint by repeating a value that already exists as a primary key in another tuple; it violates referential integrity constraints because there are other relations that refer to the existing value of Ssn.

Operation:
Update the salary of the EMPLOYEE tuple with Ssn = '999887777' to 28000.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 1.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 7.
Result: Unacceptable, because it violates referential integrity.

Operation:
Update the Ssn of the EMPLOYEE tuple with Ssn = '999887777' to '987654321'.
Result: Unacceptable, because it violates primary key constraint by repeating a value that already exists as a primary key in another tuple; it violates referential integrity constraints because there are other relations that refer to the existing value of Ssn.

Operation:
Update the salary of the EMPLOYEE tuple with Ssn = '999887777' to 28000.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 1.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 7.
Result: Unacceptable, because it violates referential integrity.

Operation:
Update the Ssn of the EMPLOYEE tuple with Ssn = '999887777' to '987654321'.
Result: Unacceptable, because it violates primary key constraint by repeating a value that already exists as a primary key in another tuple; it violates referential integrity constraints because there are other relations that refer to the existing value of Ssn.

Operation:
Update the salary of the EMPLOYEE tuple with Ssn = '999887777' to 28000.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 1.
Result: Acceptable.

Operation:
Update the Dno of the EMPLOYEE tuple with Ssn = '999887777' to 7.
Result: Unacceptable, because it violates referential integrity.

Operation:
Update the Ssn of the EMPLOYEE tuple with Ssn = '999887777' to '987654321'.
Result: Unacceptable, because it violates primary key constraint by repeating a value that already exists as a primary key in another tuple; it violates referential integrity constraints because there are other relations that refer to the existing value of Ssn.

Basic SQL

Basic SQL

SQL language

- Considered one of the major reasons for the commercial success of relational databases

SQL

- The origin of SQL is relational predicate calculus called tuple calculus (see Ch.8) which was proposed initially as the language SQUARE.
- SQL Actually comes from the word “SEQUEL” [Structured English QUEry Language] which was the original term used in the paper: “SEQUEL TO SQUARE” by Chamberlin and Boyce. IBM could not copyright that term, so they abbreviated to SQL and copyrighted the term SQL.
- Now popularly known as “Structured Query language”.
- SQL is an informal or practical rendering of the relational data model with syntax

SQL Data Definition, Data Types, Standards

Terminology:

- **Table**, **row**, and **column** used for relational model terms relation, tuple, and attribute

`CREATE` statement

- Main SQL command for data definition

SQL Standards

SQL has gone through many standards: starting with SQL-86 or SQL 1.A. SQL-92 is referred to as SQL-2.

Later standards (from SQL-1999) are divided into **core** specification and specialized **extensions**. The extensions are implemented for different applications – such as data mining, data warehousing, multimedia etc.

SQL-2006 added XML features (Ch. 13); In 2008 they added Object-oriented features (Ch. 12).

SQL-3 is the current standard which started with SQL-1999

Schema and Catalog Concepts in SQL

We cover the basic standard SQL syntax – there are variations in existing RDBMS systems

SQL schema

- Identified by a **schema name**
- Includes an **authorization identifier** and **descriptors** for each element

Schema elements include

- Tables, constraints, views, domains, and other constructs

Each statement in SQL ends with a **semicolon**

In some systems, Schema is called as Database

Schema and Catalog Concepts in SQL (cont'd.)

`CREATE SCHEMA` statement

```
CREATE SCHEMA COMPANY AUTHORIZATION 'Jsmith';
```

Catalog

Named collection of schemas in an SQL environment

SQL also has the concept of a cluster of catalogs

Authorization is to make the owner of the Schema

The CREATE TABLE Command in SQL

Specifying a new relation

- Provide name of table
- Specify attributes, their types and initial constraints

Can optionally specify schema:

```
CREATE TABLE COMPANY.EMPLOYEE ...
```

or

```
CREATE TABLE EMPLOYEE ...
```

The CREATE TABLE Command in SQL (cont'd.)

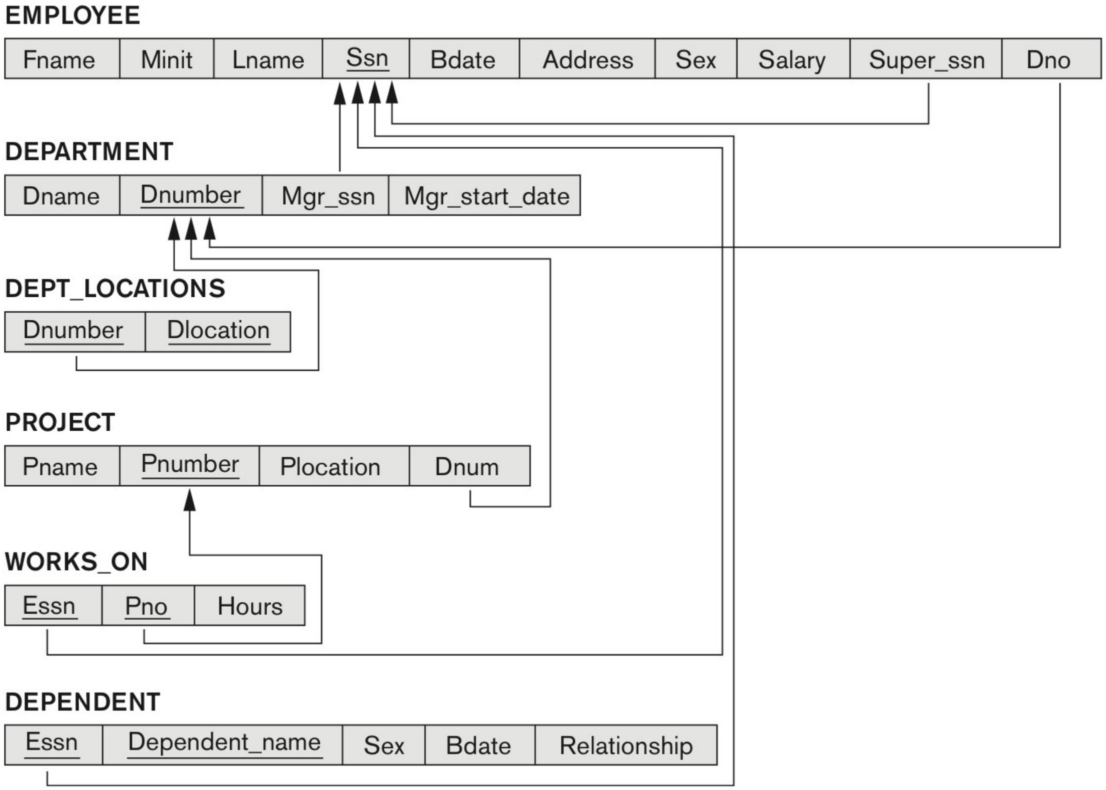
Base tables (**base relations**)

Relation and its tuples are actually created and stored as a file by the DBMS

Virtual relations (views)

Created through the `CREATE VIEW` statement. Do not correspond to any physical file.

COMPANY relational database schema (Fig. 5.7)



One possible database state for the COMPANY relational database schema (Fig. 5.6)

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

One possible database state for the COMPANY relational database schema – continued (Fig. 5.6)

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

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Pname	Pnumber	Plocation	Dnum
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ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

SQL CREATE TABLE data definition statements for defining the COMPANY schema from Figure 5.7 (Fig. 6.1)

```
CREATE TABLE EMPLOYEE
        ( Fname              VARCHAR(15)          NOT NULL,
          Minit              CHAR,
          Lname              VARCHAR(15)          NOT NULL,
          Ssn                CHAR(9)              NOT NULL,
          Bdate              DATE,
          Address            VARCHAR(30),
          Sex                CHAR,
          Salary             DECIMAL(10,2),
          Super_ssn          CHAR(9),
          Dno                INT                  NOT NULL,
        PRIMARY KEY (Ssn),
CREATE TABLE DEPARTMENT
        ( Dname              VARCHAR(15)          NOT NULL,
          Dnumber            INT                  NOT NULL,
          Mgr_ssn            CHAR(9)              NOT NULL,
          Mgr_start_date     DATE,
        PRIMARY KEY (Dnumber),
        UNIQUE (Dname),
        FOREIGN KEY (Mgr_ssn) REFERENCES EMPLOYEE(Ssn) );
CREATE TABLE DEPT_LOCATIONS
        ( Dnumber            INT                  NOT NULL,
          Dlocation          VARCHAR(15)          NOT NULL,
        PRIMARY KEY (Dnumber, Dlocation),
        FOREIGN KEY (Dnumber) REFERENCES DEPARTMENT(Dnumber) );
```

continued on next slide

SQL CREATE TABLE data definition statements for defining the COMPANY schema from Figure 5.7 (Fig. 6.1)-continued

```
CREATE TABLE PROJECT
        ( Pname                 VARCHAR(15)        NOT NULL,
          Pnumber               INT                NOT NULL,
          Plocation             VARCHAR(15),
          Dnum                  INT                NOT NULL,
        PRIMARY KEY (Pnumber),
        UNIQUE (Pname),
        FOREIGN KEY (Dnum) REFERENCES DEPARTMENT(Dnumber) );
CREATE TABLE WORKS_ON
        ( Essn                  CHAR(9)            NOT NULL,
          Pno                   INT                NOT NULL,
          Hours                 DECIMAL(3,1)       NOT NULL,
        PRIMARY KEY (Essn, Pno),
        FOREIGN KEY (Essn) REFERENCES EMPLOYEE(Ssn),
        FOREIGN KEY (Pno) REFERENCES PROJECT(Pnumber) );
CREATE TABLE DEPENDENT
        ( Essn                  CHAR(9)            NOT NULL,
          Dependent_name        VARCHAR(15)        NOT NULL,
          Sex                   CHAR,
          Bdate                 DATE,
          Relationship          VARCHAR(8),
        PRIMARY KEY (Essn, Dependent_name),
        FOREIGN KEY (Essn) REFERENCES EMPLOYEE(Ssn) );
```

Attribute Data Types and Domains in SQL

Basic **data types**

- **Numeric** data types
  - Integer numbers: `INTEGER`, `INT`, and `SMALLINT`
  - Floating-point (real) numbers: `FLOAT` or `REAL`, and `DOUBLE PRECISION`
- **Character-string** data types
  - Fixed length: `CHAR(`*n*`)`, `CHARACTER(`*n*`)`
  - Varying length : `VARCHAR(`*n*`)`, `CHAR VARYING(`*n*`)`, `CHARACTER VARYING(`*n*`)`

Data type	Range	Storage
BIGINT	-2^{63} (-9,223,372,036,854,775,808) to $2^{63}-1$ (9,223,372,036,854,775,807)	8 Bytes
INT	**-2^{31} (-2,147,483,648) to $2^{31}-1$ (2,147,483,647)**	**4 Bytes**
SMALLINT	-2^{15} (-32,768) to $2^{15}-1$ (32,767)	2 Bytes
TINYINT	0 to 255	1 Byte

Attribute Data Types and Domains in SQL (cont'd.)

Bit-string data types [0s, 1s]

- Fixed length: `BIT(`*n*`)`
- Varying length: `BIT VARYING(`*n*`)`

Boolean data type

- Values of `TRUE` or `FALSE` or `NULL`

DATE data type

- Ten positions
- Components are `YEAR`, `MONTH`, and `DAY` in the form YYYY-MM-DD
- Multiple mapping functions available in RDBMSs to change date formats

Attribute Data Types and Domains in SQL (cont'd.)

Additional data types

- **Timestamp** data type
- Includes the `DATE` and `TIME` fields
  - Plus a minimum of six positions for decimal fractions of seconds
  - Optional `WITH TIME ZONE` qualifier
- **INTERVAL** data type
  - Specifies a relative value that can be used to increment or decrement an absolute value of a date, time, or timestamp
- **DATE, TIME, Timestamp, INTERVAL** data types can be **cast** or converted to string formats for comparison.

Lets look at all data types

Data type	Description
CHAR(size)	A FIXED length string (can contain letters, numbers, and special characters). The *size* parameter specifies the column length in characters - can be from 0 to 255. Default is 1
VARCHAR(size)	A VARIABLE length string (can contain letters, numbers, and special characters). The *size* parameter specifies the maximum string length in characters - can be from 0 to 65535
BINARY(size)	Equal to CHAR(), but stores binary byte strings. The *size* parameter specifies the column length in bytes. Default is 1
VARBINARY(size)	Equal to VARCHAR(), but stores binary byte strings. The *size* parameter specifies the maximum column length in bytes.
TINYBLOB	For BLOBs (Binary Large Objects). Max length: 255 bytes
TINYTEXT	Holds a string with a maximum length of 255 characters
TEXT(size)	Holds a string with a maximum length of 65,535 bytes

https://www.w3schools.com/sql/sql_datatypes.asp

Attribute Data Types and Domains in SQL (cont'd.)

Domain

Name used with the attribute specification

Makes it easier to change the data type for a domain that is used by numerous attributes

Improves schema readability

Example:

```
CREATE DOMAIN SSN_TYPE AS CHAR(9);

CREATE DOMAIN CPI_DATA AS REAL CHECK
(value >= 0 AND value <= 10);
```

TYPE

User Defined Types (UDTs) are supported for object-oriented applications. (See Ch.12) Uses the command: `CREATE TYPE`

`CREATE TYPE AUDIO  AS BLOB (1M) [Binary Large OBject]`

Specifying Constraints in SQL

Basic constraints:

Relational Model has 3 basic constraint types that are supported in SQL:

- **Key** constraint: A primary key value cannot be duplicated
- **Entity Integrity** Constraint: A primary key value cannot be null
- **Referential integrity** constraints : The “foreign key “ must have a value that is already present as a primary key, or may be null.

String Data Types

Data type	Description
CHAR(size)	A FIXED length string (can contain letters, numbers, and special characters). The *size* parameter specifies the column length in characters - can be from 0 to 255. Default is 1
VARCHAR(size)	A VARIABLE length string (can contain letters, numbers, and special characters). The *size* parameter specifies the maximum string length in characters - can be from 0 to 65535
BINARY(size)	Equal to CHAR(), but stores binary byte strings. The *size* parameter specifies the column length in bytes. Default is 1
VARBINARY(size)	Equal to VARCHAR(), but stores binary byte strings. The *size* parameter specifies the maximum column length in bytes.
TINYBLOB	For BLOBs (Binary Large Objects). Max length: 255 bytes
TINYTEXT	Holds a string with a maximum length of 255 characters
TEXT(size)	Holds a string with a maximum length of 65,535 bytes
BLOB(size)	For BLOBs (Binary Large Objects). Holds up to 65,535 bytes of data
MEDIUMTEXT	Holds a string with a maximum length of 16,777,215 characters
MEDIUMBLOB	For BLOBs (Binary Large Objects). Holds up to 16,777,215 bytes of data

https://www.w3schools.com/sql/sql_datatypes.asp

Numeric Data Types

Data type	Description
BIT(*size*)	A bit-value type. The number of bits per value is specified in *size*. The *size* parameter can hold a value from 1 to 64. The default value for *size* is 1.
TINYINT(*size*)	A very small integer. Signed range is from -128 to 127. Unsigned range is from 0 to 255. The *size* parameter specifies the maximum display width (which is 255)
BOOL	Zero is considered as false, nonzero values are considered as true.
BOOLEAN	Equal to BOOL
SMALLINT(*size*)	A small integer. Signed range is from -32768 to 32767. Unsigned range is from 0 to 65535. The *size* parameter specifies the maximum display width (which is 255)
MEDIUMINT(*size*)	A medium integer. Signed range is from -8388608 to 8388607. Unsigned range is from 0 to 16777215. The *size* parameter specifies the maximum display width (which is 255)
INT(*size*)	A medium integer. Signed range is from -2147483648 to 2147483647. Unsigned range is from 0 to 4294967295. The *size* parameter specifies the maximum display width (which is 255)
INTEGER(*size*)	Equal to INT(size)
BIGINT(*size*)	A large integer. Signed range is from -9223372036854775808 to 9223372036854775807. Unsigned range is from 0 to 18446744073709551615. The *size* parameter specifies the maximum display width (which is 255)

https://www.w3schools.com/sql/sql_datatypes.asp

Date & Time Data Types

Data type	Description
DATE	A date. Format: YYYY-MM-DD. The supported range is from '1000-01-01' to '9999-12-31'
DATETIME(*fsp*)	A date and time combination. Format: YYYY-MM-DD hh:mm:ss. The supported range is from '1000-01-01 00:00:00' to '9999-12-31 23:59:59'. Adding DEFAULT and ON UPDATE in the column definition to get automatic initialization and updating to the current date and time
TIMESTAMP(*fsp*)	A timestamp. TIMESTAMP values are stored as the number of seconds since the Unix epoch ('1970-01-01 00:00:00' UTC). Format: YYYY-MM-DD hh:mm:ss. The supported range is from '1970-01-01 00:00:01' UTC to '2038-01-09 03:14:07' UTC. Automatic initialization and updating to the current date and time can be specified using DEFAULT CURRENT_TIMESTAMP and ON UPDATE CURRENT_TIMESTAMP in the column definition
TIME(*fsp*)	A time. Format: hh:mm:ss. The supported range is from '-838:59:59' to '838:59:59'
YEAR	A year in four-digit format. Values allowed in four-digit format: 1901 to 2155, and 0000. MySQL 8.0 does not support year in two-digit format.

https://www.w3schools.com/sql/sql_datatypes.asp

Specifying Attribute Constraints

Other Restrictions on attribute domains:

Default value of an attribute

DEFAULT <value>

NULL is not permitted for a particular attribute (NOT NULL)

CHECK clause

```
Dnumber INT NOT NULL CHECK (Dnumber > 0 AND Dnumber < 21);
```

Specifying Key and Referential Integrity Constraints

`PRIMARY KEY` clause

Specifies one or more attributes that make up the primary key of a relation

```
Dnumber INT PRIMARY KEY;
```

`UNIQUE` clause

Specifies alternate (secondary) keys (called CANDIDATE keys in the relational model).

```
Dname VARCHAR(15) UNIQUE;
```

Both the UNIQUE and PRIMARY KEY constraints provide a guarantee for uniqueness for a column or set of columns.

A PRIMARY KEY constraint automatically has a UNIQUE constraint.

However, you can have many UNIQUE constraints per table, but only one PRIMARY KEY constraint per table.

https://www.w3schools.com/sql/sql_unique.asp

Specifying Key and Referential Integrity Constraints (cont'd.)

`FOREIGN KEY` clause

- Default operation: reject update on violation
- Attach **referential triggered action** clause
  - Options include `SET NULL`, `CASCADE`, and `SET DEFAULT`
  - Action taken by the DBMS for `SET NULL` or `SET DEFAULT` is the same for both `ON DELETE` and `ON UPDATE`
  - `CASCADE` option suitable for some propagation needs to be done [Manager leaving organization, or somebody stepping down as manager]

Giving Names to Constraints

Using the Keyword **`CONSTRAINT`**

- Name a constraint
- Useful for later altering

```
CREATE TABLE EMPLOYEE
    ( … ,
      Dno           INT           NOT NULL      DEFAULT 1,
    CONSTRAINT EMPPK
      PRIMARY KEY (Ssn),
    CONSTRAINT EMPSUPERFK
      FOREIGN KEY (Super_ssn) REFERENCES EMPLOYEE(Ssn)
                    ON DELETE SET NULL          ON UPDATE CASCADE,
    CONSTRAINT EMPDEPTFK
      FOREIGN KEY(Dno) REFERENCES DEPARTMENT(Dnumber)
                    ON DELETE SET DEFAULT       ON UPDATE CASCADE);
CREATE TABLE DEPARTMENT
    ( … ,
      Mgr_ssn CHAR(9)           NOT NULL        DEFAULT '888665555',
      … ,
    CONSTRAINT DEPTPK
      PRIMARY KEY(Dnumber),
    CONSTRAINT DEPTSK
      UNIQUE (Dname),
    CONSTRAINT DEPTMGRFK
      FOREIGN KEY (Mgr_ssn) REFERENCES EMPLOYEE(Ssn)
                    ON DELETE SET DEFAULT       ON UPDATE CASCADE);
CREATE TABLE DEPT_LOCATIONS
    ( … ,
    PRIMARY KEY (Dnumber, Dlocation),
    FOREIGN KEY (Dnumber) REFERENCES DEPARTMENT(Dnumber)
                  ON DELETE CASCADE             ON UPDATE CASCADE);
```

Default attribute values and referential integrity triggered action specification (Fig. 6.2)

Specifying Constraints on Tuples Using CHECK

Additional Constraints on individual tuples within a relation are also possible using CHECK

`CHECK` clauses at the end of a `CREATE TABLE` statement

- Apply to each tuple individually

```
CHECK (Dept_create_date <= Mgr_start_date);
```

Basic Retrieval Queries in SQL

`SELECT` statement

- One basic statement for retrieving information from a database

SQL allows a table to have two or more tuples that are identical in all their attribute values [Results from the query]

- Unlike relational model (relational model is strictly set-theory based)
- Multiset or bag behavior
- Tuple-id may be used as a key

The SELECT-FROM-WHERE Structure of Basic SQL Queries

Basic form of the `SELECT` statement:

```
SELECT    <attribute list>
FROM      <table list>
WHERE     <condition>;
```

where

- <attribute list> is a list of attribute names whose values are to be retrieved by the query.
- <table list> is a list of the relation names required to process the query.
- <condition> is a conditional (Boolean) expression that identifies the tuples to be retrieved by the query.

The SELECT-FROM-WHERE Structure of Basic SQL Queries (cont'd.)

Logical comparison operators

- =, <, <=, >, >=, and <>

Projection attributes

- Attributes whose values are to be retrieved

Selection condition

- Boolean condition that must be true for any retrieved tuple. Selection conditions include join conditions (see Ch.8) when multiple relations are involved.

Basic Retrieval Queries

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

Query 0. Retrieve the birth date and address of the employee(s) whose name is 'John B. Smith'.

Basic Retrieval Queries

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

Query 0. Retrieve the birth date and address of the employee(s) whose name is 'John B. Smith'.

```
Q0:   SELECT   Bdate, Address
      FROM     EMPLOYEE
      WHERE    Fname='John' AND Minit='B' AND Lname='Smith';
```

Basic Retrieval Queries

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

Query 0. Retrieve the birth date and address of the employee(s) whose name is 'John B. Smith'.

```
Q0:    SELECT   Bdate, Address
       FROM     EMPLOYEE
       WHERE    Fname='John' AND Minit='B' AND Lname='Smith';
```

Bdate	Address
1965-01-09	731Fondren, Houston, TX

Basic Retrieval Queries

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

Query 1. Retrieve the name and address of all employees who work for the 'Research' department.

Basic Retrieval Queries

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

Query 1. Retrieve the name and address of all employees who work for the 'Research' department.

```
Q1:   SELECT   Fname, Lname, Address
      FROM     EMPLOYEE, DEPARTMENT
      WHERE    Dname='Research' AND Dnumber=Dno;
```

Basic Retrieval Queries

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

Query 1. Retrieve the name and address of all employees who work for the 'Research' department.

```
Q1:   SELECT   Fname, Lname, Address
      FROM     EMPLOYEE, DEPARTMENT
      WHERE    Dname='Research' AND Dnumber=Dno;
```

Fname	Lname	Address
John	Smith	731 Fondren, Houston, TX
Franklin	Wong	638 Voss, Houston, TX
Ramesh	Narayan	975 Fire Oak, Humble, TX
Joyce	English	5631 Rice, Houston, TX

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