Lecture Notes on

4AID4-05

Database Management System

Unit 3

Department of Artificial Intelligence & Data Science
Jaipur Engineering College & Research Centre, Jaipur

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AI&DS

Vision of the Institute

To become a renowned centre of outcome based learning and work toward academic, professional, cultural and social enrichment of the lives of individuals and communities.

Mission of the Institute

M1: Focus on evaluation of learning outcomes and motivate students to inculcate research aptitude by project based learning.
M2: Identify, based on informed perception of Indian, regional and global needs, the areas of focus and provide platform to gain knowledge and solutions.
M3: Offer opportunities for interaction between academia and industry.
M4: Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders can emerge in a range of professions.

Vision Of The Department

To prepare students in the field of Artificial Intelligence and Data Science for competing with the global perspective through outcome based education, research and innovation.

Mission Of The Department

1. To impart outcome based education in the area of AI&DS.
2. To provide platform to the experts from institutions and industry of repute to transfer the knowledge to students for providing competitive and sustainable solutions.
3. To provide platform for innovation and research.

Program Outcomes (PO)

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and Artificial Intelligence & Data Science specialization to the solution of complex Artificial Intelligence & Data Science problems.
2. **Problem analysis**: Identify, formulate, research literature, and analyze complex Artificial Intelligence & Data Science problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex Artificial Intelligence & Data Science problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of Artificial Intelligence & Data Science experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex Artificial Intelligence & Data Science activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional Artificial Intelligence & Data Science practice.
7. **Environment and sustainability**: Understand the impact of the professional Artificial Intelligence & Data Science in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the Artificial Intelligence & Data Science practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings in Artificial Intelligence & Data Science
10. **Communication**: Communicate effectively on complex Artificial Intelligence & Data Science activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the Artificial Intelligence & Data Science and management principles and apply these to one"s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change in Artificial Intelligence & Data Science.

Program Educational Objectives (PEO)

PEO1: To provide students with the fundamentals of Engineering Sciences with more emphasis in Artificial Intelligence & Data Science by way of analyzing and exploiting engineering challenges.

PEO2: To train students with good scientific and engineering knowledge so as to comprehend, analyze, design, and create novel products and solutions for the real life problems in Artificial Intelligence & Data Science

PEO3: To inculcate professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, entrepreneurial thinking and an ability to relate engineering issues with social issues for Artificial Intelligence & Data Science.

PEO4: To provide students with an academic environment aware of excellence, leadership, written ethical codes and guidelines, and the self-motivated life-long learning needed for a successful professional career in Artificial Intelligence & Data Science.

PEO5: To prepare students to excel in Industry and Higher education by Educating Students along with High moral values and Knowledge in Artificial Intelligence & Data Science.

COURSE OUTCOME: After studying this subject, student will be able

CO-1	Design an ER model for an enterprise
CO-2	Perform and analysis Query database using Relational Algebra, Relational Calculus and SQL
CO-3	Apply normalization based on functional dependency.
C0-4	Illustrate for serialzability among concurrent transactions and apply concurrency control protocols, and Outline database recovery techniques

CO_PO Mapping

SUBJECT CODE	subject name		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
4AID4-05	Database Management System	CO-1	3	3	3	3	3	2	1	2	1	2	2	2
		CO-2	3	3	3	3	3	2	1	1	1	2	2	2
		CO-3	3	3	3	3	3	2	1	1	1	2	2	2
		CO-4	3	3	3	2	2	2	1	1	1	2	2	2

4AID4-05: Database Management System

Credit: 3 — **Max. Marks: 100(IA:30, ETE:70)**

3L+0T+0P — **End Term Exam: 3 Hours**

SN	Contents	Hours
1	**Introduction:** Objective, scope and outcome of the course.	1
2	**Introduction to database systems:** Overview and History of DBMS. File System v/s DBMS.Advantage of DBMS Describing and Storing Data in a DBMS.Queries in DBMS.Structure of a DBMS. **Entity Relationship model:** Overview of Data Design Entities, Attributes and Entity Sets, Relationship and Relationship Sets. Features of the ER Model- Key Constraints, Participation Constraints, Weak Entities, Class Hierarchies, Aggregation, Conceptual Data Base, and Design with ER Model- Entity v/s Attribute, Entity vs Relationship Binary vs Ternary Relationship and Aggregation v/s ternary Relationship Conceptual Design for a Large Enterprise.	7
3	**Relationship Algebra and Calculus:** Relationship Algebra Selection and Projection, Set Operations, Renaming, Joints, Division, Relation Calculus, Expressive Power of Algebra and Calculus. **SQL queries programming and Triggers:** The Forms of a Basic SQL Query, Union, and Intersection and Except, Nested Queries, Correlated Nested Queries, Set-Comparison Operations, Aggregate Operators, Null Values and Embedded SQL, Dynamic SQL, ODBC and JDBC, Triggers and Active Databases.	8
4	**Schema refinement and Normal forms:** Introductions to Schema Refinement, Functional Dependencies, Boyce-Codd Normal Forms, Third Normal Form, Normalization-Decomposition into BCNF Decomposition into 3-NF.	8
5	**Transaction Processing:** Introduction-Transaction State, Transaction properties, Concurrent Executions. Need of Serializability, Conflict vs. View Serializability, Testing for Serializability, Recoverable Schedules, Cascadeless Schedules.	8
6	**Concurrency Control: Implementation of Concurrency:** Lock-based protocols, Timestamp-based protocols, Validation-based protocols, Deadlock handling, **Database Failure and Recovery:** Database Failures, Recovery Schemes: Shadow Paging and Log-based Recovery, Recovery with Concurrent transactions.	8
	Total	**40**

UNIT-3

RELATIONAL MODEL

A database is a collection of 1 or more 'relations', where each relation is a table with rows and columns.

This is the primary data model for commercial data processing applications. The major advantages of the relational model over the older data models are,

1. It is simple and elegant.
2. simple data representation.
3. The ease with which even complex queries can be expressed.

Introduction:

The main construct for representing data in the relational model is a 'relation'.

A relation consists of

1. Relation Schema.
2. Relation Instance.

Explanation is as below.

1. Relation Schema:

The relation schema describes the column heads for the table.

The schema specifies the relation's name, the name of each field (column, attribute) and the 'domain' of each field.

A domain is referred to in a relation schema by the domain name and has a set of associated values. Example:

Student information in a university database to illustrate the parts of a relation schema.

Students (Sid: string, name: string, login: string, age: integer, gross: real)

This says that the field named 'sid' has a domain named 'string'.
The set of values associated with domain 'string' is the set of all character strings.

2. Relation Instance:

This is a table specifying the information.

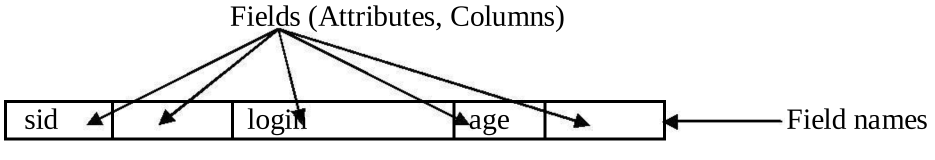
An instance of a relation is a set of 'tuples', also called 'records', in which each tuple has the same number of fields as the relation schemas.

A relation instance can be thought of as a table in which each tuple is a row and all rows have the same number of fields.

The relation instance is also called as 'relation'.

Each relation is defined to be a set of unique tuples or rows.

Example:



1111	Dave	dave@cs	19	1.2
2222	Jones	Jones@cs	18	2.3
333	Smith	smith@ee	18	3.4
4444	Smith	smith@math	19	4.5

Tuples (Records, Rows)

This example is an instance of the students relation, which consists 4 tuples and 5 fields. No two rows are identical.

Degree:

The number of fields is called as ‘degree’.
This is also called as ‘arity’.

Cardinality:

The cardinality of a relation instance is the number of tuples in it. Example:

In the above example, the degree of the relation is 5 and the cardinality is 4.

Relational database:

It is a collection of relations with distinct relation names. Relational database schema:

It is the collection of schemas for the relations in the database. Instance:

An instance of a relational database is a collection of relation instances, one per relation schema in the database schema.

Each relation instance must satisfy the domain constraints in its schema.

2.Integrity constraints over relations

An integrity constraint (IC) is a condition that is specified on a database schema and restricts the data can be stored in an instance of the database.

Various restrictions on data that can be specified on a relational database schema in the form of ‘constraints’.

A DBMS enforces integrity constraints, in that it permits only legal instances to be stored in the database. Integrity constraints are specified and enforced at different times as below.

1. When the DBA or end user defines a database schema, he or she specifies the ICs that must hold on any instance of this database.
2. When a data base application is run, the DBMS checks for violationsand disallows changes to the data that violate the specified ICs.

Legal Instance:

If the database instance satisfies all the integrity constraints specified on the database schema. The constraints can be classified into 4 types as below.

1. Domain Constraints.
2. Key Constraints.
3. Entity Integrity Constraints.
4. Referential Integrity Constraints.

Explanation is as below.

1.Domain Constraints

Domain constraints are the most elementary form of integrity constraints. They are tested easily by the system whenever a new data item is entered into the database.

Domain constraints specify the set of possible values that may be associated with an attribute. Such constraints may also prohibit the use of null values for particular attributes.

The data types associated with domains typically include standard numeric data types for integers A relation schema specifies the domain of each field or column in the relation instance.

These domain constraints in the schema specify an important condition that each instance of the relation to satisfy: The values that appear in a column must be drawn from the domain associated with that column. Thus the domain of a field is essentially the type of that field.

2.Key Constraints

1.Explain the concept of Super Key, Candidate Key and Primary Key with examples?(6 Marks, Feb-2004)

A key constraint is a statement that a certain minimal subset of the fields of a relation is a unique identifier for a tuple.

<u>Example:</u>

The ‘students’ relation and the constraint that no 2 students have tha same student id (sid). These can be classified into 3 types as below.

a. Candidate Key or Key.
b. Super Key.
c. Primary Key.

Explanation is as below.

a. Candidate Key or Key:

1. Explain 'Candidate Key'?(4 Marks, Semptember-2003)

A set of fields that uniquely identifies a tuple according to a key constraint is called as a 'Candidate Key' for the relation.

This is also called as a 'key'.

From the definition of candidate key, we have,

1. Two distinct tuples in a legal instance cannot have identical values in all the fields of a key.i.e, in any legal instance, the values in the key fields uniquely identify a tuple in the instance.

i.e,the values in the key fields uniquely identify a tuple in the instance. **2.** No subset of the set of fields in key is a unique identifier for a tuple,

i.e., the set of fields {sid, name} is not a key for Students. A relation schema may have more than key.

Example: In the above Students relation, the 'sid' field is a candidate key. {sid}.

The value of a key attribute can be used to identify uniquely each tuple in the relation.

'A set of attributes constituting a key' is a property of the relation schema.

- A key is determined from the meaning of attributes.
- Every relation is guaranteed to have a key. Since a relation is a set of tuples, the set of all fields is always a super key.

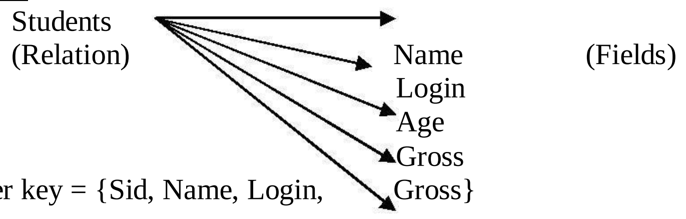
b. Super Key:

The set of fields that contains a key is called as a 'super key'.

The set of 1 or more attributes that allows us to identify uniquely an entity in the entity set.

A super key specifies a uniqueness constraint that no 2 distinct tuples can have the same value. Every relation has at least 1 default super key as the set of all attributes.

Example:



One of the super key = {Sid, Name, Login, Gross}

c. Primary Key:

This is also a candidate key, whose values are used to identify tuples in the relation.

- It iscommon to designate one of the candidate keys as a primary key of the relation.
- The attributes that form the primary key of a relation schema are underlined.
- It is used to denote a candidate key that is chosen by the database designer as the principal means of identifying entities with an entity set.

Example:

'Sid' of Students relation.

d. Specifying Key Constraints in SQL-92:

In SQL, we are declaring the set of fields of a table consisting a key by using 'UNIQUE' constraint.

This 'UNIQUE' constraint specifies that 2 distinct tuples cannot have identical Values.

Candidate keys can be declared as a 'primary key' using the constraint 'PRIMARY KEY'.

We can name a constraint by using the syntax as below.

CONSTRAINT constraint_name KEY_NOTATION (key_names);

If the constraint is violated, then the constraint_name is returned and it can be used to identify the error.

Example:

Express ‘sid’ as a primary key and the combination {name, age} as a key.

```
CREATE TABLE Students (sid CHAR (20),  name CHAR (30),   login CHAR(20),
                                age INTEGER,  gross REAL,   UNIQUE (name, age),
`                              CONSTRAINT sid1 PRIMARY KEY (sid));
```

3. Entity Integrity Constraints

This states that no primary key value can be null.

The primary key value is used to identify individual tuples in a relation.

Having null values for the primary key implies that we cannot identify some tuples. NOTE: Key Constraints, Entity Integrity Constraints are specified on individual relations. PRIMARY KEYS comes under this.

4. Referential Integrity Constraints

The Referential Integrity Constraint is specified between 2 relations and is used to maintain the consistency among tuples of the 2 relations.

Informally, the referential integrity constraint states that ‘a tuple in 1 relation that refers to another relation must refer to an existing tuple in that relation.

We can diagrammatically display the referential integrity constraints by drawing a directed arc from each foreign key to the relation it references. The arrowhead may point to the primary key of the referenced relation.

SELECT Statement Basics

In the subsequent text, the following 3 example tables are used:

p Table (parts)

pno	descr	color
P1	Widget	Blue
P2	Widget	Red
P3	Dongle	Green

s Table (suppliers)

sno	name	city
S1	Pierre	Paris
S2	John	London
S3	Mario	Rome

sp Table (suppliers & parts)

sno	pno	qty
S1	P1	NULL
S2	P1	200
S3	P1	1000
S3	P2	200

The SQL SELECT statement queries data from tables in the database. The statement begins withthe SELECT keyword. The basic SELECT statement has 3 clauses:

SELECT
FROM
WHERE

The SELECT clause specifies the table columns that are retrieved. The FROM clause specifies thetables accessed. The WHERE clause specifies which table rows are used. The WHERE clause is optional; if missing, all table rows are used.
For example,

SELECT name FROM s WHERE city='Rome'

This query accesses rows from the table - *s*. It then filters those rows where the *city* columncontains Rome. Finally, the query retrieves the *name* column from each filtered row. Using the example *s* table, this query produces:

name
Mario

A detailed description of the query actions:

The FROM clause accesses the *s* table. Contents:

sno	name	city
S1	Pierre	Paris
S2	John	London
S3	Mario	Rome

The WHERE clause filters the rows of the FROM table to use those whose *city* column contains Rome. This chooses a single row from *s*:

sno	name	city
S3	Mario	Rome

The SELECT clause retrieves the *name* column from the rows filtered by the WHEREclause:

name
Mario

SELECT Clause

The SELECT clause is mandatory. It specifies a list of columns to be retrieved from the tables in the FROM clause. It has the following general format:

SELECT [ALL|DISTINCT] select-list

select-list is a list of column names separated by commas. The ALL and DISTINCT specifiers are optional. DISTINCT specifies that duplicate rows are discarded. A duplicate row is when each corresponding *select-list* column has the same value. The default is ALL, which retains duplicate rows.

For example,

SELECT descr, color FROM p

The column names in the select list can be qualified by the appropriate table name:

SELECT p.descr, p.color FROM p

A column in the select list can be renamed by following the column name with the new name. Forexample:

SELECT name supplier, city location FROM s

This produces:

supplier	location
Pierre	Paris
John	London
Mario	Rome

A special select list consisting of a single '*' requests all columns in all tables in the FROM clause.For example,

SELECT * FROM sp

sno	pno	qty
S1	P1	NULL
S2	P1	200
S3	P1	1000
S3	P2	200

The ***** delimiter will retrieve just the columns of a single table when qualified by the table name.For example:

SELECT sp.* FROM sp

This produces the same result as the previous example.

An unqualified ***** cannot be combined with other elements in the select list; it must be stand alone. However, a qualified ***** can be combined with other elements. For example,

SELECT sp.*,
city FROM sp,s
WHERE
sp.sno=s.sno

sno	pno	qty	city
S1	P1	NULL	Paris

S2	P1	200	London
S3	P1	1000	Rome
S3	P2	200	Rome

Note: this is an example of a query joining

2 tables. FROM Clause

The FROM clause always follows the SELECT clause. It lists the tables accessed by the query. Forexample,

SELECT * FROM s

When the From List contains multiple tables, commas separate the table names. For example,

SELECT sp.*,
city FROM sp,s
WHERE
sp.sno=s.sno

When the From List has multiple tables, they must be *joined* together.

Correlation Names

Like columns in the select list, tables in the from list can be renamed by following the table namewith the new name. For example,

SELECT supplier.name FROM s supplier

The new name is known as the correlation (or range) name for the table. Self joins require correlation names.

WHERE Clause

The WHERE clause is optional. When specified, it always follows the FROM clause. The WHEREclause filters rows from the FROM clause tables. Omitting the WHERE clause specifies that all rows are used. Following the WHERE keyword is a *logical* expression, also known as a predicate.

The predicate evaluates to a SQL logical value -- **true**, **false** or **unknown**. The most basic predicateis a comparison:

color = 'Red'

This predicate returns:

true -- if the *color* column contains the string value -- 'Red',

false -- if the *color* column contains another string value (not 'Red'), or unknown -- if the *color* column contains *null*.

Generally, a comparison expression compares the contents of a table column to a literal, as above. A comparison expression may also compare two columns to each other. Table joins use this type of comparison.

The = (equals) comparison operator compares two values for equality. Additional comparison operators are:

> --
greater
than < --
less than

>= -- greater than or
equal to <= -- less than
or equal to <> --not
equal to

For example,

SELECT * FROM sp WHERE qty >= 200

sno	pno	qty
S2	P1	200
S3	P1	1000

S3 P2 200

Note: In the *sp* table, the *qty* column for one of the rows contains *null*. The comparison - **qty >= 200**, evaluates to *unknown* for this row. In the final result of a query, rows with a WHERE clause evaluating to *unknown* (or false) are eliminated (filtered out).

Both operands of a comparison should be the same data type, however automatic conversions are performed between numeric, datetime and interval types. The CAST expression provides explicit type conversions.

Extended Comparisons

In addition to the basic comparisons described above, SQL supports extended comparison operators -- BETWEEN, IN, LIKE and IS NULL.

BETWEEN Operator

The BETWEEN operator implements a range comparison, that is, it tests whether a value is *between* two other values. BETWEEN comparisons have the following format:

value-1 [NOT] BETWEEN value-2 AND value-3

This comparison tests if *value-1* is greater than or equal to *value-2* **and** less than or equal to *value-3*. It is equivalent to the following predicate:

value-1 >= value-2 AND value-1 <= value-3

Or, if NOT is included:

NOT (value-1 >= value-2 AND value-1 <= value-3)

For example,

SELECT *

FROM sp
WHERE qty BETWEEN 50 and 500

sno	pno	qty
S2	P1	200
S3	P2	200

IN Operator

The IN operator implements comparison to a list of values, that is, it tests whether a valuematches any value in a list of values. IN comparisons have the following general format:

value-1 [NOT] IN (value-2 [, value-3] ...)

This comparison tests if *value-1* matches *value-2* or matches *value-3*, and so on. It is equivalent to the following logical predicate:

value-1 = value-2 [OR value-1 = value-3] ...

or if NOT is included:

NOT (value-1 = value-2 [OR value-1 = value-3] ...)

For example,

SELECT name FROM s WHERE city IN ('Rome','Paris')

name
Pierre
Mario

LIKE Operator

The LIKE operator implements a pattern match comparison, that is, it matches a stringvalue against a pattern string containing wild-card characters.

The wild-card characters for LIKE are percent -- '%' and underscore -- '_'. Underscore matches any *single* character. Percent matches zero or more characters.

Examples,

Match Value	Pattern	Result
'abc'	'_b_'	True
'ab'	'_b_'	False
'abc'	'%b%'	True
'ab'	'%b%'	True
'abc'	'a_'	False
'ab'	'a_'	True
'abc'	'a%_'	True
'ab'	'a%_'	True

LIKE comparison has the following general format:

value-1 [NOT] LIKE value-2 [ESCAPE value-3]

All values must be string (character). This comparison uses *value-2* as a pattern to match *value-1*. The optional ESCAPE sub-clause specifies an escape character for the pattern, allowing the pattern to use '%' and '_' (and the escape character) for matching. The ESCAPE value must be a single character string. In the pattern, the ESCAPE character precedes any character to be escaped.

For example, to match a string ending with '%', use:

x LIKE '%/%' ESCAPE '/'

A more contrived example that escapes the escape character:

y LIKE '/%//%' ESCAPE '/'

... matches any string beginning with '%/'. The

optional NOT reverses the result so that:

z NOT LIKE 'abc%'

is equivalent to:

NOT z LIKE 'abc%'

IS NULL Operator

A database *null* in a table column has a special meaning -- the value of the column is not currently known (missing), however its value may be known at a later time. A database *null* may represent any value in the future, but the value is not available at this time. Since two *null* columns may eventually be assigned different values, one *null* can't be compared to another in the conventional way. The following syntax is illegal in SQL:

WHERE qty = NULL

A special comparison operator -- IS NULL, tests a column for *null*. It has the following general format:

value-1 IS [NOT] NULL

This comparison returns true if *value-1* contains a *null* and false otherwise. The optional NOT reverses the result:

value-1 IS NOT NULL

is equivalent to:

NOT value-1 IS NULL

For example,

SELECT * FROM sp WHERE qty IS NULL

sno	pno	qty
S1	P1	NULL

Logical Operators

The logical operators are AND, OR, NOT. They take logical expressions as operands and produce alogical result (True, False, Unknown). In logical expressions, parentheses are used for grouping.

AND Operator

The AND operator combines two logical operands. The operands are comparisons or logical expressions. It has the following general format:

predicate-1 AND predicate-2

AND returns:

- True -- if both operands evaluate to true
- False -- if either operand evaluates to false
- Unknown -- otherwise (one operand is true and the other is unknown or both are unknown)

The truth table for AND:

AND	T	F	U
T	T	F	U
F	F	F	F
U	U	F	U

For example,

SELECT *
FROM sp
WHERE sno='S3' AND qty < 500

sno	pno	qty
S3	P2	200

OR Operator

The OR operator combines two logical operands. The operands are comparisons or logical expressions. It has the following general format:

predicate-1 OR predicate-2

OR returns:

o True -- if either operand evaluatesto
true o False -- if both operands evaluate
to false
o Unknown -- otherwise (one operand is false and the other is unknown or both are unknown)

The truth table for OR:

OR	T	F	U
T	T	T	T
F	T	F	U
U	T	U	U

For example,

SELECT *
FROM s
WHERE sno='S3' OR city = 'London'

sno	name	city
S2	John	London
S3	Mario	Rome

AND has a higher precedence than OR, so the following expression:

a OR b AND c

is equivalent to:

a OR (b AND c)

NOT Operator

The NOT operator inverts the result of a comparison expression or a logical expression. It has the following general format:

NOT predicate-1

The truth table for NOT:

NOT	
T	F
F	T
U	U

Example query:

```
SELECT *
FROM sp
WHERE NOT sno = 'S3'
```

sno	**pno**	**qty**
S1	P1	NULL
S2	P1	200

ORDER BY Clause

The ORDER BY clause is optional. If used, it must be the last clause in the SELECT statement. The ORDER BY clause requests sorting for the results of a query.

When the ORDER BY clause is missing, the result rows from a query have no defined order (they are *unordered*). The ORDER BY clause defines the ordering of rows based on columns from the SELECT clause. The ORDER BY clause has the following general format:

ORDER BY column-1 [ASC|DESC] [column-2 [ASC|DESC]] ...

column-1, *column-2*, ... are column names specified (or implied) in the select list. If a select column is renamed (given a new name in the select entry), the new name is used in the ORDER BY list. ASC and DESC request ascending or descending sort for a column. ASC is the default.

ORDER BY sorts rows using the ordering columns in left-to-right, major-to-minor order. The rows are sorted first on the first column name in the list. If there are any duplicate values for the first column, the duplicates are sorted on the second column (within the first column sort) in the Order By list, and so on. There is no defined inner ordering for rows that have duplicate values for all Order By columns.

Database *nulls* require special processing in ORDER BY. A *null* column sorts higher than all regular values; this is reversed for DESC.

In sorting, *nulls* are considered duplicates of each other for ORDER BY. Sorting on *hidden* information makes no sense in utilizing the results of a query. This is also why SQL only allows select list columns in ORDER BY.

For convenience when using expressions in the select list, select items can be specified by number (startingwith 1). Names and numbers can be intermixed.

Example queries:

SELECT * FROM sp ORDER BY 3 DESC

sno	pno	qty
S1	P1	NULL
S3	P1	1000
S3	P2	200
S2	P1	200

SELECT name, city FROM s ORDER BY name

name	city
John	London
Mario	Rome
Pierre	Paris

SELECT * FROM sp ORDER BY qty DESC, sno

sno	pno	qty
S1	P1	NULL
S3	P1	1000
S2	P1	200
S3	P2	200

Expressions

In the previous subsection on basic Select statements, column values are used in the select list and where predicate. SQL allows a *scalar value expression* to be used instead. A SQL value expression can be a:

Literal -- quoted string, numeric value, datetime value
Function Call -- reference to builtin SQL function System
Value -- current date, current user, ...
Special Construct -- CAST, COALESCE, CASE Numeric or
String Operator -- combining sub-expressions

Literals

A literal is a typed value that is self-defining. SQL supports 3 types of literals:

- String -- ASCII text framed by single quotes ('). Within a literal, a single quote is represented by 2single quotes ('').
- Numeric -- numeric digits (at least 1) with an optional decimal point and exponent. The format is

  [ddd][[.]ddd][E[+|-]ddd]

  Numeric literals with no exponent or decimal point are typed as Integer. Those with a decimal pointbut no exponent are typed as Decimal. Those with an exponent are typed as Float.

- Datetime -- datetime literals begin with a keyword identifying the type, followed by a string literal:
  - Date -- DATE 'yyyy-mm-dd'
  - Time -- TIME 'hh:mm:ss[.fff]'
  - Timestamp -- TIMESTAMP 'yyyy-mm-dd hh:mm:ss[.fff]'
  - Interval -- INTERVAL [+|-] string interval-qualifier

  The format of the *string* in the Interval literal depends on the interval qualifier. For year-month intervals, the format is: 'dd[-dd]'. For day-time intervals, the format is '[dd]dd[:dd[:dd]][.fff]'.

SQL Functions

SQL has the following builtin functions: SUBSTRING(exp-

1 FROM exp-2 [FOR exp-3])

Extracts a substring from a string - *exp-1*, beginning at the integer value - *exp-2*, for the length of the integer value - *exp-3*. *exp-2* is 1 relative. If *FOR exp-3* is omitted, the length of the remaining string is used. Returns the substring.

UPPER(exp-1)

Converts any lowercase characters in a string - *exp-1* to uppercase. Returns the converted string.

LOWER(exp-1)

Converts any uppercase characters in a string - *exp-1* to lowercase. Returns the converted string.

TRIM([LEADING|TRAILING|BOTH] [FROM] exp-1)
TRIM([LEADING|TRAILING|BOTH] exp-2 FROM exp-1)

Trims leading, trailing or both characters from a string - *exp-1*. The trim character is a space, or if *exp-2* is specified, it supplies the trim character. If LEADING, TRAILING, BOTH are missing, the default is BOTH. Returns the trimmed string.

POSITION(exp-1 IN exp-2)

Searches a string - *exp-2*, for a match on a substring - *exp-2*. Returns an integer, the 1 relative position of the match or 0 for no match.

CHAR_LENGTH(exp-1)
CHARACTER_LENGTH(exp-1)

Returns the integer number of characters in the string - *exp-1.*

OCTET_LENGTH(exp-1)

Returns the integer number of octets (8-bit bytes) needed to represent the string - *exp-1.*

EXTRACT(sub-field FROM exp-1)

Returns the numeric sub-field extracted from a datetime value - *exp-1. sub-field* is YEAR,QUARTER, MONTH, DAY, HOUR, MINUTE, SECOND, TIMEZONE_HOUR or TIMEZONE_MINUTE. TIMEZONE_HOUR and TIMEZONE_MINUTE extract sub-fields fromthe Timezone portion of *exp-1*. QUARTER is (MONTH-1)/4+1.

System Values

SQL System Values are reserved names used to access builtin values:

USER -- returns a string with the current SQL authorization identifier. CURRENT_USER -- same as USER.

SESSION_USER -- returns a string with the current SQL session authorization identifier.

- SYSTEM_USER -- returns a string with the current operating system user.
- CURRENT_DATE -- returns a Date value for the current system date.
- CURRENT_TIME -- returns a Time value for the current system time.
- CURRENT_TIMESTAMP -- returns a Timestamp value for the current system timestamp.

SQL Special Constructs

SQL supports a set of special expression constructs:

CAST(exp-1 AS data-type)

Converts the value - *exp-1*, into the specified *date-type*. Returns the converted value.

COALESCE(exp-1, exp-2 [, exp-3] ...)

Returns *exp-1* if it is not *null*, otherwise returns *exp-2* if it is not *null*, otherwise returns *exp-3*, andso on. Returns *null* if all values are *null*.

CASE exp-1 { WHEN exp-2 THEN exp-3 } ... [ELSE exp-4] END CASE { WHEN predicate-1THEN exp-3 } ... [ELSE exp-4] END

The first form of the CASE construct compares *exp-1* to *exp-2* in each WHEN clause. If a match is found, CASE returns *exp-3* from the corresponding THEN clause. If no matches are found, it returns *exp-4* from the ELSE clause or *null* if the ELSE clause is omitted.

The second form of the CASE construct evaluates *predicate-1* in each WHEN clause. If thepredicate is true, CASE returns *exp-3* from the corresponding THEN clause. If no predicates evaluate to true, it returns *exp-4* from the ELSE clause or *null* if the ELSE clause is omitted.

Expression Operators

Expression operators combine 2 subexpressions to calculate a value. There are 2 basic types -- numeric andstring.

String Operators

There is just one string operator - ||, for string concatenation. Both operands of || must be strings.The operator concatenates the second string to the end of the first. For example,

'ab' || 'cd' ==> 'abcd'

Numeric operators

The numeric operators are common to most languages:

- + -- addition
- **-** -- subtraction
- ***** -- multiplication
- / -- division

All numeric operators can be used on the standard numeric data types:

- Integer -- TINYINT, SMALLINT, INT, BIGINT
- Exact -- NUMERIC, DECIMAL
- Approximate -- FLOAT, DOUBLE, REAL

Automatic conversion is provided for numeric operators. If an integer type is combined with an exact type, the integer is converted to exact before the operation. If an exact (or integer) type is combined with an approximate type, it is converted to approximate before the operation.

The **+** and **-** operators can also be used as unary operators.

The numeric operators can be applied to datetime values, with some restrictions. The basic rules fordatetime expressions are:

- A date, time, timestamp value can be added to an interval; result is a date, time, timestampvalue.
- An interval value can be subtracted from a date, time, timestamp value; result is a date,time, timestamp value.
- An interval value can be added to or subtracted from another interval; result is an intervalvalue.
- An interval can be multiplied by or divided by a standard numeric value; result is an intervalvalue.

A special form can be used to subtract a date, time, timestamp value from another date, time, timestamp value to yield an interval value:

(datetime-1 - datetime-2) interval-qualifier

The *interval-qualifier* specifies the specific interval type for the result.A

second special form allows a ? parameter to be typed as an interval:

? interval-qualifier

In expressions, parentheses are used for grouping.

Joining Tables

The FROM clause allows more than 1 table in its list, however simply listing more than one table will *very* rarely produce the expected results. The rows from one table must be correlated with the rows of the others. This correlation is known as *joining*.

An example can best illustrate the rationale behind joins. The following query:

SELECT * FROM sp, p

Produces:

sno	pno	qty	pno	descr	color
S1	P1	NULL	P1	Widget	Blue
S1	P1	NULL	P2	Widget	Red
S1	P1	NULL	P3	Dongle	Green
S2	P1	200	P1	Widget	Blue
S2	P1	200	P2	Widget	Red
S2	P1	200	P3	Dongle	Green
S3	P1	1000	P1	Widget	Blue
S3	P1	1000	P2	Widget	Red
S3	P1	1000	P3	Dongle	Green
S3	P2	200	P1	Widget	Blue
S3	P2	200	P2	Widget	Red
S3	P2	200	P3	Dongle	Green

Each row in *sp* is arbitrarily combined with each row in *p*, giving 12 result rows (4 rows in *sp* X 3 rows in *p*.) This is known as a *cartesian product.*

A more usable query would correlate the rows from *sp* with rows from *p*, for instance matching on thecommon column -- *pno*:

SELECT *
FROM sp, p
WHERE sp.pno = p.pno

This produces:

sno	pno	qty	pno	descr	color
S1	P1	NULL	P1	Widget	Blue
S2	P1	200	P1	Widget	Blue
S3	P1	1000	P1	Widget	Blue
S3	P2	200	P2	Widget	Red

Rows for each part in *p* are combined with rows in *sp* for the same part by matching on part number (*pno*). In this query, the WHERE Clause provides the join predicate, matching *pno* from *p* with *pno* from *sp*.

The join in this example is known as an *inner equi*-join. *equi* meaning that the join predicate uses = (equals) to match the join columns. Other types of joins use different comparison operators. For example, a query might use a *greater-than* join.

The term *inner* means only rows that match are included. Rows in the first table that have no matchingrows in the second table are excluded and vice versa (in the above join, the row in *p* with *pno* P3 is not included in the result.) An *outer* join includes unmatched rows in the result.

More than 2 tables can participate in a join. This is basically just an extension of a 2 table join. 3 tables -- *a*, *b*, *c*, might be joined in various ways:

a joins *b* which joins *c*
a joins *b* and the join of *a* and *b* joins *ca*
joins *b* and *a* joins *c*

Plus several other variations. With *inner* joins, this structure is not explicit. It is implicit in the nature of the join predicates. With *outer* joins, it is explicit;

This query performs a 3 table

SELECT name, qty, descr, color
FROM s, sp, p
WHERE s.sno = sp.sno
AND sp.pno = p.pno

It joins *s* to *sp* and *sp* to *p*, producing:

name	**qty**	**descr**	**color**
Pierre	NULL	Widget	Blue
John	200	Widget	Blue
Mario	1000	Widget	Blue
Mario	200	Widget	Red

Note that the *order* of tables listed in the FROM clause should have no significance, nor does the order of join predicates in the WHERE clause.

Outer Joins

An *inner* join excludes rows from either table that don't have a matching row in the other table. An *outer* join provides the ability to include unmatched rows in the query results. The outer join combines the unmatched row in one of the tables with an artificial row for the other table. This artificial row has all columns set to *null*.

The outer join is specified in the FROM clause and has the following general format:

table-1 { LEFT | RIGHT | FULL } OUTER JOIN table-2 ON predicate-1

predicate-1 is a join predicate for the outer join. It can only reference columns from the joined tables. TheLEFT, RIGHT or FULL specifiers give the type of join:

LEFT -- only unmatched rows from the left side table (*table-1*) are retained RIGHT -
- only unmatched rows from the right side table (*table-2*) are retainedFULL --
unmatched rows from both tables (*table-1* and *table-2*) are retained

Outer join example:

SELECT pno, descr, color, sno, qty
FROM p LEFT OUTER JOIN sp ON p.pno = sp.pno

pno	**descr**	**color**	**sno**	**qty**
P1	Widget	Blue	S1	NULL
P1	Widget	Blue	S2	200
P1	Widget	Blue	S3	1000
P2	Widget	Red	S3	200
P3	Dongle	Green	NULL	NULL

Self Joins

A query can join a table to itself. Self joins have a number of real world uses. For example, a self join can determine which parts have more than one supplier:

SELECT DISTINCT a.pno
FROM sp a, sp b
WHERE a.pno = b.pno
AND a.sno <> b.sno

pno
P1

As illustrated in the above example, self joins use *correlation* names to distinguish columns in the selectlist and where predicate. In this case, the references to the same table are renamed - *a* and *b*.

Self joins are often used in subqueries.

Subqueries

Subqueries are an identifying feature of SQL. It is called *Structured Query Language* because a query cannest inside another query.
There are 3 basic types of subqueries in SQL:

- Predicate Subqueries -- extended logical constructs in the WHERE (and HAVING) clause.
- Scalar Subqueries -- standalone queries that return a single value; they can be used anywhere ascalar value is used.
- Table Subqueries -- queries nested in the FROM clause.

All subqueries must be enclosed in parentheses.

Predicate Subqueries

Predicate subqueries are used in the WHERE (and HAVING) clause. Each is a special logical construct.Except for EXISTS, predicate subqueries must retrieve one column (in their select list.)

- IN Subquery

The IN Subquery tests whether a scalar value matches the single query column value in anysubquery result row. It has the following general format:

value-1 [NOT] IN (query-1)

Using NOT is equivalent to:

NOT value-1 IN (query-1)

For example, to list parts that have suppliers:

```
SELECT *
FROM p
WHERE pno IN (SELECT pno FROM sp)
```

pno	**descr**	**color**
P1	Widget	Blue
P2	Widget	Red

The Self Join example in the previous subsection can be expressed with an IN Subquery:

```
SELECT DISTINCT pno
FROM sp a
WHERE pno IN (SELECT pno FROM sp b WHERE a.sno <> b.sno)
```

pno
P1

Note that the subquery where clause references a column in the outer query (*a.sno*). This is known as an *outer reference*. Subqueries with outer references are sometimes known as *correlated subqueries*.

- Quantified Subqueries

A quantified subquery allows several types of tests and can use the full set of comparison operators.It has the following general format:

value-1 {=|>|<|>=|<=|<>} {ANY|ALL|SOME} (query-1)

The comparison operator specifies how to compare *value-1* to the single query column value from each subquery result row. The ANY, ALL, SOME specifiers give the type of match expected. ANY and SOME must match at least one row in the subquery. ALL must match all rows in the subquery.

For example, to list all parts that have suppliers:

```
SELECT *
FROM p
WHERE pno =ANY (SELECT pno FROM sp)
```

pno	descr	color
P1	Widget	Blue
P2	Widget	Red

A self join is used to list the supplier with the highest quantity of each part (ignoring *null* quantities):

```
SELECT *
FROM sp a
WHERE qty >ALL (SELECT qty FROM sp b
        WHERE a.pno = b.pno
        AND a.sno <> b.sno AND
        qty IS NOT NULL)
```

sno	pno	qty
S3	P1	1000
S3	P2	200

EXISTS Subqueries

The EXISTS Subquery tests whether a subquery retrieves at least one row, that is, whether a qualifying row *exists*. It has the following general format

EXISTS(query-1)

Any valid EXISTS subquery must contain an *outer reference*. It must be a *correlated subquery*.

Note: the select list in the EXISTS subquery is not actually used in evaluating the EXISTS, so it can contain any valid select list (though ***** is normally used).

To list parts that have suppliers:

```
SELECT *
FROM p
WHERE EXISTS(SELECT * FROM sp WHERE p.pno = sp.pno)
```

pno	descr	color
P1	Widget	Blue
P2	Widget	Red

Scalar Subqueries

The Scalar Subquery can be used anywhere a value can be used. The subquery must reference just one column in the select list. It must also retrieve no more than one row.

When the subquery returns a single row, the value of the single select list column becomes the value of the Scalar Subquery. When the subquery returns no rows, a database *null* is used as the result of the subquery. Should the subquery retreive more than one row, it is a *run-time* error and aborts query execution.

A Scalar Subquery can appear as a scalar value in the select list and where predicate of an another query. The following query on the *sp* table uses a Scalar Subquery in the select list to retrieve the supplier city associated with the supplier number (*sno* column in *sp*):

SELECT pno, qty, (SELECT city FROM s WHERE s.sno =
sp.sno) FROM sp

pno	qty	city
P1	NULL	Paris
P1	200	London
P1	1000	Rome
P2	200	Rome

The next query on the *sp* table uses a Scalar Subquery in the where clause to match parts on the color associated with the part number (*pno* column in *sp*):

SELECT *
FROM sp
WHERE 'Blue' = (SELECT color FROM p WHERE p.pno = sp.pno)

sno	pno	qty
S1	P1	NULL
S2	P1	200
S3	P1	1000

Note that both example queries use outer references. This is normal in Scalar Subqueries. Often, Scalar Subqueries are Aggregate Queries.

Table Subqueries

Table Subqueries are queries used in the FROM clause, replacing a table name. Basically, the result set of the Table Subquery acts like a base table in the from list. Table Subqueries can have a correlation name in the from list. They can also be in outer joins.
The following two queries produce the same result:

SELECT p.*, qty
FROM p, sp
WHERE p.pno = sp.pno
AND sno = 'S3'

pno	descr	color	qty
P1	Widget	Blue	1000
P2	Widget	Red	200

SELECT p.*, qty
FROM p, (SELECT pno, qty FROM sp WHERE sno = 'S3')
WHERE p.pno = sp.pno

pno	descr	color	qty
P1	Widget	Blue	1000
P2	Widget	Red	200

Grouping Queries

A Grouping Query is a special type of query that groups and summarizes rows. It uses the GROUP BY Clause.

A Grouping Query groups rows based on common values in a set of grouping columns. Rows with the same values for the grouping columns are placed in distinct groups. Each *group* is treated as a single row in the query result.

Even though a *group* is treated as a single row, the underlying rows can be subject to summary operations known as Set Functions whose results can be included in the query. The optional HAVING Clause supports filtering for group rows in the same manner as the WHERE clause filters FROM rows.
For example, grouping the *sp* table on the *pno* column produces 2 groups:

sno	**pno**	**qty**	
S1	P1	NULL	'P1' Group
S2	P1	200	
S3	P1	1000	
S3	P2	200	'P2' Group

The *P1* group contains 3 *sp* rows with *pno='P1'*
The *P2* group contains a single *sp* row with *pno='P2'*

Nulls get special treatment by GROUP BY. GROUP BY considers a *null* as distinct from every other *null*. Each row that has a *null* in one of its grouping columns forms a separate group.
Grouping the *sp* table on the *qty* column produces 3 groups:

sno	**pno**	**qty**	
S1	P1	NULL	NULL Group
S2	P1	200	200 Group
S3	P2	200	
S3	P1	1000	1000 Group

The row where *qty is null* forms a separate group.

GROUP BY Clause

GROUP BY is an optional clause in a query. It follows the WHERE clause or the FROM clause if the WHERE clause is missing. A query containing a GROUP BY clause is a *Grouping Query*. The GROUP BY clause has the following general format:

GROUP BY column-1 [, column-2] ...

column-1 and *column-2* are the grouping columns. They must be names of columns from tables in the FROM clause; they can't be expressions.

GROUP BY operates on the rows from the FROM clause as filtered by the WHERE clause. It collects the rows into groups based on common values in the grouping columns. Except *nulls*, rows with the same set of values for the grouping columns are placed in the same group. If any grouping column for a row contains a *null*, the row is given its own group.
For example,

```
SELECT pno
FROM sp
GROUP BY pno
```

pno
P1
P2

In Grouping Queries, the select list can only contain grouping columns, plus literals, outer references and expression involving these elements. Non-grouping columns from the underlying FROM tables cannot be referenced directly. However, non-grouping columns can be used in the select list as arguments to Set Functions. Set Functions summarize columns from the underlying rows of a group.

Set Functions

Set Functions are special summarizing functions used with Grouping Queries and Aggregate Queries. They summarize columns from the underlying rows of a group or aggregate.

Using the Group By example from above, grouping the *sp* table on the *pno* column:

sno	**pno**	**qty**	
S1	P1	NULL	'P1' Group
S2	P1	200	
S3	P1	1000	
S3	P2	200	'P2' Group

A Set Function can compute the total quantities for each group:

sno	**pno**	**qty**		**qty total**
S1	P1	NULL	'P1' Group	1200
S2	P1	200		
S3	P1	1000		
S3	P2	200	'P2' Group	200

Null columns are ignored in computing the summary. The Set Function -- SUM, computes the arithmeticsum of a numeric column in a set of grouped/aggregate rows. For example,

SELECT pno,
SUM(qty) FROM sp

GROUP BY pno

pno	
P1	1200
P2	200

Set Functions have the following general format: **set-**
function ([DISTINCT|ALL] column-1)

set-function is:

COUNT -- count of rows
SUM -- arithmetic sum of numeric column
AVG -- arithmetic average of numeric column; should be SUM()/COUNT().MIN --
minimum value found in column
MAX -- maximum value found in column

The result of the COUNT function is always integer. The result of all other Set Functions is the same data type as the argument.

The Set Functions skip columns with *nulls*, summarizing *non-null* values. COUNT counts rows with non- null values, AVG averages non-null values, and so on. COUNT returns 0 when no non-null column values are found; the other functions return *null* when there are no values to summarize.

A Set Function argument can be a column or a scalar expression.

The DISTINCT and ALL specifiers are optional. ALL specifies that *all* non-null values are summarized; it is the default. DISTINCT specifies that *distinct* column values are summarized; duplicate values are skipped. Note: DISTINCT has no effect on MIN and MAX results.

COUNT also has an alternate format:

COUNT(*)

... which counts the underlying rows regardless of column

Set Function examples:

SELECT pno, MIN(sno), MAX(qty), AVG(qty), COUNT(DISTINCT sno) FROM sp
GROUP BY pno

pno				
P1	S1	1000	600	3 P2
S3	200	200	1	

SELECT sno, COUNT(*) parts
FROM sp
GROUP BY sno

sno	parts
S1	1
S2	1
S3	2

HAVING Clause

The HAVING Clause is associated with Grouping Queries and Aggregate Queries. It is optional in both cases. In *Grouping Queries*, it follows the GROUP BY clause. In *Aggregate Queries*, HAVING follows the WHERE clause or the FROM clause if the WHERE clause is missing.

The HAVING Clause has the following general format:

HAVING predicate

Like the WHERE Clause, HAVING filters the query result rows. WHERE filters the rows from the FROM clause. HAVING filters the *grouped* rows (from the GROUP BY clause) or the aggregate row (for Aggregate Queries).

predicate is a logical expression referencing grouped columns and set functions. It has the same restrictions as the select list for Grouping Queries and Aggregate Queries.

If the Having predicate evaluates to true for a grouped or aggregate row, the row is included in the query result, otherwise, the row is skipped (not included in the query result).

For example,

SELECT sno, COUNT(*) parts
FROM sp
GROUP BY sno HAVING
COUNT(*) > 1

sno	parts
S3	2

Aggregate Queries

An Aggregate Query can use Set Functions and a HAVING Clause. It is similar to a Grouping Query except there are *no* grouping columns. The underlying rows from the FROM and WHERE clauses are *grouped* into a single aggregate row. An Aggregate Query always returns a single row, except when the Having clause is used.

An Aggregate Query is a query containing Set Functions in the select list but no GROUP BY clause. The Set Functions operate on the columns of the underlying rows of the single aggregate row. Except for outer references, any columns used in the select list must be arguments to Set Functions.

An aggregate query may also have a Having clause. The Having clause filters the single aggregate row. If the Having predicate evaluates to true, the query result contains the aggregate row. Otherwise, the query result contains no rows.

For example,

SELECT COUNT(DISTINCT pno) number_parts, SUM(qty) total_parts FROM sp

number_parts	total_parts

2	1400

Subqueries are often Aggregate Queries. For example, parts with suppliers:

SELECT
*** FROM p**
WHERE (SELECT COUNT(*) FROM sp WHERE sp.pno=p.pno) > 0

pno	**descr**	**color**
P1	Widget	Blue
P2	Widget	Red

Parts with multiple suppliers:

SELECT
*** FROM p**
WHERE (SELECT COUNT(DISTINCT sno) FROM sp WHERE sp.pno=p.pno) > 1

pno	**descr**	**color**
P1	Widget	Blue

Union Queries

The SQL UNION operator combines the results of two queries into a *composite* result. The component queries can be SELECT/FROM queries with optional WHERE/GROUP BY/HAVING clauses. The UNION operator has the following general format:

query-1 UNION [ALL] query-2

query-1 and *query-2* are full query specifications. The UNION operator creates a new query result that includes rows from each component query.

By default, UNION eliminates duplicate rows in its composite results. The optional ALL specifier requests that duplicates be retained in the UNION result.

The component queries of a Union Query can also be Union Queries themselves. Parentheses are used for grouping queries.

The select lists from the component queries must be *union-compatible*. They must match in degree (number of columns). For Entry Level SQL92, the column descriptor (data type and precision, scale) for each corresponding column must match. The rules for Intermediate Level SQL92 are less restrictive.

Union-Compatible Queries

For Entry Level SQL92, each corresponding column of both queries must have the same column descriptorin order for two queries to be *union-compatible*. The rules are less restrictive for Intermediate Level SQL92. It supports automatic conversion within type categories. In general, the resulting data type will be the *broader* type. The corresponding columns need only be in the same data type category:

Character (String) -- fixed/variable lengthBit
String -- fixed/variable length
Exact Numeric (fixed point) -- integer/decimal
Approximate Numeric (floating point) -- float/double
Datetime -- sub-category must be the same,
- Date
- Time
- Timestamp

Interval -- sub-category must be the same,
- Year-month
- Day-time

UNION Examples
SELECT * FROM sp
UNION
SELECT CAST(' ' AS VARCHAR(5)), pno, CAST(0 AS INT)

FROM p
WHERE pno NOT IN (SELECT pno FROM sp)

sno	pnc	qty
S1	P1	NULL
S2	P1	200
S3	P1	1000
S3	P2	200
	P3	0

SQL Modification Statements

The SQL Modification Statements make changes to database data in tables and columns. There are 3 modification statements:

- INSERT Statement -- add rows to tables
- UPDATE Statement -- modify columns in table rows
- DELETE Statement -- remove rows from tables

INSERT Statement

The INSERT Statement adds one or more rows to a table. It has two formats:

INSERT INTO table-1 [(column-list)] VALUES (value-list)

and,

INSERT INTO table-1 [(column-list)] (query-specification)

The first form inserts a single row into *table-1* and explicitly specifies the column values for the row. The second form uses the result of *query-specification* to insert one or more rows into *table-1*. The result rows from the query are the rows added to the insert table. Note: the query cannot reference *table-1*.

Both forms have an optional *column-list* specification. Only the columns listed will be assigned values. Unlisted columns are set to *null*, so unlisted columns must allow *nulls*. The values from the VALUES Clause (first form) or the columns from the *query-specification* rows (second form) are assigned to the corresponding column in *column-list* in order.

If the optional *column-list* is missing, the default column list is substituted. The default column list contains all columns in *table-1* in the order they were declared in CREATE TABLE, or CREATE VIEW.

VALUES Clause

The VALUES Clause in the INSERT Statement provides a set of values to place in the columns of a newrow. It has the following general format:

VALUES (value-1 [, value-2] ...)

value-1 and *value-2* are Literal Values or Scalar Expressions involving literals. They can also specifyNULL.

The values list in the VALUES clause must match the explicit or implicit column list for INSERT in degree (number of items). They must also match the data type of corresponding column or be convertibleto that data type.

INSERT Examples

INSERT INTO p (pno, color) VALUES ('P4', 'Brown')

Before

pno	descr	color
P1	Widget	Blue
P2	Widget	Red
P3	Dongle	Green

=>

After

pno	descr	color
P1	Widget	Blue
P2	Widget	Red
P3	Dongle	Green

P4	*NULL*	*Brown*

INSERT INTO sp
SELECT s.sno, p.pno, 500
FROM s, p
WHERE p.color='Green' AND s.city='London'

Before

sno	pno	qty
S1	P1	NULL
S2	P1	200
S3	P1	1000
S3	P2	200

=>

After

sno	pno	qty
S1	P1	NULL
S2	P1	200
S3	P1	1000
S3	P2	200
S2	*P3*	*500*

UPDATE Statement

The UPDATE statement modifies columns in selected table rows. It has the following general format:

UPDATE table-1 SET set-list [WHERE predicate]

The optional WHERE Clause has the same format as in the SELECT Statement. See WHERE Clause. TheWHERE clause chooses which table rows to update. If it is missing, all rows are in *table-1* are updated.

The *set-list* contains assignments of new values for selected columns.

The SET Clause expressions and WHERE Clause predicate can contain subqueries, but the subqueriescannot reference *table-1*. This prevents situations where results are dependent on the order of processing.

SET Clause

The SET Clause in the UPDATE Statement updates (assigns new value to) columns in the selected table rows. It has the following general format:

SET column-1 = value-1 [, column-2 = value-2] ...

column-1 and *column-2* are columns in the Update table. *value-1* and *value-2* are expressions that can reference columns from the update table. They also can be the keyword -- NULL, to set the column to *null*. Since the assignment expressions can reference columns from the current row, the expressions are evaluated first. After the values of all Set expressions have been computed, they are then assigned to the referenced columns. This avoids results dependent on the order of processing.

UPDATE Examples

UPDATE sp SET qty = qty + 20

Before

sno	pno	qty
S1	P1	NULL
S2	P1	200
S3	P1	1000
S3	P2	200

=>

After

sno	pno	qty
S1	P1	NULL
S2	P1	*220*
S3	P1	*1020*
S3	P2	*220*

UPDATE s
SET name = 'Tony', city = 'Milan'
WHERE sno = 'S3'

Before

sno	name	city
S1	Pierre	Paris
S2	John	London
S3	Mario	Rome

=>

After

sno	name	city
S1	Pierre	Paris
S2	John	London
S3	*Tony*	*Milan*

DELETE Statement

The DELETE Statement removes selected rows from a table. It has the following general format:

DELETE FROM table-1 [WHERE predicate]

The optional WHERE Clause has the same format as in the SELECT Statement. See WHERE Clause. TheWHERE clause chooses which table rows to delete. If it is missing, all rows are in *table-1* are removed.
The WHERE Clause predicate can contain subqueries, but the subqueries cannot reference *table-1*. Thisprevents situations where results are dependent on the order of processing.

DELETE Examples

DELETE FROM sp WHERE pno = 'P1'

Before

sno	**pno**	**qty**
S1	P1	NULL
S2	P1	200
S3	P1	1000
S3	P2	200

=>

After

sno	**pno**	**qty**
S3	P2	200

DELETE FROM p WHERE pno NOT IN (SELECT pno FROM sp)

Before

pno	**descr**	**color**
P1	Widget	Blue
P2	Widget	Red
P3	Dongle	Green

=>

After

pno	**descr**	**color**
P1	Widget	Blue
P2	Widget	Red

SQL-Transaction Statements

SQL-Transaction Statements control transactions in database access. This subset of SQL is also called the Data Control Language for SQL (SQL DCL).
There are 2 SQL-Transaction Statements:

COMMIT Statement -- commit (make persistent) all changes for the current transaction
ROLLBACK Statement -- roll back (rescind) all changes for the current transaction

Transaction Overview

A database transaction is a larger unit that frames multiple SQL statements. A transaction ensures that the action of the framed statements is *atomic* with respect to recovery.

A SQL Modification Statement has limited effect. A given statement can only directly modify the contents of a single table (Referential Integrity effects may cause indirect modification of other tables.) The upshot is that operations which require modification of several tables must involve multiple modification statements. A classic example is a bank operation that transfers funds from one type of account to another, requiring updates to 2 tables. Transactions provide a way to group these multiple statements in one atomic unit.

In SQL92, there is no BEGIN TRANSACTION statement. A transaction begins with the execution of a SQL-Data statement when there is no current transaction. All subsequent SQL-Data statements until COMMIT or ROLLBACK become part of the transaction. Execution of a COMMIT Statement or ROLLBACK Statement completes the current transaction. A subsequent SQL-Data statement starts a new transaction.

In terms of direct effect on the database, it is the SQL Modification Statements that are the main consideration since they change data. The total set of changes to the database by the modification statements in a transaction are treated as an atomic unit through the actions of the transaction. The set of changes either:

Is made fully persistent in the database through the action of the COMMIT Statement, orHas no persistent effect whatever on the database, through:

- the action of the ROLLBACK Statement,
- abnormal termination of the client requesting the transaction, or
- abnormal termination of the transaction by the DBMS. This may be an action by the system (deadlock resolution) or by an administrative agent, or it may be an abnormal termination of the DBMS itself. In the latter case, the DBMS must roll back any active transactions during recovery.

The DBMS *must* ensure that the effect of a transaction is not partial. All changes in a transaction must be made persistent, or no changes from the transaction must be made persistent.

Transaction Isolation

In most cases, transactions are executed under a client connection to the DBMS. Multiple client connections can initiate transactions at the same time. This is known as concurrent transactions.

In the relational model, each transaction is completely isolated from other active transactions. After initiation, a transaction can only see changes to the database made by transactions *committed* prior to starting the new transaction. Changes made by concurrent transactions are not seen by SQL DML query and modification statements. This is known as full isolation or *Serializable* transactions.

SQL92 defines Serializable for transactions. However, full serialized transactions can impact performance. For this reason, SQL92 allows additional isolation modes that reduce the isolation between concurrent transactions. SQL92 defines 3 other isolation modes, but support by existing DBMSs is often incomplete and doesn't always match the SQL92 modes. Check the documentation of your DBMS for more details.

SQL-Schema Statements in Transactions

The 3rd type of SQL Statements - SQL-Schema Statements, may participate in the transaction mechanism. SQL-Schema statements can either be:

included in a transaction along with SQL-Data statements,
required to be in separate transactions, or
ignored by the transaction mechanism (can't be rolled back).

SQL92 leaves the choice up to the individual DBMS. It is *implementation defined* behavior.

COMMIT Statement

The COMMIT Statement terminates the current transaction and makes all changes under the transaction persistent. It *commits* the changes to the database. The COMMIT statement has the following general format:

COMMIT [WORK]

WORK is an optional keyword that does not change the semantics of COMMIT.

ROLLBACK Statement

The ROLLBACK Statement terminates the current transaction and rescinds all changes made under the transaction. It *rolls back* the changes to the database. The ROLLBACK statement has the followinggeneral format:

ROLLBACK [WORK]

WORK is an optional keyword that does not change the semantics of ROLLBACK.

SQL-Schema Statements

SQL-Schema Statements provide maintenance of catalog objects for a schema -- tables, views andprivileges. This subset of SQL is also called the Data Definition Language for SQL (SQL DDL).
There are 6 SQL-Schema Statements:

CREATE TABLE Statement -- create a new base table in the current schema
CREATE VIEW Statement -- create a new view table in the current schema DROP
TABLE Statement -- remove a base table from the current schema

DROP VIEW Statement -- remove a view table from the current schema

GRANT Statement -- grant access privileges for objects in the current schema to other users
REVOKE Statement -- revoke previously granted access privileges for objects in the currentschema from other users

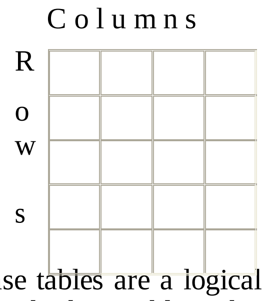
Schema Overview

A relational database contains a *catalog* that describes the various elements in the system. The catalog divides the database into sub-databases known as schemas. Within each schema are database objects -- tables, views and privileges.

The catalog itself is a set of tables with its own schema name - *definition_schema*. Tables in the catalog cannot be modified directly. They are modified indirectly with SQL-Schema statements.

Tables

The database table is the root structure in the relational model and in SQL. A table (called a *relation* in relational) consists of rows and columns. In relational, rows are called *tuples* and columns are called *attributes*. Tables are often displayed in a flat format, with columns arrayed horizontally and rows vertically:



Database tables are a logical structure with no implied physical characteristics. Primary among the various logical tables is the *base* table. A base table is persistent and self contained, that is, all data is part of the table itself with no information dynamically *derived* from other tables.

A table has a fixed set of columns. The columns in a base table are not accessed positionally but by name, which must be unique among the columns of the table. Each column has a defined data type, and the value for the column in each row must be from the defined data type or *null*. The columns of a table are accessed and identified by name.

A table has 0 or more rows. A row in a base table has a value or *null* for each column in the table. The rows in a table have no defined ordering and are not accessed positionally. A table row is accessed and identified by the values in its columns.

In SQL92, base tables can have duplicate rows (rows where each column has the same value or *null*). However, the relational model does not recognize tables with duplicate rows as valid base tables (*relations*). The relational model requires that each base table have a unique identifier, known as the *Primary Key*. The primary key for a table is a designated set of columns which have a unique value for each table row. For a discussion of Primary Keys, see Entity Integrity under CREATE TABLE below.

A base table is defined using the CREATE TABLE Statement. This statement places the table description in the catalog and initializes an internal entity for the actual representation of the base table.
Example base table - *s*:

sno	**name**	**city**
S1	Pierre	Paris
S2	John	London
S3	Mario	Rome

The *s* table records suppliers. It has 3 defined columns:

sno -- supplier number, an unique identifier that is the primary keyname
-- the name of the supplier
city -- the city where the supplier is located

At the current time, there are 3 rows.

Other types of tables in the system are *derived* tables. SQL-Data statements use internally derived tables in computing results. A query is in fact a derived table. For instance, the query operator - Union, combines two derived tables to produce a third one. Much of the power of SQL comes from the fact that its higher level operations are performed on tables and produce a table as their result.

Derived tables are less constrained than base tables. Column names are not required and need not be unique. Derived tables may have duplicate rows. *Views* are a type of derived table that are cataloged in the database.

Views

A view is a derived table registered in the catalog. A view is defined using a SQL query. The view is dynamically derived, that is, its contents are *materialized* for each use. Views are added to the catalog withthe CREATE VIEW Statement.

Once defined in the catalog, a view can substitute for a table in SQL-Data statements. A view name can be used instead of a base table name in the FROM clause of a SELECT statement. Views can also be the subject of a modification statement with some restrictions.

A SQL Modification Statement can operate on a view if it is an *updatable view*. An updatable view has the following restrictions on its defining query:

- The query FROM clause can reference a single table (or view)The single table in the FROM clause must be:
  - a base table,
  - a view that is also an *updatable view*, or
  - a nested query that is updatable, that is, it follows the rules for an updatable view query.The query must be a basic query, not a:
  - Grouping Query,
  - Aggregate Query, or
  - Union Query.
- The select list cannot contain:
  - the DISTINCT specifier,
  - an Expression, or
  - duplicate column references

Subqueries are acceptable in updatable views but cannot reference the underlying base table for the view's FROM clause.

Privileges

SQL92 defines a SQL-agent as an *implementation-dependent* entity that causes the execution of SQL statements. Prior to execution of SQL statements, the SQL-agent must establish an *authorization identifier* for database access. An authorization identifier is commonly called a *user name*.

A DBMS user may access database objects (tables, columns, views) as allowed by the *privileges* assigned to that specific *authorization identifier*. Access privileges may be granted by the system (automatic) or by other users. System granted privileges include:

- All privileges on a table to the *user* that created the table. This includes the privilege to *grant* privileges on the table to other users.
- SELECT (readonly) privilege on the catalog (the tables in the schema - *definition_schema*). This isgranted to all users.

User granted privileges cover privileges to access and modify tables and their columns. Privileges can begranted for specific SQL-Data Statements -- SELECT, INSERT, UPDATE, DELETE.

CREATE TABLE Statement

The CREATE TABLE Statement creates a new base table. It adds the table description to the catalog. Abase table is a logical entity with persistence. The logical description of a base table consists of:

- Schema -- the logical database *schema* the table resides in
- Table Name -- a name unique among tables and views in the Schema
- Column List -- an ordered list of column declarations (name, data type)
- Constraints -- a list of constraints on the contents of the table

The CREATE TABLE Statement has the following general format:

CREATE TABLE table-name ({column-descr|constraint} [,{column-descr|constraint}]...)*table-name* is the new name for the table. *column-descr* is a column declaration. *constraint* is a *table* constraint.

The column declaration can include optional *column* constraints. The declaration has the following generalformat:

column-name data-type [column-constraints]

column-name is the name of the column and must be unique among the columns of the table. *data-type* declares the type of the column. Data types are described below. *column-constraints* is an optional list of column constraints with no separators.

Constraints

Constraint specifications add additional restrictions on the contents of the table. They are automatically *enforced* by the DBMS. The *column* constraints are:

- NOT NULL -- specifies that the column can't be set to *null*. If this constraint is not specified, the column is *nullable*, that is, it can be set to *null*. Normally, primary key columns are declared as NOT NULL.
- PRIMARY KEY -- specifies that this column is the only column in the primary key. There can be only one primary key declaration in a CREATE TABLE. For primary keys with multiple columns, use the PRIMARY KEY *table* constraint. See Entity Integrity below for a detailed description of primary keys.
- UNIQUE -- specifies that this column has a unique value or *null* for all rows of the table. REFERENCES -- specifies that this column is the only column in a foreign key. For foreign keyswith multiple columns, use the FOREIGN KEY *table* constraint. See Referential Integrity below for a detailed description of primary keys.
- CHECK -- specifies a user defined constraint on the table. See the table constraint - CHECK,below.

The *table* constraints are:

- PRIMARY KEY -- specifies the set of columns that comprise the primary key. There can be only one primary key declaration in a CREATE TABLE Statement. See Entity Integrity below for a detailed description of primary keys.
- UNIQUE -- specifies that a set of columns have unique values (or *nulls*) for all rows in the table. The UNIQUE specifier is followed by a parenthesized list of column names, separated by commas. FOREIGN KEY -- specifies the set of columns in a foreign key. See Referential Integrity below for a detailed description of foreign keys.
- CHECK -- specifies a user defined constraint, known as a *check condition*. The CHECK specifier isfollowed by a predicate enclosed in parentheses. For Intermediate Level SQL92, the CHECK predicate can only reference columns from the current table row, with no subqueries. ManyDBMSs support subqueries in the check predicate.

  The check predicate must evaluate to true before a modification or addition of a row takes place. The check is effectively made on the contents of the table after the modification. For INSERT Statements, the predicate is evaluated as if the INSERT row were added to the table. For UPDATE Statements, the predicate is evaluated as if the row were updated. For DELETE Statements, the predicate is evaluated as if the row were deleted (Note: A check predicate is only useful for DELETE if a subquery is used.)

Data Type

This subsection describes *data type* specifications. The data type categories are:

- Character (String) -- fixed or variable length character strings. The character set is implementationdefined but often defaults to ASCII.
- Numeric -- values representing numeric quantities. Numeric values are divided into these two broad categories:
  - Exact (also known as *fixed-point*) -- Exact numeric values have a fixed number of digits tothe left of the decimal point and a fixed number of digits to the right (the scale). The totalnumber of digits on both sides of the decimal are the precision. A special subset of exact numeric types with a scale of 0 is called *integer*.
  - Approximate (also known as *floating-point*) -- Approximate numeric values that have afixed precision (number of digits) but a *floating* decimal point.

All numeric types are signed.

- Datetime -- Datetime values include calendar and clock values (Date, Time, Timestamp) and intervals. The datetime types are:
  - Date -- calendar date with year, month and day
  - Time -- clock time with hour, minute, second and fraction of second, plus a timezone component (adjustment in hours, minutes)
  - Timestamp -- combination calendar date and clock time with year, month, day, hour,minute, second and fraction of second, plus a timezone component (adjustment in hours, minutes)
  - Interval -- intervals represent time and date intervals. They are signed. An interval value cancontain a subset of the interval fields, for example - hour to minute, year, day to second. Interval types are subdivided into:
    - year-month intervals -- may contain years, months or combination years/months value.
    - day-time intervals -- days, hours, minutes, seconds, fractions of second.

Data type declarations have the following general format:

Character (String)

CHAR [(length)]

CHARACTER [(length)]

VARCHAR (length)

CHARACTER VARYING (length)

length specifies the number of characters for fixed size strings (CHAR, CHARACTER); spaces are supplied for shorter strings. If *length* is missing for fixed size strings, the default length is 1. For variable size strings (VARCHAR, CHARACTER VARYING), *length* is the maximum size of the string. Strings exceeding *length* are truncated on the right.

Numeric

SMALLINT
INT
INTEGER

The integer types have default binary precision -- 15 for SMALLINT and 31 for INT, INTEGER.

NUMERIC (precision [, scale])
DECIMAL (precision [, scale])

Fixed point types have a decimal precision (total number of digits) and scale (which cannot exceed the precision). The default scale is 0. NUMERIC scales must be represented exactly. DECIMAL values can be stored internally with a larger scale (implementation defined).

FLOAT [(precision)]
REAL
DOUBLE

The floating point types have a binary precision (maximum significant binary digits).Precision values are implementation dependent for REAL and DOUBLE, although thestandard states that the default precision for DOUBLE must be *larger* than for REAL.FLOAT also uses an implementation defined default for precision (commonly this is the same as for REAL), but the binary *precision* for FLOAT can be explicit.

Datetime DATE
TIME [(scale)] [WITH TIME ZONE]
TIMESTAMP [(scale)] [WITH TIME ZONE]

TIME and TIMESTAMP allow an optional seconds fraction (*scale*). The default *scale* for TIME is 0, for TIMESTAMP 6. The optional WITH TIME ZONE specifier indicates that the timezone adjustment is stored with the value; if omitted, the current system timezone is assumed.

INTERVAL interval-qualifier

Interval Qualifier

An interval qualifier defines the specific type of an interval value. The *qualifier* for an interval type declares the sub-fields that comprise the interval, the precision of the highest (left-most) sub-field and the scale of the SECOND sub-field (if any).

Intervals are divided into sub-types -- year-month intervals and day-time intervals. Year-month intervals can only contain the sub-fields - year and month. Day-time intervals can contain day, hour, minute, second. The interval qualifier has the following formats:

YEAR [(precision)] [TO MONTH]

MONTH [(precision)]

{DAY|HOUR|MINUTE} [(precision)] [TO SECOND [(scale)]]DAY

[(precision)] [TO {HOUR|MINUTE}]

HOUR [(precision)] [TO MINUTE]

SECOND [(precision [, scale])]

The default *precision* is 2. The default *scale* is 6.

Entity Integrity

As mentioned earlier, the relational model requires that each base table have a Primary Key. SQL92, on the other hand, allows a table to created without a primary key. The advice here is to create all tables with primary keys.

A primary key is a constraint on the contents of a table. In relational terms, the primary key maintains *Entity Integrity* for the table. It constrains the table as follows,

For a given row, the set of values for the primary key columns must be unique from all other rowsin the table,
No primary key column can contain a *null*, and
A table can have only one primary key (set of primary key columns).

Note: SQL92 does not require the second restriction on *nulls* in the primary key. However, it is requiredfor a relational system.

Entity Integrity (Primary Keys) is enforced by the DBMS and ensures that every row has a proper uniqueidentifier. The contents of any column in the table with Entity Integrity can be uniquely accessed with 3 pieces of information:

- table identifier
- primary key value
- column name

This capability is crucial to a relational system. Having a clear, consistent identifier for table rows (and their columns) distinguishes relational systems from all others. It allows the establishment of relationships between tables, also crucial to relational systems. This is discussed below under Referential Integrity.

The primary key constraint in the CREATE STATEMENT has two forms. When the primary key consists of a single column, it can be declared as a *column constraint*, simply - PRIMARY KEY, attached to the column descriptor. For example:

sno VARCHAR(5) NOT NULL PRIMARY KEY

As a *table constraint*, it has the following format:

PRIMARY KEY (column-1 [, column-2] ...)

column-1 and *column-2* are the names of the columns of the primary key. For example,

PRIMARY KEY (sno, pno)

The order of columns in the primary key is not significant, except as the default order for the *FOREIGN KEY* table constraint.

Referential Integrity

Foreign keys provide relationships between tables in the database. In relational, a foreign key in a table is aset of columns that reference the primary key of another table. For each row in the referencing table, the foreign key must match an existing primary key in the referenced table. The enforcement of this constraint is known as *Referential Integrity*.

Referential Integrity requires that:

- The columns of a foreign key must match in number and type the columns of the primary key in the *referenced* table.
- The values of the foreign key columns in each row of the *referencing* table must match the valuesof the corresponding primary key columns for a row in the *referenced* table.

The one exception to the second restriction is when the foreign key columns for a row contain *nulls*. Since primary keys should not contain *nulls*, a foreign key with *nulls* cannot match any row in the referenced table. However, a row with a foreign key of all *nulls* (all foreign key columns contain *null*) is allowed in the *referencing* table. It is a *null* reference.

Like other constraints, the *referential integrity* constraint restricts the contents of the referencing table, but it also may in effect restrict the contents of the *referenced* table. When a row in a table is referenced (through its primary key) by a foreign key in a row in another table, operations that affect its primary key columns have side-effects and may restrict the operation. Changing the primary key of or deleting a row which has referencing foreign keys would violate the referential integrity constraints on the referencing table if allowec to proceed. This is handled in two ways,

- The referenced table is restricted from making the change (and violating referential integrity in thereferencing table), or
- Rows in the referencing table are modified so the referential integrity constraint is maintained.

These actions are controlled by the *referential integrity* effects declarations, called referential triggers bySQL92. The referential integrity effect actions defined for SQL are:

- NO ACTION -- the change to the referenced (primary key) table is not performed. This is thedefault.

- CASCADE -- the change to the referenced table is propagated to the referencing (foreign key)table.
- SET NULL -- the foreign key columns in the referencing table are set to *null*.

Update and delete have separate action declarations. For CASCADE, update and delete also operate differently:

- For update (the primary key column values have been modified), the corresponding foreign keycolumns for referencing rows are set to the new values.
- For delete (the primary key row is deleted), the referencing rows are deleted.

A referential integrity constraint in the CREATE STATEMENT has two forms. When the foreign keyconsists of a single column, it can be declared as a *column constraint*, like:

column-descr REFERENCES references-specification

As a *table constraint*, it has the following format:

FOREIGN KEY (column-list) REFERENCES references-specification

column-list is the referencing table columns that comprise the foreign key. Commas separate column names in the list. Their order must match the explicit or implicit column list in the *references-specification.* The *references-specification* has the following format:

```
table-2 [ ( referenced-columns ) ]
        [ ON UPDATE { CASCADE | SET NULL | NO ACTION }][ ON
        DELETE { CASCADE | SET NULL | NO ACTION }]
```

The order of the ON UPDATE and ON DELETE clauses may be *reversed*. These clauses declare the effect action when the referenced primary key is updated or deleted. The default for ON UPDATE and ON DELETE is NO ACTION.

table-2 is the referenced table name (primary key table). The optional *referenced-columns* list the columns of the referenced primary key. Commas separate column names in the list. The default is the primary key list in declaration order.

Contrary to the relational model, SQL92 allows foreign keys to reference any set of columns declared with the *UNIQUE* constraint in the referenced table (even when the table has a primary key). In this case, the *referenced-columns* list is required.

Example table constraint for referential integrity (for the *sp* table):

```
FOREIGN KEY (sno)
REFERENCES s(sno)
ON DELETE NO ACTION
ON UPDATE CASCADE
```

CREATE TABLE Examples

Creating the example tables:

```
CREATE TABLE s
(sno VARCHAR(5) NOT NULL PRIMARY KEY,
 name VARCHAR(16),
 city VARCHAR(16)
)

CREATE TABLE p
(pno VARCHAR(5) NOT NULL PRIMARY KEY,
 descr VARCHAR(16),
 color VARCHAR(8)
)

CREATE TABLE sp
(sno VARCHAR(5) NOT NULL REFERENCES s, pno
 VARCHAR(5) NOT NULL REFERENCES p,
 qty INT,
 PRIMARY KEY (sno, pno)
)
```

Create for *sp* with a constraint that the qty column can't be negative:

```
CREATE TABLE sp
(sno VARCHAR(5) NOT NULL REFERENCES s, pno
 VARCHAR(5) NOT NULL REFERENCES p, qty INT
 CHECK (qty IS NULL OR qty >= 0),
 PRIMARY KEY (sno, pno)
)
```

CREATE VIEW Statement

The CREATE VIEW statement creates a new database view. A view is effectively a SQL query stored in the catalog. The CREATE VIEW has the following general format:

```
CREATE VIEW view-name [ ( column-list ) ] AS query-1
        [ WITH [CASCADED|LOCAL] CHECK OPTION ]
```

view-name is the name for the new view. *column-list* is an optional list of names for the columns of the view, comma separated. *query-1* is any SELECT statement without an ORDER BY clause. The optional WITH CHECK OPTION clause is a constraint on *updatable* views.

column-list must have the same number of columns as the select list in *query-1*. If *column-list* is omitted,all items in the select list of *query-1* must be named. In either case, duplicate column names are not allowed for a view.

The optional WITH CHECK OPTION clause only applies to *updatable* views. It affects SQL INSERT andUPDATE statements. If WITH CHECK OPTION is specified, the WHERE predicate for *query-1* must evaluate to true for the added row or the changed row.

The CASCADED and LOCAL specifiers apply when the underlying table for *query-1* is another view. CASCADED requests that WITH CHECK OPTION apply to *all* underlying views (to any level.) LOCAL requests that the current WITH CHECK OPTION apply only to this view. LOCAL is the default.

CREATE VIEW Examples

Parts with suppliers:

```
CREATE VIEW supplied_parts AS
        SELECT *
        FROM p
        WHERE pno IN (SELECT pno FROMsp)
     WITH CHECK OPTION
```

Access example:

```
SELECT * FROM supplied_parts
```

pno	descr	color
P1	Widget	Red
P2	Widget	Blue

Joined view:

```
CREATE VIEW part_locations (part, quantity, location) AS
        SELECT pno, qty, city
        FROM sp, s
        WHERE sp.sno = s.sno
```

Access examples:

```
SELECT * FROM part_locations
```

part	quantity	location
P1	NULL	Paris
P1	200	London

P1	1000	Rome
P2	200	Rome

```
SELECT part, quantity
FROM part_locations
WHERE location = 'Rome'
```

part	quantity
P1	1000
P2	200

DROP TABLE Statement

The DROP TABLE Statement removes a previously created table and its description from the catalog. It has the following general format:

DROP TABLE table-name {CASCADE|RESTRICT}

table-name is the name of an existing base table in the current schema. The CASCADE and RESTRICT specifiers define the disposition of other objects dependent on the table. A base table may have two typesof dependencies:

- A view whose query specification references the *drop* table.
- Another base table that references the *drop* table in a constraint - a CHECK constraint or REFERENCES constraint.

RESTRICT specifies that the table not be dropped if any dependencies exist. If dependencies are found, anerror is returned and the table isn't dropped.

CASCADE specifies that any dependencies are removed before the drop is performed:

- Views that reference the base table are dropped, and the sequence is repeated for their dependencies.
- Constraints in other tables that reference this table are dropped; the constraint is dropped but thetable retained.

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- A view whose query specification references the *drop* view.
- A base table that references the *drop* view in a constraint - a CHECK constraint.

RESTRICT specifies that the view not be dropped if any dependencies exist. If dependencies are found, anerror is returned and the view isn't dropped.

CASCADE specifies that any dependencies are removed before the drop is performed:

- Views that reference the *drop* view are dropped, and the sequence is repeated for their dependencies.
- Constraints in base tables that reference this view are dropped; the constraint is dropped but thetable retained.