# CSCI 4333 Section 2 Design of DB Systems

## 2/12/2024 (self - annotation)

**The Relational Model**

by K. Yue

**1. Introduction**

**1.1 Data Model**

* There are many *data models* used by database systems.
* The **data models** of database systems define how data is organized, structured, connected, processed, and queried in the databases.
* It is important to recognize the basic data structures used by these models.
* Examples:
  1. Relational model: set-theoretic relation/table:
     + Set: unduplicated element; unordered. {1,2} = {2,1} = {1,1,1,2,2}
  2. Excel: table, and to be more exact, a two-dimensional array: ordered, duplicated elements [1,2] <> [2,1] <> [1,1,2]
  3. Hierarchical model (old): tree
  4. Network model (old): graph
  5. Object-oriented model: directed graph
  6. XML: tree with many different types of nodes, plus sets of attributes.
  7. Cassandra: columnar or wild column model
  8. MongoDB: document model
  9. Neo4J: graph model

**1.2 The Relational Model: an introduction**

* The basic relational data model in layman terms:
  + A database is composed of a collection of *tables* (relations).
  + A table contains many *rows* (tuples) and *columns* (attributes/fields).
  + Each row contains many *column values*.
  + Every row of a table has the same set of columns.
  + Values of the same column have the same data *type*.
  + A *candidate key* of a table is a *minimal unique identifier* of a row in the table.
  + A *primary key* is a selected candidate key (for storing the table).
  + *Alternative/secondary keys* are candidate keys not selected as the primary key.
  + A *foreign key* of a relation refers to a primary key of another relation (known as the parent or refered table).

More theoretically:

* The (theoretical) relational model is based on the concept of a relation.
* It is a *set-theoretic* model: the definitions are based on mathematical sets.
* If you are note familar with set theory, read about it. This is a basic, short, good, and good-enough introduction: <https://www.ucl.ac.uk/~ucahmto/0005_2021/Ch2.S1.html> (note that in the set builder form, the author used ":" to represent "such that". We usually use "|" instead.)
* Note that practical DBMS do not implement the pure relational model.
* In the theoretical relational model:
  1. An *attribute* (*column/field*) is a name.
  2. A *domain* is a *set* of values an attribute can take.
     1. It is the set of values of the*data type* of the attribute.
     2. The value of an attribute should be *atomic* (cannot be divided into smaller components with individual meanings):
        1. If all attributes of a relation are atomic, the relation is said to be in *First Normal Form*.
     3. *Null* may or may not be an acceptable value for an attribute.
  3. A *relation schema*, R, is a *set* of attributes A1, A2,…,An with their domains D1, D2,…, Dn.

A screenshot of a computer

Description automatically generated

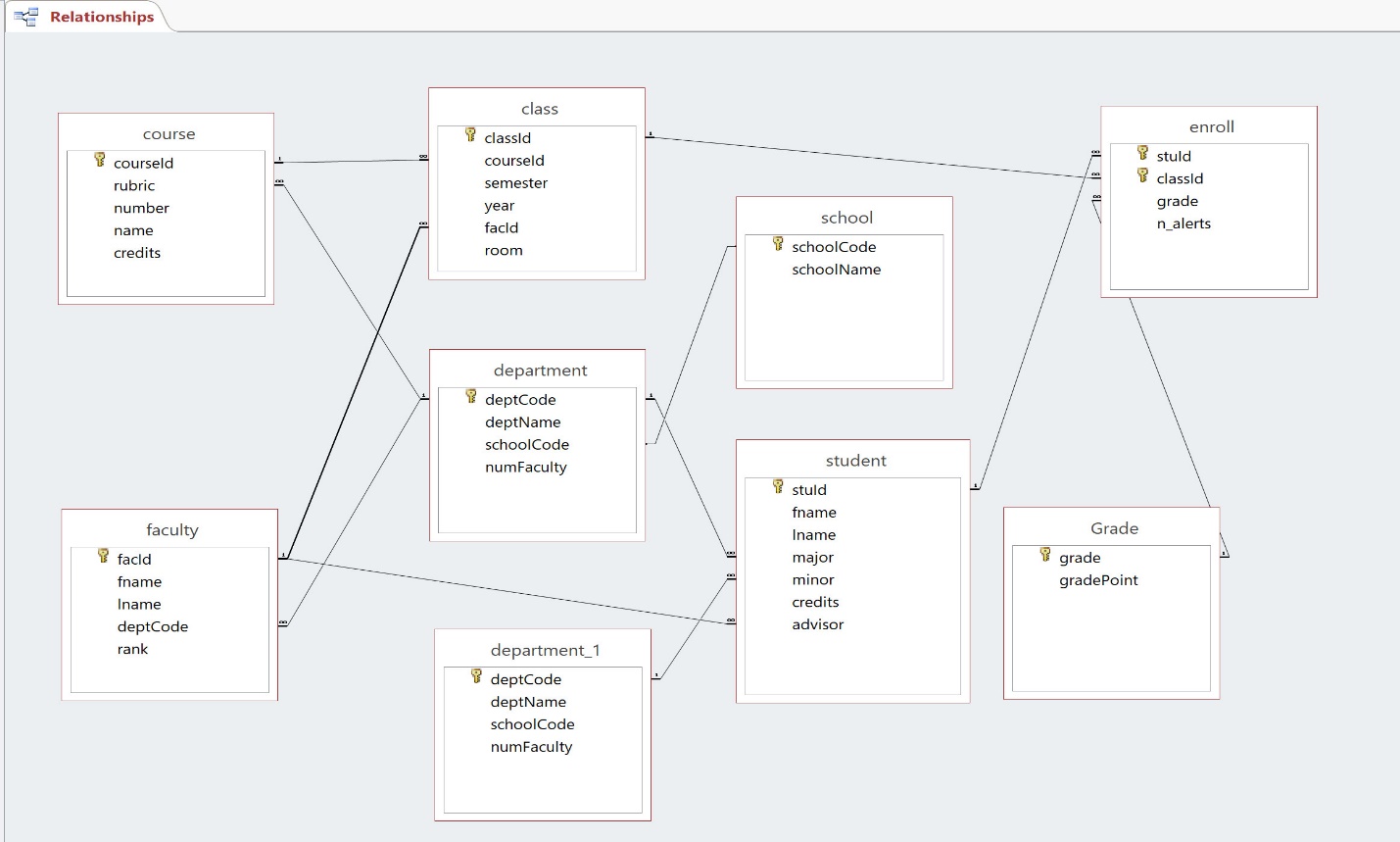
* 1. A *tuple* (*row*) is a *set* of *mapping* of a *set* of attributes to a *set* of values: Ai -> di where di ∈ Di, for i = 1 to n (∈: belongs to)
  2. A *relation* (*instance*) is a set of tuples.
  3. The *degree* (or *arity*) of a relation is the number of attributes in its schema.
* Some advantages of the *relational model* and relational DBMS (as compared to other databases)
  1. Strong mathematical foundation
  2. Simple
  3. Strong design theory
  4. Strong support of data integrity and consistency
  5. Strong support of transactions
  6. Strong industrial support and community
  7. High popularity
* Some disadvantages of the relational model and relational DBMS:
  1. The data model may not match the problem requirements well.
  2. Impedance mismatch with object-oriented models.
  3. Do not scale well.
  4. Structured data ay be too restrictive.

***Example:***

Toyu: A drastically simplified university: toyu

*Relationship* Diagram (in MS Access):

1. Each rectange is a relation, not a class.
2. Relationships are usually between foreign keys and refered primary keys.



A version of an ER Diagram (created by using MySQL Workbench).

1. This version of ER diagram has more commonality with Access relationship diagram.
2. A rectangle is a relation.
3. In other versions of ER diagrams, a rectangle is an entity (similar to a class).

A computer screen shot of a diagram

Description automatically generated

MS Access: [toyu.accdb](https://dcm.uhcl.edu/yue/courses/joinDB/Spring2024/notes/access/toyu.accdb)

Toyu in MySQL: [createtoyu.sql.txt](https://dcm.uhcl.edu/yue/courses/joinDB/Spring2024/notes/query/createtoyu.sql.txt)

CREATE TABLE IF NOT EXISTS Class (  
    classId     INT NOT NULL,  
    courseId    INT NOT NULL,  
    semester    VARCHAR(10) NOT NULL,  
    year        DECIMAL(4,0) NOT NULL,  
    facId       INT NOT NULL,  
    room        VARCHAR(6) NULL,  
    CONSTRAINT Class\_classId\_pk PRIMARY KEY (classId),  
    CONSTRAINT Class\_courseId\_fk FOREIGN KEY (courseId)  
        REFERENCES Course(courseId) ON DELETE CASCADE,  
    CONSTRAINT Class\_facId\_fk FOREIGN KEY (facId)  
        REFERENCES Faculty (facId) ON DELETE CASCADE  
);

INSERT INTO Class(classId, courseId, semester, year, facId, room) VALUES  
    (10000,2000,'Fall',2019,1011,'D241'),  
    (10001,2001,'Fall',2019,1011,'D242'),  
    (10002,2002,'Fall',2019,1012,'D136'),  
    (10003,2020,'Fall',2019,1014,'D241'),  
    (10004,2021,'Fall',2019,1014,'D241'),  
    (10005,2040,'Fall',2019,1015,'D237'),  
    (10006,2041,'Fall',2019,1019,'D217'),  
    (10007,2060,'Fall',2019,1020,'B101'),  
    (10008,2080,'Fall',2019,1018,'D241'),  
    (11000,2000,'Spring',2020,1011,'D241'),  
    (11001,2001,'Spring',2020,1012,'D242'),  
    (11002,2002,'Spring',2020,1013,'D136'),  
    (11003,2020,'Spring',2020,1016,'D217'),  
    (11004,2061,'Spring',2020,1018,'B101');

MariaDB [toyu]> SELECT \* FROM class;  
+---------+----------+----------+------+-------+------+  
| classId | courseId | semester | year | facId | room |  
+---------+----------+----------+------+-------+------+  
|   10000 |     2000 | Fall     | 2019 |  1011 | D241 |  
|   10001 |     2001 | Fall     | 2019 |  1011 | D242 |  
|   10002 |     2002 | Fall     | 2019 |  1012 | D136 |  
|   10003 |     2020 | Fall     | 2019 |  1014 | D241 |  
|   10004 |     2021 | Fall     | 2019 |  1014 | D241 |  
|   10005 |     2040 | Fall     | 2019 |  1015 | D237 |  
|   10006 |     2041 | Fall     | 2019 |  1019 | D217 |  
|   10007 |     2060 | Fall     | 2019 |  1020 | B101 |  
|   10008 |     2080 | Fall     | 2019 |  1018 | D241 |  
|   11000 |     2000 | Spring   | 2020 |  1011 | D241 |  
|   11001 |     2001 | Spring   | 2020 |  1012 | D242 |  
|   11002 |     2002 | Spring   | 2020 |  1013 | D136 |  
|   11003 |     2020 | Spring   | 2020 |  1016 | D217 |  
|   11004 |     2061 | Spring   | 2020 |  1018 | B101 |  
+---------+----------+----------+------+-------+------+  
14 rows in set (0.005 sec)

A tuple/row: {classId: 10004, courseId: 2021, semester: 'Fall', year: 2019, facId: 1014, room: 'D241'}. Note that it is a set of mappings from attribute names to attribute values.

It can also be represented as:

{classId: 10004, facId: 1014, room: 'D241', semester: 'Fall', year: 2019, courseId: 2021}

or

{10004, 2021, 'Fall', 2019, 1014, 'D241'} if the attribute names are assumed.

or using a more computer science-style notation.

(10004, 2021, 'Fall', 2019, 1014, 'D241')

Identify some examples of the database terms in the class table above as much as possible.

* Some important properties of a relation:
  + There is no duplicate tuple.
    - Because a relation is a set.
    - Consequence: the relational model does not support 'object identity' directly.
  + The relational model is known to be '*value-oriented*':
    - A row is a set of attribute values.
    - Two rows with the same values of all attributes are the same row.
    - Cannot store two duplicate rows in a table.
  + The terms tables and relations are not exactly the same. "Table" is a more generic term.
* Tuples within a relation are unordered.
  + Changing the order of displaying the tuples does not change (the meaning of) the relation.
* Attributes within a relation schema are unordered.
  + Changing the order of the attributes within a relation schema does not change the information stored in the relation.

Example:

+---------+----------+----------+------+-------+------+  
| classId | courseId | semester | year | facId | room |  
+---------+----------+----------+------+-------+------+  
|   10000 |     2000 | Fall     | 2019 |  1011 | D241 |  
|   10001 |     2001 | Fall     | 2019 |  1011 | D242 |  
|   10002 |     2002 | Fall     | 2019 |  1012 | D136 |  
|   10003 |     2020 | Fall     | 2019 |  1014 | D241 |  
|   10004 |     2021 | Fall     | 2019 |  1014 | D241 |  
|   10005 |     2040 | Fall     | 2019 |  1015 | D237 |  
|   10006 |     2041 | Fall     | 2019 |  1019 | D217 |  
|   10007 |     2060 | Fall     | 2019 |  1020 | B101 |  
|   10008 |     2080 | Fall     | 2019 |  1018 | D241 |  
|   11000 |     2000 | Spring   | 2020 |  1011 | D241 |  
|   11001 |     2001 | Spring   | 2020 |  1013 | D242 |  
|   11002 |     2002 | Spring   | 2020 |  1013 | D136 |  
|   11003 |     2020 | Spring   | 2020 |  1016 | D217 |  
|   11004 |     2061 | Spring   | 2020 |  1018 | B101 |  
+---------+----------+----------+------+-------+------+

and

+---------+------+----------+----------+------+-------+  
| classId | year | semester | courseId | room | facId |  
+---------+------+----------+----------+------+-------+  
|   11004 | 2020 | Spring   |     2061 | B101 |  1018 |  
|   10007 | 2019 | Fall     |     2060 | B101 |  1020 |  
|   10002 | 2019 | Fall     |     2002 | D136 |  1012 |  
|   11002 | 2020 | Spring   |     2002 | D136 |  1013 |  
|   11003 | 2020 | Spring   |     2020 | D217 |  1016 |  
|   10006 | 2019 | Fall     |     2041 | D217 |  1019 |  
|   10005 | 2019 | Fall     |     2040 | D237 |  1015 |  
|   10000 | 2019 | Fall     |     2000 | D241 |  1011 |  
|   11000 | 2020 | Spring   |     2000 | D241 |  1011 |  
|   10003 | 2019 | Fall     |     2020 | D241 |  1014 |  
|   10004 | 2019 | Fall     |     2021 | D241 |  1014 |  
|   10008 | 2019 | Fall     |     2080 | D241 |  1018 |  
|   10001 | 2019 | Fall     |     2001 | D242 |  1011 |  
|   11001 | 2020 | Spring   |     2001 | D242 |  1013 |  
+---------+------+----------+----------+------+-------+  
  
  
store the same information.

The second table can be obtained in SQL by:

SELECT classId, year, semester, courseId, room, facId  
FROM class  
ORDER BY room, facId;

**2. Null values**

* Generally used for representing missing information.
* SQL DBSM provide a method to test whether a value is null or not (IS NULL and IS NOT NULL).

***Example:***

-- students with no advisor  
SELECT s.\*  
FROM student AS s  
WHERE s.advisor IS NULL;  
  
-- Show all students with a declared minor.  
SELECT DISTINCT s.\*  
FROM student AS s  
WHERE s.minor IS NOT NULL;  
  
-- Show enrollment without a n\_alerts value.  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts IS NULL;  
  
Result:

MariaDB [toyu]> -- students with no advisor  
MariaDB [toyu]> SELECT s.\*  
    -> FROM student AS s  
    -> WHERE s.advisor IS NULL;  
+--------+-----------+-------+-------+-------+------+---------+  
| stuId  | fname     | lname | major | minor | ach  | advisor |  
+--------+-----------+-------+-------+-------+------+---------+  
| 100003 | Catherine | Lim   | ITEC  | CINF  |   20 |    NULL |  
| 100007 | Ben       | Zico  | NULL  | NULL  |   16 |    NULL |  
| 100008 | Bill      | Ching | ARTS  | NULL  |   90 |    NULL |  
+--------+-----------+-------+-------+-------+------+---------+  
3 rows in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- Show all students with a declared minor.  
MariaDB [toyu]> SELECT DISTINCT s.\*  
    -> FROM student AS s  
    -> WHERE s.minor IS NOT NULL;  
+--------+-----------+---------+-------+-------+------+---------+  
| stuId  | fname     | lname   | major | minor | ach  | advisor |  
+--------+-----------+---------+-------+-------+------+---------+  
| 100000 | Tony      | Hawk    | CSCI  | CINF  |   40 |    1011 |  
| 100001 | Mary      | Hawk    | CSCI  | CINF  |   35 |    1011 |  
| 100002 | David     | Hawk    | CSCI  | ITEC  |   66 |    1012 |  
| 100003 | Catherine | Lim     | ITEC  | CINF  |   20 |    NULL |  
| 100005 | Linda     | Johnson | CINF  | ENGL  |   13 |    1015 |  
| 100006 | Lillian   | Johnson | CINF  | ITEC  |   18 |    1016 |  
| 100009 | Linda     | King    | ARTS  | CSCI  |  125 |    1018 |  
+--------+-----------+---------+-------+-------+------+---------+  
7 rows in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- Show enrollment without a n\_alerts value.  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts IS NULL;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100001 |   10000 | NULL  |     NULL |  
| 100005 |   10003 | NULL  |     NULL |  
| 100004 |   10004 | B+    |     NULL |  
| 100006 |   10004 | C+    |     NULL |  
| 100006 |   10005 | A     |     NULL |  
| 100005 |   10006 | B+    |     NULL |  
+--------+---------+-------+----------+  
6 rows in set (0.000 sec)

**Null and Boolean Expressions**

1. MySQL does not have a Boolean data type. A Boolean value is converted to TINYINT: 0 as FALSE, otherwise TRUE.
2. If a Boolean value is expected, null is implicitly type converted to FALSE.
3. However, NULL is a special value different with 0 or empty string.
4. Comparing null to other values return false.

***Example:***

-- 1. Boolean values are TINYINT. FALSE is 0.  
SELECT FALSE,  
   TRUE;  
    
SELECT \*  
FROM student  
WHERE 0;  
  
SELECT \*  
FROM student  
WHERE 1;  
  
SELECT \*  
FROM student  
WHERE 2697;  
  
SELECT \*  
FROM student  
WHERE '0';  
  
SELECT \*  
FROM student  
WHERE '145';  
  
-- warning: '' cannot be converted to a number.  
-- "Warning 1292 Truncated incorrect DOUBLE value: ''"  
SELECT \*  
FROM student  
WHERE '';  
  
-- warning: '' cannot be converted to a number.  
-- "Warning 1292 Truncated incorrect DOUBLE value: ''"  
SELECT \*  
FROM student  
WHERE 'Hello world';  
  
SELECT \*  
FROM student  
WHERE 1.49;

Result:

MariaDB [toyu]> SELECT FALSE,  
    -> TRUE;  
+-------+------+  
| FALSE | TRUE |  
+-------+------+  
|     0 |    1 |  
+-------+------+  
1 row in set (0.001 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE 0;  
Empty set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE 1;  
+--------+-----------+----------+-------+-------+------+---------+  
| stuId  | fname     | lname    | major | minor | ach  | advisor |  
+--------+-----------+----------+-------+-------+------+---------+  
| 100000 | Tony      | Hawk     | CSCI  | CINF  |   40 |    1011 |  
| 100001 | Mary      | Hawk     | CSCI  | CINF  |   35 |    1011 |  
| 100002 | David     | Hawk     | CSCI  | ITEC  |   66 |    1012 |  
| 100003 | Catherine | Lim      | ITEC  | CINF  |   20 |    NULL |  
| 100004 | Larry     | Johnson  | ITEC  | NULL  |   66 |    1017 |  
| 100005 | Linda     | Johnson  | CINF  | ENGL  |   13 |    1015 |  
| 100006 | Lillian   | Johnson  | CINF  | ITEC  |   18 |    1016 |  
| 100007 | Ben       | Zico     | NULL  | NULL  |   16 |    NULL |  
| 100008 | Bill      | Ching    | ARTS  | NULL  |   90 |    NULL |  
| 100009 | Linda     | King     | ARTS  | CSCI  |  125 |    1018 |  
| 100111 | Cathy     | Johanson | NULL  | NULL  |    0 |    1018 |  
+--------+-----------+----------+-------+-------+------+---------+  
11 rows in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE 2697;  
+--------+-----------+----------+-------+-------+------+---------+  
| stuId  | fname     | lname    | major | minor | ach  | advisor |  
+--------+-----------+----------+-------+-------+------+---------+  
| 100000 | Tony      | Hawk     | CSCI  | CINF  |   40 |    1011 |  
| 100001 | Mary      | Hawk     | CSCI  | CINF  |   35 |    1011 |  
| 100002 | David     | Hawk     | CSCI  | ITEC  |   66 |    1012 |  
| 100003 | Catherine | Lim      | ITEC  | CINF  |   20 |    NULL |  
| 100004 | Larry     | Johnson  | ITEC  | NULL  |   66 |    1017 |  
| 100005 | Linda     | Johnson  | CINF  | ENGL  |   13 |    1015 |  
| 100006 | Lillian   | Johnson  | CINF  | ITEC  |   18 |    1016 |  
| 100007 | Ben       | Zico     | NULL  | NULL  |   16 |    NULL |  
| 100008 | Bill      | Ching    | ARTS  | NULL  |   90 |    NULL |  
| 100009 | Linda     | King     | ARTS  | CSCI  |  125 |    1018 |  
| 100111 | Cathy     | Johanson | NULL  | NULL  |    0 |    1018 |  
+--------+-----------+----------+-------+-------+------+---------+  
11 rows in set (0.001 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE '0';  
Empty set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE '145';  
+--------+-----------+----------+-------+-------+------+---------+  
| stuId  | fname     | lname    | major | minor | ach  | advisor |  
+--------+-----------+----------+-------+-------+------+---------+  
| 100000 | Tony      | Hawk     | CSCI  | CINF  |   40 |    1011 |  
| 100001 | Mary      | Hawk     | CSCI  | CINF  |   35 |    1011 |  
| 100002 | David     | Hawk     | CSCI  | ITEC  |   66 |    1012 |  
| 100003 | Catherine | Lim      | ITEC  | CINF  |   20 |    NULL |  
| 100004 | Larry     | Johnson  | ITEC  | NULL  |   66 |    1017 |  
| 100005 | Linda     | Johnson  | CINF  | ENGL  |   13 |    1015 |  
| 100006 | Lillian   | Johnson  | CINF  | ITEC  |   18 |    1016 |  
| 100007 | Ben       | Zico     | NULL  | NULL  |   16 |    NULL |  
| 100008 | Bill      | Ching    | ARTS  | NULL  |   90 |    NULL |  
| 100009 | Linda     | King     | ARTS  | CSCI  |  125 |    1018 |  
| 100111 | Cathy     | Johanson | NULL  | NULL  |    0 |    1018 |  
+--------+-----------+----------+-------+-------+------+---------+  
11 rows in set (0.001 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- warning: '' cannot be converted to a number.  
MariaDB [toyu]> -- "Warning 1292 Truncated incorrect DOUBLE value: ''"  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE '';  
Empty set, 1 warning (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- warning: '' cannot be converted to a number.  
MariaDB [toyu]> -- "Warning 1292 Truncated incorrect DOUBLE value: ''"  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE 'Hello world';  
Empty set, 1 warning (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE 1.49;  
+--------+-----------+----------+-------+-------+------+---------+  
| stuId  | fname     | lname    | major | minor | ach  | advisor |  
+--------+-----------+----------+-------+-------+------+---------+  
| 100000 | Tony      | Hawk     | CSCI  | CINF  |   40 |    1011 |  
| 100001 | Mary      | Hawk     | CSCI  | CINF  |   35 |    1011 |  
| 100002 | David     | Hawk     | CSCI  | ITEC  |   66 |    1012 |  
| 100003 | Catherine | Lim      | ITEC  | CINF  |   20 |    NULL |  
| 100004 | Larry     | Johnson  | ITEC  | NULL  |   66 |    1017 |  
| 100005 | Linda     | Johnson  | CINF  | ENGL  |   13 |    1015 |  
| 100006 | Lillian   | Johnson  | CINF  | ITEC  |   18 |    1016 |  
| 100007 | Ben       | Zico     | NULL  | NULL  |   16 |    NULL |  
| 100008 | Bill      | Ching    | ARTS  | NULL  |   90 |    NULL |  
| 100009 | Linda     | King     | ARTS  | CSCI  |  125 |    1018 |  
| 100111 | Cathy     | Johanson | NULL  | NULL  |    0 |    1018 |  
+--------+-----------+----------+-------+-------+------+---------+  
11 rows in set (0.000 sec)

***Example:***

-- 2. If a Boolean value is expected, null is implicitly type-converted to FALSE.  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts;

Result:

MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100002 |   10000 | B-    |        3 |  
| 100000 |   10001 | A     |        2 |  
| 100000 |   10002 | B+    |        1 |  
| 100002 |   10002 | B+    |        2 |  
| 100002 |   10003 | D     |        4 |  
| 100000 |   10004 | A-    |        1 |  
| 100007 |   10007 | F     |        4 |  
| 100000 |   11001 | D     |        4 |  
+--------+---------+-------+----------+  
8 rows in set (0.000 sec)

***Example:***

-- 3. null is a special value different with 0 or empty string.  
SELECT FALSE IS NULL,    
   TRUE IS NULL,  
   0 IS NULL,  
   1 IS NULL,  
   "" IS NULL,  
   "Hey" IS NULL,  
   NULL IS NULL,  
   NULL IS NOT NULL;

Result:

MariaDB [toyu]> SELECT FALSE IS NULL,  
    -> TRUE IS NULL,  
    -> 0 IS NULL,  
    -> 1 IS NULL,  
    -> "" IS NULL,  
    -> "Hey" IS NULL,  
    -> NULL IS NULL,  
    -> NULL IS NOT NULL;  
+---------------+--------------+-----------+-----------+------------+---------------+--------------+------------------+  
| FALSE IS NULL | TRUE IS NULL | 0 IS NULL | 1 IS NULL | "" IS NULL | "Hey" IS NULL | NULL IS NULL | NULL IS NOT NULL |  
+---------------+--------------+-----------+-----------+------------+---------------+--------------+------------------+  
|             0 |            0 |         0 |         0 |          0 |             0 |            1 |                0 |  
+---------------+--------------+-----------+-----------+------------+---------------+--------------+------------------+  
1 row in set (0.000 sec)

***Example:***

-- 4. Comparing null to other values return null, which is converted to false.  
SELECT NULL > 3,  
   NULL <= 3,  
   5 >= NULL,  
   5 < NULL,  
   NULL > NULL,  
   NULL <= NULL;  
    
SELECT \*  
FROM student  
WHERE NULL > 3;  
  
-- Comparisons must be mindful of null.  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts >= 2;  
  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts < 2;  
  
SELECT e.\*  
FROM enroll AS e;  
  
-- Q. List all enrollment records without 2 or more n\_alerts.  
-- Naive solution  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts < 2;  
  
-- Q. List all enrollment records without 2 or more n\_alerts.  
-- More likely solution  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts IS NULL  
OR e.n\_alerts < 2;  
  
-- Q. List all enrollment records without a value in n\_alerts.  
-- incorrect answer.  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts <> NULL;  
  
-- Q. List all enrollment records without a value in n\_alerts.  
-- correct answer.  
SELECT e.\*  
FROM enroll AS e  
WHERE e.n\_alerts IS NOT NULL;

Result:

MariaDB [toyu]> -- 4. Comparing null to other values return null, which is converted to false.  
MariaDB [toyu]> SELECT NULL > 3,  
    -> NULL <= 3,  
    -> 5 >= NULL,  
    -> 5 < NULL,  
    -> NULL > NULL,  
    -> NULL <= NULL;  
+----------+-----------+-----------+----------+-------------+--------------+  
| NULL > 3 | NULL <= 3 | 5 >= NULL | 5 < NULL | NULL > NULL | NULL <= NULL |  
+----------+-----------+-----------+----------+-------------+--------------+  
|     NULL |      NULL |      NULL |     NULL |        NULL |         NULL |  
+----------+-----------+-----------+----------+-------------+--------------+  
1 row in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT \*  
    -> FROM student  
    -> WHERE NULL > 3;  
Empty set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- Comparisons must be mindful of null.  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts >= 2;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100002 |   10000 | B-    |        3 |  
| 100000 |   10001 | A     |        2 |  
| 100002 |   10002 | B+    |        2 |  
| 100002 |   10003 | D     |        4 |  
| 100007 |   10007 | F     |        4 |  
| 100000 |   11001 | D     |        4 |  
+--------+---------+-------+----------+  
6 rows in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts < 2;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100000 |   10000 | A     |        0 |  
| 100001 |   10001 | A-    |        0 |  
| 100000 |   10002 | B+    |        1 |  
| 100000 |   10003 | C     |        0 |  
| 100004 |   10003 | A     |        0 |  
| 100000 |   10004 | A-    |        1 |  
| 100005 |   10004 | A-    |        0 |  
| 100005 |   10005 | A-    |        0 |  
| 100008 |   10007 | C-    |        0 |  
| 100007 |   10008 | A-    |        0 |  
+--------+---------+-------+----------+  
10 rows in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100000 |   10000 | A     |        0 |  
| 100001 |   10000 | NULL  |     NULL |  
| 100002 |   10000 | B-    |        3 |  
| 100000 |   10001 | A     |        2 |  
| 100001 |   10001 | A-    |        0 |  
| 100000 |   10002 | B+    |        1 |  
| 100002 |   10002 | B+    |        2 |  
| 100000 |   10003 | C     |        0 |  
| 100002 |   10003 | D     |        4 |  
| 100004 |   10003 | A     |        0 |  
| 100005 |   10003 | NULL  |     NULL |  
| 100000 |   10004 | A-    |        1 |  
| 100004 |   10004 | B+    |     NULL |  
| 100005 |   10004 | A-    |        0 |  
| 100006 |   10004 | C+    |     NULL |  
| 100005 |   10005 | A-    |        0 |  
| 100006 |   10005 | A     |     NULL |  
| 100005 |   10006 | B+    |     NULL |  
| 100007 |   10007 | F     |        4 |  
| 100008 |   10007 | C-    |        0 |  
| 100007 |   10008 | A-    |        0 |  
| 100000 |   11001 | D     |        4 |  
+--------+---------+-------+----------+  
22 rows in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- Q. List all enrollment records without 2 or more n\_alerts.  
MariaDB [toyu]> -- Naive solution  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts < 2;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100000 |   10000 | A     |        0 |  
| 100001 |   10001 | A-    |        0 |  
| 100000 |   10002 | B+    |        1 |  
| 100000 |   10003 | C     |        0 |  
| 100004 |   10003 | A     |        0 |  
| 100000 |   10004 | A-    |        1 |  
| 100005 |   10004 | A-    |        0 |  
| 100005 |   10005 | A-    |        0 |  
| 100008 |   10007 | C-    |        0 |  
| 100007 |   10008 | A-    |        0 |  
+--------+---------+-------+----------+  
10 rows in set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- Q. List all enrollment records without 2 or more n\_alerts.  
MariaDB [toyu]> -- More likely solution  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts IS NULL  
    -> OR e.n\_alerts < 2;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100000 |   10000 | A     |        0 |  
| 100001 |   10000 | NULL  |     NULL |  
| 100001 |   10001 | A-    |        0 |  
| 100000 |   10002 | B+    |        1 |  
| 100000 |   10003 | C     |        0 |  
| 100004 |   10003 | A     |        0 |  
| 100005 |   10003 | NULL  |     NULL |  
| 100000 |   10004 | A-    |        1 |  
| 100004 |   10004 | B+    |     NULL |  
| 100005 |   10004 | A-    |        0 |  
| 100006 |   10004 | C+    |     NULL |  
| 100005 |   10005 | A-    |        0 |  
| 100006 |   10005 | A     |     NULL |  
| 100005 |   10006 | B+    |     NULL |  
| 100008 |   10007 | C-    |        0 |  
| 100007 |   10008 | A-    |        0 |  
+--------+---------+-------+----------+  
16 rows in set (0.000 sec) MariaDB [toyu]> -- Q. List all enrollment records without a value in n\_alerts.  
  
MariaDB [toyu]> -- incorrect answer.  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts <> NULL;  
Empty set (0.000 sec)  
  
MariaDB [toyu]>  
MariaDB [toyu]> -- Q. List all enrollment records without a value in n\_alerts.  
MariaDB [toyu]> -- correct answer.  
MariaDB [toyu]> SELECT e.\*  
    -> FROM enroll AS e  
    -> WHERE e.n\_alerts IS NOT NULL;  
+--------+---------+-------+----------+  
| stuId  | classId | grade | n\_alerts |  
+--------+---------+-------+----------+  
| 100000 |   10000 | A     |        0 |  
| 100002 |   10000 | B-    |        3 |  
| 100000 |   10001 | A     |        2 |  
| 100001 |   10001 | A-    |        0 |  
| 100000 |   10002 | B+    |        1 |  
| 100002 |   10002 | B+    |        2 |  
| 100000 |   10003 | C     |        0 |  
| 100002 |   10003 | D     |        4 |  
| 100004 |   10003 | A     |        0 |  
| 100000 |   10004 | A-    |        1 |  
| 100005 |   10004 | A-    |        0 |  
| 100005 |   10005 | A-    |        0 |  
| 100007 |   10007 | F     |        4 |  
| 100008 |   10007 | C-    |        0 |  
| 100007 |   10008 | A-    |        0 |  
| 100000 |   11001 | D     |        4 |  
+--------+---------+-------+----------+  
16 rows in set (0.000 sec)

**Interpretation of null values**

* Three possible interpretations:
  1. Not applicable.
  2. Missing value.
  3. No information at all.

***Example:***

Consider the attribute SpouseName. A Null value may mean:

1. not applicable: the person is not married.
2. missing information: the person is married but we do not have the name of the spouse.
3. no information at all: we do not know whether the person is married or not.

How do we distinguish between the three meanings of the null value in this case?

By using an extra attribute, such as MaritalStatus.

|  |  |  |  |
| --- | --- | --- | --- |
| **...** | **SpouseName** | **MaritalStatus** | **...** |
|  | Null | Married |  |
|  | Null | Not married |  |
|  | Null | Null |  |

**3. Keys**

* A*set* of attributes K is a *candidate key* (CK) of a relation R if it minimally identifies a tuple at any time:
  1. Uniqueness: No two tuples of R have the same value of K.
  2. Minimality: No proper subset of K has the uniqueness property.
* A candidate key is a property of the semantic (meaning) of a relation.
* In other words, a candidate key is the result of the requirements of an application.
* A relation always has at least one candidate keys. Why?
  1. Because a relation instance r is a set of rows, no two rows will have the exact same values.
  2. Thus, the relation schema R by itself satisfy the uniqueness properties.
  3. R or one of its proper subsets will satisfy the minimal properties as extraneous attributes are removed.
* A set of attributes may be a candidate key for a relation R but not a candidate key of another relation S.
* For *any* relation instance, the candidate key of a tuple must have an unique value.
* Whether a set of attributes is a key or not depend on the semantic (meaning) of the relation on modeling the application.
* A *primary* key is a selected candidate key for a relation in the DBMS. It is used for practical purpose (of how the relation is stored physically) and does not have a special meaning in the theory of the relational model.
* An*alternate/secondary* key is a candidate key that is not the primary key.
* Questions people may ask:
  1. What is the key of the database toyu? Wrong question.
  2. What is the primary key of the database toyu? more precise but still wrong question.
  3. What is the key of the school table of the toyu database? good question but a bit ambiguous. Answer: schoolCode.
  4. What is the primary key of the school table of the toyu database? schoolCode.
  5. What are the candidate keys of the school table of the toyu database? [1] schoolCode, [2] schoolName.
  6. What are the secondary/alternative keys of the school table of the toyu database? schoolName.

***Example:***

Consider:  
MariaDB [toyu]> SELECT \* FROM faculty;  
+-------+----------+----------+----------+---------------------+  
| facId | fname    | lname    | deptCode | rank                |  
+-------+----------+----------+----------+---------------------+  
|  1011 | Paul     | Smith    | CSCI     | Professor           |  
|  1012 | Mary     | Tran     | CSCI     | Associate Professor |  
|  1013 | David    | Love     | CSCI     | NULL                |  
|  1014 | Sharon   | Mannes   | CSCI     | Assistant Professor |  
|  1015 | Daniel   | Kim      | CINF     | Professor           |  
|  1016 | Andrew   | Byre     | CINF     | Associate Professor |  
|  1017 | Deborah  | Gump     | ITEC     | Professor           |  
|  1018 | Art      | Allister | ARTS     | Assistant Professor |  
|  1019 | Benjamin | Yu       | ITEC     | Lecturer            |  
|  1020 | Katrina  | Bajaj    | ENGL     | Lecturer            |  
|  1021 | Jorginlo | Neymar   | ACCT     | Assistant Professor |  
+-------+----------+----------+----------+---------------------+  
11 rows in set (0.001 sec)  
  
MariaDB [toyu]> SELECT \* FROM department;  
+----------+------------------------------+------------+----------+  
| deptCode | deptName                     | schoolCode | numStaff |  
+----------+------------------------------+------------+----------+  
| ACCT     | Accounting                   | BUS        |       10 |  
| ARTS     | Arts                         | HSH        |        5 |  
| CINF     | Computer Information Systems | CSE        |        5 |  
| CSCI     | Computer Science             | CSE        |       12 |  
| ENGL     | English                      | HSH        |       12 |  
| ITEC     | Information Technology       | CSE        |        4 |  
| MATH     | Mathematics                  | CSE        |        7 |  
+----------+------------------------------+------------+----------+  
7 rows in set (0.001 sec)

* deptCode is a candidate key of the relation department. Assumptions made:
  1. Each tuple in the department relation represents an unique department.
  2. Each department has an unique code, or no two departments can have the same code.
* deptName is also a candidate key of the relation department. Assumptions made:
  1. Each tuple in the department relation represents an unique department.
  2. Each department has an unique name, or no two departments can have the same name.
* deptCode is not a candidate key of the relation faculty. Assumptions made:
  1. Each tuple in the faculty relation represents a faculty member.
  2. Each faculty serves only one department.
  3. A department may have many faculty members.

Consider the tables student and enroll:

* stuid is a candidate key of the relation student. Assumptions made:
  1. Each tuple in the student relation represents an unique student.
  2. Each student has an unique student id, or no two students can have the same stuid.
* stuid is not a candidate key of the relation enroll. Assumptions made:
  1. Each tuple in the Enroll relation represents the enrollment of a student in a class, ending up with a grade.
  2. A student can take many classes.
* Note again that a candidate key is a property of a relation.

***Classroom Exercise:***

(1) Give a realistic example of a relation with two candidate keys. State the assumptions you have made.

(2) A relation R has an *arity* of 4. What are the possible minimum and maximum number of superkeys of R? What are the possible minimum and maximum number of candidate keys of R?

What about the general case?

**More about keys:**

* A key is *simple* if it has only one attribute.
* A key is a *composite* key if it has more than one attributes.
* A key is a *compound* key if it is a composite and each attribute in the key is a foreign key.
* Every relation has at least one candidate key.
* An attribute that appears in one or more candidate keys is a *prime attribute* (or key attribute).
* An attribute that does not appears in any candidate key is a *non-prime* (non-key) attribute.
* A superkey of a relation is a set of attributes that uniquely identify a row (uniqueness). It may not be minimal. (A Superkey may have extraneous attributes not needed for unique identification.)
* A *foreign key* of a relation is a set of attributes that is a candidate key in another relation. The other relation is sometimes called the parent (or referenced) table of the foreign key.
* A foreign key may or may not have null value. It depends on the problem requirements.

Consider the example above. The attribute deptCode is a foreign key in the relation faculty, referencing department(deptCode)

* A deptCode in the department relation must be referring to a department in the database, identified by deptCode in the relation department (referential integrity).
* In Relational DB, rows (data) from different tables are linked together using *foreign keys*.
* A foreign key of a child table links to a primary key of the parent table.

Likewise, stuid is a foreign key in the relation Enroll: stuid references student(stuid)

Note that the student table has three foreign keys.

***Example:***

The list of all foreign keys in toyu:

1. Student(advisor) references Faculty(facId)  
2. Student(major) references Department(deptCode)  
3. Student(minor) references Department(deptCode)  
4. Faculty(deptCode) references Department(deptCode)  
5. Department(schoolCode) references School(schoolCode)  
6. Enroll(stuId) references Student(stuId)  
7. Enroll(classId) references Class(classId)  
8. Enroll(grade) references Grade(grade)  
9. Class(courseId) references Course(courseId)  
10. Class(facId) references Faculty(facId)

* The INNER JOIN operation can be used to join tables through foreign keys.

***Example:***

-- INNER JOIN  
SELECT \* FROM faculty;  
SELECT \* FROM department;  
SELECT s.fname, s.lname, s.advisor, f.`rank`  
FROM student AS s INNER JOIN faculty AS f  
   ON (s.advisor = f.facId);  
    
Result:

MariaDB [toyu]> SELECT \* FROM faculty;  
+-------+----------+----------+----------+---------------------+  
| facId | fname    | lname    | deptCode | rank                |  
+-------+----------+----------+----------+---------------------+  
|  1011 | Paul     | Smith    | CSCI     | Professor           |  
|  1012 | Mary     | Tran     | CSCI     | Associate Professor |  
|  1013 | David    | Love     | CSCI     | NULL                |  
|  1014 | Sharon   | Mannes   | CSCI     | Assistant Professor |  
|  1015 | Daniel   | Kim      | CINF     | Professor           |  
|  1016 | Andrew   | Byre     | CINF     | Associate Professor |  
|  1017 | Deborah  | Gump     | ITEC     | Professor           |  
|  1018 | Art      | Allister | ARTS     | Assistant Professor |  
|  1019 | Benjamin | Yu       | ITEC     | Lecturer            |  
|  1020 | Katrina  | Bajaj    | ENGL     | Lecturer            |  
|  1021 | Jorginlo | Neymar   | ACCT     | Assistant Professor |  
+-------+----------+----------+----------+---------------------+  
11 rows in set (0.000 sec)  
  
MariaDB [toyu]> SELECT \* FROM department;  
+----------+------------------------------+------------+----------+  
| deptCode | deptName                     | schoolCode | numStaff |  
+----------+------------------------------+------------+----------+  
| ACCT     | Accounting                   | BUS        |       10 |  
| ARTS     | Arts                         | HSH        |        5 |  
| CINF     | Computer Information Systems | CSE        |        5 |  
| CSCI     | Computer Science             | CSE        |       12 |  
| ENGL     | English                      | HSH        |       12 |  
| ITEC     | Information Technology       | CSE        |        4 |  
| MATH     | Mathematics                  | CSE        |        7 |  
+----------+------------------------------+------------+----------+  
7 rows in set (0.000 sec)  
  
MariaDB [toyu]> SELECT s.fname, s.lname, s.advisor, f.`rank`  
    -> FROM student AS s INNER JOIN faculty AS f  
    -> ON (s.advisor = f.facId);  
+---------+----------+---------+---------------------+  
| fname   | lname    | advisor | rank                |  
+---------+----------+---------+---------------------+  
| Tony    | Hawk     |    1011 | Professor           |  
| Mary    | Hawk     |    1011 | Professor           |  
| David   | Hawk     |    1012 | Associate Professor |  
| Larry   | Johnson  |    1017 | Professor           |  
| Linda   | Johnson  |    1015 | Professor           |  
| Lillian | Johnson  |    1016 | Associate Professor |  
| Linda   | King     |    1018 | Assistant Professor |  
| Cathy   | Johanson |    1018 | Assistant Professor |  
+---------+----------+---------+---------------------+  
8 rows in set (0.000 sec)