





The relational model was proposed by E. F. Codd in 1970. Commercial implementations appeared in the late 1970s and early 1980s.

One of the first relational database systems, System R, developed at IBM led to several important breakthroughs:

- the first version of SQL
- various commercial products such as Oracle and DB2
- extensive research on concurrency control, transaction management, and query processing and optimization

Currently, the relational model is the foundation of the majority of commercial database systems.

# The Relational Model: Terminology



The *relational model* organizes data into tables called relations.

A *relation* is a table with columns and rows.

An attribute is a named column of a relation.

A *tuple* is a row of a relation.

A domain is a set of allowable values for one or more attributes.

The *degree* of a relation is the number of attributes it contains.

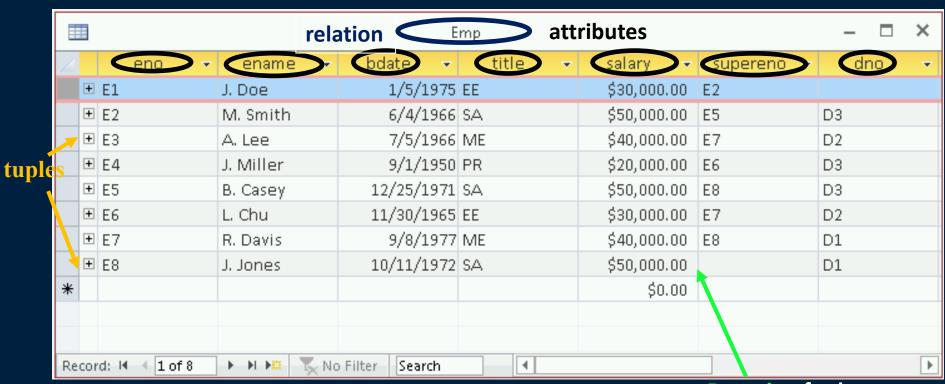
The *cardinality* of a relation is the number of tuples it contains.

The *intension* is the structure of the relation including its domains.

The extension is the set of tuples currently in the relation. All data in the DB

# Relation Example





Degree =7
Cardinality = 8

Domain of salary is currency

## **Relational Model Formal Definition**



The relational model is formally defined in terms of sets and set operations.

A relation schema R ( $A_1$ ,  $A_2$ , ...,  $A_n$ ) has each attribute  $A_i$  with a name and a domain  $dom(A_i)$ .

A relation instance denoted r(R) is a set of n-tuples  $< d_1, d_2, ..., d_n > where each <math>d_i$  is an element of  $dom(A_i)$  or is **null**.

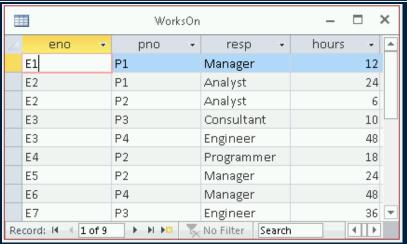
- The relation instance is the *extension* of the relation.
- A value of null represents a missing or unknown value.

Example: Product (id, name, supplierId, categoryId, price)

- **R** = Product (relation name)
- Set A = {id, name, supplierId, categoryId, price}
- dom(price) is set of all possible positive currency values
- dom(name) is set of all possible strings that represent people's names







- 1) What is the name of the relation?
- 2) What is the cardinality of the relation?
- 3) What is the degree of the relation?
- 4) What is the domain of resp? What is the domain of hours?
- 5) What is larger the size of the intension or extension?
- 6) Is a relation's cardinality always bigger than its degree?



# **Database Definition Matching Question**

**Question:** Given the three definitions, select the ordering that contains their related definitions.

- 1) relation
- 2) tuple
- 3) attribute
- A) column, row, table
- B) row, column, table
- table, row, column
- D) table, column, row



# **Cardinality and Degree Question**

**Question:** A database table has 5 rows and 10 columns. Select **one** true statement.

- A) The table's degree is 50.
- B) The table's cardinality is 5.
- C) The table's degree is 5.
- D) The table's cardinality is 10.





- 1) No two relations have the same name.
- 2) Each attribute of a relation has a distinct name.
- 3) Each tuple is distinct. There are no duplicate tuples. Only in FIM not SQL
- 4) The order of attributes is not important.
- 5) The order of tuples has no significance.

# Relational Keys



Keys are used to uniquely identify a tuple in a relation.

Note that keys apply to the schema not to the data. That is, looking at the current data cannot tell you for sure if the set of attributes is a key.

A superkey is a set of attributes that uniquely identifies a tuple in a relation.

A (candidate) key is a minimal set of attributes that uniquely identifies a tuple in a relation.

• There may be more than 1 candidate key for a relation with different # of attributes.

A *primary key* is the candidate key <u>designated</u> as the distinguishing key of a relation.

A *foreign key* is a set of attributes in one relation referring to the primary key of a relation.

Foreign keys enforce referential integrity. Note: A FK may refer to its own relation.





**Question:** True or false: A key is always a superkey.

A) true

B) false



# **Keys and Superkeys Question (2)**

Question: True or false: It is possible to have more than one key for a table and the keys may have different numbers of attributes.

A) true

B) false





## **Keys and Superkeys Question (3)**

Question: True or false: It is possible to always determine if a field is a key by looking at the data in the table.

A) true

B) false

# **Example Relational Data Questions**



#### **Emp Relation**

# **Keys are underlined**

	Linp Relation					
eno	ename	title	salary			
EI	J. Doe	EE	30000			
E2	M. Smith	SA	50000			
E3	A. Lee	ME	40000			
E4	J. Miller	PR	20000			
E5	B. Casey	SA	50000			
E6	L. Chu	EE	30000			
E7	R. Davis	ME	40000			
E8	J. Jones	SA	50000			

### Proj Relation

<u>pno</u>	pname	budget
P1	Instruments	150000
P2	DB Develop	135000
P3	CAD/CAM	250000
P4	Maintenance	310000
P5	CAD/CAM	500000

#### WorksOn Relation

eno	<u>pno</u>	resp	hours
E1	P1	Manager	12
E2	P1	Analyst	24
E2	P2	Analyst	6
E3	P3	Consultant	10
E3	P4	Engineer	48
E4	P2	Programmer	18
E5	P2	Manager	24
E6	P4	Manager	48
E7	P3	Engineer	36
E7	P5	Engineer	23
E8	P3	Manager	40

## Questions:

- 1) Is ename a key for emp?
- 2) Is *eno* (by itself) a key for *WorksOn*?
- 3) List all the superkeys for *WorksOn*.





## Consider a relation storing driver information including:

SSN, name, license plate number and state (unique together)

#### **Driver Relation**

SSN	name	LicNum	LicState
123-45-6789	S. Smith	123-456	IA
111-11-1111	A. Lee	123-456	NY
222-22-2222	J. Miller	555-111	MT
333-33-3333	B. Casey	678-123	ОН
444-44-4444	A. Adler	456-345	IA

#### Questions:

- 1) List the candidate keys for the relation.
- 2) Pick a primary key for the relation.
- 3) Is *name* a candidate key for *Driver*?
- 4) List all the superkeys for *Driver*.

#### Assumptions:

- 1) A person has only one license plate.
- 2) A license plate uniquely identifies a person.

# Relational Integrity



Integrity rules are used to insure the data is accurate.

Constraints are rules or restrictions that apply to the database and limit the data values it may store.

## Types of constraints:

- **Domain constraint** Every value for an attribute must be an element of the attribute's domain or be null.
  - null represents a value that is currently unknown or not applicable.
  - null is not the same as zero or an empty string.
- Entity integrity constraint No attribute of a primary key can be null.
- Referential integrity constraint If a foreign key exists in a relation, then the foreign key value must match a primary key value of a tuple in the referenced relation or be null.

  A.a is a foreign key to B.a: {A.a} is a subset of {B.a}

# **Foreign Keys Example**



## **Emp Relation**

<u>eno</u>	ename	title	salai y
E1	J. Doe	EE	30000
E2	M. Smith	SA	50000
E3	A. Lee	ME	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
E6	L. Chu	EE	30000
E7	R. Davis	ME	40000
E8	J. Jones	SA	50000

## Proj Belation

pno 🖊	pname	budget
P1	Instruments	150000
P2	DB Develop	135000
P3	CAD/CAM	250000
P4	Maintenance	310000
P5	CAD/CAM	500000

## WorksOn.eno is FK to Emp.eno

WorksOn.pno is FK to Proj.pno

#### WorksOn Relation

<u>eno</u>	<u>pno</u>	resp	hours
F1	P1	Manager	12
E2	P1	Analyst	24
E2	P2	Analyst	6
E3	P3	Consultant	10
E3	P4	Engineer	48
E4	P2	Programmer	18
E5	P2	Manager	24
E6	P4	Manager	48
E7	P3	Engineer	36
E7	P5	Engineer	23
E8	P3	Manager	40





## Proj Relation

<u>pno</u>	pname	budget	dno
P1	Instruments	150000	D1
P2	DB Develop	135000	D2
P3	CAD/CAM	250000	D3
P4	Maintenance	310000	null
P5	CAD/CAM	500000	D1

Proj.dno is FK to Dept.dno

# Department Relation

	Itolation		
<u>dno</u>	dname		
D1	Management		
D2	Consulting		
D3	Accounting		
D4	Development		



## **Integrity Constraints Question**

**Question:** What constraint says that a primary key field cannot be null?

A) domain constraint

B) referential integrity constraint

c) entity integrity constraint



## **Entity Integrity Constraint Question**

**Question:** A primary key has three fields. Only one field is null. Is the entity integrity constraint violated?

A) Yes

B) No



# **Referential Integrity Constraint Question**

Question: A foreign key has a null value in the table that contains the foreign key fields. Is the referential integrity constraint violated?

A) Yes

B) No

# **Integrity Questions**



### Emp Relation

<u>eno</u>	ename	title	salary
E1	J. Doe	EE	AS
E2	null	SA	50000
E3	A. Lee	null	40000
E4	J. Miller	PR	20000
E5	B. Casey	SA	50000
null	L. Chu	EE	30000
E7	R. Davis	ME	null
E8	J. Jones	SA	50000

## Proj Relation

<u>pno</u>	pname	budget
P1	Instruments	150000
P2	DB Develop	135000
P3	CAD/CAM	250000
P4	Maintenance	310000
P5	null	null

## WorksOn Relation

<u>eno</u>	<u>pno</u>	resp	hours
E1	P0	null	12
E2	P1	Analyst	null
null	P2	Analyst	6
E3	P3	Consultant	10
E9	P4	Engineer	48
E4	P2	Programmer	18
E5	null	Manager	24
E6	P4	Manager	48
E7	P6	Engineer	36
E7	P4	Engineer	23
null	null	Manager	40

Question: How many rows have violations of integrity constraints? Note: salary, budget, hours are number fields.

- A) 8
- B) 9
- C) 10
- D) 11
- E) 12

## Conclusion



The *relational model* represents data as relations which are sets of tuples. Each relational schema is a set of attributes with domains.

- A relation is a table with columns and rows. An attribute is a named column. A tuple is a row.
- Degree is the number of attributes, and cardinality is the number of tuples.

*Keys* are used to uniquely identify tuples in relations.

• Superkey is any set of attributes that identifies a tuple in a relational. A candidate key is a minimal set of attributes that identifies a tuple.

The relational model has *constraints* to guarantee data integrity including: domain, entity integrity and referential integrity constraints.





- Define: relation, attribute, tuple, domain, degree, cardinality, intension, extension, relation schema, relation instance, null
- List the properties of relations.
- Define: superkey, key, candidate key, primary key, foreign key
- Define: integrity, constraints, domain constraint, entity integrity constraint, referential integrity constraint
- Given a relation be able to:
  - identify its cardinality, degree, domains, keys, and superkeys,
  - determine if constraints are being violated

