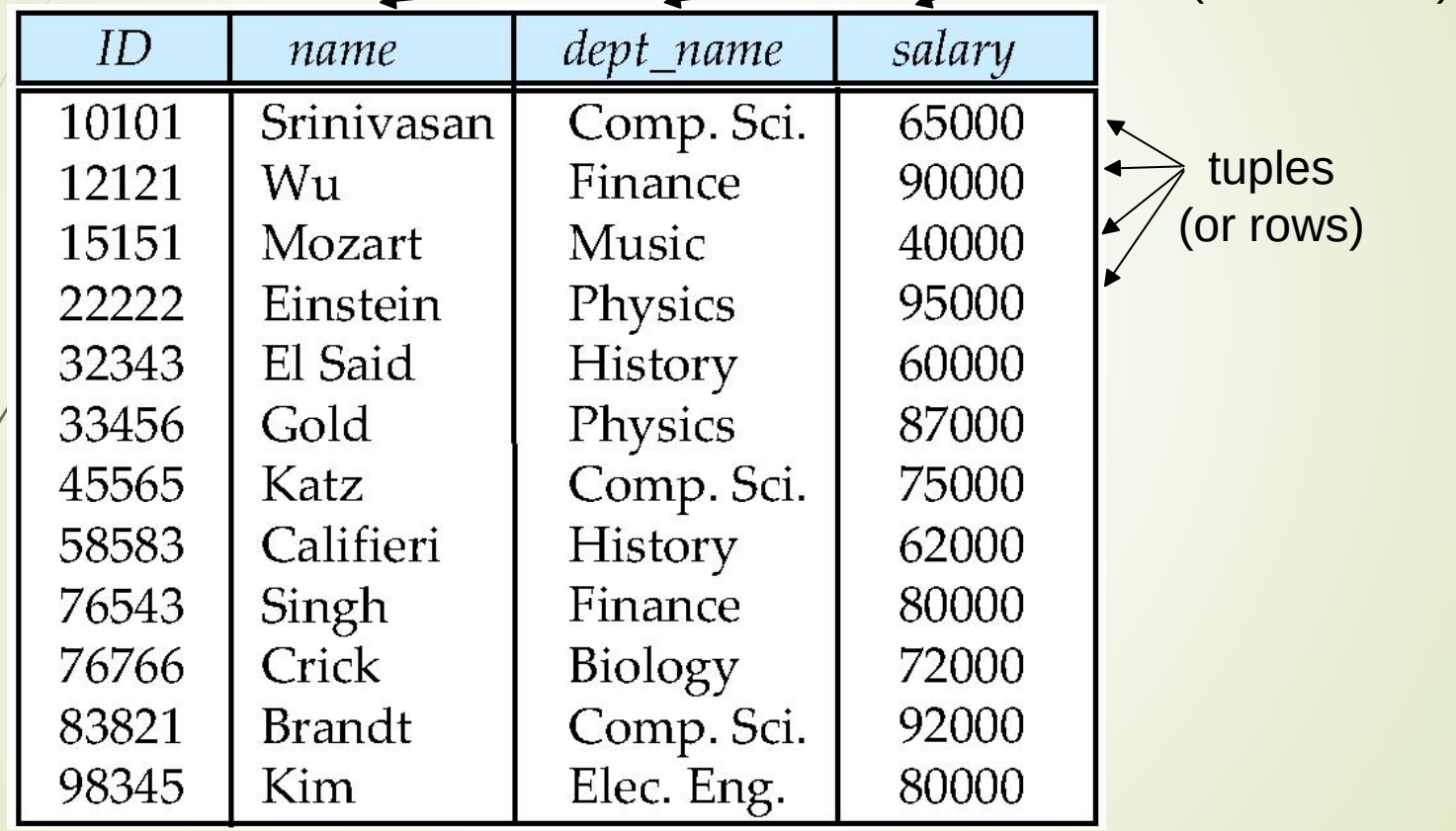
Chapter 2: Intro to Relational Model

Example of a Relation



ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Attribute Types

- The set of allowed values for each attribute is called the **domain** of the attribute
- Attribute values are (normally) required to be **atomic**; that is, indivisible
- The special value ***null*** is a member of every domain. Indicated that the value is “unknown”
- The null value causes complications in the definition of many operations

Relation Schema and Instance

- $A_1, A_2, \ldots, A_n$ are *attributes*

- $R = (A_1, A_2, \ldots, A_n)$ is a *relation schema*

  Example:

  instructor = (*ID, name, dept_name, salary*)

- Formally, given sets $D_1, D_2, \ldots. D_n$ a **relation *r*** is a subset of

  $D_1 \times D_2 \times \ldots \times D_n$

  Thus, a relation is a set of *n*-tuples $(a_1, a_2, \ldots, a_n)$ where each $a_i \in D_i$

- The current values (**relation instance**) of a relation are specified by a table
- An element *t* of *r* is a *tuple*, represented by a *row* in a table

Relations are Unordered

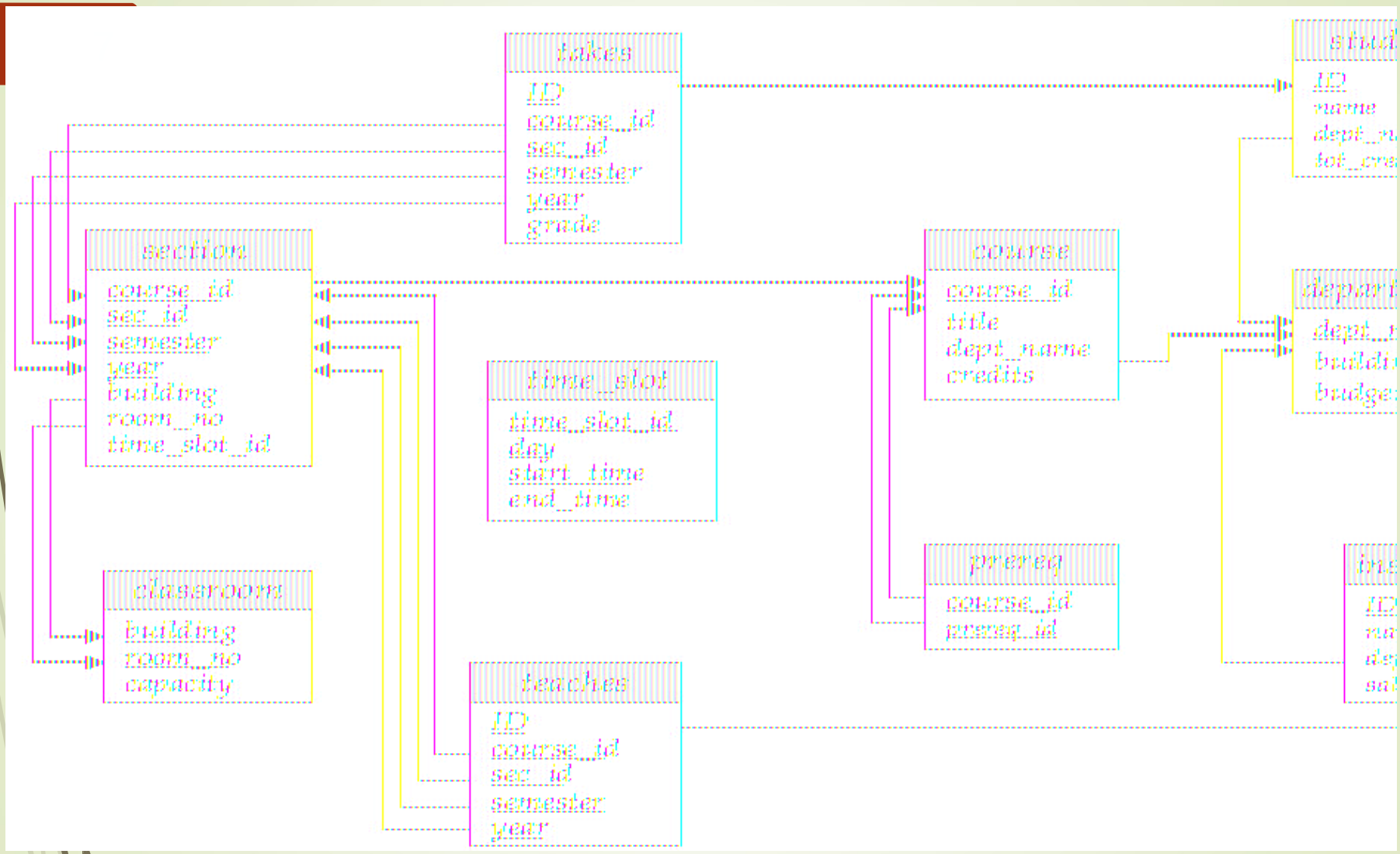
- Order of tuples is irrelevant (tuples may be stored in an arbitrary order)
- Example: *instructor* relation with unordered tuples

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

Keys

- Let K ⊆ R
- *K* is a **superkey** of *R* if values for *K* are sufficient to identify a unique tuple of each possible relation *r(R)*
  - Example: {*ID*} and {ID,name} are both superkeys of *instructor.*
- Superkey *K* is a **candidate key** if *K* is minimal

  Example: {*ID*} is a candidate key for *Instructor*
- One of the candidate keys is selected to be the **primary key**.
  - which one?
- **Foreign key** constraint: Value in one relation must appear in another
  - **Referencing** relation
  - **Referenced** relation
  - Example – *dept_name* in i*nstructor* is a foreign key from *instructor* referencing *department*


teaches
ID
course_id
sec_id
semesterdesc
year
grade
section
course_id
sec_id
semesterdesc
year
building
room_no
time_slot_id
course
course_id
title
dept_name
credits
time_slot
time_slot_id
day
start_time
end_time
classroom
building
room_no
capacity
prereq
course_id
prereq_id
department
dept_name
building
budget
instructor
ID
course_id
sec_id
semesterdesc
year

Relational Query Languages

- Procedural vs .non-procedural, or declarative
- “Pure” languages:
  - Relational algebra
  - Tuple relational calculus
  - Domain relational calculus
- The above 3 pure languages are equivalent in computing power
- We will concentrate in this chapter on relational algebra
  - Not turning-machine equivalent
  - consists of 6 basic operations

Select Operation – selection of rows (tuples)

- Relation r

A	B	C	D
α	α	1	7
α	β	5	7
β	β	12	3
β	β	23	10

- $\sigma_{A=B \wedge D > 5}(r)$

A	B	C	D
α	α	1	7
β	β	23	10

Project Operation – selection of columns (Attributes)

- Relation *r*:

A	B	C
α	10	1
α	20	1
β	30	1
β	40	2

- $\Pi_{A,C}(r)$

A	C
α	1
α	1
β	1
β	2

=

A	C
α	1
β	1
β	2

Union of two relations

- Relations *r, s:*

A	B
α	1
α	2
β	1

r

A	B
α	2
β	3

s

- r ■ s:

A	B
α	1
α	2
β	1
β	3

Set difference of two relations

- Relations *r*, *s*:

A	B
α	1
α	2
β	1

r

A	B
α	2
β	3

s

- *r – s:*

A	B
α	1
β	1

Set intersection of two relations

- Relation *r, s*:

A	B
α	1
α	2
β	1

r

A	B
α	2
β	3

s

- $r \cap s$

A	B
α	2

Note: $r \cap s = r - (r - s)$

joining two relations -- Cartesian-product

- Relations *r, s*:

A	B
α	1
β	2

r

C	D	E
α	10	a
β	10	a
β	20	b
γ	10	b

s

- *r* x *s*:

A	B	C	D	E
α	1	α	10	a
α	1	β	10	a
α	1	β	20	b
α	1	γ	10	b
β	2	α	10	a
β	2	β	10	a
β	2	β	20	b
β	2	γ	10	b

Cartesian-product – naming issue

- Relations *r, s*:

A	*B*
α	1
β	2

r

B	*D*	*E*
α	10	a
β	10	a
β	20	b
γ	10	b

s

- *r* x *s*:

A	*r.B*	*s.B*	*D*	*E*
α	1	α	10	a
α	1	β	10	a
α	1	β	20	b
α	1	γ	10	b
β	2	α	10	a
β	2	β	10	a
β	2	β	20	b
β	2	γ	10	b

Renaming a Table

- Allows us to refer to a relation, (say E) by more than one name.

$\rho_x(E)$

returns the expression *E* under the name *X*

- Relations *r*

A	B
α	1
β	2

r

- $r \times \rho_s(r)$

r.A	r.B	s.A	s.B
α	1	α	1
α	1	β	2
β	2	α	1
β	2	β	2

Composition of Operations

- Can build expressions using multiple operations
  - Example: $\sigma_{A=C}(r \times s)$
  - $r \times s$

A	B	C	D	E
α	1	α	10	a
α	1	β	10	a
α	1	β	20	b
α	1	γ	10	b
β	2	α	10	a
β	2	β	10	a
β	2	β	20	b
β	2	γ	10	b

  - $\sigma_{A=C}(r \times s)$

A	B	C	D	E
α	1	α	10	a
β	2	β	10	a
β	2	β	20	b

Joining two relations – Natural Join

- Let *r* and *s* be relations on schemas *R* and *S* respectively. Then, the "natural join" of relations *R* and *S* is a relation on schema *R* ■ *S* obtained as follows:
  - Consider each pair of tuples t_r from *r* and t_s from *s*.
  - If t_r and t_s have the same value on each of the attributes in *R* 🖫 *S*, add a tuple *t* to the result, where
    - *t* has the same value as t_r on *r*
    - *t* has the same value as t_s on *s*

Natural Join Example

- Relations r, s:

A	B	C	D
α	1	α	a
β	2	γ	a
γ	4	β	b
α	1	γ	a
δ	2	β	b

r

B	D	E
1	a	α
3	a	β
1	a	γ
2	b	δ
3	b	ε

s

- Natural Join
- $r \bowtie s$

A	B	C	D	E
α	1	α	a	α
α	1	α	a	γ
α	1	γ	a	α
α	1	γ	a	γ
δ	2	β	b	δ

$\Pi^{G+}_{A, r.B, C, r.D, E}(\sigma_{r.B = s.B \wedge r.D = s.D}(r \times s))$

Notes about Relational Languages

- Each Query input is a table (or set of tables)
- Each query output is a table.
- All data in the output table appears in one of the input tables
- Relational Algebra is not Turning complete
- Can we compute:
  - SUM
  - AVG
  - MAX
  - MIN

Symbol (Name)	Example of Use
σ (Selection)	$\sigma_{salary >= 85000}(instructor)$
	Return rows of the input relation that satisfy the predicate.
Π (Projection)	$\Pi_{ID, salary}(instructor)$
	Output specified attributes from all rows of the input relation. Remove duplicate tuples from the output.
x (Cartesian Product)	*instructor* x *department*
	Output pairs of rows from the two input relations that have the same value on all attributes that have the same name.
∪ (Union)	$\Pi_{name}(instructor) \cup \Pi_{name}(student)$
	Output the union of tuples from the *two* input relations.
- (Set Difference)	$\Pi_{name}(instructor) - \Pi_{name}(student)$
	Output the set difference of tuples from the two input relations.
⋈ (Natural Join)	*instructor* ⋈ *department*
	Output pairs of rows from the two input relations that have the same value on all attributes that have the same name.

End of Chapter 2

Chapter 3: Introduction to SQL

Outline

- Overview of The SQL Query Language
- Data Definition
- Basic Query Structure
- Additional Basic Operations
- Set Operations
- Null Values
- Aggregate Functions
- Nested Subqueries
- Modification of the Database

History

- IBM Sequel language developed as part of System R project at the IBM San Jose Research Laboratory
- Renamed Structured Query Language (SQL)
- ANSI and ISO standard SQL:
  - SQL-86
  - SQL-89
  - SQL-92
  - SQL:1999 (language name became Y2K compliant!)
  - SQL:2003
- Commercial systems offer most, if not all, SQL-92 features, plus varying feature sets from later standards and special proprietary features.
  - Not all examples here may work on your particular system.

Data Definition Language

The SQL data-definition language (DDL) allows the specification of information about relations, including:

- The schema for each relation.
- The domain of values associated with each attribute.
- Integrity constraints
- And as we will see later, also other information such as
  - The set of indices to be maintained for each relations.
  - Security and authorization information for each relation.
  - The physical storage structure of each relation on disk.

Domain Types in SQL

- **char(n).** Fixed length character string, with user-specified length *n.*
- **varchar(n).** Variable length character strings, with user-specified maximum length *n.*
- **int.** Integer (a finite subset of the integers that is machine-dependent).
- **smallint.** Small integer (a machine-dependent subset of the integer domain type).
- **numeric(p,d).** Fixed point number, with user-specified precision of *p* digits, with *d* digits to the right of decimal point. (ex., **numeric**(3,1), allows 44.5 to be stores exactly, but not 444.5 or 0.32)
- **real, double precision.** Floating point and double-precision floating point numbers, with machine-dependent precision.
- **float(n).** Floating point number, with user-specified precision of at least *n* digits.
- More are covered in Chapter 4.

Create Table Construct

- An SQL relation is defined using the **create table** command:

  create table *r* (A_1 D_1, A_2 D_2, ..., A_n D_n,
  (integrity-constraint$_1$),
  ...,
  (integrity-constraint$_k$))

  - *r* is the name of the relation
  - each A_i is an attribute name in the schema of relation *r*
  - D_i is the data type of values in the domain of attribute A_i

- Example:

  create table *instructor* (
  ID **char**(5),
  name **varchar**(20),
  dept_name **varchar**(20),
  salary **numeric**(8,2))

Integrity Constraints in Create Table

- **not null**
- **primary key** (A_1, ..., A_n)
- **foreign key** (A_m, ..., A_n) **references** *r*

Example:

```
create table instructor (
        ID              char(5),
        name            varchar(20) not null,
        dept_name       varchar(20),
        salary          numeric(8,2),
       primary key (ID),
        foreign key (dept_name) references department);
```

primary key declaration on an attribute automatically ensures **not null**

And a Few More Relation Definitions

create table *student*(
ID **varchar**(5),
name **varchar**(20) not null,
dept_name **varchar**(20),
tot_cred **numeric**(3,0),
primary key *(ID),*
foreign key *(dept_name*) **references** *department*);

- **create table** *takes* (
ID **varchar**(5),
course_id **varchar**(8),
sec_id **varchar**(8),
semester **varchar**(6),
year **numeric**(4,0),
grade **varchar**(2),
primary key *(ID, course_id, sec_id, semester, year)* ,
foreign key (*ID*) **references** *student,*
foreign key (*course_id, sec_id, semester, year*) **references** *section*);
- Note: *sec_id* can be dropped from primary key above, to ensure a student cannot be registered for two sections of the same course in the same semester

And more still

- **create table** *course* (
  course_id **varchar**(8),
  title **varchar(**50),
  dept_name **varchar**(20),
  credits **numeric**(2,0),
  primary key *(course_id),*
  foreign key *(dept_name*) **references** *department*);

Updates to tables

- **Insert**
  - **insert into** *instructor* **values** (‘10211’, ’Smith’, ’Biology’, 66000);
- **Delete**
  - Remove all tuples from the *student* relation
    - **delete from** *student*
- **Drop Table**
  - **drop table** *r*
- **Alter**
  - **alter table** *r* **add** *A D*
    - where *A* is the name of the attribute to be added to relation *r* and *D* is the domain of *A.*
    - All exiting tuples in the relation are assigned *null* as the value for the new attribute.
  - **alter table** *r* **drop** *A*
    - where *A* is the name of an attribute of relation *r*
    - Dropping of attributes not supported by many databases.

Basic Query Structure

- A typical SQL query has the form:

select A_1, A_2, ..., A_n
from r_1, r_2, ..., r_m
where P

  - A_i represents an attribute
  - R_i represents a relation
  - P is a predicate.
- The result of an SQL query is a relation.

The select Clause

- The **select** clause lists the attributes desired in the result of a query
- corresponds to the projection operation of the relational algebra
- Example: find the names of all instructors:

  select *name*

  from *instructor*

- NOTE: SQL names are case insensitive (i.e., you may use upper- or lower-case letters.)
- E.g., *Name* ≡ *NAME* ≡ *name*
- Some people use upper case wherever we use bold font.

The select Clause (Cont.)

- SQL allows duplicates in relations as well as in query results.
- To force the elimination of duplicates, insert the keyword **distinct** after select**.**
- Find the department names of all instructors, and remove duplicates

```
select distinct dept_name
from instructor
```

- The keyword **all** specifies that duplicates should not be removed.

```
select all dept_name
from instructor
```

The select Clause (Cont.)

- An asterisk in the select clause denotes "all attributes"

```
select *
from instructor
```

- An attribute can be a literal with no **from** clause

```
select '437'
```

  - Results is a table with one column and a single row with value "437"
  - Can give the column a name using:

```
select '437' as FOO
```

- An attribute can be a literal with **from** clause

```
select 'A'
from instructor
```

  - Result is a table with one column and *N* rows (number of tuples in the *instructors* table), each row with value "A"

The select Clause (Cont.)

- The **select** clause can contain arithmetic expressions involving the operation, +, –, , and /, and operating on constants or attributes of tuples.
  - The query:

    select *ID, name, salary/12*
    from *instructor*

    would return a relation that is the same as the *instructor* relation, except that the value of the attribute *salary* is divided by 12.
  - Can rename "*salary/12*" using the **as** clause:

    select *ID, name, salary/12* **as** *monthly_salary*

The where Clause

- The **where** clause specifies conditions that the result must satisfy
  - Corresponds to the selection predicate of the relational algebra.
- To find all instructors in Comp. Sci. dept

```
select name
from instructor
where dept_name = ‘Comp. Sci.'
```

- Comparison results can be combined using the logical connectives **and, or,** and **not**
  - To find all instructors in Comp. Sci. dept with salary > 80000

```
select name
from instructor
where dept_name = ‘Comp. Sci.'  and salary > 80000
```

- Comparisons can be applied to results of arithmetic expressions.

The from Clause

- The **from** clause lists the relations involved in the query
  - Corresponds to the Cartesian product operation of the relational algebra.
- Find the Cartesian product *instructor X teaches*

```
select 
from instructor, teaches
```

  - generates every possible instructor – teaches pair, with all attributes from both relations.
  - For common attributes (e.g., *ID*), the attributes in the resulting table are renamed using the relation name (e.g., *instructor.ID*)
- Cartesian product not very useful directly, but useful combined with where-clause condition (selection operation in relational algebra).

Cartesian Product

instructor

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
…	…	…	…

teaches

ID	*course_id*	*sec_id*	*semester*	*year*
10101	CS-101	1	Fall	2009
10101	CS-315	1	Spring	2010
10101	CS-347	1	Fall	2009
12121	FIN-201	1	Spring	2010
15151	MU-199	1	Spring	2010
22222	PHY-101	1	Fall	2009

Inst.ID	*name*	*dept_name*	*salary*	*teaches.ID*	*course_id*	*sec_id*	*semester*	*year*
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2009
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2009
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2010
12121	Wu	Pinance	90000	10101	CS-347	1	Fall	2009
12121	Wu	Pinance	90000	12121	FIN-201	1	Spring	2010
12121	Wu	Finance	90000	15151	MU-199	1	Spring	2010
12121	Wu	Pinance	90000	22222	PHY-101	1	Fall	2009
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…

Examples

- Find the names of all instructors who have taught some course and the course_id

  select *name, course_id*
  from *instructor , teaches*
  where *instructor.ID = teaches.ID*

- Find the names of all instructors in the Art department who have taught some course and the course_id

  select *name, course_id*
  from *instructor , teaches*
  where *instructor.ID = teaches.ID* ***and*** *instructor. dept_name* = ‘Art’

The Rename Operation

- The SQL allows renaming relations and attributes using the **as** clause:

  old-name **as** *new-name*

- Find the names of all instructors who have a higher salary than some instructor in 'Comp. Sci'.

  select distinct *T.name*
  from *instructor* **as** *T*, *instructor* **as** *S*
  where *T.salary* > *S.salary* **and** *S.dept_name* = *'Comp. Sci.'*

- Keyword **as** is optional and may be omitted

  instructor **as** *T* ≡ *instructor T*

Cartesian Product Example

- Relation *emp-super*

person	*supervisor*
Bob	Alice
Mary	Susan
Alice	David
David	Mary

- Find the supervisor of “Bob”
- Find the supervisor of the supervisor of “Bob”
- Find ALL the supervisors (direct and indirect) of “Bob

String Operations

- SQL includes a string-matching operator for comparisons on character strings. The operator **like** uses patterns that are described using two special characters:
  - percent (%). The % character matches any substring.
  - underscore (_). The _ character matches any character.
- Find the names of all instructors whose name includes the substring “dar”.

```
select name
from instructor
where name like '%dar%'
```

- Match the string “100%”

```
like ‘100 \%'  escape  '\'
```

in that above we use backslash (\) as the escape character.

String Operations (Cont.)

- Patterns are case sensitive.
- Pattern matching examples:
  - 'Intro%' matches any string beginning with "Intro".
  - '%Comp%' matches any string containing "Comp" as a substring.
  - '_ _ _' matches any string of exactly three characters.
  - '_ _ _ %' matches any string of at least three characters.
- SQL supports a variety of string operations such as
  - concatenation (using "||")
  - converting from upper to lower case (and vice versa)
  - finding string length, extracting substrings, etc.

Ordering the Display of Tuples

- List in alphabetic order the names of all instructors

  select distinct *name*
  from *instructor*
  order by *name*

- We may specify **desc** for descending order or **asc** for ascending order, for each attribute; ascending order is the default.
  - Example: **order by** *name* **desc**
- Can sort on multiple attributes
  - Example: **order by** *dept_name, name*

Where Clause Predicates

- SQL includes a **between** comparison operator
- Example: Find the names of all instructors with salary between $90,000 and $100,000 (that is, ≥ $90,000 and ≤ $100,000)

```
select name
from instructor
where salary between 90000 and 100000
```

- Tuple comparison

```
select name, course_id
from instructor, teaches
where (instructor.ID, dept_name) = (teaches.ID, 'Biology');
```

Duplicates

- In relations with duplicates, SQL can define how many copies of tuples appear in the result.
- **Multiset** versions of some of the relational algebra operators – given multiset relations r_1 and r_2:

1. $\sigma_\theta(r_1)$**:** If there are c_1 copies of tuple t_1 in r_1, and t_1 satisfies selections σ_θ, then there are c_1 copies of t_1 in $\sigma_\theta(r_1)$.
2. $\Pi_A(r)$**:** For each copy of tuple t_1 in r_1, there is a copy of tuple $\Pi_A(t_1)$ in $\Pi_A(r_1)$ where $\Pi_A(t_1)$ denotes the projection of the single tuple t_1.
3. $r_1 \times r_2$**:** If there are c_1 copies of tuple t_1 in r_1 and c_2 copies of tuple t_2 in r_2, there are $c_1 \times c_2$ copies of the tuple $t_1.t_2$ in $r_1 \times r_2$

Duplicates (Cont.)

- Example: Suppose multiset relations r_1 (A, B) and r_2 (C) are as follows:

  $r_1 = \{(1, a)\ (2, a)\}$ $r_2 = \{(2), (3), (3)\}$

- Then $\Pi_B(r_1)$ would be {(a), (a)}, while $\Pi_B(r_1) \times r_2$ would be

  {(*a*,2), (*a*,2), (*a*,3), (*a*,3), (*a*,3), (*a*,3)}

- SQL duplicate semantics:

  select $A_1, A_2, \ldots, A_n$
  from $r_1, r_2, \ldots, r_m$
  where P

  is equivalent to the *multiset* version of the expression:

$$\tilde{\Omega}_{A_1, A_2, \ldots, A_n}(\sigma_P(r_1 \times r_2 \times \ldots \times r_m))$$

Set Operations

- Find courses that ran in Fall 2009 or in Spring 2010

(**select** *course_id* **from** *section* **where** *sem* = ‘Fall’ **and** *year* = 2009)
union
(**select** *course_id* **from** *section* **where** *sem* = ‘Spring’ **and** *year* = 2010)

- Find courses that ran in Fall 2009 and in Spring 2010

(**select** *course_id* **from** *section* **where** *sem* = ‘Fall’ **and** *year* = 2009)
intersect
(**select** *course_id* **from** *section* **where** *sem* = ‘Spring’ **and** *year* = 2010)

- Find courses that ran in Fall 2009 but not in Spring 2010

(**select** *course_id* **from** *section* **where** *sem* = ‘Fall’ **and** *year* = 2009)
except
(**select** *course_id* **from** *section* **where** *sem* = ‘Spring’ **and** *year* = 2010)

Set Operations (Cont.)

- Find the salaries of all instructors that are less than the largest salary.

```
select distinct T.salary
from instructor as T, instructor as S
where T.salary < S.salary
```

- Find all the salaries of all instructors

```
select distinct salary
from instructor
```

- Find the largest salary of all instructors.

```
(select  “second query” )
except
 (select “first query”)
```

Set Operations (Cont.)

- Set operations **union**, **intersect**, and **except**
  - Each of the above operations automatically eliminates duplicates
- To retain all duplicates use the corresponding multiset versions **union all**, **intersect all** and **except all**.
- Suppose a tuple occurs *m* times in *r* and *n* times in *s*, then, it occurs:
  - *m* + *n* times in *r* **union all** *s*
  - min(*m*,*n*) times in *r* **intersect all** *s*
  - max(0, *m* – *n*) times in *r* **except all** *s*

Null Values

- It is possible for tuples to have a null value, denoted by *null*, for some of their attributes
- *null* signifies an unknown value or that a value does not exist.
- The result of any arithmetic expression involving *null* is *null*
  - Example: 5 + *null* returns null
- The predicate **is null** can be used to check for null values.
  - Example: Find all instructors whose salary is null.

select *name*
from *instructor*
where *salary* **is null**

Null Values and Three Valued Logic

- Three values – *true*, *false*, *unknown*
- Any comparison with *null* returns *unknown*
  - Example*: 5 < null or null <> null or null = null*
- Three-valued logic using the value *unknown*:
  - OR: (*unknown* **or** *true*) = *true*,
    (*unknown* **or** *false*) = *unknown*
    (*unknown* **or** *unknown*) = *unknown*
  - AND: *(true* **and** *unknown) = unknown,*
    (false **and** *unknown) = false,*
    (unknown **and** *unknown) = unknown*
  - NOT*: (***not** *unknown) = unknown*
  - "*P* **is unknown**" evaluates to true if predicate *P* evaluates to *unknown*
- Result of **where** clause predicate is treated as *false* if it evaluates to *unknown*

Aggregate Functions

- These functions operate on the multiset of values of a column of a relation, and return a value

avg: average value
min: minimum value
max: maximum value
sum: sum of values
count: number of values

Aggregate Functions (Cont.)

- Find the average salary of instructors in the Computer Science department

```
select avg (salary)
from instructor
where dept_name= 'Comp. Sci.';
```

- Find the total number of instructors who teach a course in the Spring 2010 semester

```
select count (distinct ID)
from teaches
where semester = 'Spring' and year = 2010;
```

- Find the number of tuples in the *course* relation

```
select count (*)
from course;
```

Aggregate Functions – Group By

- Find the average salary of instructors in each department

select *dept_name*, **avg** (*salary*) **as** *avg_salary*
from *instructor*
group by *dept_name*;

ID	*name*	*dept_name*	*salary*
76766	Crick	Biology	72000
45565	Katz	Comp. Sci.	75000
10101	Srinivasan	Comp. Sci.	65000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000
12121	Wu	Finance	90000
76543	Singh	Finance	80000
32343	El Said	History	60000
58583	Califieri	History	62000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
22222	Einstein	Physics	95000

dept_name	*avg_salary*
Biology	72000
Comp. Sci.	77333
Elec. Eng.	80000
Finance	85000
History	61000
Music	40000
Physics	91000

Aggregation (Cont.)

- Attributes in **select** clause outside of aggregate functions must appear in **group by** list

```
/* erroneous query */
select dept_name, ID, avg (salary)
from instructor
group by dept_name;
```

Aggregate Functions – Having Clause

- Find the names and average salaries of all departments whose average salary is greater than 42000

select *dept_name*, **avg** (*salary*)
from *instructor*
group by *dept_name*
having avg (*salary*) > 42000;

Note: predicates in the **having** clause are applied after the formation of groups whereas predicates in the **where** clause are applied before forming groups

Null Values and Aggregates

- Total all salaries

  select sum (*salary*)
  from *instructor*

  - Above statement ignores null amounts
  - Result is *null* if there is no non-null amount

- All aggregate operations except **count(*)** ignore tuples with null values on the aggregated attributes
- What if collection has only null values?
  - count returns 0
  - all other aggregates return null

Nested Subqueries

- SQL provides a mechanism for the nesting of subqueries. A **subquery** is a **select-from-where** expression that is nested within another query.
- The nesting can be done in the following SQL query

select A_1, A_2, ..., A_n
from r_1, r_2, ..., r_m
where P

as follows:

- A_i can be replaced be a subquery that generates a single value.
- r_i can be replaced by any valid subquery
- P can be replaced with an expression of the form:

  B <operation> (subquery)

  Where B is an attribute and <operation> to be defined later.

Subqueries in the Where Clause

Subqueries in the Where Clause

- A common use of subqueries is to perform tests:
  - For set membership
  - For set comparisons
  - For set cardinality.

Set Membership

- Find courses offered in Fall 2009 and in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
        course_id in (select course_id
                      from section
                      where semester = 'Spring' and year= 2010);
```

- Find courses offered in Fall 2009 but not in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
        course_id  not in (select course_id
                           from section
                           where semester = 'Spring' and year= 2010);
```

Set Membership (Cont.)

- Find the total number of (distinct) students who have taken course sections taught by the instructor with *ID* 10101

```
select count (distinct ID)
from takes
where (course_id, sec_id, semester, year) in
                    (select course_id, sec_id, semester, year
                     from teaches
                     where teaches.ID= 10101);
```

- Note: Above query can be written in a much simpler manner. The formulation above is simply to illustrate SQL features.

Set Comparison – “some” Clause

- Find names of instructors with salary greater than that of some (at least one) instructor in the Biology department.

```
select distinct T.name
from instructor as T, instructor as S
where T.salary > S.salary and S.dept name = ’Biology’;
```

- Same query using > **some** clause

```
select name
from instructor
where salary > some (select salary
                     from instructor
                     where dept name = ’Biology’);
```

Definition of “some” Clause

- F <comp> **some** *r* ∈ *t* ∈ *r* such that (F <comp> *t*)
  Where <comp> can be: < > = ≠ ≤ ≥

(5 < **some** | 0 / 5 / 6 |) = true (read: 5 < some tuple in the relation)

(5 < **some** | 0 / 5 |) = false

(5 = **some** | 0 / 5 |) = true

(5 ≠ **some** | 0 / 5 |) = true (since 0 ≠ 5)

(= **some**) ≡ **in**

However, (≠ **some**) ≠ **not in**

Set Comparison – “all” Clause

- Find the names of all instructors whose salary is greater than the salary of all instructors in the Biology department.

```
select name
from instructor
where salary > all (select salary
                    from instructor
                    where dept name = ’Biology’);
```

Definition of “all” Clause

- F <comp> **all** *r* ◫ → *t* ▦ *r* (F <comp> *t)*

(5 < **all** | 0 | 5 | 6 |) = false

(5 < **all** | 6 | 10 |) = true

(5 = **all** | 4 | 5 |) = false

(5 ≠ **all** | 4 | 6 |) = true (since 5 ≠ 4 and 5 ≠ 6)

(≠ **all**) ≡ **not in**

However, (= **all**) ≡ **in**

Test for Empty Relations

- The **exists** construct returns the value **true** if the argument subquery is nonempty.
- **exists** r □ r □ $\varnothing$
- **not exists** r □ $r = \varnothing$

Use of “exists” Clause

- Yet another way of specifying the query “Find all courses taught in both the Fall 2009 semester and in the Spring 2010 semester”

```
select course_id
from section as S
where semester = 'Fall' and year = 2009 and
        exists (select *
                from section as T
                where semester = 'Spring' and year= 2010
                        and S.course_id = T.course_id);
```

- **Correlation name** – variable S in the outer query
- **Correlated subquery** – the inner query

Use of “not exists” Clause

- Find all students who have taken all courses offered in the Biology department.

```
select distinct S.ID, S.name
from student as S
where not exists ( (select course_id
                    from course
                    where dept_name = 'Biology')
                   except
                    (select T.course_id
                     from takes as T
                     where S.ID = T.ID));
```

- First nested query lists all courses offered in Biology
- Second nested query lists all courses a particular student took

- Note that $X - Y = \emptyset$ ⇔ $X \subseteq Y$
- *Note:* Cannot write this query using = **all** and its variants

Test for Absence of Duplicate Tuples

- The **unique** construct tests whether a subquery has any duplicate tuples in its result.
- The **unique** construct evaluates to “true” if a given subquery contains no duplicates .
- Find all courses that were offered at most once in 2009

```
select T.course_id
 from course as T
 where unique (select R.course_id
                    from section as R
                    where T.course_id= R.course_id
                          and R.year = 2009);
```

Subqueries in the Form Clause

Subqueries in the Form Clause

- SQL allows a subquery expression to be used in the **from** clause
- Find the average instructors' salaries of those departments where the average salary is greater than $42,000."

```
select dept_name, avg_salary
 from (select dept_name, avg (salary) as avg_salary
          from instructor
          group by dept_name)
 where avg_salary > 42000;
```

- Note that we do not need to use the **having** clause
- Another way to write above query

```
select dept_name, avg_salary
 from (select dept_name, avg (salary)
          from instructor
          group by dept_name) as dept_avg (dept_name, avg_salary)
where avg_salary > 42000;
```

With Clause

- The **with** clause provides a way of defining a temporary relation whose definition is available only to the query in which the **with** clause occurs.
- Find all departments with the maximum budget

```
with max_budget (value) as
        (select max(budget)
         from department)
select department.name
from department, max_budget
where department.budget = max_budget.value;
```

Complex Queries using With Clause

- Find all departments where the total salary is greater than the average of the total salary at all departments

```
with dept _total (dept_name, value) as
        (select dept_name, sum(salary)
         from instructor
         group by dept_name),
dept_total_avg(value) as
       (select avg(value)
       from dept_total)
select dept_name
from dept_total, dept_total_avg
where dept_total.value > dept_total_avg.value;
```

Subqueries in the Select Clause

Scalar Subquery

- Scalar subquery is one which is used where a single value is expected
- List all departments along with the number of instructors in each department

```
select dept_name,
        (select count(*)
            from instructor
           where department.dept_name = instructor.dept_name)
        as num_instructors
from department;
```

- Runtime error if subquery returns more than one result tuple

Modification of the Database

- Deletion of tuples from a given relation.
- Insertion of new tuples into a given relation
- Updating of values in some tuples in a given relation

Deletion

- Delete all instructors

  delete from *instructor*

- Delete all instructors from the Finance department

  delete from *instructor*
  where *dept_name*= ’Finance’;

- Delete all tuples in the *instructor* relation for those instructors associated with a department located in the Watson building.

  delete from *instructor*
  where *dept name* **in** (**select** *dept name*
  from *department*
  where *building* = ’Watson’);

Deletion (Cont.)

- Delete all instructors whose salary is less than the average salary of instructors

delete from *instructor*
where *salary* < (**select avg** (*salary*)
from *instructor*);

- Problem: as we delete tuples from deposit, the average salary changes
- Solution used in SQL:
  1. First, compute **avg** (salary) and find all tuples to delete
  2. Next, delete all tuples found above (without recomputing **avg** or retesting the tuples)

Insertion

- Add a new tuple to *course*

  insert into *course*
  values (’CS-437’, ’Database Systems’, ’Comp. Sci.’, 4);

- or equivalently

  insert into *course* (*course_id*, *title*, *dept_name*, *credits*)
  values (’CS-437’, ’Database Systems’, ’Comp. Sci.’, 4);

- Add a new tuple to *student* with *tot_creds* set to null

  insert into *student*
  values (’3003’, ’Green’, ’Finance’, *null*);

Insertion (Cont.)

- Add all instructors to the *student* relation with tot_creds set to 0

```
insert into student
    select ID, name, dept_name, 0
    from   instructor
```

- The **select from where** statement is evaluated fully before any of its results are inserted into the relation.

Otherwise queries like

```
insert into table1 select * from table1
```

would cause problem

Updates

- Increase salaries of instructors whose salary is over $100,000 by 3%, and all others by a 5%
- Write two **update** statements:

```
update instructor
    set salary = salary * 1.03
    where salary > 100000;
update instructor
    set salary = salary * 1.05
    where salary <= 100000;
```

- The order is important
- Can be done better using the **case** statement (next slide)

Case Statement for Conditional Updates

- Same query as before but with case statement

```
update instructor
        set salary = case
                when salary <= 100000 then salary
* 1.05
                else salary * 1.03
                end
```

Updates with Scalar Subqueries

- Recompute and update tot_creds value for all students

```
update student S
    set tot_cred = (select sum(credits)
                    from takes, course
                    where takes.course_id = course.course_id and
                          S.ID= takes.ID.and
    takes.grade <> 'F' and
                          takes.grade is not null);
```

- Sets *tot_creds* to null for students who have not taken any course
- Instead of **sum**(*credits*), use:

```
case
    when sum(credits) is not null then sum(credits)
    else 0
 end
```

End of Chapter 3

Chapter 4: Intermediate SQL

Chapter 4: Intermediate SQL

- Join Expressions
- Views
- Transactions
- Integrity Constraints
- SQL Data Types and Schemas
- Authorization

Joined Relations

- **Join operations** take two relations and return as a result another relation.
- A join operation is a Cartesian product which requires that tuples in the two relations match (under some condition). It also specifies the attributes that are present in the result of the join
- The join operations are typically used as subquery expressions in the **from** clause

Join operations – Example

- Relation *course*

course_id	*title*	*dept_name*	*credits*
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

- Relation *prereq*

course_id	*prereq_id*
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

- Observe that
  prereq information is missing for CS-315 and
  course information is missing for CS-437

Outer Join

- An extension of the join operation that avoids loss of information.
- Computes the join and then adds tuples form one relation that does not match tuples in the other relation to the result of the join.
- Uses *null* values.

Left Outer Join

- *course* **natural left outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*

Right Outer Join

- *course* **natural right outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	*null*	*null*	*null*	CS-101

Joined Relations

- **Join operations** take two relations and return as a result another relation.
- These additional operations are typically used as subquery expressions in the **from** clause
- **Join condition** – defines which tuples in the two relations match, and what attributes are present in the result of the join.
- **Join type** – defines how tuples in each relation that do not match any tuple in the other relation (based on the join condition) are treated.

Join types
inner join
left outer join
right outer join
full outer join

Join Conditions
natural
on <predicate>
using $(A_1, A_1, \ldots, A_n)$

Full Outer Join

- *course* **natural full outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*
CS-347	*null*	*null*	*null*	CS-101

Joined Relations – Examples

- *course* **inner join** *prereq* **on** *course.course_id = prereq.course_id*

course_id	*title*	*dept_name*	*credits*	*prereq_id*	*course_id*
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190

- What is the difference between the above, and a natural join?
- *course* **left outer join** *prereq* **on** *course.course_id = prereq.course_id*

course_id	*title*	*dept_name*	*credits*	*prereq_id*	*course_id*
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190
CS-315	Robotics	Comp. Sci.	3	*null*	*null*

Joined Relations – Examples

- *course* **natural right outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	*null*	*null*	*null*	CS-101

- *course* **full outer join** *prereq* **using** (*course_id*)

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*
CS-347	*null*	*null*	*null*	CS-101

Views

- In some cases, it is not desirable for all users to see the entire logical model (that is, all the actual relations stored in the database.)
- Consider a person who needs to know an instructors name and department, but not the salary. This person should see a relation described, in SQL, by

  select *ID*, *name*, *dept_name*
  from *instructor*

- A **view** provides a mechanism to hide certain data from the view of certain users.
- Any relation that is not of the conceptual model but is made visible to a user as a “virtual relation” is called a **view**.

View Definition

- A view is defined using the **create view** statement which has the form

  create view *v* **as** < query expression >

  where <query expression> is any legal SQL expression. The view name is represented by *v.*

- Once a view is defined, the view name can be used to refer to the virtual relation that the view generates.
- View definition is not the same as creating a new relation by evaluating the query expression
  - Rather, a view definition causes the saving of an expression; the expression is substituted into queries using the view.

Example Views

- A view of instructors without their salary

  create view *faculty* **as**
  select *ID*, *name*, *dept_name*
  from *instructor*

- Find all instructors in the Biology department

  select *name*
  from *faculty*
  where *dept_name* = 'Biology'

- Create a view of department salary totals

  create view *departments_total_salary*(*dept_name*, *total_salary*) **as**
  select *dept_name*, **sum** (*salary*)
  from *instructor*
  group by *dept_name*;

Views Defined Using Other Views

- **create view** *physics_fall_2009* **as**
  select *course*.*course_id*, *sec_id*, *building*, *room_number*
  from *course*, *section*
  where *course*.*course_id* = *section*.*course_id*
  and *course*.*dept_name* = 'Physics'
  and *section*.*semester* = 'Fall'
  and *section*.*year* = '2009';
- **create view** *physics_fall_2009_watson* **as**
  select *course_id*, *room_number*
  from *physics_fall_2009*
  where *building*= 'Watson';

View Expansion

- Expand use of a view in a query/another view

```
create view physics_fall_2009_watson as
(select course_id, room_number
from (select course.course_id, building, room_number
        from course, section
        where course.course_id = section.course_id
            and course.dept_name = 'Physics'
            and section.semester = 'Fall'
            and section.year = '2009')
where building= 'Watson';
```

Views Defined Using Other Views

- One view may be used in the expression defining another view
- A view relation v_1 is said to *depend directly* on a view relation v_2 if v_2 is used in the expression defining v_1
- A view relation v_1 is said to *depend on* view relation v_2 if either v_1 depends directly to v_2 or there is a path of dependencies from v_1 to v_2
- A view relation v is said to be *recursive* if it depends on itself.

View Expansion

- A way to define the meaning of views defined in terms of other views.
- Let view v_1 be defined by an expression e_1 that may itself contain uses of view relations.
- View expansion of an expression repeats the following replacement step:

  repeat
  Find any view relation v_i in e_1
  Replace the view relation v_i by the expression defining v_i
  until no more view relations are present in e_1

- As long as the view definitions are not recursive, this loop will terminate

Update of a View

- Add a new tuple to *faculty* view which we defined earlier

  insert into *faculty* **values** (’30765’, ’Green’, ’Music’);

This insertion must be represented by the insertion of the tuple

(’30765’, ’Green’, ’Music’, null)

into the *instructor* relation

Some Updates cannot be Translated Uniquely

create view *instructor_info* **as**
select *ID*, *name*, *building*
from *instructor*, *department*
where *instructor*.*dept_name*= *department*.*dept_name*;

- **insert into** *instructor_info* **values** (’69987’, ’White’, ’Taylor’);
  - which department, if multiple departments in Taylor?
  - what if no department is in Taylor?
- Most SQL implementations allow updates only on simple views
  - The **from** clause has only one database relation.
  - The **select** clause contains only attribute names of the relation, and does not have any expressions, aggregates, or **distinct** specification.
  - Any attribute not listed in the **select** clause can be set to null
  - The query does not have a **group** by or **having** clause.

And Some Not at All

- **create view** *history_instructors* **as**
  select *
  from *instructor*
  where *dept_name*= ’History’;
- What happens if we insert (’25566’, ’Brown’, ’Biology’, 100000) into *history_instructors?*

Materialized Views

- **Materializing a view**: create a physical table containing all the tuples in the result of the query defining the view
- If relations used in the query are updated, the materialized view result becomes out of date
  - Need to **maintain** the view, by updating the view whenever the underlying relations are updated.

Transactions

- Unit of work
- Atomic transaction
  - either fully executed or rolled back as if it never occurred
- Isolation from concurrent transactions
- Transactions begin implicitly
  - Ended by **commit work** or **rollback work**
- But default on most databases: each SQL statement commits automatically
  - Can turn off auto commit for a session (e.g. using API)
  - In SQL:1999, can use: **begin atomic** …. **end**
    - Not supported on most databases

Integrity Constraints

- Integrity constraints guard against accidental damage to the database, by ensuring that authorized changes to the database do not result in a loss of data consistency.
  - A checking account must have a balance greater than $10,000.00
  - A salary of a bank employee must be at least $4.00 an hour
  - A customer must have a (non-null) phone number

Integrity Constraints on a Single Relation

- **not null**
- **primary key**
- **unique**
- **check** (P), where P is a predicate

Not Null and Unique Constraints

- **not null**
  - Declare *name* and *budget* to be **not null**

    name **varchar**(20) **not null**
    budget **numeric**(12,2) **not null**
- **unique** (A_1, A_2, …, A_m)
  - The unique specification states that the attributes *A*1, *A*2, … *A*m form a candidate key.
  - Candidate keys are permitted to be null (in contrast to primary keys).

The check clause

- **check** (P)

  where P is a predicate

Example: ensure that semester is one of fall, winter, spring or summer:

```
create table section (
    course_id varchar (8),
    sec_id varchar (8),
    semester varchar (6),
    year numeric (4,0),
    building varchar (15),
    room_number varchar (7),
    time slot id varchar (4),
    primary key (course_id, sec_id, semester, year),
    check (semester in ('Fall', 'Winter', 'Spring', 'Summer'))
);
```

Referential Integrity

- Ensures that a value that appears in one relation for a given set of attributes also appears for a certain set of attributes in another relation.
  - Example: If “Biology” is a department name appearing in one of the tuples in the *instructor* relation, then there exists a tuple in the *department* relation for “Biology”.
- Let A be a set of attributes. Let R and S be two relations that contain attributes A and where A is the primary key of S. A is said to be a **foreign key** of R if for any values of A appearing in R these values also appear in S.

Cascading Actions in Referential Integrity

- **create table** *course (*
  course_id **char**(5) **primary key**,
  title **varchar**(20),
  dept_name **varchar**(20) **references** *department*
)
- **create table** *course* (
  …
  dept_name **varchar**(20),
  foreign key (*dept_name*) **references** *department*
  on delete cascade
  on update cascade,
  . . .
)
- alternative actions to cascade: **set null**, **set default**

Integrity Constraint Violation During Transactions

- E.g.

  create table *person* (
  ID **char**(10),
  name **char**(40),
  mother **char**(10),
  father **char**(10),
  primary key *ID,*
  foreign key *father* **references** *person,*
  foreign key *mother* **references** *person*)

- How to insert a tuple without causing constraint violation ?
  - insert father and mother of a person before inserting person
  - OR, set father and mother to null initially, update after inserting all persons (not possible if father and mother attributes declared to be **not null**)
  - OR defer constraint checking (next slide)

Complex Check Clauses

- **check** (*time_slot_id* **in** (**select** *time_slot_id* **from** *time_slot*))
  - why not use a foreign key here?
- Every section has at least one instructor teaching the section.
  - how to write this?
- Unfortunately: subquery in check clause not supported by pretty much any database
  - Alternative: triggers (later)
- **create assertion** <assertion-name> **check** <predicate>;
  - Also not supported by anyone

Built-in Data Types in SQL

- **date**: Dates, containing a (4 digit) year, month and date
  - Example: **date** ‘2005-7-27’
- **time**: Time of day, in hours, minutes and seconds.
  - Example: **time** ‘09:00:30’ **time** ‘09:00:30.75’
- **timestamp**: date plus time of day
  - Example: **timestamp** ‘2005-7-27 09:00:30.75’
- **interval**: period of time
  - Example: interval ‘1’ day
  - Subtracting a date/time/timestamp value from another gives an interval value
  - Interval values can be added to date/time/timestamp values

Index Creation

- **create table** *student*
  (*ID* **varchar** (5),
  name **varchar** (20) **not null**,
  dept_name **varchar** (20),
  tot_cred **numeric** (3,0) **default** 0,
  primary key (*ID*))
- **create index** *studentID_index* **on** *student*(*ID*)
- Indices are data structures used to speed up access to records with specified values for index attributes
- e.g. **select ***
  from *student*
  where *ID* = '12345'

  can be executed by using the index to find the required record, without looking at all records of *student*

  More on indices in Chapter 11

User-Defined Types

- **create type** construct in SQL creates user-defined type

create type *Dollars* **as numeric (12,2) final**

- **create table** *department*
(*dept_name* **varchar** (20),
building **varchar** (15),
budget Dollars);

Domains

- **create domain** construct in SQL-92 creates user-defined domain types

  create domain *person_name* **char**(20) **not null**

- Types and domains are similar. Domains can have constraints, such as **not null**, specified on them.
- **create domain** *degree_level* **varchar**(10)
  constraint *degree_level_test*
  check (**value in** (’Bachelors’, ’Masters’, ’Doctorate’));

Large-Object Types

- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*:
  - **blob**: binary large object -- object is a large collection of uninterpreted binary data (whose interpretation is left to an application outside of the database system)
  - **clob**: character large object -- object is a large collection of character data
  - When a query returns a large object, a pointer is returned rather than the large object itself.

Authorization

Forms of authorization on parts of the database:

- **Read** - allows reading, but not modification of data.
- **Insert** - allows insertion of new data, but not modification of existing data.
- **Update** - allows modification, but not deletion of data.
- **Delete** - allows deletion of data.

Forms of authorization to modify the database schema

- **Index** - allows creation and deletion of indices.
- **Resources** - allows creation of new relations.
- **Alteration** - allows addition or deletion of attributes in a relation.
- **Drop** - allows deletion of relations.

Authorization Specification in SQL

- The **grant** statement is used to confer authorization

  grant <privilege list>

  on <relation name or view name> **to** <user list>

- <user list> is:
  - a user-id
  - **public**, which allows all valid users the privilege granted
  - A role (more on this later)
- Granting a privilege on a view does not imply granting any privileges on the underlying relations.
- The grantor of the privilege must already hold the privilege on the specified item (or be the database administrator).

Privileges in SQL

- **select:** allows read access to relation,or the ability to query using the view
- Example: grant users U_1, U_2, and U_3 **select** authorization on the *instructor* relation:

  grant select on *instructor* **to** U_1, U_2, U_3
- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: used as a short form for all the allowable privileges

Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.

  revoke <privilege list>

  on <relation name or view name> **from** <user list>

- Example:

  revoke select on *branch* **from** U_1, U_2, U_3

- <privilege-list> may be **all** to revoke all privileges the revokee may hold.
- If <revokee-list> includes **public,** all users lose the privilege except those granted it explicitly.
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation.
- All privileges that depend on the privilege being revoked are also revoked.

Roles

- **create role** instructor;
- **grant** *instructor* **to Amit;**
- Privileges can be granted to roles:
  - **grant select on** *takes* **to** *instructor*;
- Roles can be granted to users, as well as to other roles
  - **create role** *teaching_assistant*
  - **grant** *teaching_assistant* **to** *instructor*;
    - *Instructor* inherits all privileges of *teaching_assistant*
- Chain of roles
  - **create role** *dean*;
  - **grant** *instructor* **to** *dean*;
  - **grant** *dean* **to** Satoshi;

Authorization on Views

- **create view** *geo_instructor* **as**
  (**select** *
  from *instructor*
  where *dept_name* = 'Geology');
- **grant select on** *geo_instructor* **to** *geo_staff*
- Suppose that a *geo_staff* member issues
  - **select** *
    from *geo_instructor*;
- What if
  - *geo_staff* does not have permissions on *instructor?*
  - creator of view did not have some permissions on *instructor?*

Other Authorization Features

- **references** privilege to create foreign key
  - **grant reference** (*dept_name*) **on** *department* **to** Mariano;
  - why is this required?
- transfer of privileges
  - **grant select on** *department* **to** Amit **with grant option**;
  - **revoke select on** *department* **from** Amit, Satoshi **cascade**;
  - **revoke select on** *department* **from** Amit, Satoshi **restrict**;
- Etc. read Section 4.6 for more details we have omitted here.