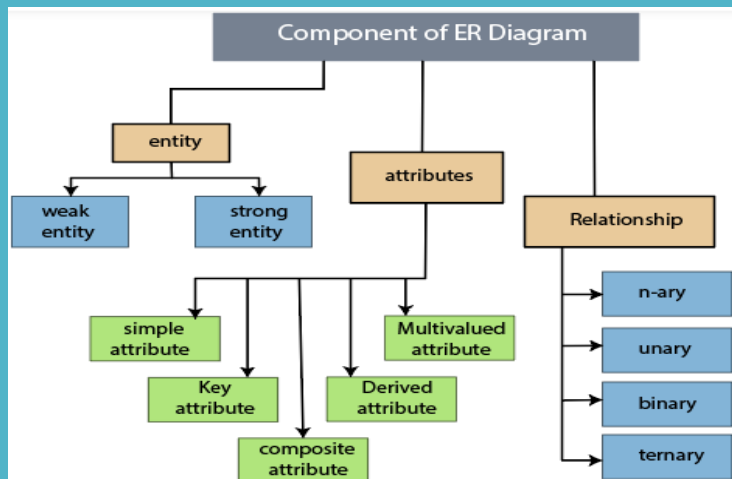
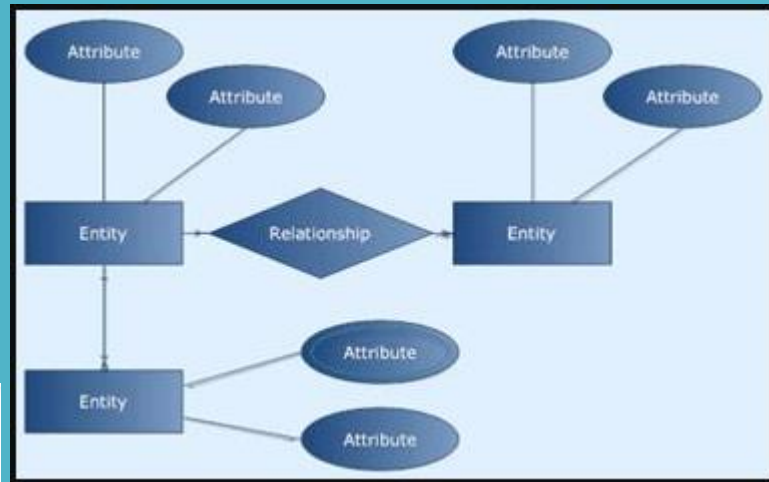


Data Base - CCE 395

Dr. Ahmed El-Shafei



Students			
ID#	Name	Phone	DOB
500	Matt	555-4141	06/03/70
501	Jenny	867-5309	3/15/81
502	Sean	876-9123	10/31/82

Takes_Course		
ID#	ClassID	Sem
500	1001	Fall02
501	1002	Fall02
501	1002	Spr03
502	1003	S203

Courses		
ClassID	Title	ClassNum
1001	Intro to Informatics	I101
1002	Data Mining	I400
1003	Internet and Society	I400

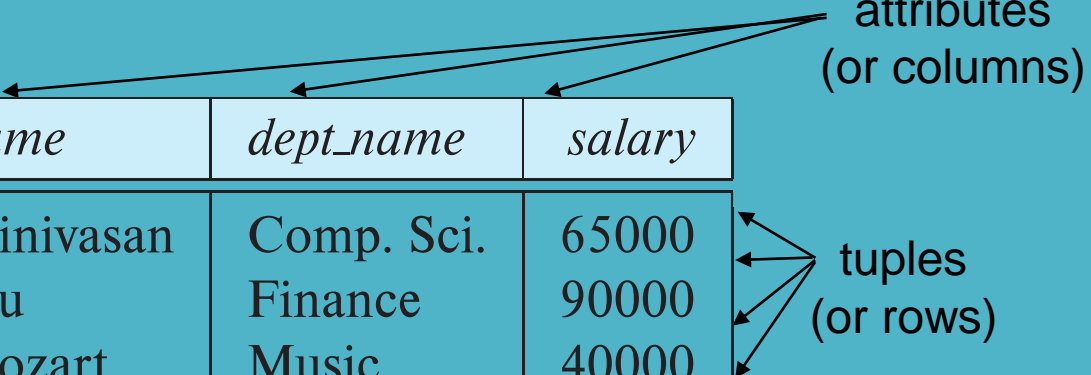
Chapter 2

Introduction to the Relational Model

Outline

- **Structure of Relational Databases**
- **Database Schema**
- **Keys**
- **Schema Diagrams**
- **Relational Query Languages**
- **The Relational Algebra**

Example of an Instructor Relation



<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
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

Relation Schema and Instance

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

Example:

instructor = (ID, name, dept_name, salary)

- A relation instance **r** defined over schema **R** is denoted by **r(R)**.
- The current values a relation are specified by a table
- An element **t** of relation **r** is called a **tuple** and is represented by a **row** in a **table**

Attributes

- 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

Relations are Unordered

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

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
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

Database Schema

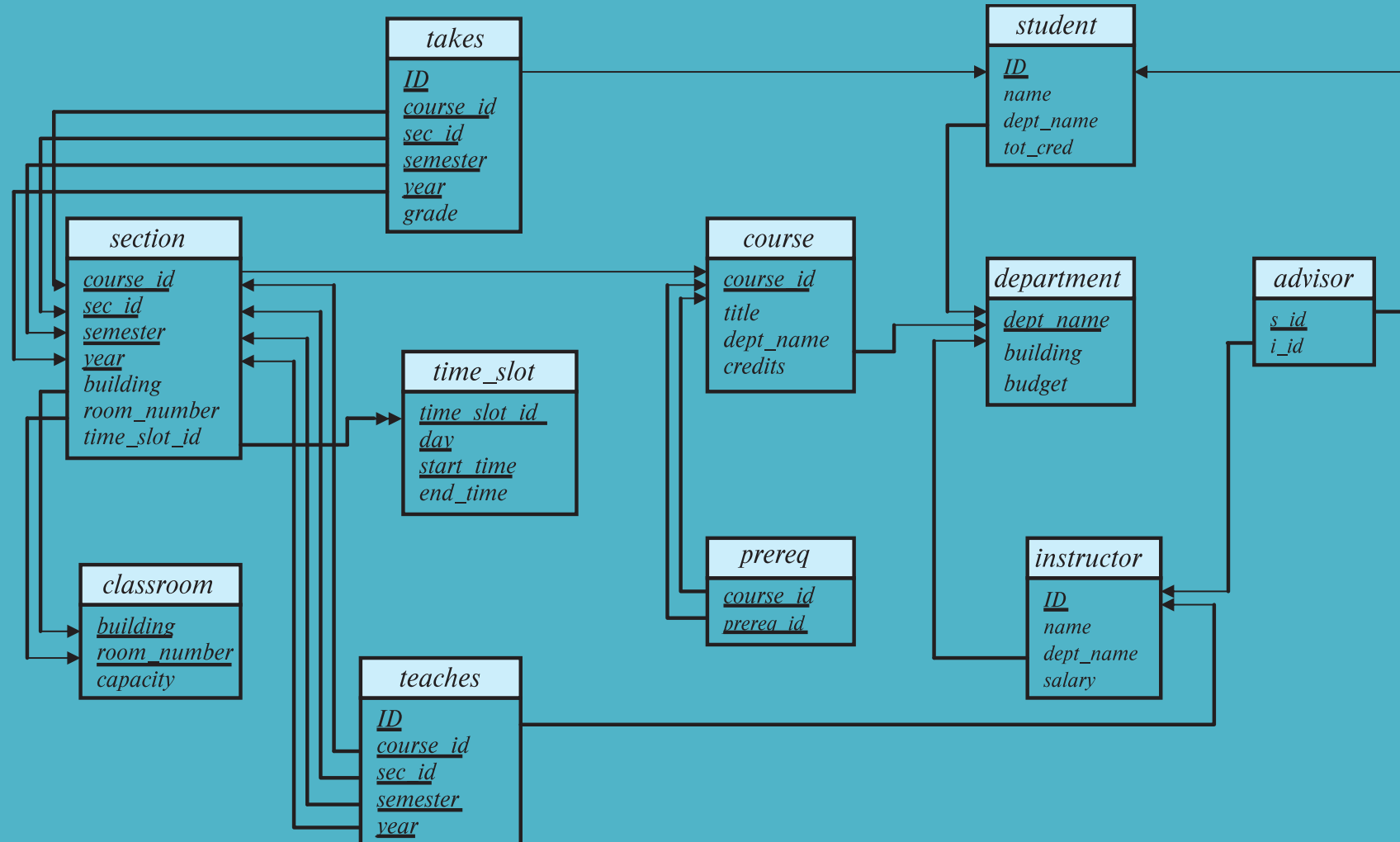
- Database schema -- is the logical structure of the database.
- Database instance -- is a snapshot of the data in the database at a given instant in time.
- Example:
 - schema: instructor (*ID, name, dept_name, salary*)
 - Instance:

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
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 $K \subseteq R$
- 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 instructor is a foreign key from instructor referencing department

Schema Diagram for University Database



Relational Query Languages

- Procedural versus 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 Turing-machine equivalent
 - Consists of **6** basic operations

Relational Algebra

- A procedural language consisting of a set of operations that take one or two relations as input and produce a new relation as their result.
- Six basic operators
 - select: σ
 - project: Π
 - union: \cup
 - set difference: $-$
 - Cartesian product: \times
 - rename: ρ

Week 4 : 6/3/2023

2013

Week 4 : 9/3/2023

2019

Select Operation

- The select operation selects tuples that satisfy a given predicate.
- Notation: $\sigma_p(r)$
- p is called the selection predicate
- **Example: select those tuples of the instructor relation where the instructor is in the “Physics” department.**

- Query

$\sigma_{dept_name="Physics"}(instructor)$

- Result

ID	name	dept_name	salary
22222	Einstein	Physics	95000
33456	Gold	Physics	87000

Select Operation (Cont.)

- We allow comparisons using

$=, \neq, >, \geq, <, \leq$

in the selection predicate.

- We can combine several predicates into a larger predicate by using the connectives:

\wedge (and), \vee (or), \neg (not)

- Example: Find the instructors in Physics with a salary greater \$90,000, we write:

$\sigma_{dept_name="Physics" \wedge salary > 90,000} (instructor)$

- The select predicate may include comparisons between two attributes.

- Example, find all departments whose name is the same as their building name:

- $\sigma_{dept_name=building} (department)$

Project Operation

- A **unary operation** that returns its argument relation, with certain attributes left out.
- Notation:

$$\Pi_{A_1, A_2, A_3, \dots, A_k}(r)$$

where A_1, A_2, \dots, A_k are attribute names and r is a relation name.

- The **result is defined as** the relation of k columns obtained **by erasing the columns that are not listed**
- **Duplicate rows removed from result, since relations are sets**

Project Operation Example

- **Example: eliminate the dept_name attribute of instructor**

- Query:

$\Pi_{ID, name, salary} (instructor)$

- Result:

<i>ID</i>	<i>name</i>	<i>salary</i>
10101	Srinivasan	65000
12121	Wu	90000
15151	Mozart	40000
22222	Einstein	95000
32343	El Said	60000
33456	Gold	87000
45565	Katz	75000
58583	Califieri	62000
76543	Singh	80000
76766	Crick	72000
83821	Brandt	92000
98345	Kim	80000

Composition of Relational Operations

- The result of a relational-algebra operation is relation and therefore of relational-algebra operations can be composed together into a relational-algebra expression.
- Consider the query -- Find the names of all instructors in the Physics department.

$\Pi_{name}(\sigma_{dept_name = "Physics"}(instructor))$

- Instead of giving the name of a relation as the argument of the projection operation, we give an expression that evaluates to a relation.

Cartesian-Product Operation

- The **Cartesian-product** operation (denoted by **X**) allows us to combine information from any two relations.
- **Example: the Cartesian product of the relations instructor and teaches is written as:**
instructor X teaches
- We construct a tuple of the result out of each possible pair of tuples: one from the **instructor relation** and one from the **teaches relation** (see next slide)
- Since the ***instructor ID*** appears in both relations, we distinguish between these attribute by attaching to the attribute the name of the relation from which the attribute originally came.
 - ***instructor.ID***
 - ***teaches.ID***

The instructor X teaches table

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
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

instructor table

<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	CS-101	1	Fall	2017
10101	CS-315	1	Spring	2018
10101	CS-347	1	Fall	2017
12121	FIN-201	1	Spring	2018
15151	MU-199	1	Spring	2018
22222	PHY-101	1	Fall	2017
32343	HIS-351	1	Spring	2018
45565	CS-101	1	Spring	2018
45565	CS-319	1	Spring	2018
76766	BIO-101	1	Summer	2017
76766	BIO-301	1	Summer	2018
83821	CS-190	1	Spring	2017
83821	CS-190	2	Spring	2017
83821	CS-319	2	Spring	2018
98345	EE-181	1	Spring	2017

teaches table

<i>instructor.ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>	<i>teaches.ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2017
...
...
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2017
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2018
12121	Wu	Finance	90000	10101	CS-347	1	Fall	2017
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2018
12121	Wu	Finance	90000	15151	MU-199	1	Spring	2018
12121	Wu	Finance	90000	22222	PHY-101	1	Fall	2017
...
...
15151	Mozart	Music	40000	10101	CS-101	1	Fall	2017
15151	Mozart	Music	40000	10101	CS-315	1	Spring	2018
15151	Mozart	Music	40000	10101	CS-347	1	Fall	2017
15151	Mozart	Music	40000	12121	FIN-201	1	Spring	2018
15151	Mozart	Music	40000	15151	MU-199	1	Spring	2018
15151	Mozart	Music	40000	22222	PHY-101	1	Fall	2017
...
...
22222	Einstein	Physics	95000	10101	CS-101	1	Fall	2017
22222	Einstein	Physics	95000	10101	CS-315	1	Spring	2018
22222	Einstein	Physics	95000	10101	CS-347	1	Fall	2017
22222	Einstein	Physics	95000	12121	FIN-201	1	Spring	2018
22222	Einstein	Physics	95000	15151	MU-199	1	Spring	2018
22222	Einstein	Physics	95000	22222	PHY-101	1	Fall	2017
...
...

Join Operation

- The Cartesian-Product

instructor X teaches

associates every tuple of instructor with every tuple of teaches.

- Most of the resulting rows have information about instructors who did NOT teach a particular course.
- To get only those tuples of “***instructor X teaches***” that pertain to instructors and the courses that they taught, we write:

$\sigma_{instructor.id = teaches.id} (instructor \times teaches)$

We get only those tuples of “***instructor X teaches***” that pertain to instructors and the courses that they taught.

- ***The result of this expression, shown in the next slide***

Join Operation (Cont.)

- The table corresponding to:

$\sigma_{instructor.id = teaches.id}(instructor \times teaches)$

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

instructor table

ID	course_id	sec_id	semester	year
10101	CS-101	1	Fall	2017
10101	CS-315	1	Spring	2018
10101	CS-347	1	Fall	2017
12121	FIN-201	1	Spring	2018
15151	MU-199	1	Spring	2018
22222	PHY-101	1	Fall	2017
32343	HIS-351	1	Spring	2018
45565	CS-101	1	Spring	2018
45565	CS-319	1	Spring	2018
76766	BIO-101	1	Summer	2017
76766	BIO-301	1	Summer	2018
83821	CS-190	1	Spring	2017
83821	CS-190	2	Spring	2017
83821	CS-319	2	Spring	2018
98345	EE-181	1	Spring	2017

teaches table

instructor.ID	name	dept_name	salary	teaches.ID	course_id	sec_id	semester	year
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2017
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2018
15151	Mozart	Music	40000	15151	MU-199	1	Spring	2018
22222	Einstein	Physics	95000	22222	PHY-101	1	Fall	2017
32343	El Said	History	60000	32343	HIS-351	1	Spring	2018
45565	Katz	Comp. Sci.	75000	45565	CS-101	1	Spring	2018
45565	Katz	Comp. Sci.	75000	45565	CS-319	1	Spring	2018
76766	Crick	Biology	72000	76766	BIO-101	1	Summer	2017
76766	Crick	Biology	72000	76766	BIO-301	1	Summer	2018
83821	Brandt	Comp. Sci.	92000	83821	CS-190	1	Spring	2017
83821	Brandt	Comp. Sci.	92000	83821	CS-190	2	Spring	2017
83821	Brandt	Comp. Sci.	92000	83821	CS-319	2	Spring	2018
98345	Kim	Elec. Eng.	80000	98345	EE-181	1	Spring	2017

Join Operation (Cont.)

- The join operation allows us to combine a select operation and a Cartesian-Product operation into a single operation.
- Consider relations $r (R)$ and $s (S)$
- Let “theta” be a predicate on attributes in the schema **R “union” S**. The join operation $r \bowtie_{\theta} s$ is defined as follows:

$$r \bowtie_{\theta} s = \sigma_{\theta} (r \times s)$$

- Thus

$$\sigma_{instructor.id = teaches.id} (instructor \times teaches)$$

- Can equivalently be written as

$$instructor \bowtie_{instructor.id = teaches.id} teaches.$$

Union Operation

- The **union** operation allows us to combine two relations
- Notation: $r \cup s$
- For $r \cup s$ to be valid.
 1. r, s must have the same **arity** (same number of attributes)
 2. The attribute domains must be **compatible**
(example: 2nd column of r deals with the same type of values as does the 2nd column of s)
- Example: to find all courses taught in the Fall 2017 semester, or in the Spring 2018 semester, or in both

$$\Pi_{course_id}(\sigma_{semester="Fall" \wedge year=2017}(section)) \cup \Pi_{course_id}(\sigma_{semester="Spring" \wedge year=2018}(section))$$

Union Operation (Cont.)

- Result of:

$$\Pi_{course_id}(\sigma_{semester="Fall" \wedge year=2017}(section)) \cup \Pi_{course_id}(\sigma_{semester="Spring" \wedge year=2018}(section))$$

<i>course_id</i>
CS-101
CS-315
CS-319
CS-347
FIN-201
HIS-351
MU-199
PHY-101

Set-Intersection Operation

- The **set-intersection** operation allows us to find tuples that are in both the input relations.
- Notation: $r \cap s$
- Assume:
 - r, s have the same arity
 - attributes of r and s are compatible
- Example: Find the set of all courses taught in both the Fall 2017 and the Spring 2018 semesters.

$$\Pi_{course_id}(\sigma_{semester="Fall" \wedge year=2017}(section)) \cap \Pi_{course_id}(\sigma_{semester="Spring" \wedge year=2018}(section))$$

- **Result**

<i>course_id</i>
CS-101

Set Difference Operation

- The set-difference operation allows us to find tuples that are in one relation but are not in another.
- Notation $r - s$
- Set differences must be taken between **compatible** relations.
 - r and s must have the **same arity**
 - attribute domains of r and s must be compatible
- **Example: to find all courses taught in the Fall 2017 semester, but not in the Spring 2018 semester**

$$\Pi_{course_id}(\sigma_{semester="Fall" \wedge year=2017}(section)) - \Pi_{course_id}(\sigma_{semester="Spring" \wedge year=2018}(section))$$

<i>course_id</i>
CS-347
PHY-101

The Assignment Operation

- It is convenient at times to write a relational-algebra expression by assigning parts of it to temporary relation variables.
- The assignment operation is denoted by \leftarrow and works like assignment in a programming language.
- **Example: Find all instructor in the “Physics” and Music department.**

Physics $\leftarrow \sigma_{dept_name="Physics"}(instructor)$
Music $\leftarrow \sigma_{dept_name="Music"}(instructor)$
Physics \cup *Music*

- With the assignment operation, a query can be written as a sequential program consisting of a series of assignments followed by an expression whose value is displayed as the result of the query.

The Rename Operation

- The results of relational-algebra expressions do not have a name that we can use to refer to them. The rename operator, ρ , is provided for that purpose
- The expression:

$$\rho_x(E)$$

returns the result of expression E under the name x

- Another form of the rename operation:

$$\rho_{x(A1,A2, \dots, An)}(E)$$

Equivalent Queries

- There is more than one way to write a query in relational algebra.
- **Example: Find information about courses taught by instructors in the Physics department with salary greater than 90,000**
- Query 1

$\sigma_{dept_name="Physics" \wedge salary > 90,000} (instructor)$

- Query 2

$\sigma_{dept_name="Physics"} (\sigma_{salary > 90,000} (instructor))$

- The two queries are not identical; they are, however, equivalent -- they give the same result on any database.

Equivalent Queries

- There is more than one way to write a query in relational algebra.
- **Example: Find information about courses taught by instructors in the Physics department**
- Query 1

$\sigma_{dept_name="Physics"} (instructor \bowtie instructor.ID = teaches.ID teaches)$

- Query 2

$(\sigma_{dept_name="Physics"} (instructor)) \bowtie instructor.ID = teaches.ID teaches$

- The two queries are not identical; they are, however, equivalent -- they give the same result on any database.

End of Chapter 2

Thank You!

